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Good work design:

Strategies to embed human-centred design in organisations

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Abstract

Human-centred design of work provides the potential to improve productivity, safety, and health. This thesis examines how organisations can achieve such good work design. Specifically, the research examines the tools, practices, activities, structures, systems, conditions, and culture by which organisations can achieve human-centred work.

The research consists of: i) case studies of participatory ergonomics projects; ii) a design review of mobile plant; iii) examination of decision-making during a task (re)design; iv) a participatory ergonomics program review; and v) a survey of managers or ergonomists about factors essential to the outcomes afforded by good work design. Through these investigations, a capability model for good work design (ReCRREate) is proposed.

Following an introduction (Chapter 1) and review of literature (Chapter 2), Chapter 3 provides a participatory ergonomics case study involving the (re)design of a road construction work task. Necessary conditions were determined: worker and ergonomist involvement and an appreciative approach. A method for outcome evaluation was presented (the Occupational Perspective of Health) with considerations for the risk reduction of catastrophe, fatality, disablement, and injury; comfort, health, and social connection; productivity; and industry liaison. Inclusivity and sustainability were identified as other likely project outcomes. A comparative case study was undertaken with conversational interviews to identify the factors influencing project success.

In Chapter 4, an example of the use of human-centred design practices to inform procurement is provided through examination of an asphalt job truck and a bitumen trailer using tools previously developed for use with mining equipment. The job truck review resulted in the identification of hazards not indicated previously. Functional Resonance Analysis Method (FRAM) was used to examine the work systems and categorise themes associated with activities that were influential to the organisation and its work design practice. Lead indicators were identified: the distribution of evidence-based literature to build tacit knowledge, establishing a target for effective design interventions, and the development of a task-based case library for hazard identification and task (re)design.

Chapter 5 examines decision making that led to the nomination of a sweeping task and selection of controls for task (re)design. A case study review was conducted through the application of a logic-based mobile App (FYI Decision Making) to determine a weighting assigned to these decision-factors. In this case, a manual, commercial-grade push broom with circular brushes and a hopper provided a low-cost, -effort, and -time strategy while achieving a significant impact to productivity and comfort.

Chapter 6 reviewed the positive outcomes achieved by an organisation through their participatory ergonomics program. A content analysis was conducted to determine the key messages conveyed by maintenance workers, a program coordinator, and a superintendent. Similar sentiments were expressed: a belief that good work design brought value to the business, improved morale, and led to systems improvement. A formative analysis provided for ongoing program improvement: a value proposition of the work should be conveyed through other business units.

Chapter 7 describes the results of case and narrative literature review, the development of statements of necessary condition, examination of these statements through a questionnaire, and the construction of a capability model for good work design. A distinction was found between project and program success: approaches, tools, and resources to effectively advance a project differed from those required to promote a program. Ergonomics projects resulted in some success however the projects nested within a highly capable program were almost six times more likely to achieve significant success.

Organisations can achieve good work design when human-centred approaches are undertaken. A successful program requires extensive leadership support, task-based work descriptions to identify opportunities for design and contextualise hazards, cost benefit analysis, and the aachievement of positive health outcomes. Projects are successful when they achieve significant risk reduction and health and business improvement. Conditions that support these methods include worker involvement, business and supply chain integration, establishment of lead indicators, communication and celebration of success, and outcome evaluation.

Declaration by Author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, financial support and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my higher degree by research candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, financial support and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my higher degree by research candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Publications During Candidature

Peer Reviewed Journal Papers

Pazell, S., Burgess-Limerick, R., Horberry, T., & Davidson, P. (2016). Human-centred design in civil road construction: Methods to inform procurement and improve performance. Journal of Health & Safety Research & Practice 8(1), 3 - 14.

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Publications Included in this Thesis

No publications included

Manuscripts Included in this Thesis

No publications included

Contribution by Others to this Thesis

The introductory and concluding chapters of the thesis, chapters 1 and 6 respectively, were completed by the candidate purely with editorial assistance and guidance from my supervisors.

Chapter 3, a review of participatory ergonomics cases, was advanced by my learnings from Professor Robin Burgess-Limerick. The appreciative approach was explored in detailed conversation with a close friend of mine and chief operating officer of a large health-care organisation, Ms Josephine Boylan. The development of the Occupational Perspective of Health Model for evaluation of these cases was inspired by my early academic education with Professor Ann Wilcock more than 20 years ago. It is not known whether this social justice health model of "doing-being-becoming-belonging" has ever before been applied in business analysis or occupational health; however, the research was entirely independent except for the editorial assistance by supervisors Of course, the workers who collaborated in the projects deserve mention.

Chapter 4, the application of human-centred design practices, Design for Operability and Maintainability Analysis Technique (d-OMAT), and the use of the risk determination and design philosophy tool, Earth Moving Equipment Safety Round Table Design Evaluation for Equipment Procurement (EDEEP), occurred at the suggestion of my supervisor, Professor Robin Burgess-Limerick, and was secured by the work of my second supervisor, Professor Timothy Horberry. The supportive vehicle review checklist was devised independently but motivated by the work of my supervisors. My learnings from Professor Erick Hollnagel enabled the application of the Functional Resonance Analysis Method (FRAM) for descriptive modelling and formative analysis in design review. Free software was accessed: the FRAM Model Visualiser (version 0.4.1.). The models were devised independently.

In Chapter 5, investigations are undertaken to explore decision making that supports good work design. The concept of the value proposition for good work design is one with which I have grappled my entire career as a field practitioner and business manager.

However, debate has occurred with my supervisor Professor Robin Burgess-Limerick and Dr. Gary Dennis which helped elevate my thinking in these areas. A free App was used (FYI Decision Making) and this was applied to the review of a participatory ergonomics study. Professor Hugh Possingham, a leader in environmental sciences and decision making, invited me to audit his classes and helped me appreciate that the same type of considerations about optimum conditions in a natural environment can be applied to the science of work. Professor Jan Dul is acknowledged for his contributions that link the business proposition of applied ergonomics. His work, also, served as the inspiration for investigations regarding Necessary Condition Analysis (NCA) (Chapters 3 – 7). The statements of conditions and hypotheses were independently formed.

In Chapter 6, my supervisor, Professor Robin Burgess-Limerick, provided introduction to the mine site that hosted the study success site visit. The outcomes of this visit were useful. The application of a language content analysis was formulated and applied independently.

Chapter 7 is influenced by the work of Professor Jan Dul, and Professor Robin Burgess-Limerick provided guidance to help determine methods of data collection. Mr Lester Lasrado (PhD Fellow at Copenhagen Business School) provided generous support and guidance through sharing details of his publication and methods for maturity model development and questionnaire analysis. Dr Steven Siller provided coaching and tutorial assistance to structure the questionnaire for validity and suitability for the chosen method of analysis (necessary condition analysis). Dr Siller, also, applied statistical analysis to raw data and, with tutorial assistance, enabled me to consider appropriate application of the tools of analysis and data synthesis. A conversation with Professor Jan Dul prompted the development of the capability model of good work design.

This candidate completed all other research and analysis unassisted except for guidance and editorial assistance by my supervisors and, of course, contributions derived from the collaboration of industry partners and the workers involved in the projects.

Statement of Parts of the Thesis Submitted to Qualify for the Award of Another Degree

None

Research Involving Human or Animal Subjects

No animal subjects were involved in this research. For site visits, interviews, and questionnaires with human participants, ethics approval number 17-001 was obtained through the Sustainable Minerals Institute Research Ethics Committee. Please refer to the ethics approval letter (Appendix A) and consent form (Appendix B).

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My family have instilled in me values of academic achievement and, more than that, inspired me to remain curious about life and fully embrace the verve of living. My parents always believed I could accomplish any endeavour of my undertaking. My father, John, challenged me to believe that I should flourish in academic pursuits, held back by no one, even if it took some time to get here. My mother, Alison, is a whiz at grammar and syntax. Thank you for your countless hours of reading to me as a child and reading these studies at all hours of the evening to provide editorial assistance (plus all the home-baked goods along the way). I give my gratitude to my brother, Robert, for his technical support and copious file transmissions to facilitate editing, and our debate about qualitative research.

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Table 8.1: Summary of Key Findings

Abbreviations

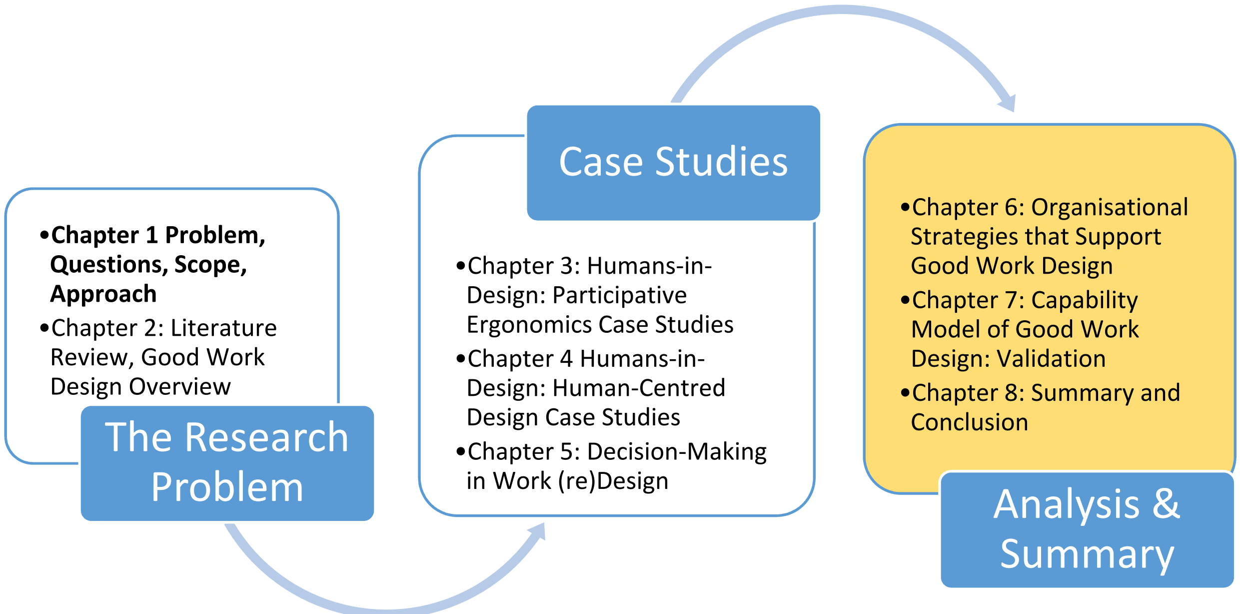
ACE:	Active Collaborative Ergonomics
AEO:	Authorised Engineering Organisation
AFOEM:	Australasian Faculty of Occupational and Environmental Medicine
AHP:	Analytic Hierarchy Process
AIFR:	All injury frequency rate
AIHW:	The Australian Institute of Health and Welfare
BLT:	Bacon, lettuce, and tomato
CAR:	Connectivity-Adequacy-Representation
CAR-E:	Connectivity-Adequacy-Representation-Efficiency
CBA:	Cost Benefit Analysis
CEA:	Cost Effectiveness Analysis
CDC:	Centers for Disease Control
CSF:	Critical Success Factors
D-OMAT:	Design for Operability and Maintainability Analysis Technique
EDEEP:	Earth Moving Equipment Safety Round Table Design for Equipment Procurement
EMESRT:	Earth Moving Equipment Safety Round Table
ETTO:	Efficiency Time Trade-Off
FMEA:	Failure Mode and Effects Analysis
FRAM:	Functional Resonance Analysis Method
GBCA:	Green Building Council of Australia
GWD:	Good Work Design
HCD:	Human-Centred Design
HFE:	Human Factors Ergonomics
HiD:	Humans in Design
ICMM:	International Council on Mining and Metals
IEA:	International Ergonomics Association
ISO:	International Standards Organisation
IWBI:	International Well Building Institute
LEED:	Leadership in Energy and Environmental Design

NCA: Necessary Condition Analysis
NIOSH: National Institute for Occupational Safety and Health
NOHSC: National Occupational Health and Safety Commission
NPV: Net Present Value
OPH: Occupational Perspective of Health
PE: Participatory Ergonomics
PERFA: Performance, ease of use, reliability, flexibility, and affectivity
PUE: Potential Unwanted Event
RACP: Royal Australian College of Physicians
RAP: Recycled Asphalt Product
RULA: Rapid Upper Limb Assessment
SWA: Safe Work Australia
TWH: Total Worker Health®
WHS: Work Health Safety
WW: Workplace Wellness

> *You can buy a person's time; you can buy their physical presence at a given place; you can even buy a measured number of their skilled muscular motions per hour, but you cannot buy enthusiasm; you cannot buy initiative; you cannot buy loyalty; you cannot buy the devotion of hearts, minds, or souls. You must earn these.*

Figure 0.1: Clarence Francis (1952) management quote *(language modified for gender-neutral use)*

Chapter 1: Problems, Questions, Scope, Approach



Abstract

Although participation in work is associated with general health benefits, many of the tasks undertaken in heavy industry are hazardous. Repeated exposure to risk diminishes the alarm associated with risk-taking conditions. When workers are systematically exposed to at-risk conditions, they may simply “run the risk” (Wagenaar & Groenweg, 1987). There are efficiency/time trade-offs associated with risk avoidance (Hollnagel, 2009) and, unless the design of work is conducive to healthful and safe work tactics, the temptation will remain to work risk-exposed in unsafe conditions (Hollnagel, 2002; Schill & Chosewood, 2016).

This review examines the impact that can be made on such risks through good work design.The primary aims of the thesis are described, and the questions are outlined. The thesis structure is presented as is a general overview of the approach to the multiple studies.

1.1 Problem Statement

Heavy industry strongly supports the Australian economy by contributing to the gross domestic product, employing many full-time workers and, thus, heads of household (Australian Bureau of Statistics, 2010a; Australian Bureau of Statistics, 2010b). The work is important to any industrialised nation, and participation in work is associated with general health benefits. Work may be conditioning (physically and cognitively), socially inclusive, and provide for economic stability (Australian Institute of Health and Welfare, 2012 and 2013; Waddell & Burton, 2006). However, work also may expose workers to high-risk conditions for fatality, disablement, and impairment (SWA, 2015b; SWA, 2013). The challenge for industry and organisations is to implement a sustainable design strategy that fosters health and productivity and mitigates unwanted events. The balance scales of “benefits” and “detriments” may be tilted by good work design.

Human factors and ergonomics, participatory ergonomics, and human-centred design are practices that address well-being and productivity, reducing injury risks and improving system performance (Dul, 2011), supply chain management, and sustainability. The practices may be applied to improvements in the built and natural environment. Managers (and advertisers, researchers, and practitioners) have commonly associated ergonomics with occupational health and safety programs and related legislation rather than business objectives; this is a common mistake (Dul, 2011).

Human-centred design strategies are referred to in this report as “good work design”. These are design-based activities fueled by creativity (Hamilton, 2012). However, in many cases, the most significant impediment to creativity and innovation is leadership (Dul, 2011). Leadership and business strategy are critical to providing the conditions, resource, and system support for good work design.

For many years, organisations have espoused the cliché of “our people are our most important asset”, yet they continually fail to address human-centric work design (Dul, 2011). The ISO Standard 27500:2016 (The human-centred organisation – Rationale and general principles) provides guidance to support these practices and complements other similar standards, such as ISO 9241-210: 2010a (Ergonomics of human-system interaction: Part 210: Human-centred design for interactive systems). In line with these guidance documents, business managers may aim to restructure operations to benefit the people who make it profitable. These actions require a radical shift to foster systems that fit humans and their work capacity and may be disruptive to routine corporate governance and process. However, a belief in the good of this investment for the organisation will help drive the process (Dul, 2011).

1.1.1 Industry Profiles and Injury Trends

Mining

Mining contributes significantly to Australia’s national production. At a state level, in 2007-08, mining accounted for 31% of total production in the Northern Territory, 29% in Western Australia, and 10% in Queensland. Contributions from coal mining, oil and gas extraction, metal ore mining, non-metallic mineral mining and quarrying, and exploration and other mining support determine industry performance (Australian Bureau of Statistics, 2010a).

Mining represents the fifth highest industry type for fatality incidence in 2015 (SWA, 2015b). Long shifts, fatigue, mental overload and underload, exposure to hazardous manual tasks (especially intermittent high exertion activities), performance of sedentary work in fixed postures, and exposure to whole body vibration are considered risks for health and safety in this industry (McPhee, 2004; McPhee, 1993). It is likely that these factors will lead to morbidity, disablement, and impairment among some workers if well-informed management decisions do not address the work exposures (McPhee, 2004). In mining, musculoskeletal disorders represent a high percentage of injury statistics resulting in potentially disabling conditions (Torma-Krajewski et al, 2009).

Construction

The construction industry is the fourth largest contributor to Gross Domestic Product (GDP) in the Australian economy (Australian Bureau of Statistics, 2010b). In 2011–12, the contribution represented 7.7% ($106.5b) to the national economy. The construction industry employed 1.01 million people in Australia in 2011 – 2012 (9% of the workforce) (SWA, 2013). The majority works full-time (86%) and is male (89%) (Australian Workforce and Productivity Agency, 2013).

Fatality incidence in 2014 in construction was the third highest among all industries in Australia representing 15.2% of all deaths (28 of 184 total deaths) (SWA, 2015b). Over the five years from 2007–08 to 2011–12, the construction industry accounted for 11% of all serious workers' compensation claims and, on average, 39 claims daily were arising from employees who required one or more weeks off work owing to work-related injury or disease. Safe Work Australia (2013) reports that between 2007–08 and 2011–12:

- *Body stressing* accounted for 34% of claims—more than half of these were due to muscular stress while handling a range of materials, tools, and other equipment.
- *Falls, trips, and slips of a person (from height or same level)* accounted for 26% of claims.
- *Being hit by moving objects* accounted for a further 16% of claims—many of these involved being hit by falling or moving materials and equipment.

Most industries employ transport-related workers, and this is true for construction and mining: for example, operators of job trucks, trucks for specialised purposes (e.g. bitumen sprayers), and mobile plant equipment. Safe Work Australia (2011d) reveals that, in 2009 – 10, the serious claim rate in transport and storage was almost double the national average (24.0 claims per 1,000 employees). The primary mechanisms of injury included muscular stress, falls, trips and slips, and being hit by moving objects, mirroring trends in construction. Safe Work Australia (2011e) also highlighted that, across Australia, the groups with the highest serious claim rate include labourers, intermediate transport, and trades workers. Construction includes all three occupational groups.

In the United States, 639 workers were killed while working at a road construction site during 2003 – 2007. This represented 7.9% of all deaths in construction. Nearly half of these fatalities were attributable to a worker being struck by a vehicle or mobile equipment—more frequently by construction equipment than by tractor-trailers, vans, and cars. In 60% of the cases where a worker was struck by backing vehicles or mobile equipment, a reversing dump truck fatally struck the worker (Center for Disease Control, November 2014).

During the 2003 to 2010 period in the U.S., 962 workers were killed while working at a road construction site. 87% of these deaths were workers who were working on site at the time of the incident. The remaining 13% were workers passing thorough the construction site. Workers were primarily killed when struck by a vehicle or mobile equipment, followed by overturns, fall from vehicle or mobile equipment, and collisions (where victim was inside vehicle or operating equipment). Workers passing through a construction site were primarily killed in collision events involving either a vehicle or mobile equipment going in the same direction, or a vehicle or mobile equipment striking a stopped vehicle or mobile equipment (Center for Disease Control, November 2014).

The equipment, trucks, and plant used in heavy industry (e.g. mining and construction) pose a major occupational hazard – they may be fast, heavy, and powerful but not crash tolerant, used in at-risk environments among pedestrian workers and other plant in proximity. The design is likely to have been focussed on the durability and required work outcome rather than human interaction needs (Horberry, 2011; Horberry et al, 2011).

Musculoskeletal disorders (sprains and strains) also rate highly for areas of concern in the construction industry. The experience of such a disorder may lead to disability (severe to minimal) and temporary impairment. It is considered the most prevalent report incident of body stresses for the construction industry (SWA, 2015b). The Australian Work Health and Safety Strategy 2012 – 2022 have selected musculoskeletal disorders as a work-related disorder of national priority in the first five years of implementation. The selection of this disorder is related to severity of consequence to workers, incidence rates, and existence of known prevention options (SWA, 2012).

1.1.2 Risk Taking in Heavy Industry

Risk-Taking Knowledge and Behaviour

Storseth et al (2010) explain that people at all levels face safety-critical decisions when there may be competing goals for budgetary compliance and project-timelines. A study of 57 accidents at sea concluded that few accidents occurred owing to deliberate risk-taking behaviour among workers. Rather, they were systemically risk-exposed in their work and simply “ran the risk” (Wagenaar & Groenweg, 1987).

Safe Work Australia (2014) reported that construction labourers were a cohort most likely to be accepting of risk-taking at work, inferring that workplace culture contributes to risk-taking and rule-breaking. A call was made for a “need to rethink the way work is designed to help to remove pressures that lead to risk-taking and rule-breaking” (SWA, 2014, pp. vi). They concluded that detailed discussions in a supportive environment among team members of diverse backgrounds is necessary to formulate and rationalise criteria for critical decisions.

Risk-taking involves spontaneous decision making: e.g. a thought process of “If I do this, what do I sacrifice…?”. The sacrifice may be the cost of time, personal comfort (such as in the compliant wear of personal protective equipment), productivity, or the judgment of our peers (Noyes, 2001). Noyes (2001) argues that equipment design with added safety features may entice a person to act with greater risk and this has important implications for designers. For example, auditory speed camera alerts may encourage driving at-speed unless or until the alert is activated. However, she also acknowledges that risk-taking behaviour is dependent upon context, familiarity, and nature of the hazard, implying that we all have the potential to be risk-takers when design does not advance the safest selection among a range of possible tactics.

Risk Management Practice

Many businesses fail to conduct a broad, integrated systems approach to risk assessment (MacDonald & Evans, 2006; MacDonald & Oakman, 2015). A participatory team approach to safe work design may help reduce risk (Oakman & Chan, 2015). Those that perform the work know their work best: they are subject-matter experts. However, even subject-matter experts may be subject to complacency and personal reference, and this may affect their ability to identify hazards or escalate risk. In short, the more familiarity a person has with a product or system, and the more frequently that task is performed, the less hazardous the product, system, or task is believed to be (Noyes, 2001; Sanders & McCormick, 1993). People tend to rely heavily on personal knowledge and historical performance. That is, if they have not been injured or have not known others injured by the hazard, they may underestimate risk (Sanders & McCormick, 1993).

In terms of human factors and ergonomics, the emphasis for risk management is on higher order controls: elimination, substation/isolation, and engineering design. Further, the practice involves consultation with workers at every stage of analysis of productivity and safety: hierarchical task analysis, hazard review, risk determination, design strategy, control development, trial, (re)design, communication, implementation, and measurement of ongoing effectiveness (Horberry et al, 2011). This thesis will question whether traditional hazard management practice provides an adequate point of leverage for ideas-generation, design strategy, and innovation.

1.1.3 Design as a Contributing Factor to an Unwanted Event

A wide range of design-related issues contribute to workplace fatalities (National Occupational Health and Safety Commission, 2004). The most frequently cited include: design error with roll-over protective structures; seat belt design; inadequate guarding; lack of residual current devices; inadequate fall protection; failed hydraulic lifts; braking errors; and inadequate protection on mobile plant and vehicles, such as enclosed cabins. In this analysis of incidents and fatalities in 2001-02, it was estimated that 90% of incidents involving humans and machinery or fixed plant appeared owing, at least in part, to design issues. Design considerations also may extend beyond the technical aspects of equipment to that of workforce strategy, organisational systems, and resource planning.

To illustrate this, Horberry et al (2014) describe studies of work incidents where inadequate design was a major contributing factor:

- 1989 – 1992: Australia: 233 plant-related work fatalities in 225 incidents, and, in 117 (52%) of these, at least one design flaw contributed to that fatal outcome such as poor guarding, controls, or safety equipment (NOHSC, 2000).
- 2000 – 2002: The role of design in fatalities increased with 90% of incidents attributed in some part to design issues. NOHSC (2004) categorised primary design issues, such as inadequate guarding, poorly situated control devices, inadequate interlock safety systems, sticking drills, and equipment failure (Creaser, 2008; Driscoll et al, 2008; NOHSC, 2004).

Driscoll et al (2008) claim that little is yet known about the extent of design issues contributing to work-related injury (industry tracking systems may not adequately capture, describe, collect, categorise, understand, or report design flaw data). However, studies that capture this information clearly substantiate the ideas that poorly designed machinery, safety measures, or work systems play a significant role in elevating the risk of occupational injury (Creaser, 2008; Driscoll et al, 2008; NOHSC, 2000; NOHSC, 2004).

Safe Design Responsibility

Safe design of work practice, tools, and equipment cannot be left to regulatory process alone. Standards provide, at best, lower limits for product acceptability and do not guarantee safe design (Weinstein et al, 1978). In response to findings that the public expects the government, through its regulator, to pre-empt and safeguard against emerging risk in industry, Safe Work Australia has reported that they rely on the participation of those being regulated. Commercial, economic, social, and psychological factors may shape the development of safety solutions. Effective solutions require workers and managers to gain an understanding of work demands and implement effective design to meet these demands. Widespread failure to comply with regulations may exhaust the resources of government to police or enforce safe work activity (SWA, 2011c). Organisations that have institutionalised work practices may be doing the bare minimum to avoid being a laggard in industry, yet not enough to be a leader with flexibility and capability to respond to a risk that is unexpected or new (SWA, 2014).

In the United Kingdom and among some countries in the European Union, legislation requires an audit of workplaces to determine risks to employee health and well-being; and voluntary initiatives support this in industry (Burke, 2014; Leka et al, 2011). Legislation provides for a minimum standard of performance. Additional regulatory guidelines, practice standards, and voluntary initiatives may support processes beyond legal obligation to manage risks to occupational health and safety and work toward health attainment, wherein work becomes conditioning for health (Burke, 2014; Joy, 2014; Leka et al, 2011), a salutogenic approach (Mittelmark et al, 2017).

In the arena of human-centred design, a two-pronged approach may be required. First, recognition that safe design is not by any means an unregulated activity. There are numerous references to the obligation to ensure safe design in the management of risk to health and safety in Australian Work Health Safety Law (e.g. ISO 12100: 2010b; WHS Act 2011; Part 3.1). Second, to progress voluntary initiatives in organisations (e.g. Joy, 2014), there must be innovations in work design. The value-proposition must be persuasive and compelling to affect progressive action.

1.2 Aims

Given the evidence that there are design-based impediments to productivity, safety, and health in heavy industry (e.g. Horberry, 2011; Horberry et al, 2011); and there are opportunities to achieve value, health, social connection, workplace engagement, and well-being through good work design (e.g. Burke, 2014; SWA, 2015a; Sorensen et al, 2016); the primary aim of this research is to identify the theories about good work design, to examine these in practice, and to determine how effective, human-centric, work design strategies can be embedded in the fabric of an organisation.

This study encompasses five main areas: Chapter 3 addresses participatory ergonomics work practices. Chapter 4 addresses human-centred design practices for capital equipment purchase and descriptive modelling of supportive organisational systems. Chapter 5 describes decision making that influences design practice. Chapter 6 provides a study of a successful human-centred work design program and compares this with the strategies recommended for performance as a Human-Centred Organisation (ISO 27500:2016). Chapter 7 provides stage development of a model of capability for good work design and this is tested through a survey of informed professionals about their experience with good work design. Conditions of necessity and sufficiency are tested, and simple correlations are provided also. A general overview of the structure is provided (Figure 1.1):

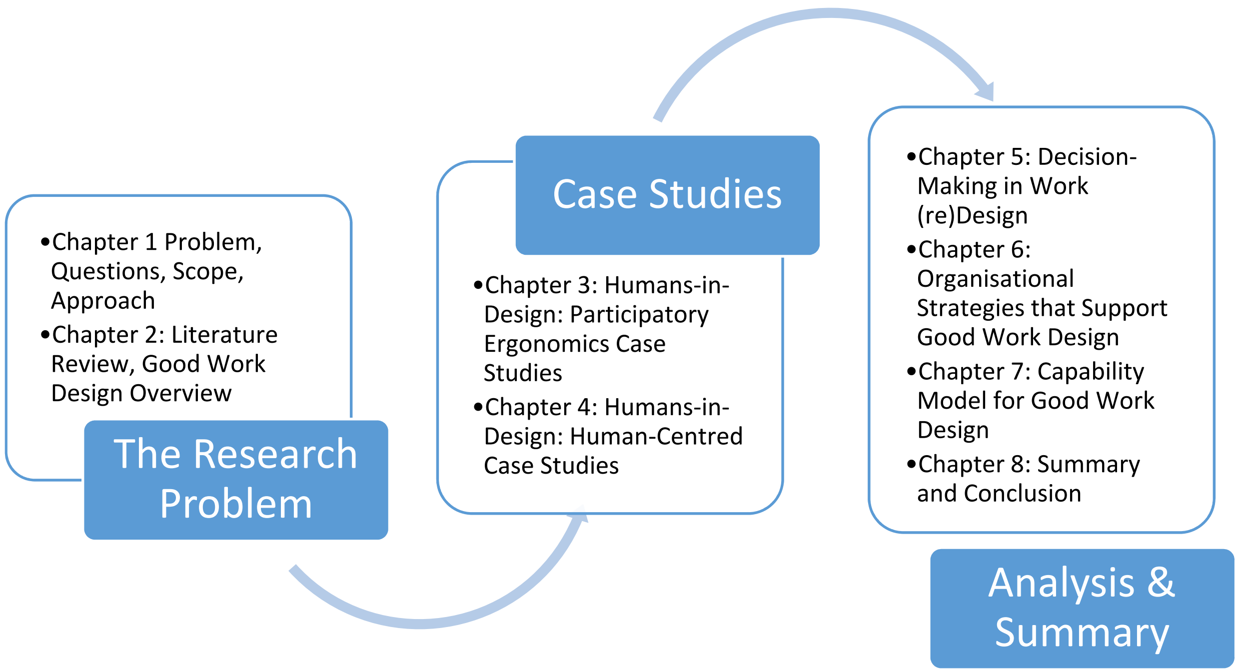


Figure 1.1: General Overview of the Thesis

1.3 Research Questions

This thesis aims to identify the resources and capabilities required for good work design and to document the outcomes that can be achieved by effective practice of work design. The overarching research question is:

How can organisations achieve good work design?

And in particular,

What are the necessary conditions to achieve good work design?

and

What tools, practices, activities, structures, systems, conditions, and culture are required to achieve human-centred work?

The organisations investigated in this thesis represent heavy industry: construction, mining, and transportation and the following sub-questions have been asked:

Chapter 3:

What were the necessary conditions for success for three participatory ergonomics projects?

Chapter 4:

What tools were useful to good work design for two cases involving capital equipment consideration and what were the necessary conditions to support this design process?

Chapter 5:

What decisions were made during a design change in a participative ergonomics project? What conditions influenced these decisions?

Chapter 6:

What conditions were necessary to enable the success of an established participatory ergonomics program?

Chapter 7:

In the opinion of specialists in this field, what organizational conditions are necessary to achieve good work design?

1.4 Thesis Structure

The investigation of the means to achieve good work design in organisation was undertaken through five interrelated components: participatory ergonomics cases; human-centred design examples; decision making to support design; a program review;

and questionnaire with the development of a preliminary capability model. An exploratory approach was undertaken, and linkages were made among human-centred design, decision making, and organisational performance. Figure 1.2 illustrates the detailed thesis structure.

Chapter 2 contains the literature review describing work as a prescription for health and relates how good work design, through participatory ergonomics, human-centred approaches, and human systems integration, may foster health, well-being, productivity, and sustainability.

In Chapter 3, participatory ergonomics case studies are described including the task selection, hazard identification, biomechanical risk determination, design processes and strategies, outcomes, and evaluation of these outcomes.

In Chapter 4, two human-centred studies about capital equipment design were described. Descriptive modeling was undertaken through application of the Functional Resonance Analysis Method (FRAM). The FRAM model visualizer software (version 0.4.1) was used to examine the macro-design of work systems that supported the reviews.

Chapter 5 provides a case study that examines the detail of decision making employed in a participatory ergonomics task (re)design project in which the program was in the early-adoption stage.

In Chapter 6, unstructured and semi-structured interviews were conducted with review of relevant documents and reports to determine program methods and outcomes of a mature participatory ergonomics program in place at a Bauxite mine.

Chapter 7 investigated statements of necessity that support good work design. A survey was conducted among informed professionals (n = 27) to evaluate their work design projects and the organisational systems that provided for those projects. Necessary condition analysis was applied and a capability model for good work design was constructed.

Chapter 8 summarises the results of the five main studies and describes how the findings link to, and advance, previous research. Contributions to knowledge were described and these include predictors of ergonomics project success and indicators of human-centred design program capability and resilience.

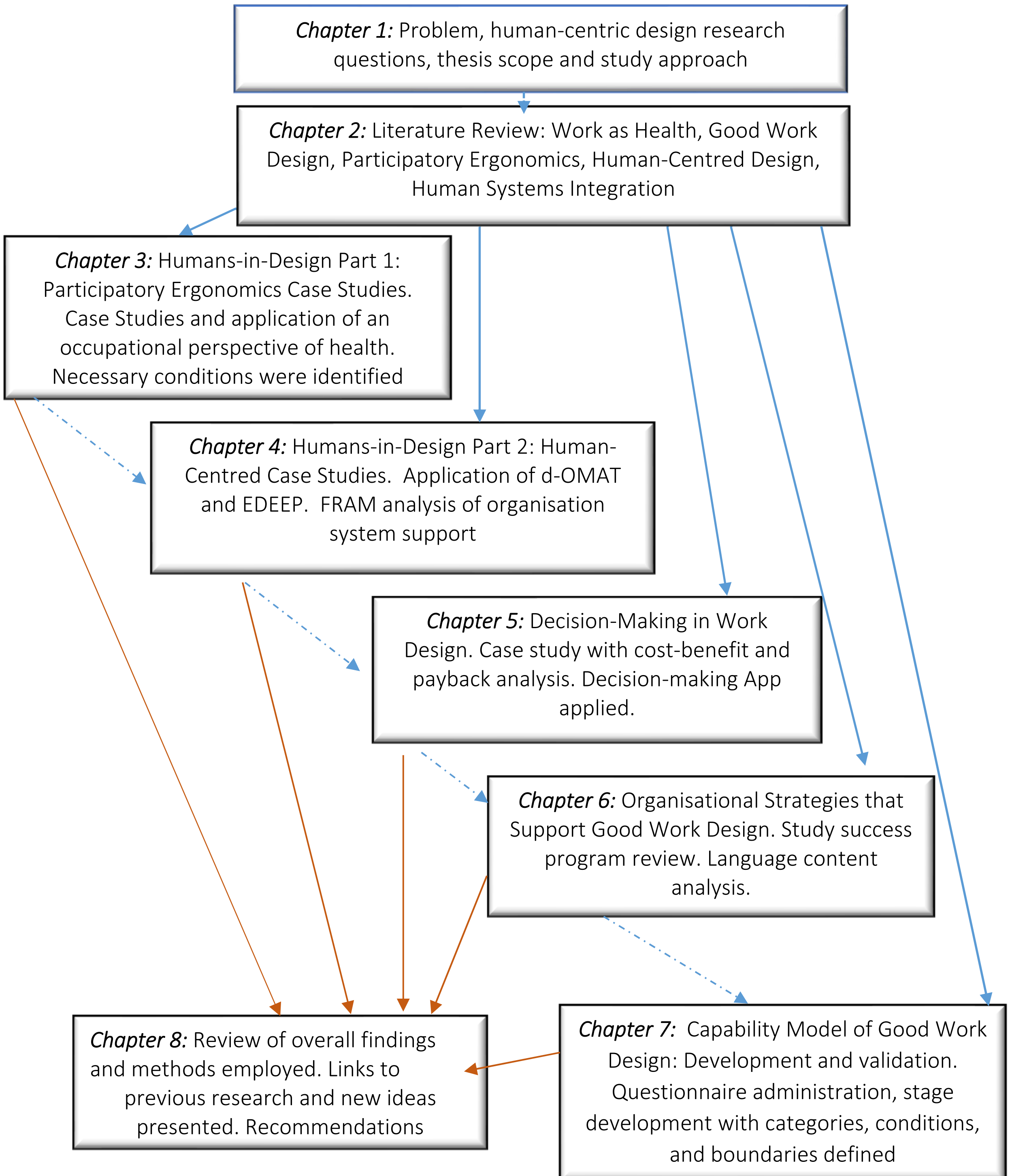


Figure 1.2: Detailed overview of thesis structure

1.5 Methodology

The research involved a series of qualitative case-studies conducted within an action-research framework. Action research includes a reflective process which enables problem solving. It involves research participants to solve problems, improve practice, and inform theory (Stringer, 2014). The outcomes of the case-studies were described for comparative case review, single case reviews, and a program review. Cases were selected for their ability to best inform the research questions and enhance the understanding of the phenomenon under study. The selection decisions were made considering the research question, theoretical perspectives, and evidence that findings could be informative (Sargeant, 2012). Survey analyses of ergonomics program specialists were also conducted.

These methods enable double-loop learning (Argyris & Schön, 1974) – a consideration of what is done; how it relates to, or contrasts with, theories governing ergonomics practice; and how theory may be revised to support successful practice. Case study research is a strategy that is useful for theory-testing and -development which may inform practice also. (Dul & Hak, 2008). The following assumptions underpin the methods employed to examine the research questions:

Theory: Good work design maximises productivity, health, and safety

- Object of study (a stable characteristic of the theory): Good work design
- Concepts (variable characteristic of the objects): conditions; and success (or effectiveness), also a variable characteristic, may be present or absent or *present to a certain extent*
- Proposition: Necessity and necessary conditions. Necessity is considered by pragmatic determinism as a proposition (e.g. Dul & Hak, 2008)
- Domain: within organisations that met the selection criteria for study. Generalisability was enhanced by survey results representing views held among participants representing several organisations anywhere in the world.

The methods employed encourage examination of espoused theories and theories-in-use (Dul, 2016b). An extensive literature review was conducted to derive espoused theories about human-centred design practice, how it should be conducted, and the outcomes that may be expected. Case studies were described to examine what is done (ie. theories-in-use). Case studies may serve as building-block studies (e.g. George & Bennett, 2005), and confer theory to support the generalisability of a proposition. The action-based learnings that support the findings in literature can be considered single-loop learning (Argyris & Schön, 1974). When discord is discovered among theories and practice, a new perspective may arise (George & Bennett, 2005) and recommendations can be made for a change in governing variables; this is representative of double-loop learning (Argyris & Schön, 1974).

The action scientist and study participants serve as interventionists in this framework, describing findings and also determining methods to improve, change, and adapt (Argyris & Schön, 1974) from which new theory can arise. Interviews with comparative case study are important to study social phenomenon. The findings reflect a sense of reality experienced by the study participants, a shared discourse and understanding of that reality with the researcher, and the subjective process of theory development that is useful (Burgess-Limerick & Burgess-Limerick, 1998).

Generalisability of findings can be enhanced through replication (further case studies) or new research to address the proposition. This was undertaken by program review and survey. Figure 1.3 depicts this action research framework.

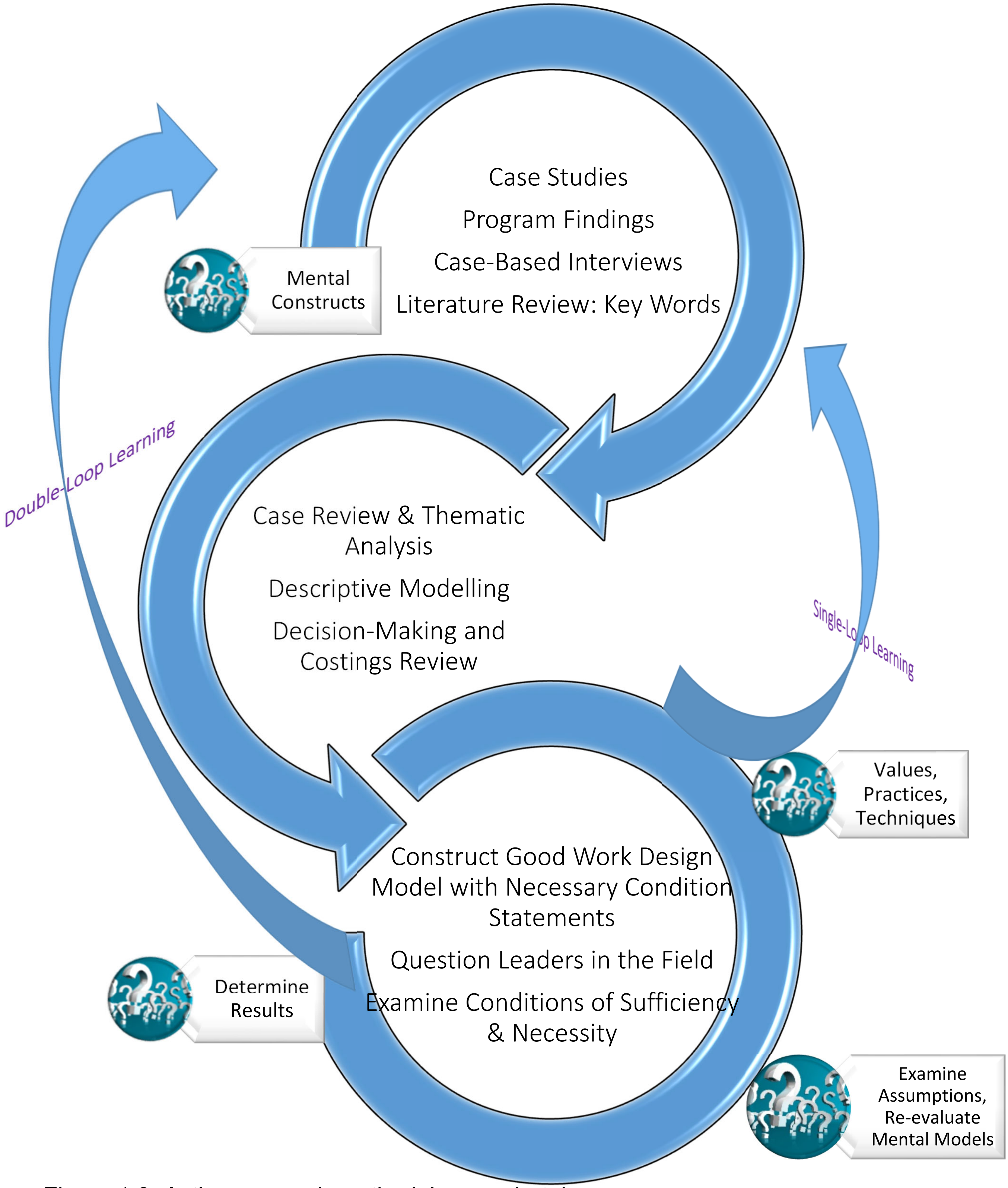


Figure 1.3: Action-research methodology undertaken

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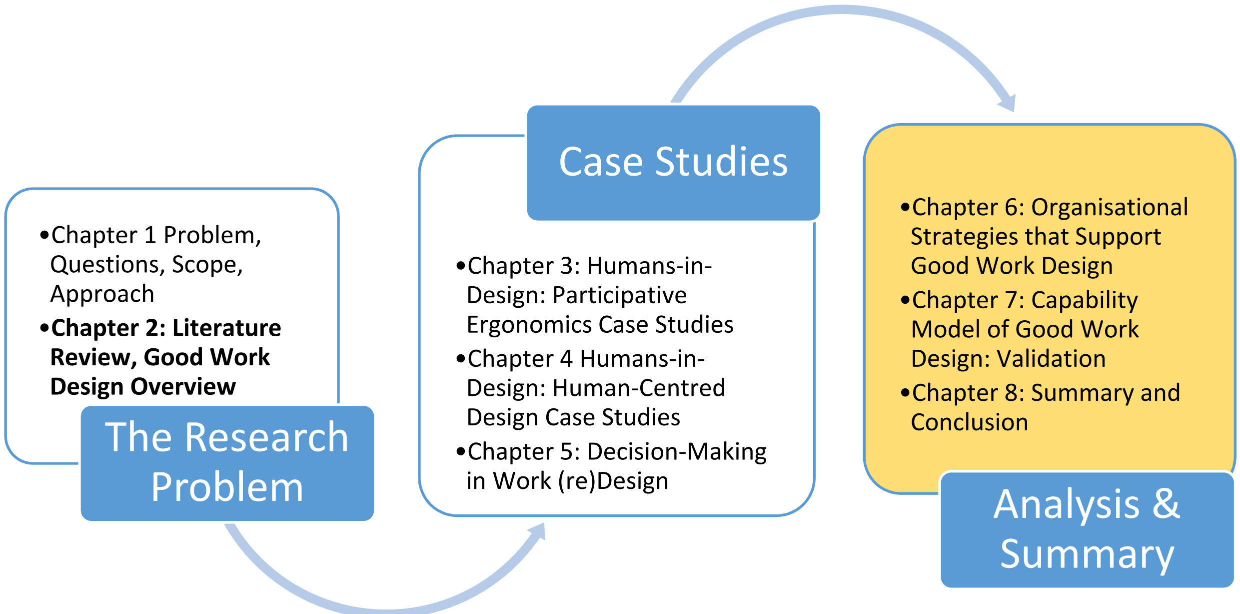
Chapter 2: Literature Review and Good Work Design Overview



Abstract

Work enables well-being: it provides daily routine and structure, a means for income and wealth creation, physical and mental conditioning, socialisation, a sense of coherence, and societal contributions (AFOEM, 2011; AIHW, 2013; Waddell & Burton, 2006). The design of work determines the extent to which work is a positive experience, conducive to health or well-being and competitively positioned in the marketplace; or an undertaking in which employees are exposed to risk leading to ill-health or injury (Burke, 2014; SWA, 2015a; Sorensen et al, 2016). The concept of well-designed work as a prescription for health and well-being is explored. Total Worker Health® precepts and the requirements for good work design are introduced. Definitions are provided and barriers to the practices are described.

2.1 Introduction

Productivity, health, happiness, and social connectivity may be attributes of ideal working conditions. Workers are most satisfied when they experience a sense of control, job security, adequate workload, and a sense of flexibility in their schedule (Thomas et al, 2006). The job content is, ideally, stimulating; and the social environment should provide opportunities to form positive relationships. The physical environment must meet work capacity. Employees prefer role definition and clarity, and they respond well when provided an opportunity to contribute to changes as they occur (Murphy & Schoenborn, 1987; Thomas et al, 2006). Further, work should provide an opportunity for learning, development, and growth (Murphy & Schoenborn, 1987).

2.1.1 Work as Health

Work provides meaning, structure, and routine. It promotes health and supports well-being. It reduces poverty and social exclusion, anxiety, and stress. It provides a forum for activity-based rehabilitation and development of people with disabilities or those who may otherwise be disadvantaged by social circumstance. Health indicators for workers and their families are more positive than for those of non-workers (AFOEM, 2011; Waddell & Burton, 2006). Work is by far one of the most influential factors linked to the reduction of social disparity. It acts to reduce the social gradient in physical and mental health and is correlated to better mortality rates. Work may be therapeutic and reverse adverse health effects attributed to unemployment (Waddell & Burton, 2006).

The Australian Institute of Health and Welfare (AIHW) (2013) describes economic participation as "… engagement in work and/or education, and … access to economic resources that result(s) from such participation" (p. 47). The Institute cites lower prevalence of risk factors to health such as smoking and obesity among working adults. Further, work fosters social conditions that provide for optimal child development and contributes to a positive link to mental health and wellbeing (AIHW, 2012; 2013).

There are societal factors associated with health for which economic participation largely contributes: income, education, and employment (Raphael, 2009; AIHW, 2013). Work engagement provides a means to achieve health. The societal forces - economic, social, and political platforms - can affect access, quality, and cost of work and education. When viewed from an opportunistic perspective, health begins where we live, learn, work, and play (World Health Organisation, 2012). To achieve well-being, we must be pre-emptive and not merely focus on ill-being. Health must start long before illness: our jobs may be one area where health may be fostered and where it may begin (Robert Wood Johnson Foundation, 2010). As such, work provides a medium to positively promote health and well-being. However, work conditions should be safe and accommodating (Waddell & Burton, 2006). The design of work systems, tools, equipment, artefacts, leadership models, communication and operational systems, workplace culture, and organisational strategic intent is, therefore, vital to health and safety (SWA, 2015a).

Traditional and stereotypical approaches to occupational health and safety are to characterise work in terms of exposure to sources of harm and to focus on the risks associated with these hazards (Waddell & Burton, 2006). Governance, safety management systems, hazard identification checklists, and risk assessment tools focus on the risks of adverse safety and health outcomes. However, there is an important link to the beneficial effects of work on health and well-being (The AFOEM, 2011; Waddell &

Burton, 2006). It is, therefore, necessary to determine qualities – the what, when, why, and how – of the governance, systems, leadership, work methods, tools and practices that may be engaged to ensure that work does not contribute to ill-health, illness, injury, or fatality but rather becomes a driver of health and well-being (Randall & Nielson, 2012; Carayon, 2006; Karanika-Murray & Weyman, 2013; Vink et al, 2006).

A frequently cited definition of health is that provided by the World Health Organisation (1948):

> *Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.*

However, health is a construct that may be interpreted in many ways. It is influenced by culture, and the meaning may change with the zeitgeist (Biron et al, 2012; Karanika-Murray & Weyman, 2013). Health reflects a state of being and relativity which will affect health determination (Australian Bureau of Statistics, 2001). In the workplace, health is often determined and measured by prevalence and severity of injury, or fatality (Rivilis et al, 2008).

Some agreement exists regarding the general tenets of good health: it occurs during our everyday existence of work, play, and living and serves as a pathway toward attainment of well-being (Kickbush, 2013; Ostrowski & Sikorsa, 2014). Workplace health programs offer residual, effective, positive changes when programming is integrated into core organisational strategies and aligns with business need. The programs are most useful when they engage all levels of the organisation, target populations most in need of intervention, and the messages and programs are simple (Karanika-Murray & Weyman, 2013; Kickbush, 2013).

An organisational systems approach to the design of work is required to achieve effective outcomes (Henning et al, 2009; Karanika-Murray & Weyman, 2013; Nobrega et al, 2017). Targeted intervention with changes to socio-technological systems may be far more constructive than less evidence-based models of behavioural change (Carayon, 2006; Henning et al, 2009; Karanika-Murray & Weyman, 2013). Herein lies the tension between traditional public health initiatives employed in the workplace: when an individual behavioural change model is adopted, there is risk to divert attention from deep and fundamental workplace influence on employee well-being (that is founded in the design of work) (Karanika-Murray & Weyman, 2013; Kohler & Munz, 2006; Mellor et al, 2012; Munz et al, 2001). Organisational interventionists posit that, to promote health and achieve organisational high-performance, changing the nature of work and work environment is far more effective than changing people. Changing the nature of the work and conditions of the workplace addresses sources of stress: it is preventive. Changing people is a latent intervention to wrestle with consequences of stress exposure: the action is corrective (Burke, 2014). However, implementation of an organisational-level intervention is a complex and difficult undertaking (e.g. Wester & Burgess-Limerick, 2015) and this may be part of the reason organisations continually default to individual-based behaviour programs (Burke, 2014; Kompier et al, 1998; Pazell & Burgess-Limerick, 2015b). Health may extend beyond that of individual workers to the health of team dynamics and the organisation, its goodwill and reputation, social justice, sustainability practices, and business objectives.

Total Worker Health®: Integration of Practices

Total Worker Health® (TWH) is a concept that signifies the expansion of traditional occupational safety and health initiatives to include targeted practices that also achieve well-being in the workplace (Anger et al, 2015). The term was trademarked in 2011 by the National Institute for Occupational Safety and Health (NIOSH). A TWH approach is defined as policies, programs, and practices that integrate protection from work related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being (CDC, 2016a).

TWH activities prioritise a hazard-free workplace to protect the safety and health of workers, contractors, suppliers, and visitors. The approach advocates integration of the policies, procedures, and practices that contribute to a continuum of safety to well-being. This encompasses workforce strategy, inclusive work policies, procurement strategies, design of work and equipment, the creation of a health-supporting built environment, positive workplace relations, and assignment of work (Schill & Chosewood, 2016; Sorensen et al, 2016). It represents organisational systems-based thinking and planning. TWH is not an isolated wellness program. It does not advocate a singular behavioural approach to health intervention, nor does it represent a collection of health promotion activities without recognition that the very organisation of work, environment, and tasks may contribute to injury and illness. TWH advocates a co-design approach with collaboration of design specialists, employers, and workers. The work environment, by its nature and design, should provide a forum in which workers may be most likely to make safe and healthful choices and employ safe work tactics (Schill & Chosewood, 2016). Flexibility in work design is one method to empower workers, as is providing role clarity and enabling workers to focus on tasks most critical to high-performance (Hammer & Sauter, 2013). The emphasis is on changing the work environment, tasks performed, and equipment, not changing the worker. The tendency to provide programs solely for individuals and behaviour-change, rather than tackling system-wide policies and work practices, has been labelled "regression to the individual" (Sorensen et al, 2016); and it is considered ineffective (Karanika-Murray & Weyman, 2013; Sorensen et al, 2016).

The methods describing how to achieve such integration are unclear (Anger et al, 2015; Pronk et al, 2016; Sorensen et al, 2016). There is no off-the-shelf recipe and programs must be customised and contextualised. Evidence supporting the actions is required and the research is emerging (Pronk et al, 2016; Sorensen et al, 2016). Despite this, efforts are being made to advance the ideas and initiatives. The Australasian Faculty of Occupational and Environmental Medicine (AFOEM) has released a consensus statement to reflect shared beliefs regarding the health benefits of good work and how this may occur (AFOEM, 2015). The consensus statement addresses the need to facilitate connectivity to the workplace during rehabilitation or recovery from illness, to embrace inclusive employment practices, and to foster positive relationships to provide for a work environment that supports physical and mental well-being. The statement acknowledges the connection among good work, health, and increased productivity as well as socioeconomic benefits on a broad scale (AFOEM, 2015).

2.1.2 Good Work Design

Safe Work Australia's Good Work Design handbook (SWA, 2015a) describes the how, what, and why of positive features of "good work":

> *"…where the hazards and risks are eliminated or minimised so far as is reasonably practicable… (where) … design optimises human performance, job satisfaction, and productivity" (p. 5).*

Good work is "*healthy and safe work where the hazards and risks are eliminated or minimised… (and) where the work design optimises human performance, job satisfaction, and business success*" (Hawkins, 2015). While this concept of designing work for health is well-rooted in ergonomic practice (e.g. Horberry et al, 2011; Horberry et al, 2014; Grandjean, 1986; Karwowski, 2012; Oakman & Chan, 2015), it is now also a sentiment emerging in safety management sciences (e.g. Safety I and II, Hollnagel et al, 2013).

Ten fundamental principles of good work design are described in the table below (SWA, 2015a):

Table 2.1

Safe Work Australia: 10 Principles of Good Work Design (2015a)

Tenets	Principle
Why?	1. Good work design gives the highest level of protection so far as is reasonably practicable 2. Good work design enhances health and well-being 3. Good work design enhances business success and productivity

What?	4. Good work design addresses physical, biomechanical, cognitive, and psychosocial characteristics of work together with the needs and capabilities of the people involved 5. Good work design considers the business needs, context, and work environment 6. Good work design is applied along the supply chain and across the operational lifecycle.
How?	7. Engage decision makers and leaders 8. Actively involve the people who do the work, including those in the supply chain and networks 9. Identify hazards, assess, and control risks, and seek continuous improvement 10. Learn from experts, evidence, and experience

A "work designer" makes decisions or regulates design or (re)design of work (Hawkins, 2015). This may include design experts such as engineers, ergonomists, architects, or interior or industrial designers, and decision-makers including operations and team leaders (e.g. Hawkins, 2015). Good work design preferably would occur throughout the supply chain. One such example is that found in the department of New South Wales Rail Transport Industry to ensure contracted vendors of engineering or design services adopt a human factors integration practice (Transport for New South Wales, 2015). This is an important driver because, despite its positive role in the design process, few designers use human factors & ergonomics methods (Salmon et al, 2016).

2.1.3 Humans-in-Design

A human-centric design practice provides for good work design: it is collaborative and consultative (Burgess-Limerick, 2011); considerate of hierarchical risk-based task requirements (Horberry et al, 2011); addresses the continuum of safety to well-being (e.g. Cantley et al, 2014; Laing et al, 2007; Laitinen et al, 1998; Lallemand, 2012); and lends to effective business performance (Dul & Neumann, 2009; Vidal et al, 2012). Humans-in-Design (HiD) is a term coined by Tristan Cooke (http://humansindesign.com/). It is reflective of human-centric design practices such as participatory ergonomics, human-centred design, human factors and ergonomics, and human systems integration; and it is likely a variation of the term used to describe the momentum of Safety in Design (e.g. Horberry, 2014).

Definitions of key terms used in this thesis about human-centred and good work design in organisations include:

- **Human Factors**: A body of science derived from core disciplines – e.g. psychology, engineering, exercise physiology, sociology, anthropology, environmental science, occupational science, and design – to consider human motivation, drives, behaviour, habits, cognitive patterns, performance capabilities, physical fit, preferences, task demands, cultural context, and environmental exposure, to provide for effective work systems design (Horberry et al, 2014; Horberry et al, 2011; Karwowski, 2012). Human factors enable consideration of a range of human tactics that may occur because of system design. When results are not desired (such as a fatality, injury, or production decline), systems review, and design strategies are warranted. The interpretation of events does not rest with "human error". Humans are viewed as contributors to a system in which implicit decision making may enable effective work practice.
- **Ergonomics**: Ergonomics is a term arising from "ergon-nomos" or "the study of (humans at) work" (Grandjean, 1986). The term is often used synonymously with Human Factors, with applications spanning physical, cognitive, and organisational realms.
- **Participatory Ergonomics**: a practice that actively engages end-users as participants in task analysis, hazard identification, risk determination, and control development (Burgess-Limerick, 2011). In this way, valid and contextualised analysis of work is evidential and provides meaningful rationale for intervention. Outcomes typically involve the (re)design of tasks or equipment.
- **Human-Centred Design**: Design to organise equipment, technology, and work practice centric to the goals, tasks, capabilities, and needs, of operators and maintainers. This approach is recognised to enhance user ability to interact with

equipment, process information, make decisions, be productive, maintain situation awareness, and it increases user acceptance (Endsley & Jones, 2012; Horberry et al, 2011). This often includes task-based, predictive design review, considerate of workforce strategy, to inform procurement of purchasing specifications.

- **Human Systems Integration**: the consideration of human capabilities into lifecycle design of work systems and equipment; an integration of human-centred design methods with safety systems engineering (Booher, 2003a; Burgess-Limerick, 2010).
- **Human Performance Technology**: The tools and systems of approach that may be applied to optimise productivity, success, and competence and contribute to resilient, adaptable problem-solving capability at an individual, team, and organisational level (US Department of Energy, 2009).

A definition of good work design is provided (adapted from Spirovski, 2018):

- **Good Work Design:** The process of identifying human opportunities and problems through inquiry and bringing people & teams together to create solutions that can be empirically demonstrated to provide robust, positive outcomes; a method of achieving prosperous human conditions**.** The term “good work design” may be considered synonymous with “good work (re)design” or “effective work design”. It advances Total Worker Health® and is underpinned by the tenets of human-centred design and participatory ergonomics.

The entity is defined:

- **An organisation:** The framework and environment in which people and teams apply tools, practices, and activities; engage and interface with equipment; navigate structures, systems, and conditions; and create culture to achieve a common goal and advance business (operations, strategy, and profit).

Human Factors and Participatory Ergonomics

Human factors and ergonomics involve design-based sciences so that the human experience may be enhanced. While the science and intervention are grouped into three primary domains: physical, cognitive, and organisational (International Ergonomics Association, 2015), they also reach into the space of green design: energy efficiency and sustainability in which there is interplay within the triad of people, plant, and productivity (Hedge et al, 2010; Thatcher, 2012).

"Activity ergonomics" (Daniellou and Rabardel, 2005; Barcellini et al, 2015) is another emerging term referring to a constructive design approach. It is seen to contribute to strengthening sociotechnical systems, demonstrative of organisational justice, and refers to the interplay of:

1. Ergonomic work analysis
2. A participatory approach
3. Simulation of work

This process encourages robust, dynamic, participatory, collaborative, and engaged activity (processes) rather than focusing on one specific design solution. It develops skills among workers, distributes decision making functions, maintains investment of key stakeholders, restructures social relations, and promotes design activities. Design, in this vein, captures the rich understanding of the variability of work as it occurs in the real world (Barcellini et al, 2015).

Activity ergonomics, akin to participatory ergonomics, involves field research. Field research helps investigators best understand the adaptive responses and variability in work tactics. This process permits a valid understanding of human performance and work conditions (Gauthereau, 2003; Hollnagel, 2002; Nuutinen, M., 2005).

Dennis (2016) coined another term, "active collaborative ergonomics (ACE)", a variation to participatory and activity ergonomics. The rationale being that this implies a stronger co-design partnership with workers than the term "participatory" may suggest.

Benefits of Participatory Ergonomics

Participatory ergonomics helps workers become architects of work systems, procedures, and equipment (Burgess-Limerick, 2011; Cantley et al, 2014; Pazell & Burgess-Limerick, 2015a; 2015b). These methods go beyond co-design and user-experience because they draw upon evidence-based findings related to optimum work conditions. A participatory process, involving workers in the identification of hazards, determination of risk, development of strategies to design and (re)design work, iterative design trials, and evaluation of work improvement, is central to the practice (Burgess-Limerick, 2018).

The benefits of participatory ergonomics include improved productivity and efficiency; fewer design-induced errors; reduced risk of adverse health and safety events; improved user satisfaction, uptake, and engagement; and reduced costs overall (Burgess-Limerick, 2010; Burgess-Limerick et al, 2011). Through these participatory practices, there is improved flow of helpful information, rapid change processes, and improvement in the meaningfulness of work (Burgess-Limerick, 2018). Participatory ergonomics is recognised to improve work climate, positively affect safety culture, and improve communication (Laing et al, 2007; Lallemand, 2012). It also prevents musculoskeletal disorders (Burgess-Limerick, 2011).

Wilson (1994) presented three primary elements required to effectively manage ergonomics programs: providing a foundation, supporting the proliferation of ergonomics, and embedding ergonomics in workplace design and organisational systems. A major task facing occupational ergonomists is to work with companies to evolve random or incremental activities and incorporate these in core business strategy (Wilson, 1994).

Participatory Ergonomics and Workplace Health Intervention

The International Ergonomics Association Council provides a definition in which ergonomics is considered to, "… optimise (human) well-being and overall system performance" (IEA 2015). Ergonomics programs have merit well beyond the link to safety performance and occupational health (Dul & Neumann, 2009; Vidal et al, 2012). Design of work for health is part of a continuum of design of work for safety (e.g. Dul & Neumann, 2009; Laitinen et al, 1998; Punnet et al, 2009). Laitinen et al (1998) demonstrated a significant link between psychosocial and physical work conditions by observing the dynamic state of an organisation and assessing worker perception about the company, their jobs, their future, and their work. They concluded that technical improvements in equipment, work, and work systems, through a participatory ergonomic process, provided an absolute and tangible means to achieve favourable impact on psychological health profiles of work. Post-intervention their subjects perceived improved prospects for their future and viewed their company more favourably as one that became more goal-oriented. Communication and learning possibilities were perceived more positively.

The health interventions of participatory ergonomics are, typically, referred to as those that target occupational health and safety and the absence of infirmity, not promotion of public or organisational health (Haslam, 2002; Henning et al, 2009; Vink et al, 2006). Vink et al (2006) argue the need to focus on the positive side of ergonomics: aspects to promote productivity and comfort, for example.

Ergonomics may be integrated with sustainability and well-being in the built environment for offices through voluntary initiatives. In Australian green building design, an ergonomics credit for offices requires consideration of interior conditions and equipment that is supportive to worker health and comfort by design. It also must represent sustainable manufacture for construct, recycling, and deconstruct (GBCA, 2015). A new Well Building Certification is available for competitive design and build projects to support conditions of health and sustainability (International Well Building Institute, 2015).

Clearly, models for safe design are aligned with health promotion initiatives when approached from a perspective of organisational design (e.g. Haslam, 2002; Karanika-Murray & Weyman, 2013; Randall & Nielson, 2012; Vink et al, 2006). Methods to improve occupational health and safety in the workplace are similar to those employed in community health promotion. The platform of design for safety through the continuum of health and wellness must be better articulated, integrated, and exhibited (Urlings et al, 1990; Haslam, 2002). This is a challenge to traditional practice. Few organisations engage a broad perspective to associate health and well-being promotion with their own organisational drivers – job design and role assignment, leadership, reward, and the underpinning work climate. In fact, when workplace health or wellness programs are ad-hoc, not integrated with business strategy, and adopt only a lifestyle perspective, they do little to address leading causes of absence: e.g. workplace stress and anxiety, mental health overall, critical events resulting in death or disability, and musculoskeletal disorders (Karanika-Murray & Weyman, 2013).

Human-Centred Design

Human-centred design considers humans to be the focus of design: human needs, work capacity, tasks, environmental conditions to which they are exposed, conditioning and health needs, social performance, and productivity goals. Design philosophy organises technology and work systems around the users' and stakeholders' goals, tasks, capabilities, and needs. The process minimises exposure to hazards and mitigates safety and operational risks. Human-centred design organises technology around the ways users process information and make decisions. It aims to keep users in control and aware of the state of the system. Human-centred design results in providing a user with vital information, optimising situation awareness, reducing errors, and improving productivity. Ultimately, human centred-design is found to increase user acceptance (Endsley & Jones, 2012; Horberry et al, 2014; ISO 9241-210: 2010a). Human-centred design enables product interaction that is intuitive or consistent with past adaptive habits and behaviours. For example, the QWERTY keyboard input format or the use of foot pedal plantar-flexion ("push down") for both braking and accelerating functions in a vehicle may not be considered intuitive and require adaptive learning (Noyes, 2001). Since adaptations have been made in the past, those design formats may need to persevere in design iterations in years to come to enable ongoing positive performance. Innovation and new products, however, may provide for intuitive interaction, where instruction and learning are minimised (e.g. touch screen interface supports children's use of technology). The outcomes of human-centred design may positively engage operators and maintainers who, through the process of guided consultation, are involved in the task analysis, risk determination, and design process. Successful design requires smart leadership, sound group dynamics, and solid communication (Horberry et al, 2014).

When applied to a system lifecycle, human-centred design is a subset of "human-systems integration" (Booher, 2003a; Horberry et al, 2014). Human-systems integration has been defined as "the process of integrating domains of human factors engineering, systems safety, training, personnel, manpower, health hazards, and survivability into each stage of the … systems capability lifecycle" (Burgess-Limerick, 2010, p. 51). Human-systems integration emphasises the availability of human-centred methods throughout a work life cycle (ISO 9241-210: 2010a). This approach specifies that design is based upon an explicit understanding of users and stakeholders, work requirements, task demands and task flow, and environment. Accompanying this should be a multidisciplinary design team with varying skill sets. Design is driven and refined by user-centred evaluation; the process is iterative; and the design addresses the whole-user experience (Horberry et al, 2015; ISO 9241-210: 2010a).

A systems approach to design is a strategy in which business units from operations, procurement, workforce strategy, maintenance, engineering design, safety, environment, and health, for example, work in unison toward shared objectives (Horberry et al, 2014; SWA, 2015a; US Air Force, 2009; Wilson, 2014). To support this, fieldwork is often essential. Fieldwork enables observation in the natural environment and enhances knowledge of the complex socio-technical system in which safe, health-promoting, and productive activity is desired (Carayon, 2006; Vincente, 1999).

Benefits of Human-Centred Design

"Healthy and safe by design" is one of seven key action areas of the Australian Work Health and Safety Strategy 2012 – 2022 (SWA, 2012). Safe design, through a systems approach to human-centred design, is purported to be the most resilient means to create a healthy and safe work environment (SWA, 2015a; SWA, 2012). Design is inclusive of equipment, task, and workstation; management practice; and work processes. Similarly, The Center for Disease Control (CDC), National Institute for Occupational Safety and Health (NIOSH) (2016b) states:

"One of the best ways to prevent and control occupational injuries, illnesses, and fatalities is to design out and minimise hazards and risks early in the design process." (p 1).

Human-centred design saves money and prevents injury. In a project commissioned by the Australian Department of Defence, Burgess-Limerick (2010) conducted a review of publications describing benefits of human-systems integration. A systematic, life-cycle approach to human-centred design and risk management led to return on investment in ratios of 40 – 60:1 (Burgess-Limerick, 2010). Stand-out examples include:

- The Comanche helicopter acquisition program in which design investment of 4% of the research and development budget ($75M) resulted in a cost avoidance of $3.29B or 44:1 return on investment, with consideration of 91 fatalities and 116 disabling injuries over 20 years (Booher, 2003a).
- The US Air Force report (2009) confirms that return on investment of human systems integration in design planning ranges 40 – 60: 1.

In New South Wales, Australia, the Transport Assets Standards Authority of the Department of Transport for New South Wales has issued requirements for any Authorised Engineering Organisations (AEO's) with whom they may contract to adopt, at minimum, a human factors integration practice. Their criteria require the integration of human factors in risk and engineering design analysis, with an approach aligned with system engineering. The goal is "to ensure human-system interactions contribute to optimise system performance, and identify and mitigate risk*" (Transport for New South Wales, 2015; p.7)*

In addition to the adoption of standard human-centred design practices, the Department of Transport for New South Wales requires engineering suppliers to capture, record, and communicate learnings associated with the operability and maintainability of project designs. In this way, sustainable design process is supported. The carry-over from lessons learned may enhance future design projects *(Transport for New South Wales, 2015)*.

Human-centred design is believed to reduce injury risks, and lead to fewer errors in operation, reduced training costs and user support requirements; as well as enhanced distributed situation awareness, and avoidance of costly system failures or unwanted and irrelevant (Giacomin, 2012; Horberry et al, 2015; ISO 9241-210: 2010a; Stanton et al, 2007).

Given that participatory ergonomics and human-centred design has a positive effect on work culture (Lallemand, 2012); offers strong return-on investment (Booher, 2003a; Burgess-Limerick, 2010; US Air Force, 2009); reduces risk for illness, injury and disablement (Burgess-Limerick, 2010; Burgess-Limerick et al, 2011; Cantley et al, 2014); and contributes to health (Horberry et al, 2011; Horberry et al, 2014; Grandjean, 1986; Karwowski, 2012; SWA, 2015a); the research required is not a summative evaluation of whether the practice is effective, but a rather formative or process evaluation as to how, why, in what circumstances, and under what conditions the practice should be undertaken (Cox et al, 2007; Nielson et al, 2007).

Barriers to Human-Centred Design

Despite the strong evidence conveying the efficacy of human-centred design to enhance a system in which humans (operators and maintainers) are a part, there are barriers to implementation. Kompier et al (1998), for example, lament the effort spent undertaking behavioural-based intervention programs rather than systemic organisational design because of an inclination of decision-makers to blame personality factors and lifestyles adopted by their workers. The risk attached to this view, they explain, is that the employee is considered at fault for their own health problems and potential threats and opportunities within organisational design are overlooked. Further, it may be that human factors & ergonomics methods tackle deterministic parts of a problem (e.g. manual task risks) while not addressing the underlying systemic issues (Salmon et al, 2016).

Horberry et al (2015) categorise perceived barriers to human-centred design in mining:

1. <u>The nature of the industry</u>: Design may be centred on technology. The legislative framework and relevant standards may not drive a human-centred design practice.

There may be litigation risks. There may be high-risk work areas restricted by geography that limits travel on-site.

2. The nature of humans: change to a new methodology may confront sensibility, past training, and experience; a diverse array of skilled stakeholders is cumbersome to coordinate and difficult to facilitate group cohesion; there may be skills gaps associated with operating or maintaining new technology; diverse and changing human needs may complicate an otherwise smooth and predictable design process; or situational leadership styles may not support creativity and design.

3. Design practice: lack of trained human-centred design practitioners; designers slow to accept change; tools and technology to support design may not be well known or distributed; difficult access to site for skilled design teams; reluctance to build an iterative framework into the design process; solutions and strategies may require systems changes and capital investment; accountability may be unclear; and an efficiency/time trade-off may drive short-term resolutions.

4. Selling human-centred design: few case studies selling the vision and supporting the cost benefit and payback exist – more research is required. A lack of widely distributed literature and guidance material exists, a lack of transparent funding streams in the organisation or externally through research bodies, few champions leading the way to influence industry uptake, and a lack of early involvement resulting in rework (versus predictive design practice) may appear costly.

Many of these barriers reflect issues associated with organisational readiness, leadership, and governance. Process and contextual issues likely to shape the success of workplace interventions include management support, employee engagement and perception, social climate, cultural maturity, level of ownership, and change readiness (Biron et al, 2012). There are external and internal drivers to program demand and success. This may span legislative and regulatory guidelines, customer need, organisational readiness, leadership, and resource allocation. However, the programs help workers experience a sense of efficacy when they champion sustainable change (Biron et al, 2012; Carayon, 2006; Haslam, 2002; Nuutinen, 2005).

2.2 Concluding Remarks

Good work design (and re-design) is topical because it addresses initiatives spanning safety, health, well-being, and productivity. It is aligned with the CDC NIOSH initiatives of Total Worker Health®. The tenets that support such design are human-centric. If machinery performance is evaluated without consideration of the interface with the worker and maintainer and the job for which it was intended under real conditions of use, it is unlikely to achieve the most productive, efficacious, and injury-free outcome. This may seem like a simple construct, but without good communication and shared goal-setting throughout the supply chain, or considerations for the lifecycle of the product, operational activity, worker, and maintainer, flaws in the system may become evident and engineering resilience may be compromised. The challenges arise when attempting to communicate this simple construct yet complex approach to decision-makers.

This study addresses issues of good work design, performance measures, lead indicators, methods (that are sustainable), decisions and decision support, and the gaps that may exist to help link good work design to organisational values, core business strategy, and business improvement.

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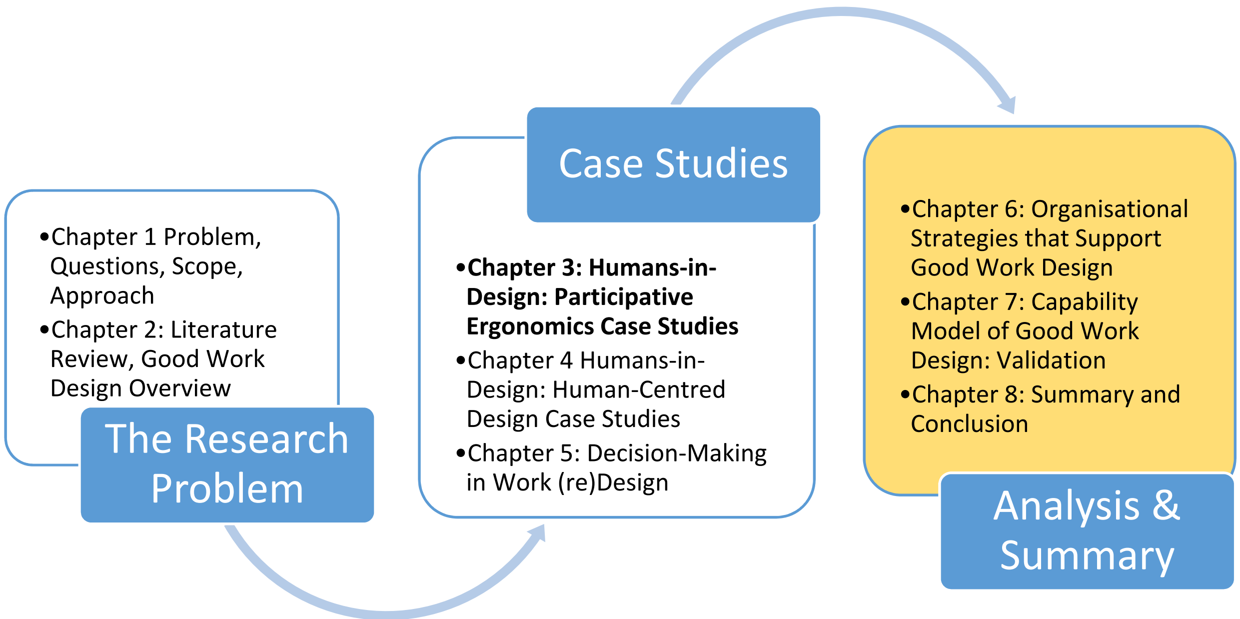
Chapter 3: Humans-in-Design: Participatory Ergonomics Case Studies



3. 1 Introduction

Participatory ergonomics programs have potential to improve worker engagement, safety, health, and productivity (Burgess-Limerick, 2018; Hignett et al, 2005; Wilson, 1994). Productivity is important in heavy industry. If one percent (1%) of productivity gains or savings could be achieved in the lifecycle of a quarry, mine, or large construction project, then a significant percentage of the initial project start-up costs (e.g. exploration, capital equipment, or planning) could be recouped. For example, a quarry that is allocated $120M start-up costs, with annual operational costs of $40 - $50M, over a 30-year life cycle, could stand to recoup 10% of initial start-up costs with a 1% positive shift in productivity (excluding calculations for the time-value of money; conservatively, $400,000 per year over 30 years = $12M). After the initial start-up costs of these projects (machinery expenses, raw supplies, and repairs), the most influential factor is productivity. Labour productivity is measured by the value-added per hour worked which, in heavy industry, tends to exceed corresponding measures in most other industries (Hendrickson, 2008; Syed et al, 2013). While these industries are capital intensive, and labour is a relatively small share of the total inputs, small changes to outputs or labour inputs lead to comparatively large changes in the measure of productivity (Syed et al, 2013).

While the impetus for good work design is often safety, a competitive business strategy uses the methods that advance worker health (e.g. Total Worker Health®, Anger et al, 2015; Hammer & Sauter, 2013; Schill & Chosewood, 2016) to achieve significant productivity gains (e.g. Burgess-Limerick, 2010; Dul & Neumann, 2009; Stanton & Baber, 2003). Unique methods are available through opportunity-based thinking (e.g. Bushe & Kassam 2005; Mishra & Bhatnagar, 2012) versus risk-based thinking (or solely risk-based thinking).

Participatory Ergonomics in Mining

The Coal Services Health and Safety Trust commissioned a feasibility study to evaluate the implementation of a participatory ergonomics program for manual tasks injury risk reduction. A formal program with risk reporting system was implemented at four underground and two surface mines (Burgess-Limerick et al, 2006; Burgess-Limerick et al, 2007). The participatory process was highly effective in determining work risks and generating intervention ideas (Burgess-Limerick et al, 2006). The sites with the most success were accepting of the idea that implementation takes time. A site champion was crucial to the process. They needed also to have support of management to drive the process (Burgess-Limerick et al, 2007).

A participatory ergonomics process implemented at a large surface coal mine was reviewed after 3 years of operation (Torma-Krajewski et al, 2007b). The program had strong leadership commitment and was successful. In three years, 55 hazards were identified, and 22 improvements resolved. Five concerns were under review and nine others were being determined for risk levels and control intervention. The remaining 19 were addressed as separate health or business concerns. To launch this program, the mine developed a separate ergonomics committee comprised of representatives of different business units who reported to the safety department. The overarching goal of the program was “to create a healthier workplace through employee involvement”. Over half of the interventions involved purchase of new equipment; however nearly all purchases were less than $USD 3000. In-house maintenance staff constructed some of the modifications. Mechanics submitted one-third of the concerns and heavy equipment operators submitted another third. The most frequently reported hazard was repetition exposure, followed by force (heavy manoeuvres), and forceful gripping. The areas of discomfort most commonly reported were in the lower back and wrists/hands. An alternative work approach was devised for impact wrenches reported to cause discomfort in hands, arms, and shoulders: the wrench was suspended from a crane, and this markedly reduced musculoskeletal injury risk and improved comfort. Another example is that of a truck which was returned to the supplier for improvement soon after delivery and inspection. Once trained in ergonomic process and manual task risk, expectations were raised, and work equipment was required to meet these new standards (Torma-Krajewski et al, 2007b).

Participatory Ergonomics in Construction

The construction industry exposes workers to hazardous manual tasks with awkward postures, force, exertion, repetition, contact stress, pinch points, vibration, and trip hazards (Boatman et al, 2015; Glimskar & Lundberg, 2013; Kramer et al, 2009). Physical demands are high and the control over product design and material selection has been limited (Kramer et al, 2009). Workers must make constant decisions in a rapidly changing environment affected by the traffic and activity of other people, mobile plant, and vehicles (Jaegers et al, 2014).

In a study of culture and change readiness, construction workers held the belief that risk of musculoskeletal disorders was inevitable in their work (Boatman et al, 2015). The study was conducted with interviews (n = 50) and focus groups (n = 4, a total of 48 workers). With little experience in ergonomic interventions, those interviewed did not consistently believe that the design of work could prevent pain or injury. However, with skilled facilitation, the workers offered a variety of control strategies and devised effective work solutions. The workers believed that awareness training and the purchase or design of new purpose-fit tools and equipment would support the workplace. However, the workers also believed that these risks were acceptable and part of the job. They described injury avoidance as a personal responsibility. They were skeptical that their employers were committed to workplace safety.

There are barriers to program implementation in the construction industry. These include perceived pressure to be productive; fear of job loss and subsequent low hazard reporting; a belief that the emphasis for safe work performance is driven by individual behaviour; a lack of awareness of risk and risk severity; a lack of awareness of methods or program models that are effective in risk reduction; and allocation of resource on behavioural strategies such as stretching programs versus work (re)design (Boatman et al 2015; Glimskar & Lundberg, 2013; Kramer et al, 2009). In contrast, program implementation is supported by workers who believe in its efficacy. When workers and management believed that work design, and not personal factors, influenced workplace risk, they were more likely to embrace the programs (Village & Ostry, 2010). Further, programs were better accepted in an environment where opinion leaders communicated positive messages about the opportunities afforded by workplace design (Kramer et al, 2014). An organisation that rated highest in readiness for change (willingness to commit budget and implement effective controls) was more likely to provide the climate for ergonomic service delivery (Rogers, 1995; van der Molenn et al, 2006; Village & Ostry, 2010).

Jaegers et al (2014) present the need to implement studies that evaluate program process as well as outcomes. Process evaluations, they argue, are not well documented by evidence of ergonomic intervention. This may include the methods of program implementation, scope, reach, and level of engagement. Further, models that provide for multi-modal evaluation of ergonomic process are more likely to be rich in meaningful data, sensitive to the complexity and uniqueness of an organisation.

Case Studies: Participatory Ergonomics

Case studies illustrate interventions and outcomes associated with participatory ergonomics. For example, in the quarrying industry, Vulcan Materials Company implemented participatory ergonomics and initiated early stages of predictive-human-centred design (Torma-Krajweski et al, 2007a). Examples include:

- Manual handling of metal from conveyor magnets replaced with the use of a container that interfaces with forklift tynes for waste removal;
- Exposure to dust, noise, and rotation forces through the body associated with driving stock trucks under bins replaced by automation of a remote-control bin-opener; and
- Exposure of risks to awkward loads and slips, trips, falls associated with pulling wash hoses up and down several levels of screen towers reduced by installing more valves and hoses on all tower levels.

In underground coal mining, Burgess-Limerick et al (2007) describe successful outcomes associated with participatory ergonomic program implementation:

- Reduction of risk for musculoskeletal disorder associated with roof bolting through design control recommendations to provide an adjustable-height platform, lowered drill motor height; (re)design of the dolly; and investigation of automatic bolting technology.
- Reduction of risk for musculoskeletal disorder and improved efficiency associated with changing pumps through the installation of an in-line air filter and lubricator to improve pump function; introduction of lighter-weight pumps; use of a rope on a frame to prevent the pump slipping during handling; and storage of pumps at different heights for improved power-lift access.

Participatory Ergonomics Program Implementation

Hignett et al (2005) outlines dimensions of participatory ergonomics programs (Table 3.1).

Table 3.1

Dimensions of Participatory Ergonomics Programs (Hignett et al, 2005)

Dimension	Description
Decision Making Power	Participatory practices suggest worker involvement. The Decision-making power may be retained by management and informed by worker consultation, or the power may be delegated to the worker.
Participant Mix	Front-line and/or technical staff, middle and/or senior management. Note: considerations may be afforded to maintainers and designers, also.
Remit	The extent to which participants are involved in establishing and monitoring the work design processes
Role of Specialist	The ergonomics specialist may be a facilitator, leader, trainer, expert team member, or available for consultation on an as-needed basis
Worker Involvement	Direct face-to-face involvement of all affected workers or a representative sample of workers
Focus	Design of tasks or equipment, or broad organisational issues and policies
Influence	The project may affect a work team, department, multiple business units, the entire organisation, or industry at-large
Requirement	Participation undertaken voluntarily or assigned within inherent job duties (this may vary among project team members)
Permanence	Temporary project or program to address an identified problem, or a program that has influence and is intended for permanent integration into ongoing continuous improvement activities.

In line with these participatory ergonomics program dimensions, Vink et al (2006) propose a classification model for success factors (Table 3.2).

Table 3.2

Classification Model: Success Factors of Ergonomics Programs (adapted from Vink et al, 2006)

Success Factors	**Description**
Involvement	Active participation of end users and maintainers, and stakeholders: participatory ergonomics.
Process	A solid inventory of issues, needs, problems, potential unwanted events, structured step-by-step approach, assigned steering group, and monitoring of effects.
Goal	Design philosophy and program intention clearly articulated in measurable terms for positive outcomes. Goals are achievable.

From this model, Vink proposes that the probability of success increases by the degree of empowerment as evidenced by "involvement" and the degree to which program participants have a positive experience as evidenced by the outcomes. Engagement, or employee participation and shared ownership of initiatives, is commonly perceived to be a prerequisite to successful implementation of organisational strategy (Kompier et al, 1998; Nielson et al, 2007). In Australian work health and safety legislation, the participatory process enables the person conducting a business or undertaking to discharge their duty to consult with workers (WHS Act 2011).

High levels of employee engagement are associated with high-performance organisations where retention of talent is likely (Harvard Business Review, 2013). Nielson et al (2007) suggest that a prerequisite to employee participation is evidence that their input will be translated into action. This is addressed in the model proposed by Vink et al (2006). Work factor success is associated with supportive process and tangible outcomes: e.g. were goals met and did task (re)design result in improved work performance? (Csikszentmihalyi, 1997; Vink et al, 2006).

3.2 Aims

The aim of this chapter is to examine the implementation of participatory ergonomics projects. Case studies will be employed to describe three participative ergonomics projects, two of which were facilitated by the investigator, and one which was facilitated externally and examined retrospectively. Verification of findings and the test for generalisability of the propositions is proposed through structured and semi-structured interview with industry partners about the factors (or conditions) that were necessary for these projects; interviews are a useful means to bring cases into conversation with one another through multi-case research (Burgess-Limerick & Burgess-Limerick, 1998).

The propositions include:

- Injury risk is reduced if tasks are (re)designed through human-centred practice
- Business improves if tasks are (re)designed through human-centred practice

3.3 Research Question: Chapter 3

What were the necessary conditions for success for three participative ergonomics projects?

3.4 Methods

Participatory ergonomics cases were included in the study first if they met the criteria of a task with moderate or higher levels of manual task risk (acute or cumulative); second, if they could be reviewed following a completed cycle of task (re)design: hazard identification, risk assessment, control identification, control trial, re-assessment, and implementation; and third, if they achieved a measure of success (risk reduction and/or business improvement) as evaluated by the organisations (e.g. Dul & Hak, 2008). Two of the cases examined were facilitated by the investigator. The third was facilitated externally and reviewed through interviews with the lead work design champion. The examinations included consideration of what occurred, and what was meaningful and influential (or necessary) to the project. Management, and workers involved in the co-design of the projects, were interviewed during review of these task (re)design projects. Analysis included review of relevant documentation such as hazard registers, risk reports, training material, newsletter communication, email communication, and policies and procedures.

The analysis included a review of outcomes and these were categorized through language content analysis with findings grouped in clusters that formed a continuum, and verified through query to the relevant participants, such as “the project achieved (outcome X), is this correct”? This was informed by a framework that can be described as an occupational perspective of health: Doing-Being-Becoming-Belonging (Wilcock, 2006).

An industry partner operations manager (road construction), a safety coordinator (road construction), and an ergonomics program coordinator (surface mining) were interviewed about their perception of factors that best supported participatory ergonomics projects. A laboratory manager was interviewed by phone about one of the projects. The questions were derived from the model proposed by Vink et al (2006): involvement, process, and goals/outcomes and by recognised dimensions in participative ergonomics (Burgess-Limerick, 2018; Hignett et al, 2005). These participants were determined owing to their capability to best inform the research questions and enhance understanding of the phenomenon of good work design (Sargeant, 2012).

3.4.1 Case Study 1: Roll-Runner: Methods

The task of re-design of a work method and the development of new equipment to lay Bitac® multi-laminate tape on a roadworks project was selected for study: it had received approval from a project manager, was of interest to the workers, and involved task (re)design and implementation. Bitac® multi-laminate tape is applied as an adhesive at structural joints in the asphalt mat during large roadwork projects. The product may be specified for use at any layer of the mat. This task required the assignment of at least three workers.

The participatory ergonomics methods involved on-site observation of the task and structured co-design of new equipment. The co-design process was facilitated by the investigator through worker consultation during all project phases: task identification and nomination, hazard identification, risk analysis, idea development for controls, verification of control ideas, iterative design, development of equipment prototypes, trial, and communication of findings. Asphalt crew, a safety representative, and management (team leader / foreman, a site superintendent, a project manager, and the regional contracting manager) were involved. The process required measurements and recordings of the human interface with tools, supplies, and equipment, and identification of work flow. Photos and video recordings were taken. The task was identified and nominated for study by the site foreman in consultation with the investigator during a routine, on-site visit in attendance with the regional safety advisor. Consent was obtained by the participants for their involvement in this study.

During this visit, observations and conversations were engaged to provide for a rich understanding of work as it was performed. The roll-out of the Bitac® tape work method had not been identified on a hazard register as a problematic task. The investigator used appreciative inquiry to construct an idea among the work crew that positive change may be possible (e.g. Bushe & Kassam, 2005; Mishra & Bhatnagar, 2012; Watkins & Cooperrider, 1998). The investigator's line of questioning included:

1. *How can we best achieve safety, health, and productivity?*
2. *If a change to task or equipment design were possible, what should that look like?*
3. *How could this change be implemented?*
4. *What contribution today might make a measurable change in performance?*
5. *What collective actions would need to occur for the change to be implemented?*
6. *When will we know when we have achieved success?*

3.4.2 Case Study 2: Wheel Dolly: Methods

The task of changing a paver tyre was selected for study because it was nominated by workshop mechanics during manual task risk management training (conducted by the investigator). The task was previously recorded on a hazard register and was consequently required to be addressed to achieve risk reduction, although no action had been undertaken to resolve this hazard and it had not been escalated by management for further action.

During training about manual task risk reduction, design ideation was encouraged by the investigator. An appreciative approach was undertaken with questions that included those listed in the methods of Case Study 1.

A follow-up visit occurred with the mechanics during which consent for their study participation was obtained. The task was described by the workers, simulated, and demonstrated for direct observation by the investigator. Questions were asked of the workers to help articulate and translate the hierarchical task steps, work flow, and hazards. A job analysis and a manual task risk report was developed. The findings were reported to the services coordinator, a safety advisor, the capital assets manager, and the regional contracting manager through email communication and reports. Two meetings were held with the regional contracting manager and the capital assets manager. TyreGate[1], a mining industry website about task (re)design for tyre handling, was reviewed and this was shared with the workers to stimulate ideas-generation for control development. The workers conducted their own investigation and web search to inform control intervention and one field mechanic visited the paver distributor to examine their methods of changing tyres.

3.4.3 Case Study 3: Geological Utility Truck Tray: Methods

The task (re)design of taking soil samples at a mining site was nominated for review by the site host. The task involved the design of an extendable utility tray for use during annual drilling campaigns at a surface bauxite mine.

[1] http://mirmgate.com.au/index.php?articleId=19

An unstructured interview was conducted on-site with the participatory ergonomics program coordinator (a physiotherapist). Observations were conducted of the geology work truck during which measurements and images were taken. Simulated work practice was undertaken. A follow-up phone call was conducted with a geology team supervisor to determine detail about the nature of the project, including the mechanism of task nomination, establishment of design philosophy, implementation timelines, and project outcomes. A project profile (via poster demonstration) was reviewed, as were three emails describing the task nomination and work process.

3.4.4 Structured Interviews: Process Review: Methods

First, the type of transactions supporting the ergonomics projects were categorised using a model of program success factors (Vink et al, 2006), and participatory ergonomics program dimensions (Burgess-Limerick, 2018; Hignet et al, 2005;).

These features were considered by the investigator in the development of a rating scale to compare the factors most influential and necessary to the participatory ergonomics process. Structured interviews were conducted with three representatives with knowledge of the case studies. Participants were asked to rate from a likelihood scale of 1 – 9 of factors that contributed to the success of a participatory ergonomics process for tool, equipment, and work system (re)design (1 = least likely and 9 = most likely). The criteria included: involvement, process, goal, and outcome. Additional factors and sub-factors were examined. These included: 6 factors and 5 sub-factors for involvement, 4 factors and 13 sub-factors for process, 5 factors and 11 sub-factors for goals, and 3 factors for outcomes achieved. Participants also were asked questions to rate their perception of the drivers of task (re)design.

3.4.5 Theory Testing & Building: Methods

Case studies were reviewed as a means for replication to test the theory derived from the literature (which includes analysis of other cases and programs), per the propositions outlined in this chapter. This enabled exploration about the boundaries of the domain. A scatterplot of instances indicating the presence of a condition in relation to a concept were created to examine sufficiency and necessity for each case study (Dul & Hak, 2008).

Comparative case study was used to build theory, and the selection of the cases was derived by convenience sampling (given that the cases in this study met the inclusion criteria), and the likelihood that a relationship pre-existed between concepts (because of shared success in outcomes and implementation). Dependent variables were determined from what emerged through case study outcomes per the process review, and independent variables were examined. Conditions of sufficiency versus necessity were examined.

3.5 Results & Discussion

3.5.1 Case Study 1: Roll-Runner: Results

Task Nomination

The Bitac® roll-out task was identified by the foreman during a site visit. The task had not previously been identified on the site's hazard reporting registers.

Task Description

The task required a worker to hold an 11.5kg, 355mm diameter, 36m roll of Bitac® and walk backward while crouching or bending low to dispense the tape close to the asphalt mat. Another worker walked on top of the paper backing to help with adhesion to the asphalt mat and, with both arms, spooled the paper backing for waste collection. A third worker lifted, carried, lowered, and dispensed boxes of the product to the junction of mat in need of tape application, every 36m, from either a work truck near-by or a stockpile positioned alongside the asphalt mat (Figures 3.1 – 3.6). At times, a job truck was driven at slow speed by the third worker, or a fourth, to drive on top of the Bitac® tape to encourage adhesion.

The roadway project under construction was scheduled to use Bitac® on one layer of the mat for over 32km, on both sides of the road, a total of 64km. Approximately 1 to 1.4km of tape was scheduled to be rolled per shift with exposure of up to 3 hours every time the tape would be applied, and, on average, the road project was scheduled for tape application every two or three weeks. The micro-cycle to lay a 36m roll was approximately 5 to 7 minutes.

Hazard Identification and Risk Determination

Hazards identified by crew members during a facilitated analysis included risks for collision with mobile plant; musculoskeletal disorder for low back, shoulders, and arms; fatigue; and slips, trips, and falls.

Risk determination for potential work-related musculoskeletal disorders and design intervention was undertaken using ErgoAnalyst software (ergoanalyst.com) with participatory review by stakeholders including the crew, project foreman, supervisor, manager, and safety advisor with the investigator. Acute risk ratings were most influenced by perceived task exertion and awkward postures; cumulative risk ratings were most affected by awkward postures, repetition, sustained exposures, and cognitive underload (Figure 3.7).

Illustrations: Bitac® Multi-Laminate Tape Roll-Out

Figures 3.3 – 3.8: Manual roll-out of Bitac®, Manual wind-up of tape backing, Unpacking tape, A group participatory ergonomics workshop on-site, and Investigator task trial

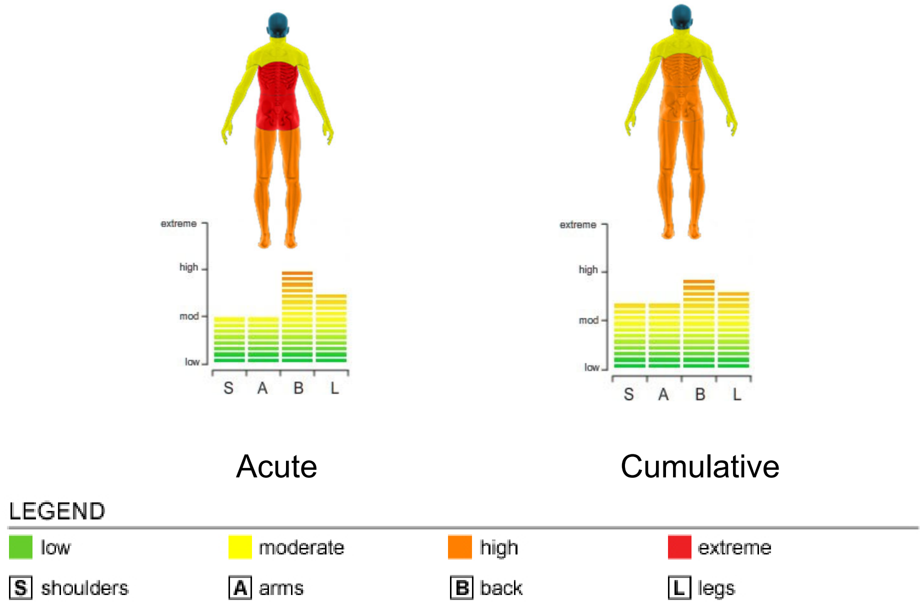


Figure 3.7: Biomechanical risk determination of manual task: Bitac® roll-out

The Design Process Elaborated

The design strategy and development of controls was an involved process:

1. During site visits, the investigator asked experienced work crew, foremen, supervisors, and the project manager about the effort required for the roll-out of Bitac® and whether other strategies had been trialled to reduce the exertion demands and safety risks. The investigator learned:
   i. The work crew, at times, used a broom handle as a rod with which to thread through the core of the Bitac® roll to reduce the forward flexion in the back and at the hips while rolling out Bitac® product.
   ii. A trolley had been devised and trialled by work teams known by the project supervisor at least fifteen years prior. However, it was determined to be awkward and cumbersome by the work crew and abandoned for scrap metal soon after trial.
   iii. Larger multi-laminate tape rolls were dispensed, at times, by tractors in regional areas, but these rolls were rarely specified for use in road design.

2. An on-line search by the investigator revealed one local multi-laminate tape supplier that displayed a trolley image on their website. The trolley enabled a worker to stand-upright, but still required the worker to walk backward during dispensing. It may be inferred that another worker rolled the paper during operation:

Figure 3.8: Past design: Trolley image from GeoFabrics website: Source: http://www.geofabrics.com.au/products/products/2-bitac-multi-laminate-tape/overview

The investigator called the company regarding this image. At first, no one in the organisation with whom the investigator spoke knew that the image was on the website. After a lengthy conversation with a sales representative, the workers in the image were identified, as was the construction firm where they worked.

3. The investigator called the other road construction firm and, eventually, located a supervisor who knew of the trolley; but he did not know that the image was used on the GeoFabrics' company website. The investigator learned that this trolley had been devised in-house by the construction firm and their fitters more than 8 years prior but was discarded soon after trial because it was perceived to be more cumbersome than the manual process. Specifically, it took a long time to fit and remove rolls, it was not time-saving, and it did not align the tape well on the road surface.

4. The investigator reported the findings to management teams and to the work crew during a subsequent site visit. The regional contract manager approved the development of a risk report and investigation of a suitable product with the belief that an off-the-shelf product existed. When the contracting manager learned that there was no commercially available solution to multi-laminate tape roll-out, he deferred to the project manager for budget approval. The project manager approved the investigation of custom design controls and the potential cost of development. Multi-laminate tape application was a highly profitable component of a roadworks project, and the project manager supported the means to further enhance the profitability.

5. A form of manual push trolley was identified as the appropriate control following a general debate about automated options. Design objectives were developed with work crew, supervisors, and the project manager, and these included:

   i. Performance & Productivity:
      (a) Reduce labour demands during product roll-out: reduce 3 workers to 1 or 2.
      (b) Reduce time to dispense roll: e.g. from 5 – 7 minutes to 2 – 3.
      (c) Design for quick change of rolls on/off trolley.
      (d) Use gearing to support the change in diameter of tape roll and paper backing during roll-out.
      (e) Trial 3- or 4-wheeled trolley, single wheel in front and two rear wheels, or two in front and two rear, to achieve stability and alignment during dispensing.
      (f) Develop a device that could dispense and roll-up tape all-in one, rather than requiring two or three separate workers to perform these tasks.

   ii. Human-Fit:
      (a) Develop a trolley that was readily adjustable in height and allowed varied grip positions during use.

(b) Design for acceptable push forces in operation (e.g. under 120N for push/pull).

iii. Safety & Protection:

(a) Walk forward to dispense tape: Reduce fall and collision risk.

(b) Permit upright postures during operation: reduce sustained awkward postures with forward flexion in the back.

(c) Ensure safe work around gearing through installation of machine guarding.

iv. Transit & Manoeuvrability:

(a) Develop a light-weight device that was < 25kg. Note: steel fabrication was approved for initial prototype development with the vision that an alloy material would likely be used for the next iteration of trolley design.

(b) The design of a collapsible/foldable trolley was considered, but this idea was agreed to be set aside during initial prototype development as a trade-off to cost and ease in design development and production.

6. The investigator met with the organisation's fitter and maintenance crew who, by request of the project manager, were asked to scope the project and provide a quote for design and development. The field maintenance staff admitted their reservations: their teams were more comfortable with equipment repair than design and development. The investigator raised this issue with the project manager. The legislative framework for safe design responsibility was explained: there is risk and liability as a designer, and it may benefit the organisation to commission an external supplier to design and certify a device for safe use.

7. The project manager subsequently approved the investigator's selection of an external engineering supplier who provided quotation for design development.

8. Once selected, a representative of the engineering supply firm was invited on-site to meet with the crew in the company of the investigator and safety advisor.

Design ideas were reviewed and consolidated with work crew. Discussions were held to determine construction material and fabrication methods. The investigator researched and provided information to the supplier for consideration of grip handles to fit a variety of users.

9. The engineering supplier provided quotation for the design and construction of a new purpose-built trolley. The investigator was required to advance negotiations among procurement, finance, and accounts payable teams to ensure expedited payments.

10. Computer-assisted drawings were developed, and the investigator shared these with the crew, supervisors, project manager, safety teams, and contracts managers for feedback, edits, and approval.

11. The investigator persuaded the multi-laminate tape supplier to provide free product samples during design development, including product to be used in Victoria, where the engineering design firm head office was located, and in Queensland, where field trials would be conducted.

12. A first prototype trial was developed and brought into the field for design review among crew. The trolley was named the "Roll-Runner" by the engineering supplier and the work crew accepted this name.

Product Uptake

The initial prototype Roll-Runner was considered highly successful by the workers, despite the need for some improvements. For example, the prototype trial resulted in very small electric shocks emitted intermittently as the trolley was rolled. However, a spray seal crew member reported: "*I don't mind that. I almost look forward to the shock. I would take the shock over the back-breaking work that this once was any time*". The foreman and his team that formed part of the design team made comments, such as:

"This is awesome, we love it".

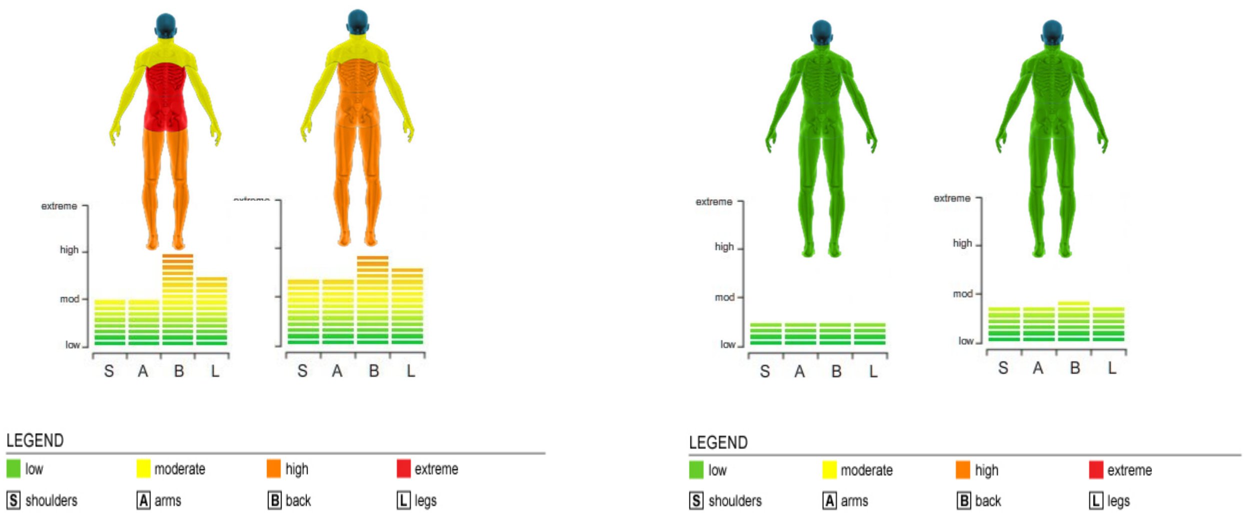
"Have you trialled this? (to other crew foremen). You have to give it a go".

The crew requested high-visibility paint, consideration of light-weight alloy material, rather than steel used for the prototype, an improved mechanism to attach and release tape spools with ease, and a grounding cable to eliminate the electric shocks. The investigator and engineering supplier had primed the study participants to expect an iterative design process in which revisions to the initial prototype would be likely. Roll-Runner images with the control in development and a field trial are below (Figures 3.9 – 3.12):

Figures 3.9 – 3.12: Design drawing of trolley in development; Prototype A: Field trial; Tape cylinder release trial

Transactional Events

The field safety officer recorded the hazard and discussions were held with the project manager, supervisor, safety advisors, and operations managers. Permission for ongoing investigation was received and, within three weeks, another on-site visit occurred with collaborative task analysis and risk determination. A series of activities followed, including sharing findings with stakeholders, enlisting management support, and recording the project in a continuous improvement reporting system that transmitted to senior management. Overall, 28 transactional events were recorded involving the investigator over an 8-month period, including the initial site induction. These transactions included site visits, supplier consultation and request for free product samples, procurement negotiation, industry liaison, and internal and external communication. The investigator attended four site visits and, through consultation with the workers, identified the issue, observed task performance, determined risks, facilitated the development of design strategy and control methods, and evaluated the control via product trials. A trolley was custom-designed, referred to by the engineering supplier and the design teams as “The Roll-Runner”; a strategy that improved efficiency by reducing labour requirements and decreasing time to lay the product. The outcomes also included a reduction in musculoskeletal risks (Figure 3.13).



Acute Risk Reduction Estimates
Shoulder: 50%; Arms: 50%; Back: 75%; Legs: 67%
Cumulative Risk Reduction Estimates
Shoulder: 45%; Arms: 45%; Back: 53%; Legs: 54%

Figure 3.13: Biomechanical risk reduction of manual task: Bitac® roll-out before & after

Outcome Review: An Occupational Perspective of Health: Case 1

The outcomes for case study 1 (Roll Runner) were reviewed with co-design team members (workers, relevant management, and the safety advisor) and compared with other cases in this chapter (Table 3.4).

3.5.2 Case Study 1: Roll-Runner: Discussion

Effective implementation of a participatory ergonomics process may lead to positive changes to the design of work systems or equipment (Burgess-Limerick, et al, 2012; Grandjean, 1986; Torma- Krajewski, et al, 2007a). The outcomes of the Roll-Runner project support this position. The trolley eliminated manual dispensing of Bitac® tape and was viewed favourably by workers. The workers involved in product evaluation included those who had been involved in the participatory practice of design development (asphalt teams) and those who trialled the design prototype (spray seal teams).

The project outcomes were reviewed along a spectrum of safety to health, based on an occupational perspective of health (Wilcock, 2006). All performance indicators were met. A design project that can meet indicators along this spectrum (and, in this case, meet all indicators) suggests that ergonomic intervention can impact safety, health and organisational performance.

Interestingly, the tasks involving Bitac® roll-out previously had not been identified on the workplace hazard register. Enquiry by the investigator inspired the workers to identify and report this task. Enquiry from a design perspective with a positive line of questioning can inspire workers to think of possibilities beyond routine practice. It is a future-oriented, transformative, and constructive model (e.g. Watkins and Cooperrider, 1998) which may lead to innovation and proactive changes in the design of work for health.

The investigator's role included enlisting management support for design development, sourcing an engineering supplier, and securing the commitment of funding resources by the project manager. The investigator facilitated hazard identification, task analysis, risk assessment, identification of design objectives, and control (design) development through a participatory process. The design evaluation indicated significant risk reduction for acute and cumulative musculoskeletal disorders in the shoulders, arms, low back, and legs. Further risks were reduced for slip, trip and fall hazards and collisions with mobile plant or trucks. Additional manual task risk reduction was achieved for the worker who would otherwise manually roll the paper discard from the Bitac® tape by eliminating this task. Productivity was improved through reduced labour requirements. Overall, the design objectives were well met with the development of this initial trolley prototype. The comments made by field workers suggested that their involvement contributed to positive morale.

The implementation of a plan to design work for health is often described as a relatively simple, staged process (e.g. SWA, 2015a, in Principles of Good Work Design Handbook; or Horberry et al, 2011). However, these descriptions may not fully reveal the complexity required to implement a sustainable program. The Roll-Runner project involved 28 general ergonomic transactions including four field visits over eight months. The iterative process of design involving work in an open, organic, and changing system with human-users suggests that a sensitive, qualitative, and broad analytic process may be required to identify and determine the most effective methods to achieve the desired outcome.

3.5.3 Case Study 2: Wheel Dolly: Results

Task Description

Removing paver tyres involved a three-person approach for the removal of a large split-rim wheel, with a tyre measuring 1470mm in diameter and weighing 400kg when filled with water. One person operated the forklift and the other two used tools such as a rattle gun, spanner, socket, breaker bar, crow bar, chain, jack stands, timber blocks, and wheel chocks to help remove side bars and release the wheel. The three-person task involved: isolating the equipment, lifting and setting the paver, changing hydraulics, removing the side arm, removing secure bolts, two people to manoeuvre and release the wheel and set it on the tynes of the forklift, and forklift operation to move the wheel within the workshop (Figures 3.14 and 3.15). A similar process occurred in reverse to replace the wheel.

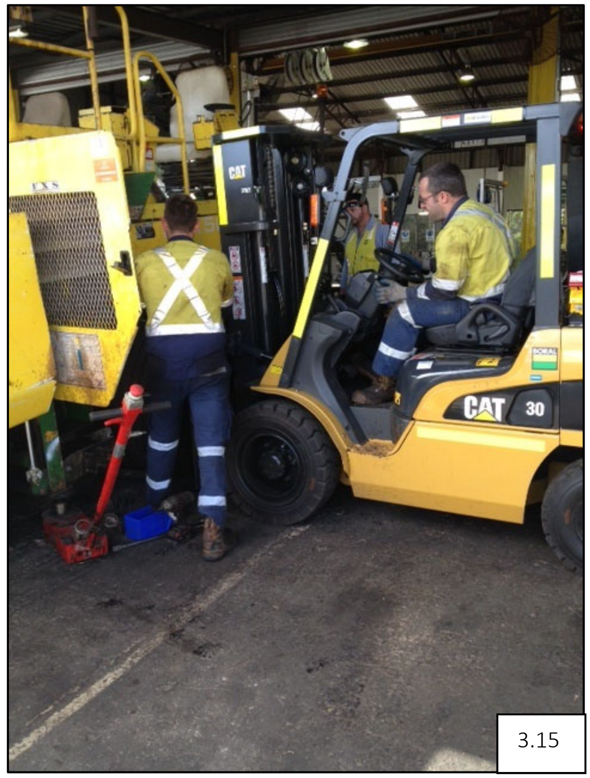
Hazard Identification and Risk Determination

The workers helped determine hazards: working near mobile plant (a forklift), compression injury, pinch points, and musculoskeletal disorder. Biomechanical risk was evaluated with findings of high risks for injury to the low back, shoulders, and pinch points for hand crush injury (Figure 3.16).

Design Objectives

Participatory review led to the identification of design objectives: increased productivity (two rather than three workers required); reduced risk for collision with mobile plant (forklift) through elimination of forklift use; reduced pinch-point risk; reduced risk for musculoskeletal disorders; improved ease, and comfort in job task; and reduced time to complete the task.

3.14



3.15

Figures 3.14 & 3.15: Paver tyre removal: 3-person traditional practice with use of forklift tynes

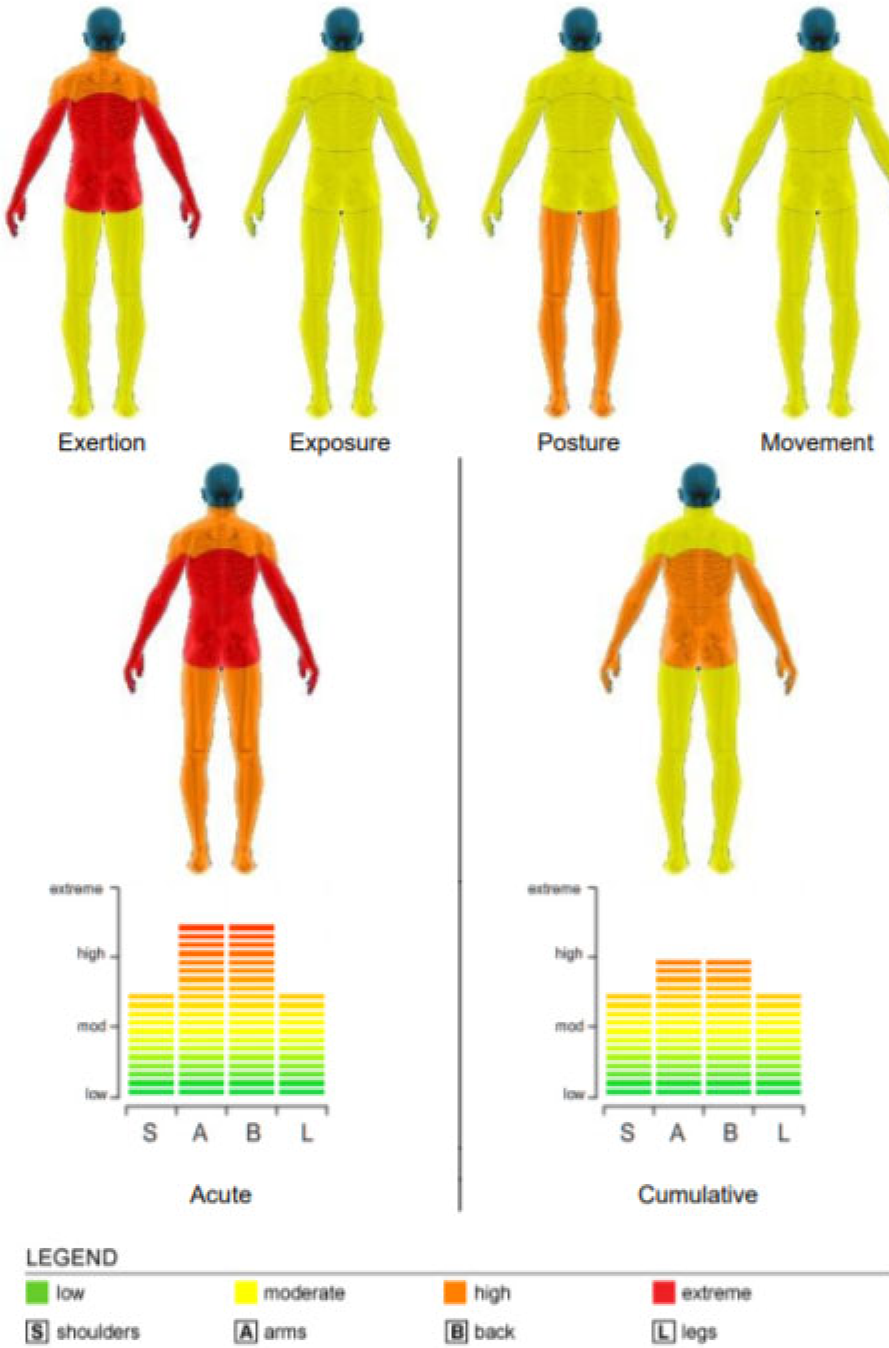


Figure 3.16: Risk assessment: Paver tyre removal

Process Review

The investigator provided health and manual task hazard management training to seven workshop mechanics. Design ideation was used to encourage the nomination of this task for (re)design. The mechanics had communicated this issue to management on previous occasions but felt that their efforts were unrewarded and no subsequent action had occurred. The investigator raised this issue in a monthly management report and verbally reported this to a regional contracting and line manager. A subsequent meeting was held between the regional contracting manager, a capital equipment manager, and the investigator. The capital equipment manager questioned why the task had not been reported previously through appropriate channels. It had been reported as a hazard, and nominated for quality improvement on a written register, but the request had not been addressed. During the seven-month delay that followed, the workers had continued investigations on their own time to determine design solutions, attending supplier warehouses and other asphalt workshops. They discussed design strategies with the investigator and considered wheel dollies suited for use within a narrow space under the wheel arch. The workers had found a potential solution, a specialised wheel dolly, however line management declined their initial request for product trial. The delay ended when a state general manager visited the depot and heard from the maintenance workers about their concerns. He confronted the line manager and capital equipment manager. The next day, the workers reported that they were permitted to pursue the task, but they received severe warning by line managers not to go above or around their line of communication again. The biomechanical risk ratings and potential risk reductions were determined through collaborative review with workers. This report was submitted to area managers to support capital expenditure requests, and they, in turn, submitted this to divisional and state managers and approvals were obtained.

Control Evaluation

Workers reported their satisfaction with the wheel dolly (Figure 3.17). Time savings were found, as was the efficiency achieved by reducing the task team from three to two. Risk reduction for exposure to hazardous manual tasks was determined: acute risk reduction:

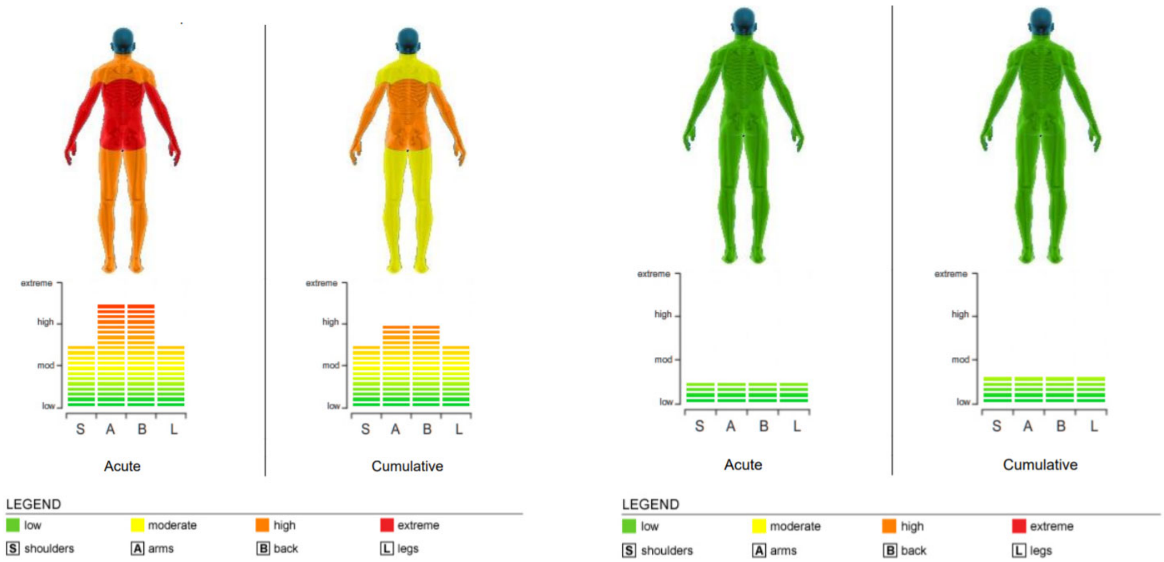
50% for low back, 25 – 33% for shoulders and arms, cumulative risk reduction: 45% for low back, 22% for legs, and 27 – 30% for shoulders and arms (Figure 3.18).

Leveraging from this success, a second region within the business also purchased a dolly for their workshop. The project was celebrated through communication in regional newsletters, and senior management teams were notified of the control intervention. This case was included in a paper and presented at an international industry conference.

Figure 3.17: The use of a wheel dolly to eliminate the forklift use

Transactional Events

This case study involved 14 interventions including training provision, task identification and analysis, risk determination, product sourcing, control intervention, management liaison, and advocacy. The period of task identification to project management reporting was relatively short (two weeks), with on-site detailed task analysis occurring four weeks afterward. Permissions were required to conduct risk assessment, and this was not received for another seven months (total project time: 9 ½ months).



Acute Risk Reduction Estimates
Shoulder: 67%; Arms: 80%; Back: 80%; Legs: 67%
Cumulative Risk Reduction Estimates
Shoulder: 58%; Arms: 69%; Back: 69%; Legs: 58%

Figure 3.18: Risk assessment comparison: pre- and post- wheel dolly use

Outcome Review: An Occupational Perspective of Health: Case 1

The outcomes for case study 2 (Wheel Dolly) were reviewed retrospectively as per an occupational perspective of health, with co-design team members (workers), and compared with other cases in this chapter (Table 3.4).

3.5.4 Case Study 2: Wheel Dolly: Discussion

Ergonomic intervention was required to escalate hazard management associated with changing paver tyres. This intervention included training provision, ideas-generation, advocacy to management, and risk reporting. The outcomes of the intervention were positive in that the new wheel dolly contributed to increased productivity and reduced injury risk. Qualitative feedback suggested that impact on morale was mixed. The mechanics seemed pleased to have implemented a new design control that improved their work, however they described the effort required to procure support for the project as disheartening. The delay between hazard reporting and the control trial may have cemented a perception of “us” and “them” among workers and management. Some workers reported a divisive attitude toward management owing to their impression that they had to self-advocate at the risk of poor relations with their line managers to achieve their project success. Leadership support had existed with the advocacy of the regional contracting and state manager, but not initially from their line management.

3.5.5 Case Study 3: Geological Utility Truck Tray: Results

Task Description

A geology drilling campaign is an annual event which typically occurs over 5 to 6 months. The task is performed by contractors to Rio Tinto Weipa. The workers involved in this practice include a geologist to conduct logging, a sampler, and a driller. However, at times the geologist may be involved in sampling and logging. The work occurs over 12-hour shifts during which time 40 – 50 holes are drilled, and each hole will comprise 25 samples (per shift: 1000 - 1250 samples). Seasonal demands will vary, with some seasons requiring < 40,000 samples taken, others up to 125,000 samples.

The geology team reported that in 2009 they had access to a 3m side tray bench that allowed for up to 12 samples to be viewed but there was a risk to mismatch sample numbers and lose sample sequencing. To review a greater number of samples and achieve more working space, the team brought the samples from the cyclone section of the drilling rig and spread them on the ground (Figure 3.19). The ground-based task procedure typically involved:

1. Driller placed samples onto the ground in two rows of 2 – 3 metre length
2. Logger identified the samples to log
3. Logger assigned a sample ticket to the relevant sample
4. The sampler attached the tickets
5. The sampler tied the sample bag

6. The sampler collected the samples, stands from crouched position, to place in a box located in the back of the utility vehicle
7. The logger assisted the sampler to carry and process samples
8. The logger walked behind the drill rig to the next hole (approximately 80 metres)
9. The sampler entered the utility vehicle and drove to the next hole
10. The sampler alighted the vehicle to repeat the task

Hazard Identification and Risk Determination

The physical demands included repetitive lifting of 2kg sample bags at or above shoulder height; repetitive and sustained bending below knee height, squatting, and crouching; repetitive forearm pronation and supination; and repetitive wrist flexion, extension, and deviation. In the analysis of a 2007 campaign, the sampler was required to bend and reach below knee height at least 207,900 times in their 5 months of work. Additional hazards included fatigue while working in hot and humid conditions over long shifts with high production demands; reduced hydration; exposure to trip hazards with the bags on the ground and work across uneven terrain; exposure to sun, wind, and outdoor elements; and breech of vehicle exclusion zones while working near a drill rig. The cumulative risk for musculoskeletal disorder to the low back and lower limbs was determined to be high (Figure 3.20). There was also risks of collision or contact injury particularly during the high-risk activity of the rod changing activities. Despite a 6m exclusion “red zone”, the geology team admitted that this was not always a practice to which they adhered.

Resource Commitment & Work Flow Process

The local teams agreed to target this task for (re)design. However, a compelling case was required to be brought forward by the participatory ergonomics program coordinator to obtain management support and the risk assessment report was used to advocate change. The initial assessment occurred late November 2013. During the 2014 campaign season, the work teams wanted to assess whether there was a need to screen individuals performing the work or if, systematically, they believed the task design may be a precipitator and cause of workplace injury. In 2013 and 2014, four injury and/or early intervention reports were received with request for onsite physiotherapy management. In these seasons, 25,000 to 40,000 samples were taken.

Agreement to commit resource to the project was received in May 2015. The (re)design project followed an iterative and participatory design process and was undertaken in 2015 and completed late November 2015. This included conclusion of a final assessment of the control, job safety analysis, and risk re-assessment. The design brief comprised the need to view at least 20 samples at one time (requiring 5 to 6 m length of work area) to assure quality control.

The resulting design was a custom utility vehicle side tray with an embedded, extendable work bench to eliminate the work on the ground (Figure 3.21). The fabrication occurred on-site by local fitters/mechanics.

The ergonomics program coordinator reported that, on average, most projects took 12 – 18 months for hazard identification through to (re)design. He reported, also, that the iterative design process meant that several obstacles or clumsy design variations often occurred before accomplishing a satisfactory finished product. For example, before evolving to an extendable work bench, the early design ideas included a drop-down, three-layered, hinged side tray bench with handles; but they found that the repetitive reach to high handles with lifting and lowering was a potential hazard and source of frustration.

Outcome Review

The geology team conveyed the value proposition of this design initiative in several ways: discomfort and injury reports decreased (refer to risk reduction calculations, Figure 3.22). Despite approximately 4 times more productivity (< 125,000 samples taken), there were no physiotherapy treatments sought in 2015 when the standing work bench was used and this resulted in 1) less downtime and fewer treatment-related costs; 2) improved morale; 3) improved quality control; 4) a more efficient work flow; and 5) there were reduced risks for collision or contact with the rod as a result of the improved visibility and having the utility vehicle as a barrier to help isolate workers from the proximity of the air core driller.

Hand tying bags were also addressed and improved from the use of twine or string to the use of cable zip ties. The team is currently reviewing automated tying devices.

3.5.6 Case Studies 3 (Ute Tray): Discussion

Case 3 (geological utility truck side tray) reveals design changes that can be undertaken to support suppliers throughout the supply chain. Liabilities exist when contractors supply work to an organisation and benefits can be derived when performance is improved throughout the supply chain. The human-centred design practice resulted in injury risk-reduction and business improvement. The leadership had been supportive, although a compelling case had to be presented to the decision-makers for resource allocation. The project coordinator reported a high level of employee engagement leading to improved morale.

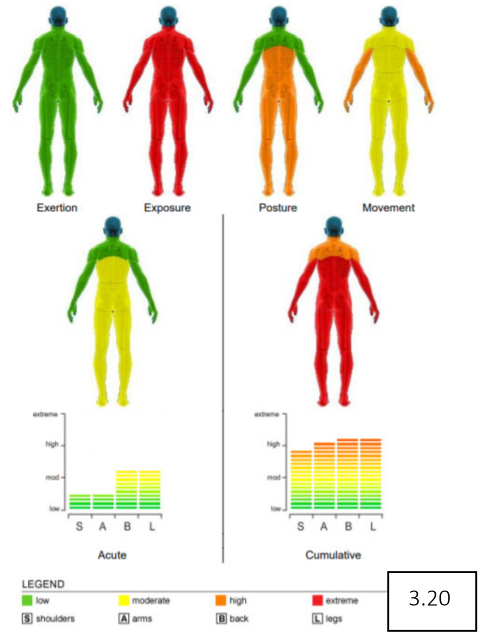


Figure 3.19: Geological campaign with soil sampling required squatting while working

Figure 3.20: Manual task risk assessment of the task of soil sampling

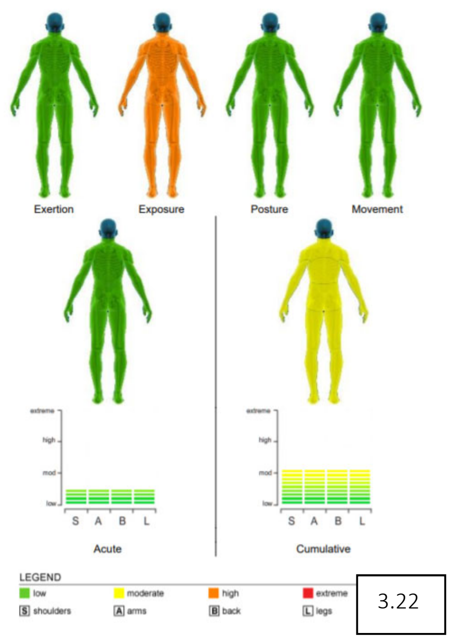


Figure 3.21: A custom drop-side was designed with an extendable slide-tray

Figure 3.22: Manual task risk reduction post (re)design of the soil sampling task

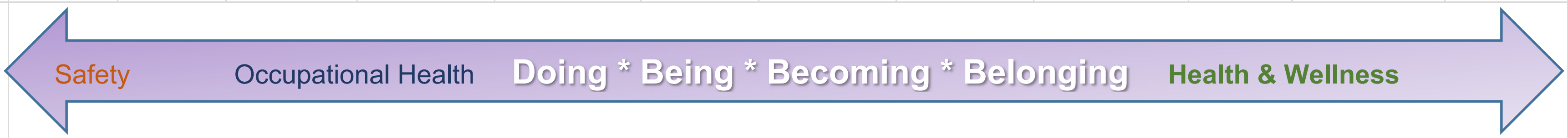
Occupational Perspective of Health Model

The design outcomes of the first three cases were evaluated along a spectrum per philosophy of an occupational perspective of health: Doing-Being-Becoming-Belonging (Hitch et al, 2014; and Wilcock, 2006).

Table 3.4

Design Outcomes per an Occupational Perspective of Health

Project	Catas-trophe	Fatality	Severe Disability	Mild to Moderate Disability	Temporary Injury	Discom-fort	Comfort / Efficiency	Condition-ing	Social Connection	Profit-ability	Business Unit Integration	Industry Liaison
Roll Runner	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wheel Dolly	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	–	✓
Ute Tray	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓



The Roll-Runner and Ute Tray case met design criteria spanning each potential outcome per this Occupational Perspective of Health. For example, fatality risk reduction was determined with reduced risk for collision with mobile plant. Industry liaison was considered to have occurred when information was shared industry wide (e.g. through conference presentation and paper publication, as occurred in all three cases).

The Wheel Dolly case met most outcomes, but the adverse impact to morale that arose from the line management's initial obstruction and untimely response to their concerns resulted in a risk for stress associated with social relations with the supervisors and, thus, no positive rating was achieved for "conditioning" (mental, in this case). However, the leadership support by upper echelon management was necessary for the project to progress. As such, leadership was necessary for the task (re)design but not enough to meet all positive design objectives. Also, no significant cross-team cooperation was required to advance the project, so the outcome of "business unit integration" was not given merit.

3.5.7 Structured Interview: Process Review: Results

A model of success factors (involvement, process, and goals [Vink et al 2006]), and project dimensions (Hignet et al, 2005) informed the synthesis of findings about these three participative ergonomics projects (Table 3.5).

Table 3.5

Process review of three participative ergonomics projects: Common themes

Intervention	Participatory Ergonomics (PE) Activities
I. Involvement	Worker consultation: site visit Worker empowerment to contribute to risk analysis and design development Hazard identified by foreman Supplier involvement Designer involvement Project or Operations Manager commitment Safety advisor commitment Ergonomist involvement
Dimensions:	• Decision making power: With management - either to access an established capital expenditure budget or for special funding approval
II. Process	Appreciative inquiry Training and education in health and risk Hazard ID participatory Site visits to observe work as performed and trial controls Establish a PE review team Task analysis and risk assessment ID risks: MSDs, low productivity, collision, slip/trip/fall, fatigue Record and report with thermal body map illustrations Selection of quality reporting tool Communicate findings Establish design philosophy and potential unwanted events

Process review of three participative ergonomics projects: Common themes	
Intervention	**Participatory Ergonomics (PE) Activities**
	Determine control intervention Simulate trials Trial design/control in natural environment Evaluate control Iterative design development Analyse and project cost benefits Establish resource to support control development or design change Trial controls in natural environment: evaluate Communicate outcomes: internally & externally Commend or reward workers Develop case-based library Single Coordinator Oversight
Dimensions:	• Participant mix: Workers, safety advisors, ergonomics program coordinator, team leaders, project managers • Remit: High for identification of problems, and the generation and evaluation of control ideas; Low for involvement in setting up and monitoring the process. • Specialist role: Setting up and monitoring the process; facilitating design-thinking and project efficacy (i.e. to stimulate the idea that change is possible and realistic): and reporting and communication Requirement: expected within job roles
III. Goals	Design objectives: Safety; Health; Comfort; Productivity; Cost Control intervention (outcome) realistic and achievable Control intervention fit for purpose: meets design objectives Worker satisfaction high Control represents sustainable practice to continue in the field
Dimensions:	• Focus: task (re)design

Process review of three participative ergonomics projects: Common themes	
Intervention	**Participatory Ergonomics (PE) Activities**
	• Influence: Work teams in one business unit, work teams across business units (in other states), product suppliers, industry-at-large • Permanence: High; equipment (re)designed or procured to change task methods

The three interview participants rated worker involvement as the most important criteria leading to ergonomics program success. Other criteria included hazard identification, risk determination, design strategy, (re)design work trials, and communication of the findings. Also important was the presence, involvement, and facilitation of an ergonomist or ergonomics project coordinator. The safety team representative or product supplier were rated the least important for effective work design (Tables 3.6).

Fatality and severe disability or impairment were deemed the most important outcomes to be achieved through task (re)design (Table 3.5). The criterion perceived to be most important to influence the design process was the pre-project content (mean rating of 7.67). This included training in work health needs and hazard identification and the application of appreciative inquiry to facilitate transformative thinking. The collaborative construct of design philosophy was rated highly also (mean rating of 7.0). The rating of the mine site representative differed significantly to those by the road construction representatives when asked to signify the importance of the tools for reporting and risk determination. The mine representative, who had familiarity with ErgoAnalyst, rated this as 8.0 (very important). The construction representatives, who did not have a recognised tool specific for participatory ergonomics practice, rated this as an average of 4.5 (moderate level of importance). Product trials with an iterative design process were rated important (mean = 6.0).

Table 3.6

Perceived Levels of Importance of Outcomes Achieved on the OPH Model	
Occupational Perspective of Health (OPH) Outcome	**Mean Rating**
Catastrophe or Fatality	9.0
Severe Disability	8.7
Moderate to Mild Disability	8.3
Temporary Impairment	7.7
Discomfort	6.3
Efficiency	6.3
Conditioning	6.0
Business Unit Integration	5.7
Profitability	5.3
Social Connection	4.7
Industry Liaison	4.3

The interviewees rated the sub-factors associated with possible work design outcomes on a scale of 1 – 9 of importance. Unanimously, fatality risk was rated the most important (mean rating = 9). Profitability (mean of 5.3) was deemed less important than prevention of risk for disability, impairment, comfort, efficiency in work (which may still imply profitability), work conditioning, and business unit integration. It was, however, deemed more important than social connection and industry liaison.

Table 3.7

Perception of Importance of Parties Involved in PE Programs	
Party Involved	Mean Rating
Worker Involvement	9.0
Ergonomist	7.0
Engineering designer	5.6
Operations Manager	5.3
Safety Team	4.7
Supplier	3.7

The project goals were deemed very important (mean rating 8.0 to 8.3 for all sub-factors) including establishing a realistic design objective with sustainable outcomes, meeting fit-for-purpose objectives, and achieving high levels of worker satisfaction. The most effective work strategy was design-based intervention (mean = 8.0), in contrast to behavioural-based or low-level controls, such as administrative changes or training (mean = 5.0).

On a Likert scale of 1 – 5, the mining representative, whose organisation operated a mature participatory ergonomics program, rated worker feedback as the most significant factor that drove change in their business, rating this 5.0. The road construction representatives, in contrast, whose organisation had not adopted a widespread participatory ergonomics program, rated worker feedback as 3.0. This contrasted with the unanimous rating of worker influence as the most important factor to influence program success. Regulatory drive and corporate initiatives were unanimously rated as 4.0 (significant) to drive work (re)design.

3.5.8 Theory Testing & Building: Results & Analysis

The following propositions were confirmed through the case studies which all achieved a measure of risk reduction for acute and cumulative injury risk and resulted in business improvement:

- *Injury risk is reduced through human-centred task (re)design practice*
- *Business is improved through human-centred task (re)design practice*

In these cases, human-centred task (re)design represented a condition of sufficiency to achieve the outcomes of injury risk reduction and business improvement. In other words, injury risk reduction and business improvement can occur without a human-centred approach (such as a mandated safety initiative that did not involve worker consultation), but when a human-centred approach was undertaken, these outcomes always occurred.

The case studies gave rise to the following propositions of necessity which are also indicated in the literature.

- *Injury risk reduction can be accomplished if task (re)design is driven by supportive leadership*
- *Business improvement can be accomplished if task (re)design is driven by supportive leadership*
- *Effective task (re)design can occur if employees are consulted and involved*
- *Worker consultation is important to the design process, but the specialist role (e.g. an ergonomist) is required for process management and facilitation of design-thinking*

In other words, these conditions (supportive leadership, employee consultation, specialist intervention) are necessary components of good work design, but not sufficient in and of themselves. Another interesting factor noted by interviewees as influential to projects in the case and process review but not sufficient or necessary, is regulation. This can be presented as a proposition:

- *A regulatory directive is influential, but not necessary or sufficient to result in good work design*

The following new proposition was derived:

- *To implement good work design,* ***traditional hazard management practice may provide insufficient conditions*** *for the nomination and resolution of tasks for effective (re)design*
    - *Appreciative inquiry is a useful approach (and can be necessary) for the nomination of tasks for (re)design and ideation of design strategy*

And in the case of the paver wheel dolly, it was evident that:

- *A project may have some level of success if there is leadership support at the level of decision making*

This is unique in that literature has suggested that, broadly, leadership support is required. In the case of the paver wheel dolly case, leadership was required to authorise the resource allocation for task (re)design even when other levels of management were initially obstructive. The measure of success was affected because of this lack of uniformity, however injury risk reduction and business improvement still resulted.

The scatterplots display these conditions[2]. Table 3.8 and 3.9 show injury risk reduction and business improvement as the dependent variable (that which may be measured).

Table 3.8: Scatterplot: Injury Risk Reduction

Injury risk reduction	Present	x x x	x x x
	Absent	x x x	
		Absent	Present
		Human-centred task (re)design	

Table 3.9: Scatterplot: Business Improvement

Business improvement	Present	x x x	x x x
	Absent	x x x	
		Absent	Present
		Human-centred task (re)design	

The new propositions can be displayed as a dichotomous proposition:

[2] The scatterplots display theoretical framework; the "x's" displayed are in-concept to illustrate the proposition and they are not a reflection of each instance in the case studies in this chapter

Table 3.10: Scatterplot: Traditional Hazard Management Practice & Task (Re)Design

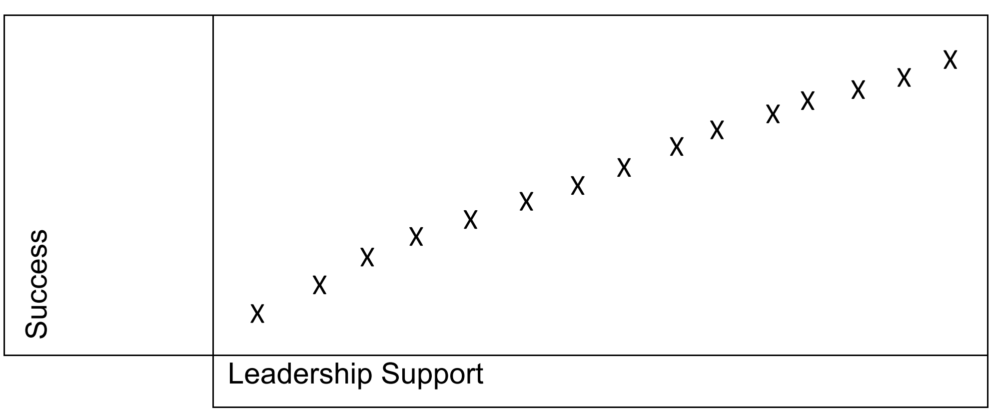
Task (re) design nomination and resolution	Present	x x x	x x x
	Absent	x x x	x x x
		Absent	Present
		Traditional hazard management practice (not sufficient or necessary)	

Table 3.11: Scatterplot: Appreciative Inquiry & Task (Re)design

Task (re) design nomination and ideation of design strategy	Present		x x x
	Absent	x x x	x x x
		Absent	Present
		Appreciative inquiry	

And in the case of the paver wheel dolly and the level of leadership support, this may be presented as a continuous proposition:

Table 3.12: Scatterplot: Levels of Leadership Support & Success



3.6 Research Question: Chapter 3: Discussion

> *What were the necessary conditions for success for three participatory ergonomics projects?*

The conditions necessary to ensure success for three participative ergonomics projects (the Roll-Runner, the paver wheel dolly, and the geological utility truck tray) were supportive leadership, employee consultation, the involvement of an ergonomics (or good work design) specialist, and traditional hazard management practice. Additional propositions were deemed necessary: an appreciative approach and continuous levels of leadership support, especially when decisions were needed. Appreciative inquiry is a transformative, forward-thinking, future-oriented, design-based method of engaging with people (Bushe & Kassam, 2005; Mishra & Bhatnagar, 2012). The discovery of appreciative inquiry as an effective and necessary method for good work design arose through early-stage application of Grounded Theory (Dul & Hak, 2008; Strauss & Corbin, 1998): identification of a new phenomenon and inductive reasoning. Replication studies are required to verify this conclusion.

Case study research is important to increase the robustness of theory and to enable theory to become generalised. It is the preferred research strategy for testing deterministic propositions, case-by-case (Dul & Hak, 2008). Through these cases, it was determined that human-centred task (re)design (or good work design) was sufficient to ensure injury risk reduction and business improvement. In business case methodology, the levels of dependent variables (risk reduction or business improvement, in these instances; or success in other instances) cannot be defined by the researcher but need to be defined by the business to be meaningful (Dul & Hak, 2008). Verification of these outcomes occurred through consultation with the study participants and interviewees and, thus, meaning could be applied to these outcomes and the variables were true.

These cases form an essential part of a nested, building-block, approach to the thesis (e.g. George & Bennett, 2005). From this comparative case study approach, it was discovered that significant improvements may arise from good work design in multiple domains of outcomes (injury risk reduction, conditioning, social connectivity, business unit integration, profitability, or industry liaison, for example). However, the cases were selected because of their potential to reduce injury risk. This inference is that manual task risk reduction campaigns can address multiple strategic objectives.

The process review contributed to the generalisability of findings and nested study of a broad, systems-based perspective about how to embed human-centred design within an organisation (i.e. marco-ergonomics) (Carayon, 2006; and Carayon & Smith, 2000). Overall, the most important factors and sub-factors identified by the interviewees were worker involvement, an ergonomics/good work design project coordinator, an appreciative approach, pre-project contact that included training in health topics and hazard identification, and a sound design philosophy. The ability to meet design objectives that were purpose-fit and which led to high levels of worker satisfaction was also important. Design, and (re)design, was considered the most effective means to address safety, health, and productivity issues. Interviews were an effective method to capture the socially-constructed framework of reality in these instances (e.g. Burgess-Limerick & Burgess-Limerick, 1998). The finding that human-centred task (re)design (good work design) leads to injury risk reduction and business improvement and is sufficient to achieve such outcomes is an important verification of theory.

Limitations

There are limitations to case study methodology for large-scale inference because the validity is accomplished internally rather than externally. However, replication and comparative case study, as provided in this chapter, aids the generalisability of findings.

Recommendations for Future Work

The decisions that businesses make to pursue a task for (re)design, or one design method above another, are yet unclear. These decisions, sensitive to business operation cycles and maturity of a good work design program, are not well addressed in guidance documents either. Study about decision making would be useful and a case study is analysed in the next chapter.

The occupational perspective of health (Wilcock, 2006) was used to construct a performance model and examine project outcomes along a spectrum of health and business benefits. The model provided for transparent design outcomes that were easily translated. The model was central to discussions held during semi-structured interviews. Consensus was achieved easily regarding the outcomes described along the continuum, suggesting that the descriptors were clear and meaningful. This model may be useful for ongoing project review. To improve the model, inclusions could be made for considerations of inclusivity and diversity (such as design for women in the workforce) and sustainability (e.g. green ergonomics, Thatcher & Milner, 2014; Thatcher, 2012) resulting in 14 descriptors along the continuum. The weighting of the outcomes along the continuum may be a necessary practice but unique to each organisation (e.g. assigning a level of importance and measurement to the outcome, per Dul & Hak, 2008, to determine if the outcome has been adequately achieved).

Methods to enlist leadership support prior to program launch could benefit from more instructive detail as could methods to communicate and manage expectations of persons of influence on the decision making. Further, financial cost analysis methods for projects could be better explored. Replication studies are required to test the proposition that appreciative inquiry is a necessary component of good work design.

Given the importance of good work design to competitive business strategy, and the influence of an ergonomics program coordinator to design ideation and process management, the positioning of these specialists within the organisation is important to study (Hedge, 2015; Wilson, 2014). Wilson (2014) described the success of positioning specialists within engineering, continuous improvement, and procurement teams - a less traditional approach given that, typically, ergonomics projects serve as ad-hoc assignments under the health and safety banner (Dul et al, 2012; Hedge, 2015). There are implications from these cases that an ergonomist, and an ergonomics program, may be more important to an organisation’s bottom-line and collective work performance than indicated by the widespread lack of investment in these professional roles and practices in heavy industry (Wilson, 1994).

3.7 Summary

Three participative ergonomics case studies were described to inform theory about the conditions that ensure successful task (re)design (a deterministic paradigm). Comparative case study methods aided generalisability of tested theories and enabled the discovery of another condition: that an appreciative approach is beneficial for good work design. The application of a project review model was effective and could be useful in other organisations once the levels of importance and measurement of determinants are defined. The case study approach was useful to provide rich detail of complex undertakings with unique learning opportunities.

Conclusions

- *Good work design is sufficient to achieve productivity and reduce injury risk*
- *Good work design is vital to organisational performance*
    - Well-designed work provides the conditions for a productive and healthful workforce.
- *Design-thinking is essential to business improvement*
    - Design-thinking is opportunity-based and an appreciative approach is useful
    - Traditional risk-based safety management systems may not provide adequate leverage for effective task (re)design
    - There is complexity and challenge associated with embedding design-based thinking in organisations

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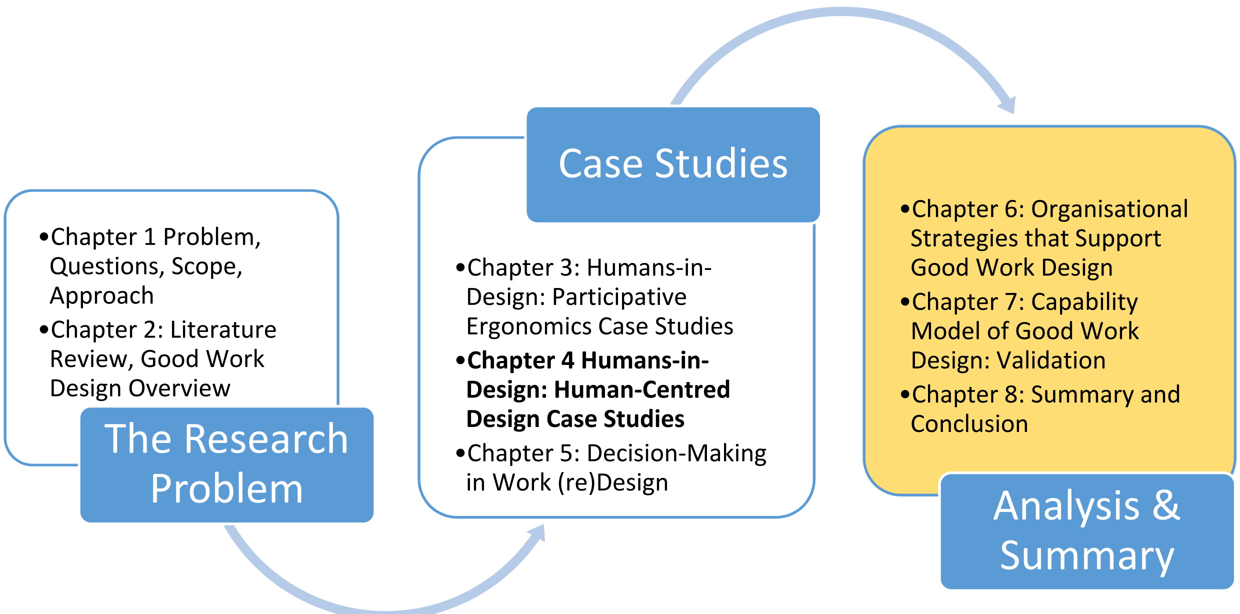
Chapter 4: Humans-in-Design: Human-Centred Design Case Studies



4.1 Introduction

Human-centred design focuses design on end users, their tasks, and the environmental context in which tasks are performed (Horberry et al., 2018). Where equipment is concerned, the interfaces between people and equipment become a focus. This chapter examines the use of a range of tools to assist in this process.

4.1.1 Design OMAT, EDEEP and EMESRT

Design OMAT “Design for Operability and Maintainability Analysis Technique” is a hierarchical, task-oriented, risk-based approach to design for safety, health, and productivity (Horberry et al, 2011). Design OMAT involves a six-step process (Horberry et al, 2011):

1) Prioritisation of critical tasks
2) Task analysis: identification of the physical, cognitive, or communicative components of the task
3) Hazard identification, escalation, and risk determination
4) Control strategy (solution) development
5) Consultation with workers through seeking feedback during concept, trials, design, or (re)design (an iterative design process)
6) Maintenance of a risk register

The Design-OMAT also forms part of the Earth Moving Equipment Safety Round Table (EMESRT) Design Evaluation for Equipment Procurement (EDEEP) process. The EMESRT is a collaboration of multi-national mining companies formed in 2006 with the aim of engaging with equipment manufacturers to facilitate design improvements for mining equipment. EMESRT member companies have collaborated to create “design philosophies” which capture the collective view of the companies regarding hazards that should be considered during the design of earth-moving equipment. The EDEEP process is intended to provide potential equipment purchasers with information to assess how well the EMESRT design philosophies are addressed in equipment design. The process also provides guidance for manufacturers to improve design for safety and productivity (Burgess-Limerick et al, 2012). Potential unwanted events are derived from the design philosophies (Table 4.1).

Table 4.1

Potential Unwanted Events Considered by EDEEP

No.	Event	No.	Event
1	Fall from height	11	Inadvertent or erroneous operation of a control
2	Fall on same level	12	Incorrect understanding of a display or label
3	Egress blocked during emergency	13	Failure to respond to an alarm
4	Struck by / contact with materials, substances, or objects	14	Extreme temperature exposure
5	Caught between moving objects	15	Respirable dust exposure
6	Wheel assembly, rim, or tyre failure or explosion	16	Exposure to diesel particulate material or other particulates
7	Fire	17	Noise exposure
8	Exposure to manual tasks	18	Whole-body or peripheral vibration exposure
9	Collision	19	Failure of control system
10	Loss of machine stability	20	Exposure to irrespirable atmosphere in confined space

For each potential unwanted event, the maximum reasonable consequence is coded on a five-point scale:

1: Minor: No treatment or first aid only

2: Medium: Medical treatment, no lost time

3: Serious: Lost time injury

4: Major: Single fatality or severe irreversible injury/illness (disablement)

5: Catastrophic: Multiple fatalities or severe irreversible injuries

Task exposure levels are considered also.

Hazard Reporting Versus Task-Based Reporting

The EDEEP provides for task-based risk determination. Many organisations communicate safety management by hazard registers and safe work methods. Guidance documents typically explain the first step in a risk management process by "identifying hazards" (e.g. Workplace Health and Safety Queensland, 2011; SWA, 2011b). An alternative is to begin with the identification of critical job roles, tasks, activities, environmental conditions, and production demands; and then, through hazard management practice, prioritise intervention. In human factors and ergonomics, the hazard, determined risk, design philosophy, interventions, and scope of influence are rooted in the hierarchical analysis of task performance (Stanton, 2006).

A feature of human factors and ergonomics is to describe the job role and task demands required of the worker; their equipment interface, interactions with equipment, tools, artefacts and work systems; decision-making and work tactics; the cultural and physical environment; and the demands of production (Grandjean, 1986; Karwowski, 2012). A hierarchical task-based analysis enables hazards to be identified in context with tasks. Human behaviours and work variability are considered (Stanton, 2006). This practice is consistent with the international standard for design of machinery in which it is specified that human interaction must be considered during the life cycle of the machine through detailed task identification for operators, educators, cleaners, and maintainers (ISO 12100: 2010b).

Traditional hazard-based registers are unlikely to be exhaustive and, thus, only diluted, broad-stroke interventions can be addressed via communication logs. Tacit knowledge is easily lost when structural changes are made; and an organisation must consider how to collect, store, and transfer safety-critical knowledge to a dynamic workforce (Campbell et al, 1995). Transfer of information is considered critical in the management of safety systems (Westrum, 2014). Routine hazard reporting may increase workload, and the paperwork may be a deterrent (Campbell, et al, 1995). Further, organisations tend to be poor at identifying which of their employees are most at risk and, consequently, are unable to escalate important intervention (MacDonald & Evans, 2006). Traditional hazard reports do not rapidly link high hazard exposure to worker type/area/volume, task type, hierarchical task flow, seasonal work flow, or operational demand. Relying on the lag indicators of incident reporting does not provide for depth of understanding of organisational risk and opportunity for quality improvement (Burkowski, 2007).

Organisations are at risk when they do not allocate resources to interventions that may contribute most to health or productivity (Karanika-Murray & Weyman, 2013; Weyman, 2012). Hierarchical task-based reporting linked with hazard management and the subsequent development of a library of case-based interventions provides for relevant, transferrable information. These methods strengthen communication systems and enable situation awareness (Campbell et al, 1995; MacDonald & Evans, 2006; Westrum, 2014).

4.1.2 The Functional Resonance Analysis Method (FRAM)

The Functional Resonance Analysis Method (FRAM) is a descriptive modelling process from which formative analysis may be undertaken. It is an emerging practice within the domain of resilience engineering which recognises humans at the epicentre of sociotechnical systems and can be aligned with human factors and ergonomics (Eurocontrol, 2009).

The FRAM models the interplay of work dynamics. The value lies in observing things as they are without presupposition of how they should be or judgement of good or bad. The non-linear analysis helps teams review all possible outcomes given the complex interplay of tactics and system functions in a continuous scenario. The study is representative of the dynamics of humans, work and work conditions, environment, and time in motion more so than a traditional flow chart illustrative of event analysis (Hollnagel et al, 2014). In FRAM, functioning is a result of emergent properties and cause and effect is not seen as a simple construct. Errors, faults, standard operations, and optimum productivity all emerge from multivariate factors. Interdependent activities affect the system. Tight couplings (known as “controls” in traditional systems safety) may mitigate system resonance to achieve greater probability of desired outcomes. A positive output of the system may be quality production. An undesired output may be a system error. Modelling can reveal methods to monitor and regulate a system (Eurocontrol, 2009; Hollnagel, 2012; Hollnagel et al, 2014).

The FRAM involves four primary steps and, within these, identification of six general characteristics associated with task functions (“actions” of humans or technology). These characteristics are referred to as “aspects”: input, output, precondition, resource, time, or control. These aspects connect functions to demonstrate their relationship. Figure 4.1 shows the diagram of a function and its aspects and Table 4.2 describes this process:

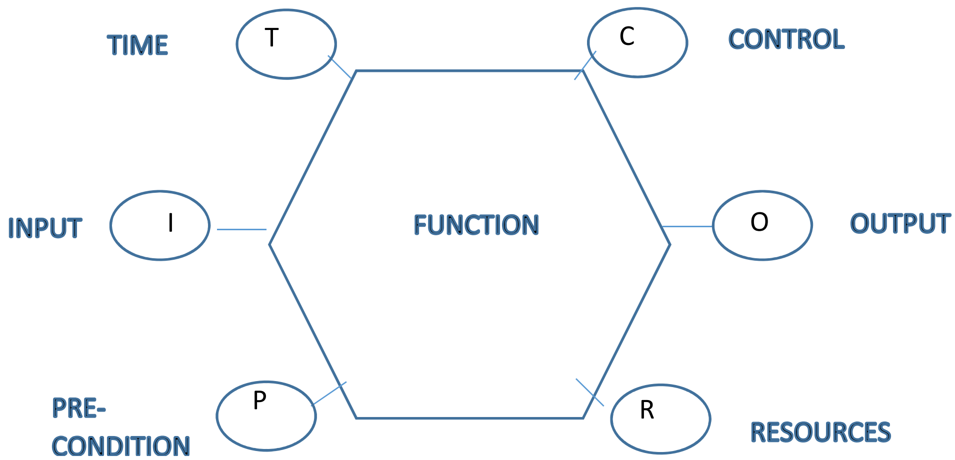


Figure 4.1: Six aspects of a FRAM function (adapted from Hollnagel et al, 2014)

Table 4.2:

FRAM Method (Hollnagel et al, 2014)	
Step	Description
1. Create the FRAM model: a. Identify and describe important system functions b. Characterise each function using six basic aspects. Note: each function may have one or more of these aspects and need not have all aspects coupled to another function to exist within the system	Six aspects include: • Input: that which activates a function – e.g. data, instruction, or energy • Output: a result of a function – e.g. material, energy or information, a change of state • Precondition: system states that must be true and verified before a function is executed but is not an input • Resource: something needed or consumed for a function to occur • Control: that which regulates a function • Time: clock time, elapsed time, or a sequential time requirement that affects performance
2. Characterise the potential variability in the model	Determine possible fluctuations with performance owing to varied actions, tactics, or decisions that may occur within that system
3. Determine the possibility of functional resonance	Determinations are made given potential and actual variability. They are not summative, just influential (e.g. not flow chart arrows, or a + b = c; rather "a" and "b" may occur to varying degrees and "c" will fluctuate)
4. Develop recommendations on how to monitor and influence variability	Consider how to diminish variability and promote predictability within the system toward achievement of desired outcomes

Functions may be described as a foreground or background action within the system. If assigned to a background function, it should be less variable. When a focus of study changes, foreground and background assignment may change per the iteration of the model (Hollnagel et al, 2014).

Rosa et al (2015) provides an example of the application of FRAM in the process of construction waste reuse with crusher operations. The analysis involved review of a) material selection (screening), b) delivery of sorted waste via loaders to the crusher, c) crushing material with a mobile jaw equipped with a magnetic extractor, and d) delivery of the material by conveyor belt into a truck. Hazards included exposure to occupational noise, vibration, dust, thermal overload, awkward postures, and manual tasks; and there were incident risks, such as collisions, crush injuries, and vehicle roll-overs. A team approach was used to evaluate risk and determine effective controls. To dampen the functional resonance (variability) of the system and reduce hazard exposure, the work involved modifications in the crusher with an anchoring system and an automated control. Implications were found regarding qualifications, training, and supervision requirements for workers.

4.2 Aims

The aim of this chapter is to examine the utility of OMAT, EDEEP and FRAM tools in two cases involving capital equipment purchase. Theory about human-centred design practice will be tested and emerging trends will be examined for the development of new propositions.

The propositions include:

- Injury risk is reduced when equipment is (re)designed through human-centred practice
- Business is improved when equipment is (re)designed through human-centred practice

4.3 Research Question

What tools were useful to good work design for two cases involving capital equipment consideration and what were the necessary conditions to support this design process?

4.4 Methods

Two cases in which a human-centred analysis had been successfully undertaken were selected for detailed analysis. The cases involved practices and tools that had been used extensively in mining - Design for Operability and Maintainability Analysis Technique (d-OMAT) and the EMESRT Design Evaluation for Equipment Procurement (EDEEP) (Burgess-Limerick et al, 2012; Horberry et al, 2011). In one project, the investigator was the facilitator of the design review and identified the opportunity through worker consultation. In the other project the investigator supported an active review process that was undertaken within an organisation of their own initiative. This comparative case study method supported the generalisability of the findings.

The FRAM, with software application (FRAM Model Visualiser 0.4.1), was used for descriptive modelling of the macro-organisational factors that were conditions of the review of equipment in these organisations. These categories were verified with study subjects (co-analysts and interviewees, i.e. workers, a safety coordinator, and business managers). A thematic analysis was undertaken to classify these functions by type (Glaser, 1969; Glaser & Strauss, 1967).

The first case, hosted in a large, multi-national organisation, gave rise to the development of positive performance measures that could underpin a good work design program. The investigator captured key intent expressed by the subjects and verified the classification applied for the performance measures with the subjects; refinements were made and a final framework for program measures was presented to managers in the organisation (of multiple business units) by way of a monthly report submission and face to face review with the regional contracting manager.

4.4.1 Case 1: Asphalt Job Truck: Methods

The design review of an asphalt job truck was selected because the equipment was known to the investigator following a hierarchical job analysis of the asphalt road worker and field mechanics. Literature was shared with ten members of a management team comprising a national procurement manager; state business unit general manager; a regional contracting manager; two operations managers; a contracts manager; a regional workforce manager; a regional and a senior health, safety, and environment manager; and a local safety advisor. Evidence-based findings of human-centred design in mining were shared to build knowledge of the merits of the practice. Training in manual task risk management was provided via six workshops to local work and maintenance teams, a management team, and members of a regional safety committee. The equipment procurement schedule was reviewed to determine whether design review could complement supplier specifications in the next tender. The local representative for capital expenditure, the national procurement manager, and a national design engineer in a complementary business unit (transportation) were notified of the study to be undertaken so that their input could be considered.

Qualitative methods included observation of work and equipment interface in the natural environment, observation of simulated work in a depot, unstructured and semi-structured interviews, and hierarchical task analyses of the job truck operator, crew, and maintenance teams. The safety advisor was involved in co-analysis.

Field Visits and Activities

The investigator conducted six site visits over eight months: five in attendance at roadworks projects and one at the depot. Investigations were undertaken in rural and urban (metro) territories. Observations occurred in day- and night-time to capture the natural working conditions of both shifts. Unstructured and semi-structured interviews were conducted with relevant stakeholders (including work crew, mechanics, team leaders, site supervisors, and project managers). Leadership support was influenced through earlier activities, such as dissemination of evidence-based findings, up to ten months prior.

The investigative activities included: participatory task analyses (including taking images, video playback, measurements for reaches, exertion requirements, and body mechanics), development of a job analysis report, hazard identification, task simulation at the depot, field visits, development and application of a truck design checklist, dissemination of literature to inform the managers of evidence for practice, coordination and facilitation of design review sessions, participatory application of EDEEP, consultation with other business units, and internal communication of findings through verbal and written reports. Consultation with industry experts and the national procurement manager also occurred. Face-to-face presentations were delivered to a regional management team and a national product group. General findings were shared with the regulator in a transport advocacy group and conversations were held with a representative of the Truck Industry Council to advance the initiatives of human-centered design among manufacturers. A representative of the board of the Australian Trucking Association was informed of the results.

d-OMAT and the Application of EDEEP

The Design-OMAT six-step process was undertaken: critical task identification, hierarchical task analysis, hazard identification and risk determination, development of control strategies, feedback and action planning, and risk register documentation (Horberry et al, 2011). The EDEEP risk matrix was completed during two meetings with the safety advisor and workshop mechanic. Periodic checks were made with crew and operations managers to affirm the validity of determinations. The risk matrix required identification of priority tasks and potential unwanted events (informed by worker opinion, historical occurrence, near misses, and near rights[3]). Linkages were made among hazards and the 20 unwanted events provided by EDEEP. These events were assigned perceived likelihood and consequence to determine risk ratings using the matrix built into the tool. The EDEEP prompts users to consider control intervention. The design strategies were elaborated using hazard to design layering, an extension of a practice applied by Cooke (2014).

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[3] Near right = a situation when workers adapt equipment, tools, tasks, or procedures to optimise performance and when it may be contrary to, or simply not addressed by, written work methods.

Supplemental Checklist

A supplemental checklist was devised to aid the process of semi-structured interview during stage two of d-OMAT. The checklist included items such as: vehicle and equipment functions, injury or incident history, discomfort survey associated with vehicle operation and access, maintenance requirements, and planned procurement schedules. Prompts to review vehicle features included: seating systems, visibility issues, ingress/egress measurements, grab rail dimensions and type, and hand and foot control measures and design (e.g. lay-out, number of controls required for operation, shape and shape coding, level length, colour, functionality, and direction of use). Investigations were undertaken to consider alarms, indicators, auditory or haptic alerts, proximity sensors, access points on the body, pinch points on cabinetry, and fixed or portable equipment required for transport. Prompts included the need to investigate whole-body vibration exposure, steering systems, tools and raw material required for transport, and environmental conditions in which the vehicle must operate.

An Appreciative Approach

The investigator used an appreciative approach (e.g. Bushe & Kassam, 2005; Mishra & Bhatnagar, 2012) to elicit ideas from operators, maintainers, and team leaders and formulate design strategy. This approach involves the application of positive psychology and the phenomenon of anticipation (e.g. Bushe & Kassam, 2005). The line of questions was formulated spontaneously to correspond with the natural flow of conversation but was generally guided by this framework. The questions acknowledged and appreciated what worked well rather than only focusing on problems and hazards. Discussions were held about best-practice design and innovations in other industries and consideration of a possible shared destiny for best-fit design of the truck to suit the workers and their tasks (human-centric design). Participants were guided away from focusing on established, predictable, prescribed methods of work and equipment interface. This was initially the default reaction, as expressed in sentiments such as, “We’ve always done it this way”, or “This is the way the truck is delivered. It just comes like this. We were never asked if it suited us and didn’t believe we had any say in the matter”.

The line of questions employed by the investigator included the following examples:

1. *How can we best achieve safety, health, and productivity (in relation to this vehicle/equipment)?*
2. *If a change to equipment design were possible, what should that look like?*
3. *How could this change be implemented?*
4. *What contribution today (in relation to this job truck design) might make a measurable change in performance?*
5. *What collective actions would need to occur for the change to be implemented?*
6. *When will we know that we have achieved success?*

Specific observations or findings were also made during the interviews, such as:

- *"Safe work methods instruct cab-facing entry/exit with 3-points of contact. However, at least 30% of the time, I observe workers doing the opposite, sometimes jumping out face-forward. Can you tell me why this might be a preferred approach?"*
- *"Your transport division changed the step-well of their fleet from those with metal fabrication and sharp-edge bull guards. They replaced those with FRP/GRP fiberglass grid (a high-degree slip-resistance material). Would that be useful to you, too?"*

This appreciative approach was employed during interactions with other representatives in the organisation - including operations and procurement managers - a supply chain representative, capital expenditure coordinators, and finance teams, when the findings and review of job truck design were broadened for discussion.

Systems Review of the Design Process: FRAM

Functions that supported the job truck design review were identified through collaborative, reflective review with the operations manager and safety advisor. The Functional Resonance Analysis Method (FRAM) was used to map design activity. The FRAM analysis involved developing an organisational model that described the practice of design-OMAT. The investigator drafted the model and refinement occurred through consultation with study participants, the manager and safety advisor over three meetings. It involved two primary stages: developing a model of the activity (processes) and, then, applying the model to analyse system performance. This two-step process is referred to as “breadth before depth” (Hollnagel, 2012).

The following steps were undertaken:

1. Identify important system functions
2. Characterise potential variability within the model
3. Determine resonance (potential variability)
4. Develop recommendations as to how to monitor and influence the variability of the model to increase the probability of high performance.

4.4.2 Case 2: Bitumen Trailer: Methods

Background

Speedie Contractors is a small, specialised road construction transport company that hosted a design review of their bitumen trailer. The family-owned organisation employs 35 people to operate 32 rigid trucks and prime movers in the road surfacing sector. The owners are two brothers: one who has served as the chair of the National Safety Committee of the Australian Trucking Association since 2013 and the other is the general manager of their business. The owners noted that the design of bitumen trailers had not been addressed for over 30 years and they were eager to do so if it resulted in improvements to efficiency and safety in operation.

Bituminous products are classified as dangerous, hazardous goods at elevated temperatures (AS 1940:2004). Depending upon the grade of bituminous product, the product may reach temperatures up to 200° C, with a heating rate of up to 40° C per hour. Bitumen, in hot or molten state, presents hazards to workers for thermal burns, fume and toxic vapour exposure, respiratory tract or eye irritation, and exposure to irritating emulsifiers (Energy Institute, 2005). Contained bitumen, under certain conditions, may be explosive (e.g. AAP General News Wire, 2012; The Canadian Press, 2009; The Times of India, 2010).

Methods

The design review of a bitumen trailer was selected because of the qualification of entry criteria described above: it was under review by the organisation (two owner/managers and their assigned staff), and they were interested to augment their design practice with human-centred tools and approaches; the review identified more than three hazards to address; and the project was known to the investigator.

The investigator worked with the owner/managers to engage the six-step d-OMAT process for design review of the bitumen trailer. Semi-structured interviews were undertaken, and task analyses were conducted of the bitumen tanker operator and the maintenance worker. Relevant measurements (reach arcs, working heights, widths, perceived exertion levels, force exposures), and images were taken. The EDEEP tool was applied, as was a supplementary checklist of vehicle design, in consultation with the general manager of the business, a maintenance worker, and operators present during site visits. The managers consulted with the National Heavy Vehicle Regulator, the Australian Trucking Association, and principal contractors in preparation for design changes. The tool quantifies severity of adverse events informed by participative consultation with subject matter experts and the design philosophy underpinning this tool.

The FRAM with software application (FRAM Model Visualiser 0.4.1) was used for descriptive modelling of the factors that influenced human-centred design review of the bitumen trailer.

4.5 Results

4.5.1 Case 1: Asphalt Job Truck: Results

Task Selection

The job truck was used routinely for asphalt roadworks project and is equipment that is retained in the business for 12 – 20 years of operation.

Hazards, Risks, and Design Considerations

Three serious or major risks (fatality or severe to moderate disability) and four moderate risks (potential injury relating to musculoskeletal disorder) were identified (Table 3.2). Overall, 15 hazards were identified and strategies for design improvement were provided. The organisation instructed some changes to be made by workshop mechanics but, ultimately, decided to development of procurement specifications and then hand the responsibility for design improvement to the truck body build supplier. Following design review, the organisation requested training from its supplier for the operation of the crane lift however, after repeated calls were unanswered, they went to another supplier.

Table 4.3

Top 7 Issues: EDEEP Risk Determination and Design Considerations

No	Consequence	Likelihood	Description	Design Considerations: Preliminary
1.	**Severe**	Unlikely	Crane lift failure: risk for loss of machine stability or hitting object or person	Lift capacity routinely engineering rated; training to workers; review with management as to cost-benefit; assess rural versus metro use
2.	**Serious**	Possible	Retrieval of diesel bath bucket: Manual task exposure (sprain/strain)	Referral for further ergonomic risk assessment; (re)design diesel bath bucket, paver lug attachment, storage, and transportation strategy
3.	**Serious**	Possible	Retrieval of vibe-plate and	Independent quick-activation control for hydraulics of lift

Top 7 Issues: EDEEP Risk Determination and Design Considerations				
No	Consequence	Likelihood	Description	Design Considerations: Preliminary
			jackhammer: manual task exposure (sprain / strain)	platform or cradle release with hydraulic or air ram to lower items to ground
4.	Serious to Medium	Possible	Access to battery behind electrical housing: manual task exposure (sprain/strain)	Specify clear access to battery housing for ease in replacement in depot and in the field
5.	Serious to Medium	Possible	Rear cab egress: fall from height	(Re)design stepwell for uniform step height, swing away access (for mechanics) and improved visibility and access; add night-time lighting; add coated safety high-vis yellow tread
6.	Serious to Medium	Possible	Front cab ingress/egress: fall from height and sprain/strain	Replace plastic top tread with metal step and add coated safety high-vis yellow tread to steps; design for even risings ≤ 5mm variation; add focal lighting and strip lighting; design for visibility day and night
7.	Medium	Possible	Hard edge and heavy weight cabinet lids: pinch point risk	Use foam insert and install gas struts to prevent pinch-point hand injuries

Organisational Activity to Support the Review

Several activities were required to support the implementation of d-OMAT in the organisation. (Table 4.4):

Table 4.4

Work Practices that Supported d-OMAT

Alpha -Order	Practices	Number-Order	Design-OMAT Steps
a.	Observations & Conversations: Field		
b.	Interactive Training Delivered		
c.	Evidence-Based Research Provided		
		1.	Critical Task Identification
d.	Review EME / Equipment Procurement Plan		
e.	Elicit Leadership Support		
		2.	Hierarchical task-analysis
f.	Refer to EME Checklist		
g.	EDEEP Tool Application Multiple visits		
		3.	Risk I.D.
h.	Coordinate Stakeholders		
		4.	Solutions Options
		5.	Feedback & Action Plan
		6.	Risk Register
i.	Cost Investigation or Justification		
j.	Present to Management Communicate & Celebrate		

The FRAM model for the asphalt job truck design review is represented in Figure 4.2. The green functions (symbolised by hexagonal shapes) represent the 6-step process of

Design-OMAT. Yellow functions represent additional resources and tools used in the equipment design review process. The blue functions represent organisational activities that supported the design process. Purple functions represent positive influences.

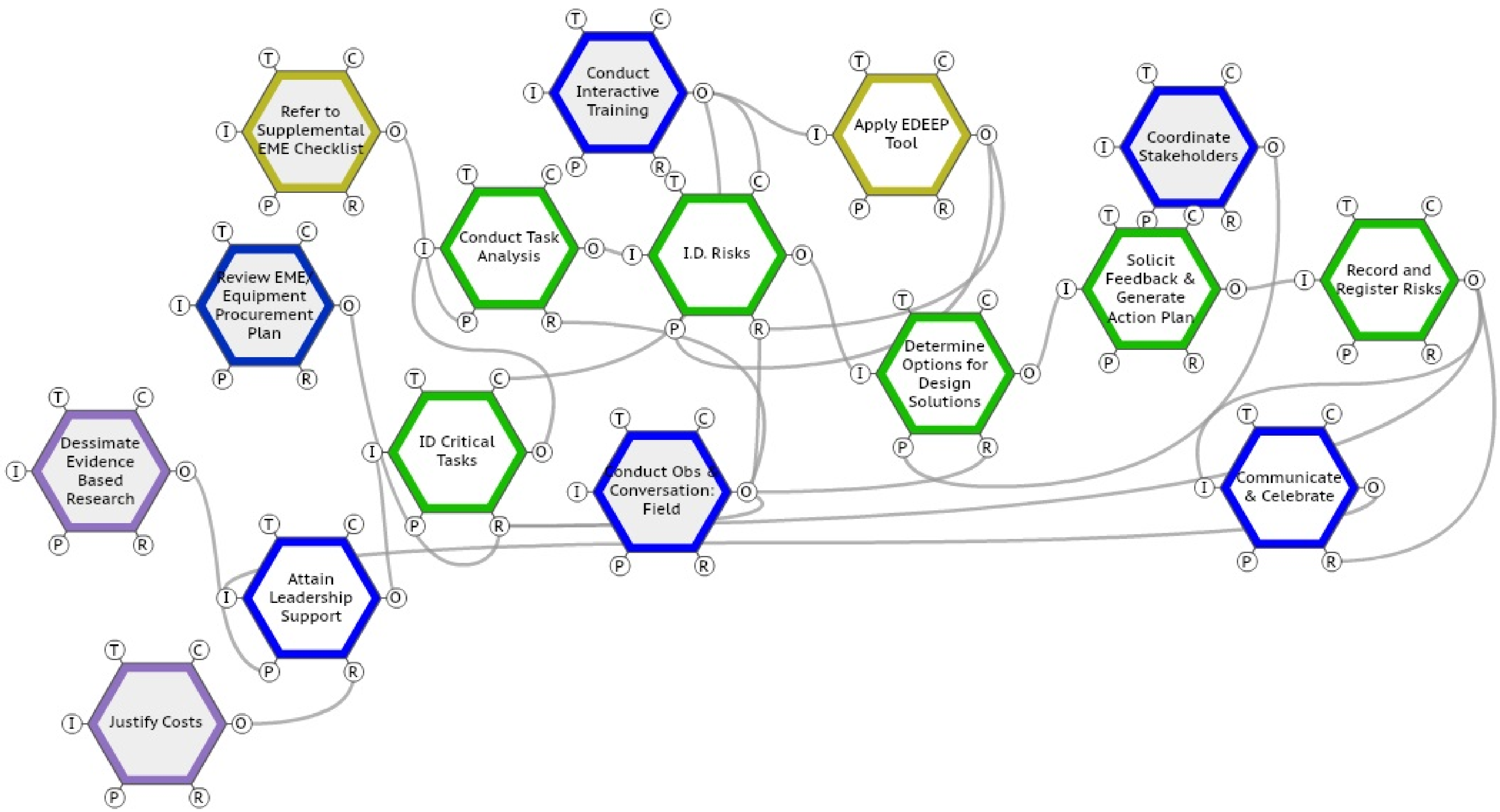


Figure 4.2: FRAM model of work practices that enabled d-OMAT

The FRAM model requires each function to be “coupled” (connected) with another function. An output of one function may lead to another by way of an aspect: e.g. Input, Control, Resource, Precondition, or Time to reflect system regulation. This process is detailed in Table 4.5 below:

Table 4.5

FRAM Model Coupling: Work Practices that Enabled d-OMAT

Colour: Type	Function	Aspect(s)
Green: Design- OMAT	a. Identify Critical Tasks	Input: Apply HCD in Design of Work Output: ID Tasks & Activities in Sequence Resource: Operators & Maintainers; Capital Equipment Plan, Communication of Findings
	b. Conduct (hierarchical) Task Analysis	Input: ID Tasks & Activities in Sequence Output: I.D. Hazards re: Equipment, Environment, Work Flow Resource: Operators & Maintainers Precondition: Refer to Checklist
	c. Identify Risks	Input: I.D. Hazards re: Equipment, Environment, Work Flow Output: Rank Risk & Consider Critical Controls Precondition: Risk Understanding: Critical Events Resource: Operators & Maintainers; Apply EDEEP Design Philosophy / Risk Rating Control: Develop Tacit Knowledge
	d. Determine Options for Design Solutions	Input: Rank Risk & Consider Critical Controls Output: Devise Design Objectives Precondition: Coordinated Plan for Design Resource: Operators & Maintainers

FRAM Model Coupling: Work Practices that Enabled d-OMAT		
Colour: Type	Function	Aspect(s)
	e. Solicit Feedback & Generate an Action Plan	Input: Devise Design Objectives Output: Prioritise Control Intervention
	f. Record and Register Risks	Input: Prioritise Control Intervention Output: Communication of Findings Output: Create Task-Based Risk/Design Case Library
Yellow: Additional Resource	a. Refer to Supplemental EME Checklist	Output: Refer to Checklist
	b. Apply EDEEP Tool	Input: Develop Tacit Knowledge Output: Apply EDEEP Design Philosophy / Risk Rating Risk Understanding: Critical Events
Blue: Organisational Drivers	a. Review EME/Equipment Procurement Plan	Output: Capital Equipment Plan
	b. Conduct Observations & Conversations: Field	Output: Operators & Maintainers
	c. Conduct Interactive Training	Output: Develop Tacit Knowledge
	d. Coordinate Stakeholders: (e.g. procurement, workforce strategy, engineers, safety, operations, suppliers)	Output: Coordinated Plan for Design
	e. Communicate & Celebrate	Input: Communication of Findings Output: Develop Collective Norms

FRAM Model Coupling: Work Practices that Enabled d-OMAT		
Colour: Type	Function	Aspect(s)
		Resource: Create Task-Based Risk/Design Case Library
Purple: Positive Influencers	a. Cost Justification	Output: Productivity & Efficiency
	b. Disseminate Evidence-Based Research	Output: Compelling Evidence

A thematic analysis of functions arising from the model of system performance for the job truck design review can be considered: the tool, the additional resource required, organisational drivers, and systemic factors that influenced the project.

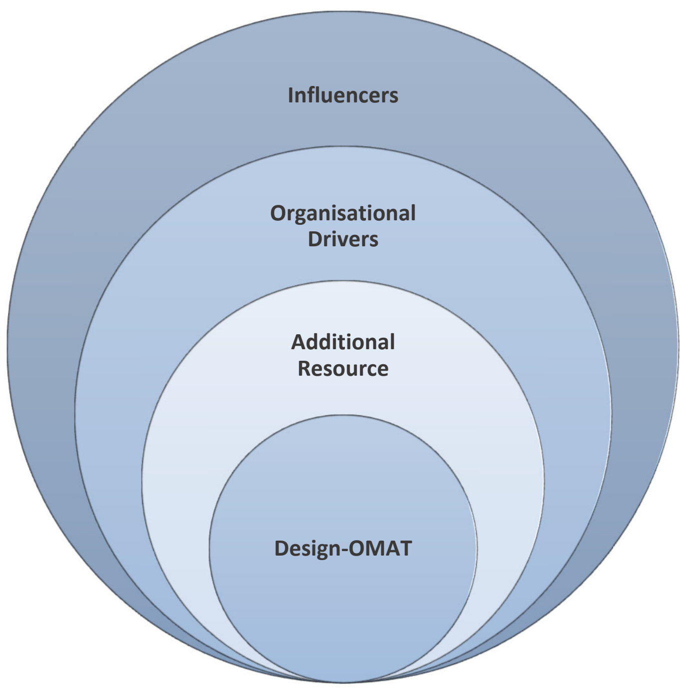


Figure 4.3: Layers of system performance

FRAM modelling permits identification of foreground and background functions. Two management representatives identified the organisational drivers as highly important to the design review (typically considered a background activity) and vital to advance the foreground activity (the design process).

Positive Performance Measures

Benchmark measures for positive performance were developed to monitor and increase the probability of positive performance (e.g. Hollnagel, 2012). This arose from discussions with the participants who identified the need to implement these projects regularly (i.e. to develop and manage a program for task and equipment design review: participatory ergonomics). These measures were categorized broadly in elements of: Learn, Do, Manage (e.g. Humantech®) and verified through consultation with the participants. Within this framework, five broad goals were established with 35 possible measures in categories of input, process, and output. The goals are described below:

1. Learn:
    a. Build tacit knowledge within the organization regarding participatory ergonomics (PE) and human-centred design (HCD)
    b. Develop leadership support for PE/HCD programs
2. Do:
    a. Know what the workers do: converse and observe in the field
    b. Document key job roles with hierarchical, risk-based task analyses
3. Manage
    a. Develop a comprehensive system of managing a PE/HCD program through effective data collection, communication systems, reporting, tracking, and evaluation

Sample measures included:

1. Input:
    a. Number of educational articles related to PE/HCD disseminated within the organization each month
    b. Presence of an organisational position statement, signed/endorsed by executive management, regarding adoption of PE/HCD
    c. Presence of policies, procedures, guidance documents and reporting tools to support PE/HCD practice

2. Process:
    a. Number of field visits undertaken to observe work tasks and converse with workers
    b. Number of relevant job analyses and hierarchical, risk-based task analyses documented and updated
    c. Number of design champions trained and assigned to good work design activities per capita in the workplace
    d. Establishment of achievable lead indicators for design improvement within work teams
    e. Percentage levels of satisfaction and engagement among participants of PE/HCD training
    f. Number of supplier contracts requiring HCD practices clearly evidenced
3. Goals/Outcome:
    a. Number of effective design interventions implemented and evaluated
    b. Percentage of capital equipment and equipment items with procurement specifications developed through HCD practice
    c. Development of a task-based good work design case library

4.5.2 Case 2: Bitumen Trailer: Results

Five site visits were made over 13 months to determine the scope of investigation for the project, conduct two job analyses, and confer with staff and management to determine risks and apply the EDEEP tool. Observation of a design control was undertaken (a remote lever to operate a discharge valve). Eighteen task-based hazards for operators were identified. The most serious were exposure to hot bituminous product and potentially explosive stored bitumen product. Fatigue risks were of great concern to the staff because of the extended hours of work with sustained driving in heavy industrial environments. Twelve task-based hazards were identified for the bitumen tanker mechanic with the greatest concerns being exposure to hot product and equipment components when conducting “hot works”; slip, trip, or fall hazards; and hazardous manual task exposure. Specifically, the following tasks were identified with the need for improved work design: administering bitumen discharge, working with contained product (explosive risks), heating product in tanker (requiring extended work hours which may be fatigue-inducing), extended driving periods, climbing atop the tanker to access hatches, hot works maintenance, and general maintenance. Two hazardous conditions were not easily attributed to the Earth Moving Equipment Design Evaluation Safety Round Table (EMESRT) design philosophy to identify potential unwanted events using the EMESRT Design Evaluation for Equipment Procurement (EDEEP) Tool: exposure to flash arcs from welding during maintenance and the risk for fatigue resulting from task exposure and product design (as opposed to the impact of fatigue affecting situation awareness and operational performance).

EDEEP Findings to Support Design Review of the Bitumen Trailer

The EDEEP findings with design considerations for the bitumen trailer are summarised in Table 4.6:

Table 4.6

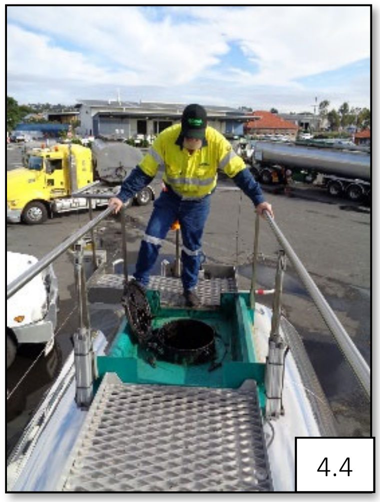
Bitumen Trailer: Application of EDEEP Risk Determination and Design Strategies				
No	Consequence	Likelihood	Task and Event Description	Design Considerations: Preliminary
1.	Catastrophic	Possible	Heating contained product: overheating, fumes, or line blockages resulting in explosion	Isolate worker from operations requiring proximity to tanker; eliminate LPG as heating fuel; remote automated controls as below
2.	Severe	Possible	Bituminous product direct body contact exposure with risk for burns during heating and transfer of product	Isolate workers from operations requiring proximity to tanker (operations and maintainers); trial remote, automated lever and valve controls, side ladder installation (versus rear) (note: maintain lightweight design and roll-over protections)
3.	Severe	Possible	Slip, trip, fall during climbing and inspecting hatches or accessing levers/valves	Isolate workers from rear of tanker with valves/product conduits; improve on-the-ground visual access to any monitoring devices; recess hatches to reduce trip hazards; guarding; reduce need for frequent inspection; fold-down steps (lightweight) or external
4.	Serious	Likely		

Bitumen Trailer: Application of EDEEP Risk Determination and Design Strategies				
No	Consequence	Likelihood	Task and Event Description	Design Considerations: Preliminary
			Heating and extended travel; extended hours waiting for heating on-site after product has cooled resulting in fatigue	step attachment for maintenance activities Design to promote heat retention; improve thermal insulation; recess hatches; flexible seals secure. Eliminate LPG as heating fuel; aim for continuous heating with electrical heating elements in tank; investigate back-up generators (diesel package with self-generating energy from load bearing wheels)
5.	Serious to Medium	Possible	Repairs and maintenance; exertion with awkward postures (e.g. change kingpins); operations: exertion and awkward posture: e.g. bitumen hose reel manoeuvres	Use lift aids where possible; construct lift aids if customisation required; e.g. kingpin stand; reduce hose weight or provide segmented support to reduce exertion in manoeuvres

Initial Prototype of New Bitumen Trailer

The industry partner worked with the trailer manufacturer and supplier over 15 months to integrate the design ideas for the development of a new bitumen trailer prototype. Despite receiving comments from industry representatives that their design ideas were over-reaching (especially the change to heating elements), the organisation persevered and received approval from the Dangerous Goods Authority to trial their prototype. The investigator reviewed the prototype trailer at the depot 28 months after conducting the first job analyses of the bitumen trailer operator. Figures 4.4 – 4.14 illustrate the integration of design changes that included: electric, continuous, heating in-transit system with a diesel package burner (eliminated LPG gas systems); temperature sensors with digital readings and GPS transfer data to inform the operator and head office of system functions; roll-over and impact sensors to shut-off the system in case of collision; trailer ladder moved to the side; pneumatic ladder and guarding activation; fewer top hatches (only one) to reduce heat dissipation and reduce operator need to be atop the trailer; remote control bitumen pump lever; lowered valves and levers at rear to permit work from ground (versus climbing on the rear bumper); and a shortened delivery pipe (minimise the use of flush and exposure to awkward postures). The trials indicated a savings of 3 to 6 hours of heating time (and, thus, operator work hours) per shift, representing a significant improvement in productivity and performance.

Images of Tasks Associated with the (Old) Bitumen Trailer

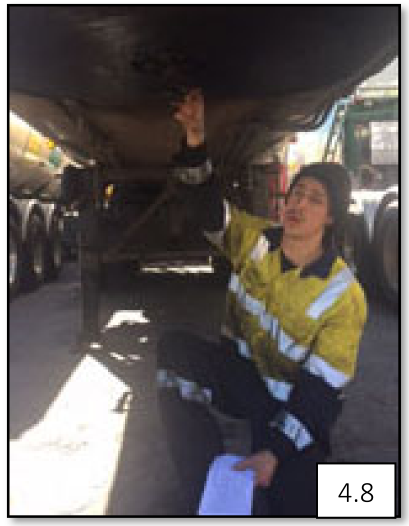


4.4

4.5

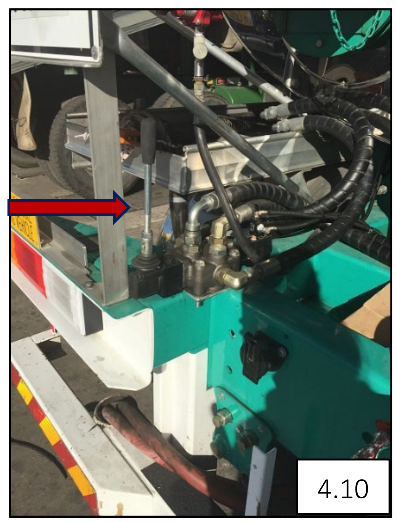
4.6

Figures 4.4 – 4.6: Inspecting hatches; operating levers at rear of tanker; and manipulating steel hoses

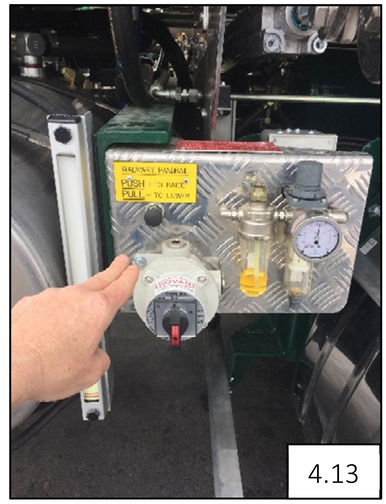


Figures 4.7– 4.8: Servicing levers; Reaching to change a kingpin required exertion with an overhead sustained activity

Images of the Design Changes



Figures 4.9 – 4.10: Simulated trial of remote control for lever operation for bitumen transfer; Remote-operated lever



Figures 4.11 – 4.13: New bitumen trailer with: side ladder, internal heat sensors with GPS relay, and lowered gauges and valves for ground-level work.

Application of FRAM

FRAM modelling was undertaken to map the d-OMAT activity associated with the review of the bitumen trailer (Figure 4.14). While d-OMAT is formatted in the diagram in its six-step process, this organisation had been working on control intervention (remote lever activation) before the task analysis was undertaken. This is indicated in the diagram with a red “1” and “2” to indicate which step was undertaken first (or the method of instantiation of the model, Hollnagel, 2016), even though this is out of order from the methods prescribed by d-OMAT. The thematic analysis is identified in this diagram by colour coding (refer to the key beneath the diagram).

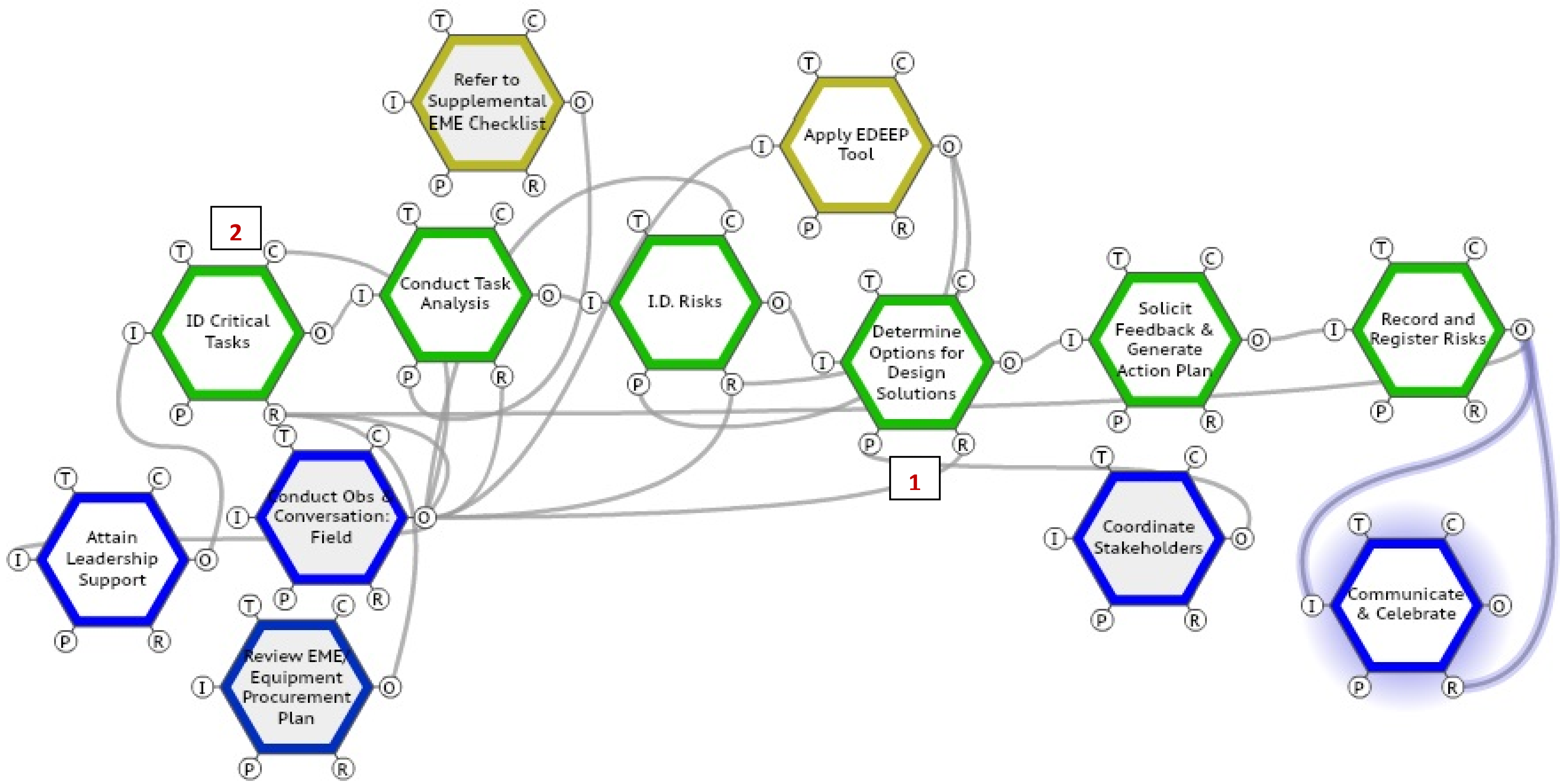


Figure 4.14: FRAM model of work practices that enabled d-OMAT: bitumen trailer

Key: Thematic Coding: Green = d-OMAT methods; Purple = Organisational drivers; Yellow = Additional resource

4.6 Discussion

This study applied d-OMAT and EDEEP to the review of road construction vehicles (an asphalt job truck and a bitumen trailer) in the first known application of these tools and methods in the construction and transportation industry. Examination of the design strategies was undertaken through descriptive modelling using FRAM model visualiser (version 0.4.1). A brief review was undertaken of the differences in the work practices that enabled human-centred design in a large, multi-national construction organisation versus the small to medium road transport company.

The propositions included:

- Injury risk is reduced if equipment is (re)designed through human-centred practice
- Business is improved if equipment is (re)designed through human-centred practice

In both cases, the findings verified these propositions as conditions of sufficiency: if human-centred equipment (re)design review is undertaken, then injury risk reduction and business improvement will occur.

Case 1: Asphalt Job Truck: Discussion

Design-OMAT, with the application of the EDEEP risk management tool, proved a targeted approach that effectively identified work hazards not previously reported. Overall, 15 hazards were identified for the asphalt job truck and strategies for design improvement were devised. Some of these improvements were scheduled for immediate fix by workshop mechanics and others advised for procurement strategy. With equipment such as this, which requires significant capital investment and is in use in high-frequency for a lengthy operational cycle (12 – 20+ years), the exposure to hazards is considerable and the opportunity for design improvement should not be overlooked. There is competitive advantage in early, predictive, human-centred design that is inclusive of supply chain integration.

The acceptance and measure of risk reduction and business improvement was determined by the organisation in which the equipment was operated and, for both dependent variables, was deemed to be significant. The EDEEP tool used quantifiable scoring to support the calculation of reduction of severity of an adverse event (likelihood is not part of this consideration, even though frequency of exposure is).

A macro-ergonomic application of FRAM was engaged to review the conditions that supported the design process. This was a useful exercise and helped to inform regulating activities that may be undertaken to engage a human-centred design process. The model illustrated that, to host Design-OMAT for predictive review of the job truck, leadership support was an inter-related and required function. Communication and celebration of good work design served as an input to leadership support, providing a continuous loop from a positive design outcome and the likelihood of ongoing support. The couplings outlined in the model suggested that a precondition to leadership support was the dissemination of evidence-based literature supporting human-centered design. A resource (aspect) that fueled “attain leadership support” (function) was cost justification (e.g. through cost benefit or payback analysis).

The FRAM model helped illustrate a systems-approach to human-centred design. Positive performance measures were devised from this as a method to sustain the program. The systems-analysis provided 10 work practices that enabled d-OMAT and was reflective of a non-linear, complex work dynamic. For practitioners and organisations wishing to sustain a practice of good work design, a complete understanding of the activities that may be required should consider those that are prescribed (guidance documents), imagined (e.g. policy documents or project management or quality improvement specifications), disclosed (revealed through interviews or conversations with informed subject matter experts), and done (observed in the field) (e.g. Hollnagel, 2016; Shorrock & Williams, 2016).

In addition to the propositions compelling this investigation, other conditions emerged:

- Cost justification was required to attain leadership support
- Leadership support was required for d-OMAT to be practiced
- Communication and celebration were required to enlist leadership support
- Multi-modal education was required to build tacit knowledge in the organisation (about human-centred design)

- Design tools used to support human-centred equipment review in the mining industry were useful in this instance (road construction industry)

The design review process of this project enlisted the interest among subjects to describe features of a sustainable program and the drivers and measures that may be required: when workers were involved in work design review, there was interest to contribute to sustainable design practices.

Case 2: Bitumen Trailer: Discussion

This organisation was small and agile and the managers were eager to achieve performance improvement. Partly, this may be attributed to their inherent knowledge and wealth of experience in all tasks required of operators and maintainers in their business arising because the managers have performed and managed every associated job role. Further, in a small private organisation there are fewer barriers to decision-making and consensus can be achieved quickly. The influencers required in the previous case study (cost justification, dissemination of evidence-based literature, and interactive training) were not required in this instance: motivation for change and improvement was already significant. Rather, they could build on their safety-in-design thinking by developing their understanding of the human-centred approach facilitated by the investigator. In this way, communication tools were devised to effectively translate ideas to other stakeholders, such as the design engineers and supplier, and the regulator(s). This is important because it means that the conditions discovered in one case were not generalised to reflect necessity in this case. A common finding was that the design tools and leadership support were deemed useful in both cases.

The application of the EDEEP tool helped classify 5 potentially serious, severe, or catastrophic events. The managers of this organisation had determined several potential design controls but had not assessed or documented the risks prior to the investigator's involvement.

Recommendations were made to the Earth Moving Equipment Safety Round Table for the EDEEP tool to include consideration of design that may contribute to worker fatigue (such as the prolonged heating of bituminous product) and the classification of arc welding flashes as a potential unwanted event for maintainers. Fatigue was not listed on the hazard register because EDEEP was framed to consider how operator fatigue may affect operations, and not the reverse.

Research Question: Chapter 4: Discussion

> *What tools were useful to good work design for two cases involving capital equipment consideration and what were the necessary conditions to support this design process?*

d-OMAT and EDEEP were useful tools to apply in these cases, leading to the proposition that:

- Design tools (e.g. d-OMAT and EDEEP as used in mining) were necessary but not sufficient to achieve successful design review of capital equipment in two organisations representing construction and transportation industries.

Conditions of sufficiency were identified:

- Injury risk is reduced when equipment is (re)designed through human-centred practice
- Business is improved when equipment is (re)designed through human-centred practice

Conditions of necessity were identified:

- Design tools (such as the d-OMAT and EDEEP) were necessary but not sufficient to achieve successful design review of capital equipment in two organisations representing construction and transportation industries.

This was a new proposition and the comparative case studies supported the generalisability of this finding.

- Leadership support was necessary but not sufficient to practice d-OMAT and achieve effective design review of capital equipment

Another interesting observation was that the d-OMAT approach did not occur in a linear fashion as the simplicity of the six-step process may imply, suggesting that the methods, not their prescribed order, were necessary for successful design review of capital equipment.

The d-OMAT and EDEEP practice is useful for predictive design review, especially prior to equipment procurement. Ideally, it will involve manufacturers and suppliers so that responsibility may be taken by the designers. When equipment is expected to be in commission for 12 – 20+ years, predictions should consider workforce strategy. In this way, visionary, forward-thinking methods are embedded in design philosophy. For example, if a business has a mission to recruit more women, design for the fit of women can be articulated. A strategy that considers the environment and context of equipment use is also important as regional versus metro users can have different needs, and these nuances may be missed in a blanket national or divisional strategy.

The FRAM modelling involved a consultative, reflective review process that contributed to effective communication and participation in design activity, a tenet of effective human-centred design practice (e.g. Carayon, 2006; Carayon & Smith, 2000; Kompier et al, 1998; Nuutinen, 2005; Reegård et al, 2015).

Limitations

As with the first case study in this chapter, there are limits to case study methods for large-scale inference, however the material has supplied detail of the design process and provided insights to rapid-change that is possible in a small organisation versus the slower, more consultative, approach that must be undertaken in a large organisation.

Recommendations for Future Work

Studies that investigate human-centred design practice with predictive design review are critical to validate the benefits and translate these in construction, transportation, and other industries. The investigation of micro-design analysis using FRAM for descriptive modelling is also a worthy project, and an engineering team may provide useful partnership in this activity. Fundamentally, the question arises: what and how do human and machine functions inter-relate, and how can this system be designed to achieve optimum performance?

The macro-ergonomics analysis of systems that support human-centred design should be continued to determine the necessary conditions in different types of organisations at varying levels of program maturity. This will aid leadership, management, practitioners, researchers, and educators to ensure successful programming.

4.7 Conclusions

The application of d-OMAT and EDEEP was useful. Hazards were determined that had not been identified previously through routine safety management. Human-centric, predictive design review can benefit organisations when the strategies are engaged during equipment procurement. These work standards should be translated with explicit performance expectations of manufacturers and suppliers (e.g. Transport for New South Wales: Transport Assets Standards Authority, 2015). Capital equipment, such as vehicles and trailers, in heavy industry are typically expensive and retained for a significant operating period. Addressing hazards through predictive design review, with a human-centred approach, effectively ensures improved performance for a significant lifecycle of operation (ISO 12100: 2010a). The cases support the propositions that: human-centred equipment design review is sufficient to ensure injury risk reduction and business improvement.

- *Predictive, human-centred design methods can optimise work performance*
    - Capital investments can be costlier without human-centred considerations
    - Hazards can be managed, and productivity enhanced, through design-thinking and agile approaches
    - Design tools, instructions, and methods can be applied usefully from one industry to the next

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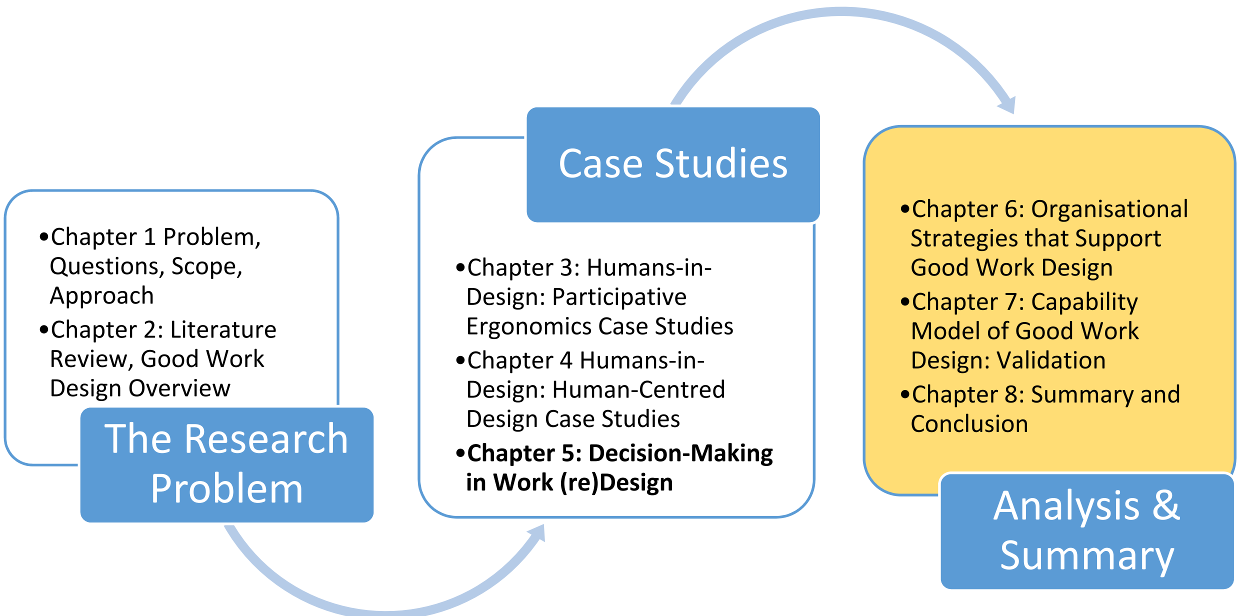
Chapter 5: Decision Making in Work Design



5.1 Introduction

5.1.1 Decision Making Taxonomies

Decision making involves choosing a course of action among a set of alternatives. It requires the urge to act, as opposed to inaction. There are three aspects of decision making: a decision situation, the decision maker(s), and the decision process (Wang & Ruhe, 2007). If the axiom of choice is adopted as a philosophy, then there are a further three components: decision goals, a set of alternative choices, and a set of selection criteria that defines the strategies undertaken (Lipschutz, 1998). A decision maker may seek an optimistic decision (utility theory) or a conservative decision (risk-based theory) (Wang & Ruhe, 2007). A determinant to decision making may lie in the understanding of an organisation's and individual's motivation for change (e.g. to achieve work, health, and safety; or to achieve high productivity at lowest cost, sometimes viewed as mutually exclusive) (Bluff, 2011). Wang and Ruhe (2007) provide a taxonomy of strategies for decision making:

- Intuitive: arbitrary and familiar, influenced by preferences and common sense that includes judgments
- Empirical: trials, experimentation, experience and existing knowledge, consultation among other field experts, and estimation
- Heuristic: principles of scientific theory, influenced by ethics, represented by a rule-of-thumb thinking model, may be based on limited information.
- Rational: Static: cost minimisation for effort, energy, time or money, cost, opportunity, benefits, and risks considered
- Rational: Dynamic: interactive events with conflict in decision making, may involve gaming and decision grids to rate the performance of outcomes; mathematical frameworks (decision matrices)

Decisions that Influence Task (Re)Design

All decisions regarding design strategy and control intervention are not equal. A decision-making process is creative and some design ideas will be more realistic, useful, and acceptable than others (Hamilton, 2012). Dale et al (2017) describe features of decision making in ergonomics that may influence the uptake of an idea: relative advantage, usability, compatibility, complexity, trialability (the ease of trialling iterative design ideas), and observability (which refers to transparency and rapidly impactful positive change owing to the control). Simple solutions may require less culture change and face fewer barriers to adoption than those that are more complex (Dale et al, 2017; Norman, 2013; Weinstein et al, 2013).

In a study of participatory ergonomics and design solutions to address construction activity, Dale et al (2017) found a strong adoption of strategies that provided for relative advantage, compatibility with existing work practice, and trialability. Relative advantage refers to the level of likely improvement with solution adoption; e.g. quality, productivity, cost, or injury prevention. The level of acceptance of an idea may be influenced by cultural-readiness and organisational maturity level for design-thinking (Norman, 2013; Martin, 2009; Weinstein et al, 2013).

5.1.2 Wicked Problems and Decision Making

Cognitive decision making at an organisational level requires complex analysis because good work design is a "wicked problem". Wicked problems are difficult to formulate and solve (Rittel & Webber, 1973; Wang & Ruhe, 2007).

The ten characteristics of wicked problems, described by Rittel and Webber (1973), as applied to good work design are:

1. There is no definitive formulation of a wicked problem:

   Good work design is difficult to conceive a solution. For example, what do we mean by "health"? or "good design"?

2. Wicked problems have no stopping rule:

   At what end-point is good work design achieved? There does not seem to be an easy barometer to suggest that a certain level of health is "healthy enough", productivity is "productive enough", or innovation is "innovative enough". If we design for safety, how safe is “safe enough”? It seems that there is always more that can be done, yet, at some point, resources may be taxed.

3. Solutions to wicked problems are not true-or-false, but measures of good and bad:

   At some point, decisions may be judged as “better or worse” or “good enough”, particularly because there is no stopping rule. Austin (2016a) explained that there may be variability in rulings when decisions and actions are tested in a court of law given political sway of public opinion.

4. There is no immediate and no ultimate test of a solution to a wicked problem:

   The best-possible design of work does not have an immediate outcome. If we design for prevention, how do we really know the likelihood of an adverse event or how much improvement has truly occurred through good work design?

5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly:

   Lives are affected by work design. Money, time, and resource will be expended. If a participatory ergonomic process is encouraged at some level among workers yet resolution is refused by line management, does this reduce morale and create a greater management divide (e.g. Case study 2, Chapter 3)?

6. Wicked problems do not have an exhaustive set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan:

   Good work design may “chip away” at problems and incrementally work toward improvement. However, unless transformation is undertaken for a large system change in which the organisation has the capability to appraise “wildly exotic” ideas to work toward innovation (Ritel & Webber, 1973; Waddock, et al, 2015), we may not know the impact of the design at any dramatic scale.

7. Every wicked problem is essentially unique:

   We cannot know too early in the design process which solution to adopt because the human users (operators, maintainers, or other relevant stakeholders) need to be involved in the design process to account for the unique variability in work approach and task demand. Each organisation and the way that they may address design and problem-solving is likely to be unique.

8. Every wicked problem may be a symptom of another problem:

   When we resolve one element of good work design, we may find that it is symptomatic of another issue. For example, if we retrofit truck seating to achieve reduced exposure to whole-body vibration and improve the comfort for operators, this may lead to the need to review procurement and supply specifications.

9. The existence of a discrepancy among wicked problems can be explained in many ways. The explanation determines the nature of the resolution:

   Design of work can be advanced by several initiatives and it may be argued that this requires resource allocation in several areas; e.g. procurement, task (re)design, and health education. Through design, the analyst may be influenced by their world view (ontology) (Rittel & Webber, 1973).

10. The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate):

    Resource allocation may be viewed with criticism if the collective eye is on the wrong target. For example, managers may expect a fundamental and rapid change in injury rates with design intervention, however this is unlikely to occur. Should an unintended consequence occur from a design change, such as collision associated with a newly installed bike lane barrier, who is held to account?

5.1.3 Organisational Change and Decision Making

Key determinants of ergonomic program success include organisational readiness (Burke, 2014; Nobrega et al, 2017) and effective leadership (Burke, 2014). It is an important yet challenging process to persuade stakeholders to collectively acknowledge a design opportunity, attribute health or productivity benefit, agree on design philosophy, harness resource and leadership support to prioritise issues, determine potential actions, act, evaluate the impact, and communicate the findings (Burke, 2014; Norman, 2013; Haines & McAtamney, 1995). Continuous systems adaptation and improvement involves the participation of end-users in analysis, evaluation, modelling, simulation, design, re-evaluation, (re)design, communication, and learning regarding work and work systems. This requires the management of change (Carayon, 2006; Nuutinen, 2005).

Two important, emerging initiatives identified in the international ergonomics community include "methodology to change work organisation and design" and "psychosocial work design" (Helander, 1997). Carayon and Smith (2000) emphasise the multi-dimensional nature of work in organisations and the opportunity to contribute to organisational strategy through design. Constructive design, as described in macro-ergonomics, leads to overall productivity improvement and systems resilience (Barcellini et al, 2015; Carayon, 2006; Daniellou & Rabardel, 2005; Gauthereau, 2003; Hollnagel, 2002; Nuutinen, M., 2005; Vincente, 1999).

Organisations represent dynamic, complex systems in which key performance drivers may be intangible, dynamic, and reflective of cognitive and motivational processes (Bluff, 2011). There are relationships among events, work climate, environment, and culture (Carayon, 2006; Hollnagel, 2009; Leveson et al, 2009; Vincente, 1999). Task selection and performance may reflect work values among individuals and groups of workers (Coutarel & Petit, 2015). There are constant considerations of efficiency time trade-offs for productivity and performance (e.g. ETTO principle, Hollnagel, 2009).

In sociotechnical systems, events are relative rather than absolute and not necessarily summative, resulting from procedural compliance, rules, and regulations. One may follow the rules and the outcome may result in an adverse event. One can obey rules and productivity can continue as planned. One can disobey or bypass the rules to adapt to a new situation, and this can result in a productive and safe event; or one can disobey the rules and the result can end badly. In the latter example, organisations often blame "human error". Organisations typically fail to plan for adaptation nor learn from adaptive behaviour when it goes “right” (Hollnagel, 2012; Hollnagel et al, 2014) (Table 5.1).

Table 5.1

Rules and Outcomes: Attribution of Blame (Hollnagel, 2012; Hollnagel et al, 2014)		
Rules-Adherence	**Possible Outcome**	
Obey Rules	Positive	Negative
Disobey Rules	Positive	Negative 

The complexity of organisations must be acknowledged if good work design is to be achieved (Waddock et al, 2015). A large system change is typically required to enable and sustain new initiatives (Martin, 2009). Through this change, power structures are redefined which means logic, systems, culture, values, and decision-making processes radically evolve (Kauffman, 1995; Waddock et al, 2015). The change-agents (such as ergonomists) may represent disruption (Norman, 2013; Martin, 2009) and the effects of this disruption can require an organisation to work at the edge of chaos (Waddock et al, 2015). Good work design that inspires a large system change may be threatening.

5.1.4 Analytics and Decision Support Systems

Austin (2016b) addressed the issue of defensible decision making for safety law. She proposed that a defensible decision for risk acceptability is one that can be proven to be reasonable based on expert opinion and regulatory acceptance. Considerations will include:

1. Action addresses a specific risk
2. Decision-maker assumptions are tolerable
3. The focus of action must be on high consequence risks
4. A work process is consultative

5. The process is consistent in industry practice and benchmarked accordingly
6. A valid reason is provided for actions. It is arguable, and assumptions and considerations are explained (risks and benefits)
7. Course of action is based on expert opinion (supported by evidence)
8. Action and outcome is not obviously unreasonable or unethical

A decision support system must provide transparency and caveats must be disclosed (Austin, 2016b). The decision support system should support, not make, the decision for the users. Several decision support systems are described below:

Qualitative Decision Making

Qualitative decision making accounts for issues such as brand image, community goodwill, reputation, or morale which are difficult to quantify.

Quantitative Decision Making

Quantitative decision making requires numerical calculations to support choices made. In these methods, there is an agreed, calculable measure of the benefit or value of action.

Cost Benefit Analysis

Cost benefit analysis (CBA) is a tool to help determine net benefits of a course of action. The costs (C) and benefits (B) of any action must be quantified for the purposes of calculation. The basic calculation is:

CBA = B – C

Most projects that are undertaken in organisations take time and this is recognised in the calculation of net present value (NPV). In this way, costs or benefits that occur late in the project are attributed a discount because there is an opportunity cost associated with money used elsewhere. NPV provides a means to accommodate opportunity costs.

The equation then becomes:

$NPV = \text{€}^{t}_{o}\ B_t\ -\ C_t\,/\,(1 = r)^{t}$

B_t = benefit at time t

C_t = cost at time t

r = discount rate

Goggins et al (2008) conducted a meta-analysis of the reported benefits of ergonomics programs and control measures, reviewing 250 relevant reports. Frequently cited benefits included reduction in work-related musculoskeletal disorders, lost work days, restricted work days, absenteeism, turn-over rates, and workers' compensation costs. Benefits were reported as gains in productivity and quality. Of these studies, only 5 used measures of CBA. When CBA was reported, the benefits outweighed costs an average of 18.7 to 1, with the range extending 2.5 through to 72 to 1. Payback period was also reported in 36 studies. The average payback period for an ergonomics project was 0.7 years and the range extended from 0.03 to 4.4 years.

The value of a CBA depends on the accuracy and assignment of costs and benefits. At times, heuristics may guide the method to monetise costs or benefits of intangibles (Stanton and Baber, 2003) such as stakeholder satisfaction, error reduction, improved response time, employee retention, organisational goodwill, or brand recognition; and it may be difficult to predict the full array of benefits derived from a given action (e.g. organisational justice).

Cost Effectiveness Analysis

1. Cost effectiveness analysis (CEA) may be employed when the costs associated with a benefit are difficult to monetise and yet there is demonstrable social value. Comparisons are made between programs to determine efficacy. This method is often employed in health care and is expressed as a ratio. For example:

2. Cost-Effectiveness Ratio: dividing costs of an alternative by the measure of effectiveness.
3. Effectiveness-Cost Ratio: dividing effectiveness measured by costs of alternative.

Using these ratios, the researcher can compare two project alternatives as follows:

$CE_{ij} = (C_i - C_j) / (E_i - E_j)$

Where:

C_i = Costs of alternative *i*

C_j = Costs of alternative *j*

E_i = Effectiveness units of alternative *i*

E_j = Effectiveness units of alternative *j*

Stanton and Baber (2003) advocate the development of sound business cases for ergonomics intervention. Case study review of return-on-investment payback periods were considered. In these four cases it was found that the costs of ergonomic intervention represented a small fraction of total project budgets, from 1 – 12%, and the payback periods were less than 1 year. Total savings brought about by the interventions were estimated over $950,000 and the implementation costs were less than 10%.

Beevis (2003) proposes a business case model to evaluate financial benefit of ergonomics projects and includes costs saved, costs avoided, and new opportunities. Yeow & Sen (2003) provide an example of a study conducted in a printed circuit assembly factory with intervention to improve the workstations for electrical testing operators. The intervention resulted in improved workstations (to rest limbs and reduce extended reach), clear segregation of testing boards to prevent errors, operator retraining, and the implementation of colour sample references to improve colour recognition. The results were estimated at an annual savings of US$574,560 as rejection costs reduced, monthly revenue increased, and there were improvements in working conditions, productivity, quality, and customer satisfaction. The costs of the interventions were under US$1100.

Risk Determination and Predictive Analytics

Predictive analytics refers to techniques to make predictions about the future. Modelling, statistics, data mining, artificial intelligence, and risk determination may be employed. The goal is to determine the best course of action for a given situation.

In safety science, risk determinations are relied upon heavily for decision making. Risk matrices, simple tools that rank and prioritise risk of adverse events to determine the threshold for tolerance, are common. Consequences, likelihood, and risk are considered discrete categories (sometimes, capital expenditure impact also is considered). The mapping occurs through informed process by way of perception among subject matter experts and, perhaps, historical data review. The risk matrix presents graphically with probability consequence diagrams and uses colour coding of red (extreme), orange (high), yellow (moderate), and green (low) to denote a probable risk rating (Dujim, 2015). There are limitations associated with a traditional consequence-severity risk matrix. The findings may not be relevant across a range of circumstances in an organisation, the scale often is determined with ambiguity, the risk ratings represent estimations and use is subjective, thus, inter-rater reliability may can be low; the risks cannot be aggregated to determine an overall risk rating; and comparative review of different categories of consequences is difficult to make. Results depend on the level of detail undertaken for the analysis (BS EN 31010:2010).

The Risk Management: Risk Assessment Techniques standard BS EN 31010:2010 provides a detailed review of risk analysis and determination systems commonly used, including their applications, strengths, and limitations. A statement is made regarding each nominated tool's applicability to criteria required for sound risk management processes: risk identification, risk analysis (consequence, probability, level of risk), and risk determination. Failure Mode Effects Analysis (FMEA), for example, is rated highly with strong applicability to meet each of these processes; however, its use is for machinery rather than human work.

Analytic Hierarchy Process

The analytic hierarchy process is used in group decision making to help prioritise critical findings and actions. A structured technique is provided to organise and analyse complexity. Stakeholders and decision-makers are often involved in a group process for participatory prioritisation of critical issues (Aminbakhsh et al, 2013; Mustafa & Al-Bahar, 1991; Rosa et al, 2015). Saaty (1990), the originator of this practice, explained that analytic hierarchy process is a structured, multi-criteria decision-making method involving a participatory approach. A hallmark feature of this analytic hierarchy process is the ability to achieve consensus and translate decisions that reflect expert opinion. The process simplifies and aids deductive process. The analytic hierarchy process includes rating (e.g. importance, preference, or likelihood) and comparison methods (one alterative in contrast to another) to facilitate decision making when trade-offs must be considered in short- and long-term situations. It is capable of modelling situations that may lack comparative measures (such as modelling risk or uncertainty), facilitating a decision that is derived from qualitative experiences, prioritising resource, benchmarking, or developing quality management processes (Aminbakhsh, 2013; Saaty, 1990). In this way, it quantifies qualitative decision making.

Saaty (1982) claims that decision making in a complex situation may not readily subscribe to logic and deductive thinking, nor may we rely on intuition alone when multi-factorial considerations cloud the capability for rational, quick, and clear thought. A cogent, penetrable decision-making approach in an organisation should be (Saaty, 1982):

1) Simple in construct
2) Adaptable to individuals and groups
3) Natural to intuition and general thinking
4) Encouraging of compromise and consensus-building
5) Without requirement of inordinate specialisation to master and communicate

Analytic hierarchy process requires six fundamental steps (Saaty, 1990):

1) Model a problem and identify the key elements and their relationships within the problem
2) Elicit judgments that combine knowledge, feeling and emotion among experts and users or stakeholders
3) Represent these judgments in a meaningful way along a scale

4) Calculate priorities of the elements along the hierarchy

5) Synthesise results to determine an outcome

6) Analyse sensitivity to change

Aminbakhsh et al (2013) have applied this decision-making process to the risk analysis of construction projects. Investment in prevention strategies was noted to be prioritised within resource constraints without compromising safety by focusing on the most critical issues. The framework decomposed the decision problems into a hierarchy of sub-problems that were easier to address when assigned weighted, ranked levels of importance.

Padma and Balasubramani (2009) employed an analytic hierarchy process to develop a knowledge-based decision support system regarding the work-related risks on musculoskeletal disorders of shoulder and neck pain. Mechanical (occupational exposures), personal physical health, and psychological risk factors were considered and sub-components of these were rated following a scaled system to denote levels of importance. Their analysis rated mechanical factors above physical health, and physical health above psychosocial as elements contributing to shoulder and neck pain.

Modelling and Simulation

Modelling

Modelling refers to building a construct that represents a system. The genesis for predictive analytics may be derived from descriptive modelling whereby there is a study of real-world events and relationships among factors. Descriptive modelling is often used in systems analysis with effort applied to better understand the relationship among human tactics and their interface with tools, equipment, and alerts; and organisational or environmental conditions.

The Functional Resonance Analysis Method (FRAM) (Eurocontrol, 2009; Hollnagel et al, 2014) provides an example of descriptive modelling (chapter 4). A model may be as simple as the construct of a cardboard replica of an office space, a LEGO® construction replica of a statue, or a small toy car that looks (and sometimes functions) very much like its muse.

Figure 5.1: A LEGO® replica of the statue of David by Michelangelo

Simulation

Simulation permits inference and prediction to test the “what-if’s” and may be used to determine the economics of a system. Continuous simulation is applied when there are infinite combinations within a continuously changing and adaptive system. Continuous simulation is applied for projections of air flow, water flow, rocket trajectories, electrical circuits, or product deformation under a continuous load. Discrete simulation is applied when there are a countable number of events at any given time: for example, customers sitting in a barber’s chair receiving or waiting for a haircut, students working in a computer room, persons in a check-out line at a supermarket, cars queued in line with their passengers waiting to order at a drive-through restaurant, or a truck being loaded under a production plant bin (Sturgul, 2016).

Modelling and simulation requires informed expert opinion to construct the model and test the “what-ifs” (Sturgul, 2016; Sturgul et al, 2015). Practices are collaborative and permit collective participation, engagement, and learning - a driver of optimum performance (Carayon & Smith, 2000). Animation visually translates the simulation and helps build collective knowledge and understanding of the system being tested (Sturgul, 2016; Sturgul et al, 2015).

Discrete simulation has been used in ergonomics to predict mechanical exposure and fatigue accumulation among operators in a manufacturing assembly line (Perez et al, 2014). In the analysis of a road construction project, discrete simulation was coupled with the benefits of system review. Early stage findings led to the discovery of different assumptions made by critical stakeholders about the roadworks project which led to new training and information sharing. Also, proposals were made to alter work efficiencies. The process of task analysis and system review, inherent to discrete simulation and compatible with organisational ergonomics, was useful even before a model was constructed (Sturgul et al, 2015).

Simulation modelling may be immersive when haptics or virtual reality is employed. Virtual constructs allow for situation analysis, solution optimization, and high-levels of learning and engagement in a protected environment. This is of benefit when the natural environment may be high-risk to new learners of the work, equipment, or system performance (Grajewski et al, 2013).

5.2 Aims

The aim of this chapter is to identify the decisions that were made to implement a design change in a straightforward participative ergonomics project. The conditions that influenced these decisions were also examined. Central to this thesis is the intent to develop an understanding of how organisations may be persuaded to adopt good work design practices.

A straightforward case is of interest to enable the extraction of the findings that reflect the decision-making processes. The involvement of study participants in this review (and throughout the case study) supports the overarching research aims of action research: to engage a reflective process to solve problems, improve practice, or inform theory (Stringer, 2014).

5.3 Research Question(s)

What decisions were made during a design change in a participative ergonomics project? What conditions influenced these decisions?

5.4 Methods

The selection criteria for a case review included being a participatory ergonomics project that had been successfully implemented; being a project involving simple solutions; occurring within a host organisation which operated an early-phase ergonomics program; and being of interest to the organisation to evaluate the outcomes. One case was selected that met these criteria: The Pushie (push-broom) study.

The case was reviewed by the investigator, a safety officer, and two workers (all of whom participated in the task [re]design, facilitated by the investigator). Also, the regional contracting and capital assets manager were involved in discussions because they had helped to provide the final approval for equipment purchase. The state finance manager was consulted to contribute to data enabling cost benefit and pay-back analyses (e.g. wages and on-costs).

The project was hosted by a road construction company at an asphalt and aggregate production plant. Task analysis was conducted, as were hazard identification and risk determination. A task (re)design process was undertaken. A review of the decision making associated with task nomination and control implementation was conducted. This review was informed by notes taken during the project term and through thematic analysis of content arising from semi-structured interviews (Glaser, 1969; Glaser & Strauss, 1967). Coding was verified through consultation with these participants. The investigator used a basic, weighted, multi-criteria decision-making smart phone application, FYI Decision Making by FYI Mobileware, Inc. These findings provided for the summation of key success factors.

5.5 Results

The transactions included three site visits (initial, control development workshop, and observation of equipment trial), observations and conversations, data collection with images and measures, communication among work teams and line managers, reporting, facilitating risk determination and design strategy, conducting biomechanical risk calculations, cost benefit analysis with meetings held with finance and operations, and procurement support to determine a supplier for the trial equipment. The good work design was reported via newsletter communications. Retrospective project and process review was conducted two months after the project, and decision-making modelling was used to review control determination. The project, inclusive of identification, escalation, control determination, procurement, equipment trial, resolution, and reporting, took eight weeks.

Task Identification

The investigator attended a recycled asphalt product production plant with a safety advisor during a routine visit. During this visit, two workers described their daily tasks. These workers were forthcoming when asked to describe work that had potential for (re)design. Production at this plant resulted in layers of dust and dirt-like particles and the grounds required daily sweeping. The workers identified sweeping the recycled asphalt product as a task perceived to be fatiguing, counter-productive, and with the potential for quick control implementation. Previously, they had reported this to a team leader however no action had been taken.

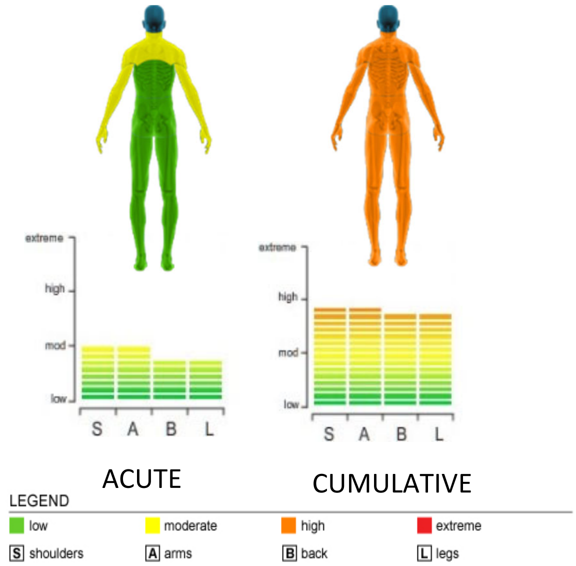
Task Description

Plant operators inspected the production grounds throughout their shift. Sweeping recycled asphalt product was a requirement of their role. As the recycled asphalt product dust collected, an operator used a long-handled standard broom to sweep the fine dust into loads. The operator then shoveled the debris into wheelbarrows and dumped the loads into bins (up to three barrow-loads per shift). Much of this task was performed at the end of shift. The sweeping task was estimated to require 4 ½ hours of effort per shift. When shared among the team of three, this equated to up to 90 minutes of work per person. Repetition, duration, and fatigue were the most concerning hazards reported by the workers. One worker also reported neck discomfort. The shifts frequently extended to 13 to 14 hours, and the work occurred in the outdoor environment around the noise and mechanics of the plant (Figure 5.2).

Risk Determination

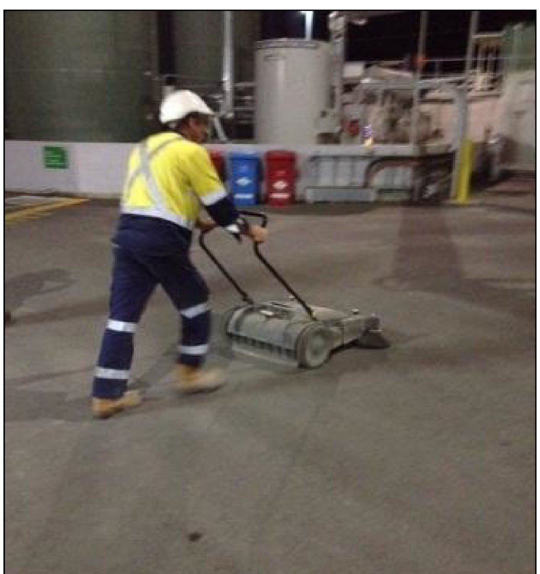
A paper-based reporting tool was initially used on-site with worker engagement and consultation to describe the hierarchy of tasks, the conditions of work, parties responsible, key stakeholders, hazard conditions, and risk determination using a customized reporting tool with some elements modified from PErforM (WHSQ, 2012). The ManTRA (Burgess-Limerick, 2003) risk calculation was applied, as was the Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993) and Job Strain Index (Moore & Garg, 1995). ErgoAnalyst was subsequently used to calculate risk ratings for acute and cumulative musculoskeletal disorders (Figure 5.3). A moderate level of risk for upper quadrant discomfort or injury and a high level of risk for cumulative whole-body musculoskeletal disorder were assessed. Productivity costs were expressed in the report and contrasted with costs associated with proposed controls.

5.2 Sweeping manually

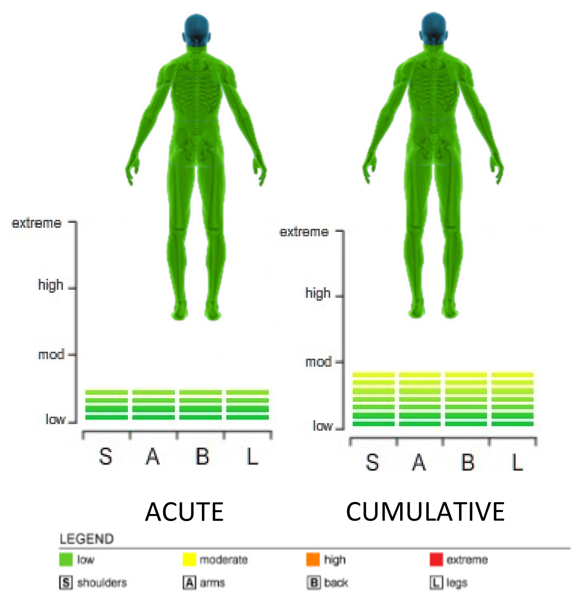


5.3 Image courtesy of ErgoAnalyst

Figures 5.2 and 5.3: Sweeping manually and musculoskeletal disorder risk calculation



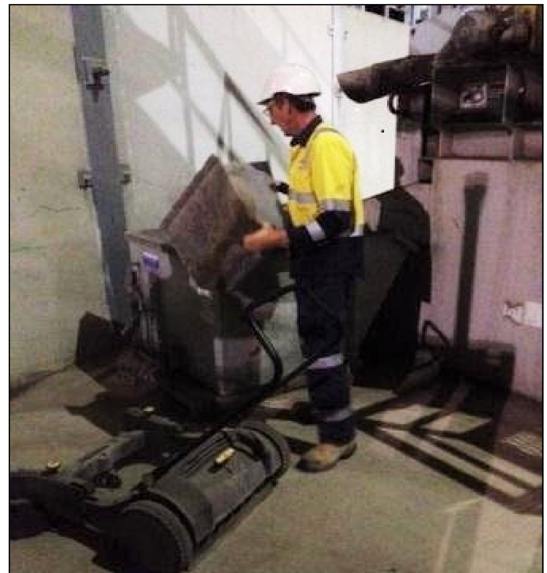
5.4 Industrial Push Broom



5.5 Image courtesy of ErgoAnalyst

Figures 5.4 – 5.5: The push broom and musculoskeletal disorder risk calculation

5.6 Remove Hopper



5.7 Empty Hopper

Figures 5.6 – 5.7: The industrial push broom task components

Design Alternatives (Control Development)

Workers were consulted during a follow-up visit and design ideas were generated. The equipment and work design alternatives included: a) an industrial manual broom with dual-circular brush heads and a hopper to eliminate the need for shovelling and wheel-barrow use; b) a motorized power broom to eliminate the need to shovel or use a wheelbarrow; c) installation of plumbing to provide for additional hose outlets to wash the grounds; or d) do nothing – continue sweeping with a standard broom. The industrial manual broom with dual circular-brush heads was selected for trial owing to its relatively low cost (< $AUD 500), ease in procurement, short time to obtain the equipment, the level of worker interest, and the potential time savings with higher productivity output. Predictive analysis indicated reduced risk comparable to the more expensive motorised broom, yet this was the most cost-effective option to trial (Figure 5.4).

Two industrial manual push brooms were approved for purchase and trial. They were commercially available, and the grounds were smooth enough to operate in this outdoor environment. The industrial broom had rotating circular brushes that collected the recycled asphalt product dust into a hopper which eliminated the need to shovel the material and use a wheelbarrow for disposal. The hopper could be removed and emptied directly into bins.

Cost Analysis

Through a task-based operator consultation process, the likely time savings was calculated at 2.5 hours per shift, or 45 – 60 minutes per worker if shared among three. The new industrial manual push broom ("Pushie") reduced task time to a little over half. Operators changed their work methods to sweep intermittently rather than predominantly at the end of production shift because the task was simplified and less time-consuming.

The financial manager provided an annualised projected cost savings associated with the use of the industrial manual push broom. This equated to just over $AUD27K (approximately 2.5 hours' work saved per shift with at least 5 shifts per week at $45 per hour, 48 weeks per annum).

Simple calculation derived the cost benefit analysis (CBA). No time value of money was considered as the project was of short duration (8 weeks) and that consideration would provide no further benefit. The calculation demonstrated $26,000 cost benefit in the first year of operation. Ongoing savings are assumed thereinafter for the life of the production plant if the task continues to be required of operators.

CBA = B – C

= $27,000 – $1000 (2 industrial push brooms were purchased at approximately $500 each)

= <u>$26,000</u> in the first year of implementation, or <u>26</u> in terms of benefit as a multiplier of cost.

Payback Analysis

The cost of two industrial manual push brooms was estimated conservatively, including shipping and handling, at $AUD 1000. Using the information provided by the industry partner financial manager, where 2.5 hours of work is saved per shift, and 5 shifts occur per week, at $45 per hour, this represents $112.50 savings per shift. The calculation shows payback of direct expenditure in under two weeks.

Payback = cost / (savings/shift)

= $1000 / $112.50

= 8.89 shifts (9 shifts)

= 9 shifts or <u>< 2 weeks</u>

Decision Making Calculations

The FYI Decision Making model supported the decision to trial the industrial push broom once decision criteria were input. Intuitively, this is the control strategy that was trialled in the workplace. The results in Figure 5.9 illustrate the aggregate findings.

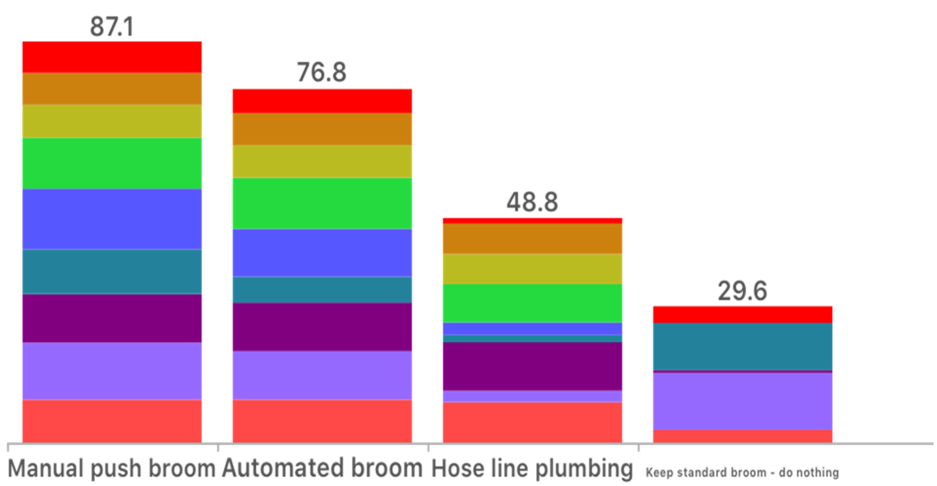


Figure 5.8: The FYI Decision Making Tool Results (Image courtesy of FYI Decision Making App)

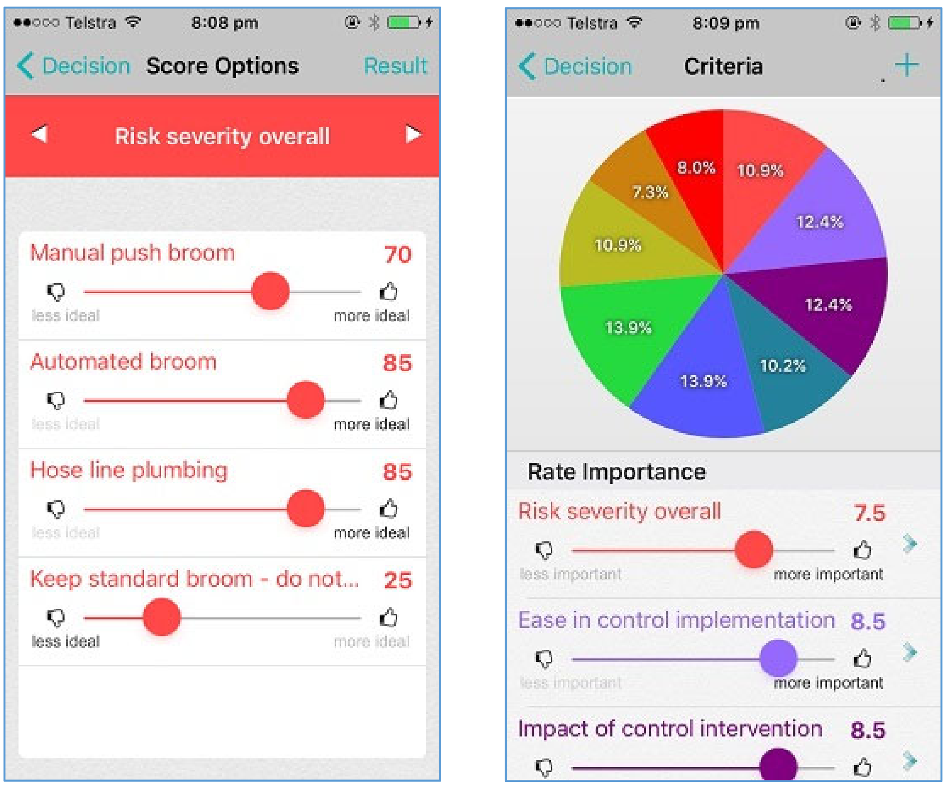
The four possible design considerations were identified (industrial manual push broom, industrial powered push broom, install hose line plumbing, or do nothing). Design philosophy criteria are listed in Table 5.2. These criteria were weighted according to their perceived importance and this was informed by a collaborative, task-based review of the project. Each design consideration was rated, again based on the previous data, conversations, and task-based project review, regarding perceived likelihood to meet design criteria. The model then ranked the criteria in comparative order and a multiplier, built-in to the program, calculated the final ranking. The criteria weighting is described in Table 5.2.

Table 5.2

Task and Design Philosophy Criteria: Weighted Importance

Criteria	**Weight (%)**
Interest Among Workers	13.9
Profitability Potential	13.9
Ease in Control Implementation	12.4
Impact of Control Intervention	12.4
Risk Severity Overall	10.9
Acute Injury Risk Exposure	10.9
Cost of Critical Control	10.2
Operations Manager’s Interest	8.0
Cumulative Injury Risk Exposure	7.3
Total	100

When rated to design philosophy criteria, the industrial manual push broom (“Pushie”) came third in the ranking of “Risk Severity” resolution, scoring 70% likelihood versus the two other options that tied at 85%, an industrial automated push broom or the installation of hose line plumbing. The Pushie came second in the rating of “Ease in Control Implementation”, with the action of “Do Nothing” rated highest. The Pushie came second in terms of the cost consideration, with “Do Nothing” leading this indicator. The Pushie rated highest for “Interest Among Workers”. It received equal high rating with the automated push broom for “Profit Potential”. It tied with the automated option and hose line plumbing for first place ranking for reduction of “Acute Injury Risk Exposure”, and shared ranking with the automated option for reduction of “Chronic Injury Risk Exposure”. The Pushie was rated equally with automated push broom and hose line plumbing for “Impact of Control Intervention”. The Pushie came first when considering “Operations Manager’s Interest” levels. The aggregate of these findings, based on the weightings assigned with each design criteria, showed that the Pushie was the best option to consider, and this was consistent with what had occurred in the field.



Figures 5.9 and 5.10: Control Selection Example and Design Criteria: Performance Evaluation

Process Review: Decision Making

The decision-making categories required to escalate and implement the design changes were thematically aligned with the review of project success factors (Vink et al, 2006).

1. Involvement: worker involvement was rated most important for communication, hazard identification, and solution development, followed by the presence of an ergonomist (moderately above operations managers and significantly above safety advisors and suppliers). The criterion “worker interest” was of significance, also. Enlistment of management support to approve push-broom purchases occurred persuasively through efforts of the workers and safety advisor, with risk analysis provided by the investigator.

2. Process: Establishment of a participatory ergonomics project team, hierarchical risk-based task analysis, and engaging positive language to inspire design thinking were determined as the most important aspects. This was followed by an iterative design process, routine and random field visits, product trials, and effective reporting tools. Task selection also was considered important. The sweeping task was a daily requirement, so exposure was high. The workers nominated this task in response to a skilled line of questioning. Further, the task (re)design had significant potential to provide for efficient work practice. The cost of the control was considered low and the potential impact was significant. Payback period was rapid (under two weeks).

3. Goals: Ability to achieve safety, reduce cumulative injury risk, improve comfort, and provide for profitable work practice were considered important. Equal to this were a fit-for-purpose, commercially available design solution; realistic outcomes; high levels of worker satisfaction; and sustainable work practice.

These decisions are depicted by simplistic flow chart (Figure 5.11).

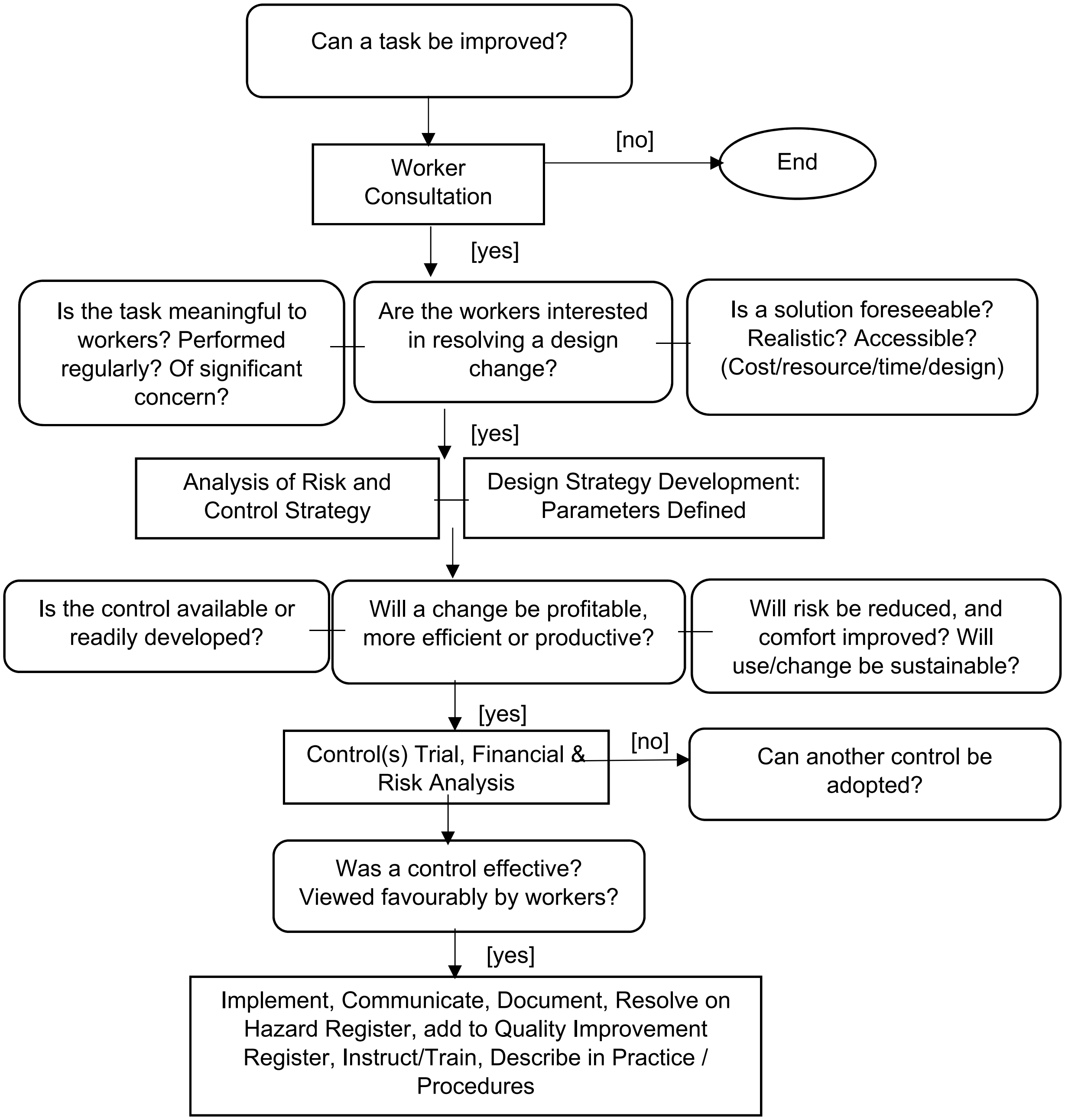


Figure 5.11: Simplistic diagram of task (re)design decisions and actions

5.6 Discussion

This chapter aimed to determine decisions that were made to implement a design change during a straightforward participative ergonomics project. The project was a sweeping task and the use of a traditional long-handled, wide-brush broom used with a shovel and wheel barrow to collect recycled asphalt product (dust and debris) at an asphalt plant. An off-the-shelf control was implemented: a manual push broom with circular brushes and a hopper. This saved time and effort, reduced risk for musculoskeletal disorder, and resulted in a far more efficient work approach with significant cost savings and timely payback for the investment, and workers were satisfied with the outcome.

The simple change made during the case study did not require significant culture change. However, even in this instance, a level of persuasion was required to influence management to purchase manual push brooms. The reports that were supplied to management had to communicate rationale for design change and this included risk and foreseeable risk reduction, design philosophy, and ease in control implementation. The level of worker interest and involvement was also influential. To provide compelling cases and achieve rigorous, ongoing support, the ergonomist must provide quality information to educate business and advance their understanding for decisions that advance effective work design. The value proposition of ergonomics must be a mission. When mapped as a matrix of decision making, the activities that are supported by quality information and reflect important decisions receive the most urgent and pervasive support (Hamilton, 2012) (Table 5.3).

Research Question

The research question was:

> *What decisions were made during a design change in a participative ergonomics project? What conditions influenced these decisions?*

While decisions had to be made about task nomination, methods to communicate findings, task selection and escalation, design parameters (what was needed to be achieved and which aspect was most important), control options, purchasing, and implementation plans, one of the most decisive factors in this project was the quick payback and the significant cost-benefit. This supports the evidence that expression of the financial outcomes (or projected outcomes) of projects is likely to help a program align with business values and needs (Dul & Neumann, 2009; Stanton & Baber, 2003). When faced with constraint-based resources, prioritising task (re)design may be difficult. Business cases may be required to advance good work design (Beevis, 2003; Dul & Neumann, 2009; Dul et al, 2012; Stanton & Baber, 2003).

This Pushie-broom case supported the proposition:

- *An economically viable and beneficial outcome of an ergonomics project was necessary (but not sufficient) to attract leadership support*

The Pushie-broom solution provided a high level of relative advantage, usability, and compatibility with established work practices. It was a simple strategy, easy to procure, and readily available for trial. Consequently, it met the criteria for features that support decision making and uptake of a solution in occupational ergonomics (Dale et al, 2017). This may be stated as a proposition, supported by this case:

- *A solution that presents with ease in implementation and few cost barriers is necessary (but not sufficient) to achieve a design change during the early phase of an ergonomics program.*

This case suggests that the potential impact of a design change, measured financially or through injury-based risk reduction, may represent a continuous condition of necessity for participative ergonomics programs; that is, the more likelihood that benefit can be derived, then the more likelihood that the project will receive support. Table 5.3 outlines a matrix of decision making that describes perceived levels of importance and urgency that may be influential to decision making. In the case of the Pushie, these elements required translation by the investigator communicated by risk reports and design recommendations.

Table 5.3

A Matrix of Decision Making: Urgency and Importance (Hamilton, 2012)

DEGREE OF UNCERTAINTY	High	Little is known Low-impact decision (subjective and creative)	Little is known Decision is important (discovery and critical thinking)
	Low	Good information Low-impact decision (objective and simple)	Good information Decision is important (objective and demanding)
Good work design value proposition		Low	High URGENT
IMPACT OF DECISION			

The FYI Decision Making model by FYI Mobileware, Inc., provided a method of transparency to support the design process and decisions that were made. The model was not designed to make the decision for the user but to provide clarity. These aspects, together with consultation and transparency, help fulfil tenets of safety law disclosures (Austin, 2016b) and further support the discharge of obligation to the duty-holder in Australian work health and safety legislation. A full-disclosure report to management is easily provided when such modelling occurs. The science behind the math may fall into the category of “fuzzy logic” heuristics (Wang & Ruhe, 2007) as the opinion of subject matter experts inform the input. As such, this system mathematises qualitative decision making. However, perhaps the benefit of the model as a tool for communication and transparency outweighs these mathematical limitations. Managers need information that informs decisions in deterministic ways, even when real-life scenarios may present with some degree of probabilistic phenomena (Dul & Hak, 2008).

Recommendations for Future Work

Decisions that support good work design will vary within organisations (and the people who lead them) and among organisation and industry type. Determining the aspects of a work culture that support good work design, and the activities undertaken as evidenced by program resilience, would be worthwhile. Information about the decisions that are made during different adoption phases of a program may also be useful.

Further research could be conducted to determine how ergonomists see themselves in relation to their scope of practice, knowledge, skill-set, and ability to act as a change-agent and facilitator of decision making involving creative process, invention, or innovation. For example, would it be useful for ergonomists to cease attempts to fit into an occupational health and safety paradigm and fully embrace their role as a design professional (i.e. a work-designer)? This would include evaluating projects according to design parameters with language used among designers: e.g. affordances, constraints, signifiers, and mental models (Norman, 2013). As a secondary measure, then, design considerations could be translated to suit a variety of stakeholders, using language of business analysts, quality improvement, procurement, engineering, workforce strategists and human resources, safety professionals, and health and rehabilitation teams.

Limitations

The decision-making analysis was limited to a single case study that involved a straight-forward level of control implementation. The generalisability of findings would require replication and testing under different conditions, such as comparative case study with projects involving increasing levels of complexity.

5.7 Conclusions

The Pushie case study provided comparative data to support the tenets of good work design: that it is sufficient practice to ensure profitable and conditioning work (through risk reduction methods). The case, with the use of decision support software and informed by subject interview and thematic analysis, supported the ideas that economic benefits of projects (and the communication of such benefits) were necessary to enlist leadership support, and the decisions that are necessary when made during an early-adoption phase of an ergonomics program include ease in implementation and few cost barriers.

Organisations may not have a transparent means to disclose the decisions that are made to support good work design. In such cases, it can be difficult to defend or advance an initiative. Documented intermittent or reflective project review can provide transparency. Intermittent review is advised to help guide the process with as little rework or misunderstanding as possible and to achieve consensus along the way. This supports principles provided by ISO Standard 27500:2016, Human-Centred Organisations, to value employees, be open and trustworthy, and be responsible. A simple, free, mobile App was used to support these methods in the Pushie control case study; and this demonstrated that the process need not be difficult. Predictive analysis of biomechanical risk was also important to influence the decision-making process. Decision support systems can support human-centred design because they translate strategic, tactical approaches adopted by organisations.

Key messages:

- *Decisions reflect belief systems, so it is important to examine them if a human-centred mindset is desired*
    - Transparent decision making can aid communication, build consensus, and defend actions supporting task (re)design

- Projects that can be addressed by a low-cost, easy solution, and are readily implemented, may simplify the decision-making process, and fortify an early-stage ergonomics program
- Cost-benefit and pay back were important to attract leadership support in this case

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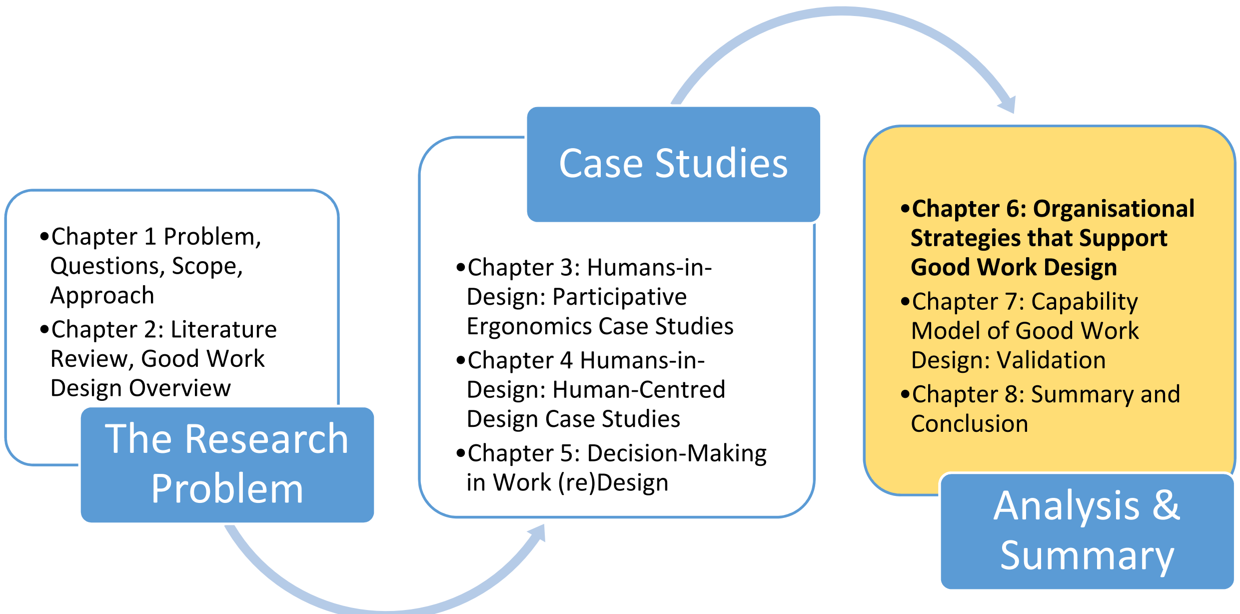
Chapter 6: Organisational Strategies that Support Good Work Design



6.1 Introduction

Good Work Design is receiving attention from the Australasian Faculty of Occupational and Environmental Medicine (AFOEM) of the Royal Australasian College of Physicians (RACP) (e.g. AFOEM, 2015), Safe Work Australia (e.g. SWA, 2015b), the National Institute of Occupational Safety and Health (e.g. CDC, 2016a), and the International Well Building Institute (e.g. IWBI, 2015). Well-designed work allows workers to live more productive lives (SWA, 2015b). The tenets of human-centred design and participatory ergonomics underpin good work design and advance Total Worker Health® (Sorensen et al, 2016).

Good Work Design encompasses and provides:

1. Critical event management (e.g. Cooke, 2014; ICMM, 2015b)
2. Significant task, equipment, and work systems design or (re)design (e.g. Burgess-Limerick et al, 2007; Horberry, 2011; Horberry et al, 2015)
3. Strategies to optimise health & well-being (e.g. Sorensen et al, 2016)
4. Social connection (e.g. Wang & Ruhe, 2007)
5. The attainment of enterprise goals for good business performance throughout the supply chain (e.g. Reegård et al, 2015; Sorensen et al, 2016)
6. Good governance supported by effective knowledge systems (e.g. Sorensen et al, 2016; ISO Standard 27500:2016)
7. Organisational justice (e.g. Westgaard & Winkel, 2011)
8. The promotion of organisational, social and environmental sustainability (e.g. Reegård et al, 2015; Hedge et al, 2010; Thatcher, 2012)

Positive performance in an organisation can be influenced by a range of variables such as the inherent variable nature of humans, unique workforce characteristics and strategies, potential unwanted events and their risk of occurrence, change readiness, inclusive work practices, participation levels among subject matter experts, leadership support, and industry trends. From a systems perspective, these are factors that reinforce or erode work performance (Hollnagel, 2012). Governance and policy, industry sector, organisation and processes, persons involved, and technology can also influence good work design (Reegård et al, 2015).

The Value Proposition of Good Work Design

The benefits of a program or service, less the costs, determines its value. Lindic and da Silva (2011) describe a value proposition as capability and impact less the trade-off (such as efficiency, time, or direct costs). They suggest that value is determined from the standpoint of the customer and propose a model to determine value from five perspectives: performance, ease of use, reliability, flexibility, and affectivity (feelings and emotions generated).

Österman (2013) describes the value of good work design at a systemic level in the maritime industry:

1. Employee: improved health and well-being, learning opportunities, skill discretion, and independence
2. Company: increased operational performance and flexibility, advantages in recruiting and retaining personnel
3. Sector: competitive strength, attractiveness of work, and increased learning cross-industry
4. Society: reduced health care costs, social security, reduced environmental impact, and the creation of sustainable working life.

Ergonomics has a social goal to improve well-being and an economic goal to enhance system performance (Dul & Neumann, 2009). Dul and Neumann (2009) suggest that human factors and ergonomics adds value by improving well-being; optimising work environments; stimulating motivation, growth, and job satisfaction; and improving performance and reward. Product users benefit from rapid familiarization and better experience with tools, equipment, or processes; an improved fit of work design to user characteristics and task requirements; and improved efficiency with reduced error rates (Dul & Neumann, 2009; Norman, 2013). System experts, such as engineers and designers, find better user acceptance of their designs and higher performance outcomes; a better fit with legislative standards for health, safety, accessibility, or ethics; and more efficient development through user consultation. Decision makers, such as managers or procurement specialists, perceive the value of human factors and ergonomics practices if considering productivity, reduced operating costs, occurrences of innovation, company reputation, and retention rates. At a systemic level, social and economic wealth is elevated through the practices (Dul & Neumann, 2009).

Dul and Neumann (2009) describe case studies to support the alignment of ergonomics with company performance. They describe the nexus with corporate and cross-functional strategy and business operations. In terms of corporate strategy, there is benefit in cost and differentiation and, consequently, the ability to outperform in the marketplace. Business is improved through product design, production engineering, procurement, corporate communication and marketing, human resource management, and finance. Ergonomics supports total quality management, lean production, and process reengineering.

Risks Associated with Failure to Adopt

There are risks associated with failure to adopt good work design practices (ISO 27500: 2016). These risks include: reduced accessibility of services, products, or systems; impaired usability of tools, devices, or systems; product failure; absent or inauthentic support for diversity; lower levels of workforce competence; and ineffective training and engagement practices (ISO 27500: 2016). Distributed situation awareness is reduced, and costly system failures may occur (Horberry et al, 2015; ISO 9241-2010: 2010a; Stanton et al, 2007). Safety may be compromised at a level that leads to catastrophic, fatal, or disabling events (ISO 27500: 2016). There will likely be little evidence-based, concerted effort to prevent musculoskeletal disorders and occupational rehabilitation return to work programs may be less effective. Security can be compromised (ISO 27500: 2016). Opportunities will be missed to improve safety culture and establish a positive work climate (Laing et al, 2007; Laitinen et al, 1998; Lallemand, 2012). Efforts to achieve sustainability in environmental and social practices may not be actualized. The value of work can be diminished and an organisation will face increased costs to address shortcomings (ISO 27500: 2016). An organisation without well integrated and inherent good work design practices can have low levels of change-readiness (Village & Ostry, 2010) and be at risk of not employing tactical, evidence-based work strategies (Boatman et al, 2015; Glimskar & Lundberg, 2013; Karanika-Murray & Weyman, 2013; Sorensen et al, 2016).

Challenges to Integrate Programs

Systemic good work design is a challenge for many organisations (Sorensen et al, 2016). Reegård et al (2015) note that human factors and ergonomics is often associated with occupational health and safety rather than organisational effectiveness (e.g. Dul & Neumann, 2009; Jenkins & Rickards, 2001). When aligned with occupational health and safety risk management systems, there are gaps. For example, Yazdani et al (2015) found that participatory ergonomics met only a small number of elements required within an occupational health and safety framework. Structural program and language differences did not facilitate easy integration in safety management systems and the ergonomics programs were left to operate as stand-alone. Generally, the programs demonstrated compatibility with occupational health and safety management systems in areas of hazard identification, risk assessment and control intervention; the identification of resource, role, and responsibility; competency and training; participation and consultation with workers; and performance measurement and monitoring. Areas that were not well conveyed in ergonomics literature, yet which would be required for alignment with traditional safety management systems, included an outline of scope, program objectives and policy requirements; legal requirements; communication systems; documentation; and document control. Areas of operational control, evaluation of systems compliance and internal audits, management reviews, and methods to address non-conformity were also not addressed (Yazdani et al, 2015). Yazdani et al (2015) found that there was infrequent mention of how ergonomics practices translated to emergency preparedness or incident investigation, however there is burgeoning research into the benefits of human factors in incident investigation (e.g. Cattermole et al, 2013; Dodshon & Hassall, 2016; NOPSEMA, 2017).

Organisations frequently attempt to tackle health issues by providing interventions targeted at individual behaviour changes instead of system-level policies and practices (Carayon, 2006; Henning et al, 2009; Karanika-Murray & Weyman, 2013; Sorensen et al, 2016). However, organisations can have more influence over these system-based interventions, and these are also more likely to be effective (Henning et al, 2009; Kohler and Munz, 2006; Mellor et al, 2012; Munz et al, 2001; Sorensen et al, 2016). The practices take time, resource, and considerable effort and the business proposition must be compelling.

The potential of human factors and ergonomics as a sustainable competitive advantage is markedly under-utilised (Dul et al, 2012). Dul et al (2012) cite four primary reasons: lack of awareness of the value proposition of human-centred design among stakeholders and, therefore, weak demand; too little high-quality or scope of practice involvement in the design process and, thus, sub-optimal outcomes; a small field of qualified practitioners; and the diversity of practices may dilute the message about how and what the paradigm should look like. Dul and Neumann (2009) conducted a review of business and management journals (n = 97) during a 10-year period and found that 93% had no mention of ergonomics practice and, of the seven that did, the scope was limited to physical ergonomics. There is an urgent need to communicate the value of effective work design through human-centred approaches (Reegård et al, 2015).

Hedge (2015) argues that program success and change opportunities are diminished when ergonomists are assigned the role of advisor rather than manager. Ergonomics projects can remain poorly executed if ergonomists are not given the power and authority to lead teams and harness resources as they see fit. The observations and findings of an ergonomics advisor may come to nothing if business leaders are not aligned with design work practice, despite legislative framework and regulatory guidelines supporting the process (Burke, 2014; Haines & McAtamney, 1995; Hedge, 2015; Helander, 1997; Horberry et al, 2015). Without ergonomists steering sustainable and meaningful business projects, siloed work practices may prevail, such as endeavours to achieve health associated with the functions of safety and environmental planning; wellness aligned with human resource and workforce strategy; and injury management roles operating outside this spectrum, focussing on treatment and accommodation (Hedge, 2015) rather than prevention (e.g. Dul & Neumann, 2009; Haslam, 2002; Henning et al, 2009; Vink et al, 2006). The profession remains under-represented in most organisations (Wilson, 1994). This is true even in the design-centric professions of engineering, architecture, and industrial and interior design (Dul et al, 2012; Hedge, 2015; Salmon et al, 2016).

Hedge (2013) claims that businesses treat ergonomics paradoxically, advertising the benefits when marketing products, yet decrying it as costly and unnecessary when it comes to design in workplaces. It is often viewed as value-added rather than integral and essential, yet the practice provides the technology and the road-map to implement design of "good work" (Hedge, 2013; SWA, 2015a).

What is Optimum Performance?

If approvals for work must be sought case-by-case rather than through a tactical, strategic approach that is integrated and embedded in organisational strategy, performance may be questionable (Dul et al, 2012). It is compelling to investigate success and determine optimum performance. This line of thinking suggest moving from studying that which is, to considering that which could be (Reegård et al, 2015).

In nature conservation, optimum performance is often determined by weighted formulae and guided by the CAR (connectivity – adequacy – representation) principles of: comprehensiveness and connectivity within a reserve ecosystem to provide population support for recolonisation; adequacy of a reserve system to conserve features indefinitely and provide for viability owing to the inclusion of sufficient levels of each ecosystem; and representative features typical to that geographical area to ensure inclusion of finer scale areas that provide variability of habitat within ecosystems (e.g. The Australian Natural Reserve System 2010). Possingham (2016) extends this analysis with consideration of CAR-E, the addition of "E" being efficiency to achieve what is desired with minimum cost, public imposition, or impact to industry. Metrics derived from other industries, such as nature conservation, could have translation to those needed to measure good work design.

Questions arise in the field of good work design, such as:

- How will we know what optimum performance looks like once we get there?
- What metrics should we aim for to achieve optimum performance? For example, is it possible to achieve a specified number of good work design initiatives implemented per capita per annum in every business unit?

- What measures may be used to quantify, qualify, and confirm a good work design outcome?

Recently, ISO Standard 27500: 2016 has provided seven principles that characterise a human-centred organisation:

1. Focus on uniqueness
2. Make usability and accessibility strategic objectives
3. Adopt a total systems approach
4. Prioritise well-being
5. Value employees
6. Be open and trustworthy
7. Be responsible

These standards could be used to develop metrics and performance benchmarks in different industry sectors for good work design.

6.2 Aims

The aim of this chapter is to examine the conditions that contributed to the success of a mature participatory ergonomics program. It seeks to identify human-centred design practices that can be embedded in organisations to achieve sustainable competitive advantage and the measures by which we might determine this has been achieved.

6.3 Research Question

What conditions were necessary to enable the success of an established participatory ergonomics program?

6.4 Methods

The selection criteria for a program review included a participatory ergonomics program that had been successfully implemented for at least three years, had an established program coordinator appointed since the inception of the program, had outcomes readily articulated, and the host organisation was willing to cooperate in the evaluation. One program was selected that met these criteria: Rio Tinto Weipa's "Hand Red Zone and Manual Task Risk Reduction" program.

Two phone conferences were held with the ergonomics program coordinator of the bauxite mine during which structured and semi-structured interviews were conducted. This was followed by a site visit during which interviews were conducted with light vehicle maintenance staff and the program coordinator. The maintenance staff displayed several custom-designed tools as well as new equipment purchased to aid efficiency and safety. The workers described changes to work systems and leadership strategies. An unstructured interview was conducted on-site with the mining superintendent. Documentation was reviewed including audit tools and ergonomics and manual handling policies and procedures. "Green Banner" design briefs were reviewed as were "Hand Red Zone" material focusing on reduction of hand and manual task injury risks. The hand injury reduction program was of interest because it was targeted and effective and significant reductions in hand injury statistics could be demonstrated. Poster material also was reviewed. PowerPoint presentation material describing key program drivers, program award submission material, and detailed email communication documenting a case design process was included in the review.

A thematic analysis of the work practices supporting the program was undertaken (Table 6.1) (Glaser, 1969; Glaser & Strauss, 1967). Persuasive language content analysis was employed to decipher the interviews, classify ideas, and describe themes (e.g. Kite & Whitley, 2018). Comparisons were made of the values and beliefs expressed by two workers and two managers (the program coordinator and the superintendent) (Table 6.2). The classification system was verified through consultation with participants.

Two contemporary frameworks describing good work design were reviewed with the program coordinator and superintendent. Through ideation and brainstorming, suggestions were made to advance the existing program to integrate some of the lead-indicators suggested by these theories (Table 6.3).

Guidance Material

Two reference documents were used to help guide discussions about program performance: a conceptual model described as a method to integrate worksite health protection and promotion (Sorensen et al, 2016) and the ISO Standard 27500: 2016. The tabulated findings describe program elements related to the principles outlined in this material (Table 6.3). Throughout the facilitation process, brainstorming occurred, and ideas were formed regarding opportunities for ongoing improvement. The improvement opportunities also are listed in Table 6.3.

6.5 Results

About Rio Tinto Weipa: The Organisation

Rio Tinto Weipa (RT Weipa) operates two continuous mines/beneficiation plants at East Weipa and Andoom to produce 28.5 million tonnes of bauxite annually. Two diesel engine power stations are operated and other facilities include main administration, warehouse, laboratory, ship loading, and port. Staff comprise approximately 1200 workers and an additional 200 contractors with seasonal adjustment in work activity (Wakeling, 2013).

RT Weipa was the winner of the Queensland Mining Industry Health and Safety Conference Health Program Award 2015. The award submission described the details and outcomes achieved through the implementation of their participatory ergonomics program that had been operational for the previous 6 years.

Outcomes Achieved Through Good Work Design

RT Weipa reduced annual hand injuries frequency from 20 to 1, and the annual frequency of musculoskeletal disorders reduced from 85 to fewer than 20. There was reduction in: all injury frequency rate (AIFR) from 0.92 at the end of 2011, halving to 0.46 by the end of 2014 and further reduced to 0.1 by October 2016; the number of statutory WorkCover claims from 29 in 2011 to 12 in 2014; statutory WorkCover costs from $159,561 in 2011 to $2,633 in 2015; and common law claims costs from $1,262,978 in 2012 to $670,082 in 2014 (Wakeling, 2015; Wakeling, 2016).

RT Weipa has trained 20 representatives as manual handling area assessors representing each department in the organisation from a range of different jobs and skill sets (e.g. diesel fitters, engineers, support officers, health, operators, maintenance, fitters & turners). Training occurs every two years to ensure currency. The initial train-the-trainer program was provided by an ergonomist who also presented the risk reporting and project management tool (ErgoAnalyst) which is still in use in the organisation. The program coordinator, with occasional assistance from a nurse on staff, also provided occupational rehabilitation and return to work management. This represented a ratio of 20 to 1 in terms of the number of preventive design champions assigned to facilitate good work design versus injury management staff assigned to treatment of workers. The program coordinator was trained in ergonomics and manual task risk assessment, as were others in his team, but he was not an ergonomist.

RT Weipa targeted 30 high-risk manual tasks per year for (re)design and, collectively, the work teams met this goal every year for the previous six years. The organisation coupled their manual task risk management approach with a program targeted to reduce hand injuries. The lead indicators and performance measures helped business units target manual task risk reduction with at least 60% of tasks selected for (re)design to include quality risk reduction design controls aimed to reduce hand injuries, referred to as “Hand Red Zone” tasks. Team leaders who were not well aligned with these values for task re-design were not retained in the business.

Good work design was celebrated with monthly and annual innovation awards. Design improvements were regularly communicated within the organisation at a site, multi-site, and corporate level. The focus for work design improvement was extended to assist contractors, e.g. child care services, waste service provider, construction and geology teams, and explosive services.

Program Review: Hand Red Zone: Results

RT Weipa conducted a targeted campaign to reduce hand injuries aligned with their hazardous manual task risk reduction program. The campaign set targets to facilitate decisions regarding resource allocation. Each business unit was required to identify and support task (re)design when at least 60% of the selected tasks included risk reduction opportunity for hand injuries. Safety teams investigated appropriate glove wear and provided training to work teams accordingly. However, the business recognised the evidence that elimination, substitution, and enginering (re)design are the most effective intervention strategies. An appreciative approach was described by the program coordinator to reflect methods of ideation. Figure 6.1 provides an illustration of the factors identified as contributing to the success of the program: a reduction of over 20 hand injuries per annum to zero in the latter 3 years of program adoption (Wakeling, 2016). Figures 6.2 and 6.3 illustrate a sample hand red zone task of hammering before and after (re)design.

Figure 6.1: Hand Red Zone program determinants: Investigation of a risk reduction program

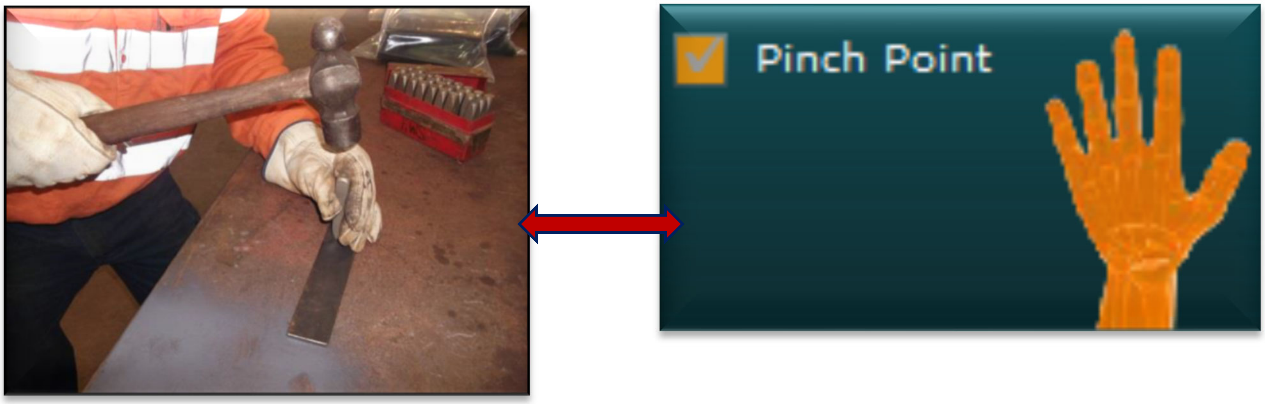


Figure 6.2: Traditional hammering activity was identified as a hand red zone task that could be improved

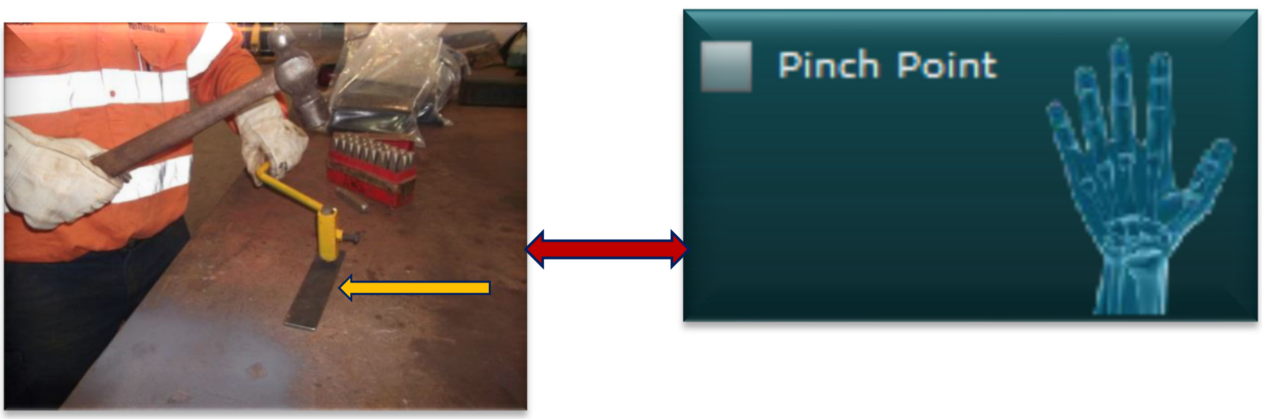


Figure 6.3: A design improvement to isolate hands and fingers from hammer blows

Thematic Analysis: Work Practices Supporting the Program

The practices that were disclosed through interview were classified as “as-is” (after establishing a process, the activities were integral to standard business operations), “to-be” or transformational activity (the activities or features of system support that ensured change was actualized), and “specialised through-put” (tools or practices that were unique to the work design program) (Table 6.1):

Table 6.1

Practices Underpinning the Work Design Program

As-Is Current Process	To-Be Transformational Activity	Specialised Through-Put
Budgetary Commitment (decentralized budget decisions allowed at a team level by corporate governance) Knowledge-skills-abilities (the coordinator received training in participatory ergonomics and, in turn, train-the-trainer workshops were held)	Supportive Leadership culture Lead indicators made transparent Communication and celebration	Risk determination and reporting systems Methods to evaluate controls: verification processes

Language Content Analysis: Persuasive Ideas Describing the Program

Comments recorded during the semi-structured and unstructured interviews with two light-vehicle maintenance workers and two management representatives were tabulated. The information was organised in terms of the persuasive technique employed (Table 6.2).

Developing a Conceptual Model of Total Health

The brainstorming about and planning for a conceptual model of total health (Sorensen et al, 2016; and ISO 27500: 2016) was described in Table 6.3. Overall, the program met the three elements advised in the Conceptual Model for an Integrated Approach to Protection and Promotion of Total Health (Sorensen et al, 2016): organisational leadership and commitment; coordination among health protection, promotion, and work functions to benefit health, safety, and well-being initiatives; and supportive participatory organisational policies and practices. The “hand red zone” campaign provided an example of targeted intervention that markedly reduced injury risk.

Table 6.2

Persuasive Language Content Analysis Describing Participatory Ergonomics Programs

	Technique	Maintenance Workers	Program Coordinator & Superintendent
1	Emphasize the message	Elements: ☐ Rhetorical statements ☐ Repetition	Elements: ☐ Describe the focus ☐ Repeated statements
		Examples: - *“… shouldn’t be hard, should it?; should be easy; should be able to just do it!”* - *“… too much hammering, then the job might need to be changed”* - *“it’s obvious to us on the tools; shouldn’t it be obvious to middle managers? These projects save time and money”.* - *“many of our (re)design projects extend into improvements for the environment, our land strategy, also”.*	Examples: - *“it has been important to us to establish our values around these projects: shared beliefs and attitudes about what is important”* - *“the value proposition must be conveyed in all of our projects; what saves money or produces more (volume or sales) for reasonable investment; yet we have not linked our safety initiatives well with business improvement strategies as we strongly value safety regardless”*
2	Convey emotion	Elements: ☐ Appeal to hope and inspiration ☐ Speak of pain or challenges	Elements: ☐ Describe values ☐ Speak of one’s vision

Persuasive Language Content Analysis Describing Participatory Ergonomics Programs			
	Technique	Maintenance Workers	Program Coordinator & Superintendent
		Examples:	Examples:
		- *"The Transformation Plan has allowed us to use our minds a lot more".* - *"In the past, with unsupportive team leadership, we had to sneak-in our innovations or seek support elsewhere knowing we may bear the consequences of going outside standard reporting channels"* - *"The messages we saw about organisational change and desire for good work design helped our confidence to keep championing our cause. We now have supportive leadership".* - *"I become excited by these projects, spending my own time on Google searches late at night to help innovate"*	- *"it's about empowerment"* - *"we treat contractors like guests; we extend our knowledge and safe performance coaching to them, also"* - *"when the guys on the shop floor live and breathe the initiatives, we know we've had some success"* - *"sustainability exists when we see it (the work) from the shop floor"* - *"we're doing well but we certainly don't have it all right; we still have a lot to learn; and we continue to strive to do better"*
3	Describe logic	Elements: ☐ Explain rationale ☐ Cite examples	Elements: ☐ Describe the logic ☐ Cite evidence

Persuasive Language Content Analysis Describing Participatory Ergonomics Programs			
	Technique	Maintenance Workers	Program Coordinator & Superintendent
		Examples - *"tasks should be easy to perform; if not, they may need change"* - *"the solutions are successful when they save time, create efficiencies, produce more output, and reduce product failure. For example, our automatic tyre changer".* - *"it would make more sense if suppliers would get involved; a lot of (re)design work occurs by us in the workshop and we become designers".*	Examples: - *"no matter the metrics used, it's still about working with humans and this requires knowing when the time is ripe to introduce and advance an initiative"* - *"when we present the value proposition of a project, it still must speak to the underlying culture and attitudes…"* - *"An enterprise must work with less. It's not that we don't have money; we do. Resource allocation must be linked to a value proposition, that's all. We must not get stuck into thinking, 'there is no money!'".* - *"Many organisations conduct widespread stretching programs but I see no evidence that this prevents injuries in industrial settings; moreover, I read evidence that this is a costly practice".*

Persuasive Language Content Analysis Describing Participatory Ergonomics Programs			
	Technique	Maintenance Workers	Program Coordinator & Superintendent
			- *"We regularly celebrate good ideas"*
4	Develop trust	Elements: □ Empathy □ Personal trust □ Anecdote □ Everyday language used	Elements: □ Inclusive language □ Use simile or business analogy □ Express ideas as though they were a shared vision
		Examples: - *"If it is inefficient, you need to think too much about it, it is not safe, (or you need to keep hammering), then it is likely too hard and you need to build a tool or buy a new tool"* - *A tour to highlight 12 good work design initiatives through a participatory process included: e.g. auto-tyre changer, swing-down hinged belly/bash plate for vehicles, drive shaft removal tool, seal installers, gear box secured plate, ball joint changer, spill guards around bath, hydraulic hose protection sleeves, radius arm bush tool,*	Examples: - *"It is basically a six-sigma process (e.g. define, measure, analyse, improve, control; OR DMADV: define, measure, analyse, design, verify) (Bertels, 2003)* - *"we all must learn how to be persuasive as, no matter the initiative, we must sell the idea to a team and almost always each individual represents competing agendas"* - *"We must help teams form good decisions in ways that seem efficient, quick, and easy; not nebulous,*

Persuasive Language Content Analysis Describing Participatory Ergonomics Programs			
	Technique	Maintenance Workers	Program Coordinator & Superintendent
		front wheel bearing plate, a turbo wash machine; and the trial of balancing beads to support wheel alignment.	*esoteric, or complicated. In other words, something that expresses (with whistles and bells or images) what we might want it to say or intuitively know"*

Table 6.3

Planning for a Conceptual Model of Total Health		
	Principle	RT Weipa Activities
1.	Organisational leadership & commitment	Industry is heavy mining industry, predominantly male, residential workers (little FIFO other than contractors). A land-use motto to support the sustainability of the community: "To work on the land, we must live on the land" even if this model is costly to pay rural living penalty awards and travel benefits Strong diversity program commitment and community sustainability efforts: 22 – 25% of workforce is of indigenous heritage Positive performance indicators include reward for lead indicators of hazard reduction; targeted trends and clear and broad communication to work teams Indicators reward design rather than incentivise non-report of injuries; contractor support is included in these objectives Communication frequency, volume, and content is high regarding safety, good work design, and health messages

Planning for a Conceptual Model of Total Health		
	Principle	RT Weipa Activities
		- Investment in technology that is adjustable to suit a wide range of users IMPROVEMENT AREA(s) - High profile Board Member / other leadership visibly championing issues of accessibility and good work design; design to achieve inclusivity and diversity is clearly articulated throughout the supply chain. Workforce initiatives are considered for procurement of capital equipment (e.g. if the organisation wishes to recruit more women, these design objectives are articulated in procurement specifications for capital equipment).
2.	Coordination among health protection, promotion, and work functions to benefit health, safety, and well-being initiatives	- Strong efforts to implement programs that are evidence-based - Stellar performance in setting improvement targets and achieving goals - High levels of program participation - Accessible early-intervention soft tissue management service to identify early hazard reports and support work surveillance - Pre-employment, functional capacity, and early intervention screening occurs regularly; work conditioning is provided for new employees and injured/ill employees returning to work IMPROVEMENT AREA(s) - Include human factors design consideration with critical event management strategies (critical risk, controls, and high-

Planning for a Conceptual Model of Total Health		
	Principle	RT Weipa Activities
		incident event analysis); capitalise on potential through organisational ergonomics - Extend progressive work conditioning for seasonal work flow changes or job role changes - Ensure "Green Banner" posters describing good work (re)design includes images of improvement in human-performance, not just machinery
3.	Supportive participatory organisational policies and practices	Policy: Classic-OHH-STD-804 (19.02.2016 version): HSEC Management System: Manual Handling and Vibration Standard: "to ensure employees and contractors do not experience adverse health effects from poor task and equipment design…." Comprehensive, targeted audit tool and annual process: "Manual Handling and Hand Red Zone Programme Protocol" Key job roles and tasks have been assessed for task flow, physical demand, work conditions, and environment Task risks are assessed regularly to meet work capacity of a wide range of workers: e.g. limit physical exertion, exposure to awkward postures, vibration, hand injuries, repetition, prolonged task exposure, fatiguing conditions, inefficiencies, or similar Effective risk determination and reporting tool that is widely known, recognised, and defined in policy statements and audit tools (ErgoAnalyst) Psychosocial support: well-celebrated monthly and annual innovation awards at a site and multi-site level; standard anti-

Planning for a Conceptual Model of Total Health		
	Principle	RT Weipa Activities
		discrimination policies but also practices design for inclusive work roles - Tacit knowledge high with shared vision to reduce hazardous manual task exposure combined with target to reduce hand red zones (hand injuries) with at least 60% to include red zone risk reduction - Visible design improvement work boards (Green Banners) and target risk reduction areas - Training inductions, tool-boxes and safety topics regularly include ergonomics issues - Communicate systems support of early symptom reporting or improvement opportunities - Retrospective program review is common; successes are analysed regarding factors that led to success (Refer: Chapter 3: Hand Red Zone Program Campaign) IMPROVEMENT AREA(s): - Procurement practices to include human factors and ergonomics as a condition of service among suppliers, transparent in product design - Develop decision support systems that facilitate priority task and control selection; communicate decisions to diverse vested parties when/as needed in digestible form; become industry leader in this practice - Business Improvement strategies to include value proposition of work (re)design - Implement “near right” reporting: to recognize when workers self-modulate or spontaneously modify work system, task,

Planning for a Conceptual Model of Total Health		
	Principle	RT Weipa Activities
		tool, or equipment to optimise performance (capture undocumented design changes) - Introduce "study success teams" for site visitation to other business units to learn from case study successes; investigate good work design externally in own and other industries to stimulate new ideas; form "mixed teams" comprised of different job roles / levels of seniority to review good work design. Capitalize on the design skills of mechanics through active inclusion of these representatives in design teams even in non-specific/different business units

6.6 Discussion

An enduring participatory ergonomics program was examined by thematic analysis of supportive work practices and persuasive language content analysis of the values expressed by two workers and two managers. This was useful to contrast the manner of expression with the synergy in values, such as a cultural commitment to improving productivity, health, and safety: conversational interviews are a powerful way to learn about an individual's interpretation of their social world and experiences (Burgess-Limerick & Burgess-Limerick, 1998). Two frameworks for good work design were used to consider how these methods could extend the program under study. This was effective to contribute to continual improvement and to discover methods to integrate good work design across business units and throughout the supply chain. The program outcomes supported the proposition that good work design is sufficient to reduce injury risk and improve business.

Research Question

> *What conditions were necessary to enable the success of an established participatory ergonomics program?*

The Rio Tinto Weipa Hand Red Zone and Manual Task Risk Reduction program was sustainable and had achieved significant results in terms of injury risk reduction. The program was supported by:

- The alignment of values among the leadership and workers, and supportive leadership
- The establishment of lead indicators
    - The targets included a goal for each of 6 teams to conclude 5 projects per annum and were strategic to involve the minimisation of hand injury risks in at least 60% of projects.
- Customised policies and procedures for good work design and manual task risk reduction
- The appointment of a good work design champion program coordinator
- Training to other work design champions throughout the organisation
- A commitment to enlisting, involving, and collaborating with workers
- A rewards and recognition program to reflect the importance of worker input to commandeer task (re)design
- Tolerance of iterative design and discovery practices
    - This organisation was tolerant of design projects that took, on average, over 12 months and often up to 18 months
- A commitment to continual improvement
    - For example, this was expressed through their willingness to help supply chain partners with good work design, providing uncompensated resources to support (re)design activity
- Consistent use of a cloud-based risk determination and project management reporting tool with thermal body map graphics to articulate acute and cumulative manual task risk rating

Traditional skills and knowledge (e.g. hazard management) were harnessed, however there was an integration of soft skills exhibited through transformational activity such as an appreciative approach to solicit ideas, celebration methods, and leadership coaching.

The conditions deemed necessary but not sufficient to operate the program included some of these supportive elements which were consistent with the propositions in the literature:

- Supportive leadership
- A good work design champion (in this case, trained by an ergonomist)
- Establishment of relevant lead indicators
- Worker involvement

The weight of resource allocation toward work design versus injury treatment was unique in this organisation and could contribute to theory emerging about how rapidly and effectively change can take place, should such shift in resource allocation occur.

Recommendations were made to include project cost and efficiency in business improvement reports and to expand systemic efforts of good work design (e.g. to engage predictive design review to inform procurement and to include these practices as a condition of capital equipment purchase and supply). “Near right” reporting was encouraged to identify task (re)design opportunities when workers spontaneously modified work to improve performance. Also, ideas were exchanged about methods to extend opportunities for innovation or encourage nomination of tasks for (re)design; this included the recommendation to form “study success” teams who could seek learnings outside their industry.

The transformational (“to-be”) activity (Table 6.1) – supportive leadership, lead indicators, and communication and celebration – were likely the most influential to change management in this organisation, freeing teams to be ready for action and empowered to make decisions that affected work design. Three pillars for good work design were identified:

I. Risk management and business improvement strategy
II. Action-readiness and decision making supported by leadership

III. Design thinking, strategy, and practice

Recommendations for Future Work

Replication of this case study is recommended. However, an effective and resilient participatory ergonomics program is far more difficult to find than a random project to review. If such programs can be found, studying success can help model future performance (Argryis & Schön, 1974; Dul et al, 2010). Chapter 7 extends this type of review through questionnaire with respondents who were familiar with successful programs.

Limitations

This study was limited to a single program review. Replication and comparative case study can aid the generalisability of findings. However, the nuanced approach to effective program operation in this case, including its drivers, such as supportive leadership and the methods to integrate lead indicators, were useful findings.

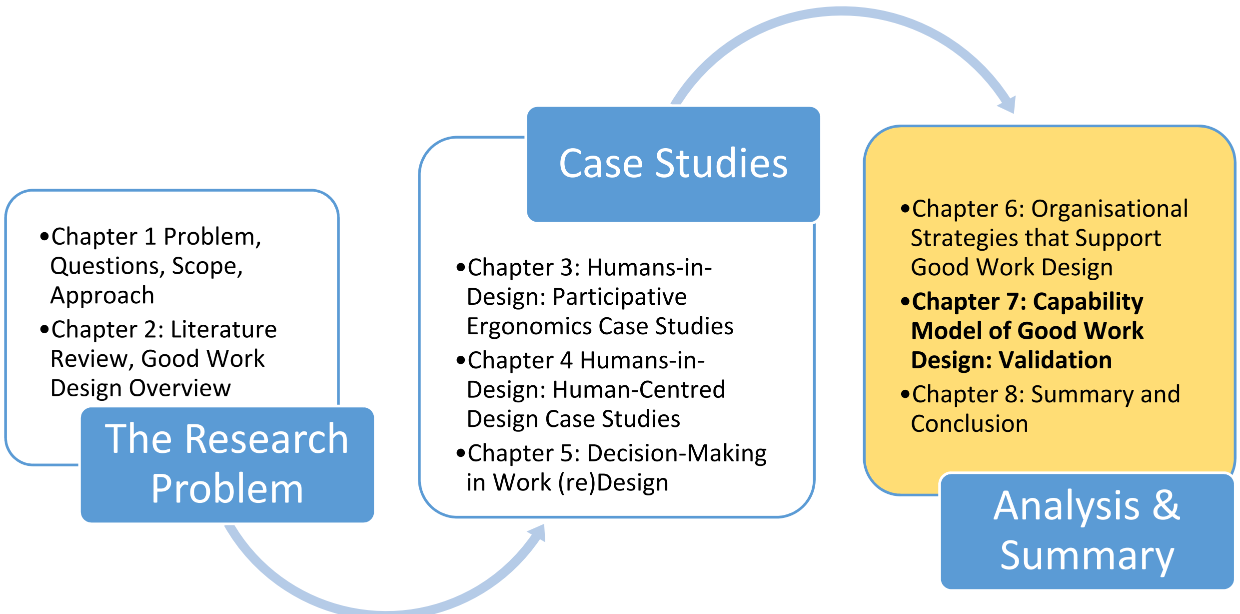
6.7 Conclusions

The study of an effective participatory program is useful to determine the activities of program coordinators and participants. In this case, values and beliefs were revealed through content analysis of persuasive language, thematic analysis helped identify transformational activities, and brain-storming with managers (informed by review of a conceptual model of total health) led to ideas that could help fortify the program. Key messages were derived:

- *Resilient good work design programs are best reflected by shared beliefs and values held among leaders and workers*
    - Lead indicators provide metrics to drive task (re)design
    - Performance is sustained by continuous improvement
    - Transformational activity (leadership, change-readiness, and design-thinking) is more important to innovation than budget, risk management, and reporting systems

- *Three pillars for good work design include:*
    - Risk management and **business improvement strategy**
    - **Action-readiness and decision making**
    - **Design thinking, strategy**, and practice

Chapter 7: Capability Model of Good Work Design



7.1 Introduction

The organisational context influences the successful implementation of good work design (Jensen, 2002; Perrow, 1983; Salmon et al, 2016; Vidal et al, 2012). A supportive environment requires appreciation of the principles of human factors and ergonomics by senior management. Often, however, human factors and ergonomics specialists are only permitted a marginal position in organisations (Hedge, 2015; Jensen, 2002; Perrow, 1983), if they are included at all. The principles of human-centred design are unfamiliar to many engineers (Jensen, 2002; Perrow, 1983; Salmon et al, 2016); and the language, scope, methods, and viewpoints of human factors and ergonomics may differ from safety science professionals to whom they often report (Dul, 2011; Yazdani et al, 2015). Organisational analysts may place little value on the absence of human-centred design strategies because they may be unaware of the practices (Perrow, 1983) or not understanding of the value of this work.

The nature of the organisation and its drivers for decision making, design capability, leadership values, and motivation for change have an impact on the level of management support for good work design (Perrow, 1983). Comparatively few resources are required to engage and implement many (re)design strategies with a human-centred perspective. Case examples provided in Chapter 3 (e.g. the paver tyre wheel dolly) and Chapter 4 (e.g. the commercial push broom) illustrate the ease of implementing off-the-shelf human-centred (re)design solutions, and yet barriers and delays were caused initially by managers.

Perrow (1983) suggested strategies that could be implemented by managers who appreciated the value and importance of good work design. These include:

1. Actively communicating the benefit to convince vendors or engineers who design and build systems and equipment to adopt a human-centred approach;
2. Position human factors and ergonomics specialists and their work stations near traditional designers (e.g. architects, engineers, industrial designers, or interior designers) to promote interaction;

3. Assign design engineers a structured mentoring “tour of duty” with human factors and ergonomics specialists;
4. Invite human factors and ergonomics specialists to meetings that involve development of design specifications;
5. Ensure contract specifications require certification by human factors and ergonomics specialists so that the design proposal meets agreed human-centred design standards;
6. Require a review by ergonomics specialists of equipment used by operators prior to and once introduced to the organisation by procurement, engineering, or operations;
7. Distribute and disseminate literature describing the contributions of human factors and ergonomics strategies among decision-makers;
8. Empower the practitioner with discretionary resources, as designers are often provided;
9. Help specialists translate the qualitative aspects of their work into quantitative data that may be of interest to the executive teams: finance, operations, and board members; and
10. Become familiar with human factors and ergonomics specialists to involve them at the level of casual conversation and inquiry.

Good work embodying human-centred design, human factors engineering, and participatory ergonomics results in system improvement, innovation, business value, positive work morale, and continual quality improvement (Jensen, 2002; Vidal et al, 2012). Consequently, it is important to examine the necessary conditions, organisational maturity, and capacity to partake in good work design if applications are to prove meaningful (Dul, 2016a). This activity will assist the discipline of ergonomics to evolve from beneath the umbrella of a safety or health paradigm toward a more pervasive business strategy (Vidal et al, 2012).

7.1.1 Necessary Conditions

Good work design is influenced by many elements: a consultative process, worker involvement, a method to identify tasks suited for design review, knowledge of worker capability and variability, an analysis of task-based work demands and environmental conditions, a task-based register of risks and design opportunities, and effective reporting and communication tools. Leadership support, a coordinated effort, a budget from which to draw to pursue design options, a method to evaluate design, outcomes that will be self-sustaining, and outcomes that are affordable or, better yet, create efficiency and productivity are also important (e.g. Burgess-Limerick, 2011; Cantley et al, 2014; Dul & Neumann, 2009). An important question is, "Which of these elements represent necessary conditions?" Could good work design be advanced without one or more of these? Are all elements required for program success? If so, to what extent? How is this contextualised for different organisations or industries, and are benchmarks easily established? How is that best measured?

If organisations are not adopting human-centred design practices, could it be that they are relying on deontic sufficiency (basic obligations and legislative requirements) to operate at status-quo (e.g. Martin, 2009)? However, if an alethic approach is taken, (e.g. "what is a truth in the world?") with multi-variate analysis (e.g. Van der Valk et al, 2016) and good work design is a mission, then there may be urgency to determine scenarios per causal factors, e.g. "Can event Y occur without the presence of X"? (McGill, 1998). This may be meaningful for the real-world adoption of good work design. It may reveal gaps and, thus, opportunities in education, training, practice, and guidance material. Without the condition, if it is necessary, an event (such as good work design) cannot and will not occur.

Like qualitative comparative analysis (Ragin, 1987), necessary condition analysis can be applied to research designs involving small to intermediate size numbers (e.g. 5 – 50) and help to bridge the gap between qualitative case review and quantitative study (Dul, 2015). It can bring set theoretic methods to social inquiry (Ragin, 1987). However, necessary condition analysis is unique in that it focuses on levels of single determinants and their combinations which are necessary but not, by axiom, sufficient (Dul, 2016a). The presence of a necessary condition does not guarantee the outcome (i.e. it may be contingent upon other conditions or factors, or, “X” is necessary to achieve “Y”, yet “X”, on its own, does not guarantee “Y”) (Dul, 2016a; Dul et al, 2010; Goertz, 2003). A necessary condition is a bare-minimum determinant (Dul, 2016a; Dul et al, 2010).

Necessary conditions form elements of a multiplicative expression (X_1 x X_2 x X_3 = outcome Y). That is, without X_1, X_2, or X_3, the outcome Y would not be achieved, and the result would be “0” (Geortz, 2003; Dul, 2016a). For the sake of illustration, one may postulate “X_1” = worker involvement; “X_2” = identification of tasks; and “X_3” = determination of effective controls (representing multi-variate determinants). Each of these elements may be necessary but not sufficient. If this were true, they cannot exist in isolation; but without any one element, good work design would not be achieved. However, even this calculation may be misleading because extent matters. If too much of A or B occurred, perhaps it would cause a system to fail rather than to increase and optimise value “Y”. For example, if too many tasks were pursued for (re)design, the effort might detract from operations and production. We need to know what is *necessary* and, also, what is *optimum* (e.g. Possingham, 2016). An investigation into what is necessary is a good start. Examples of necessary conditions follow: management commitment is required for organisational change, fertilisation is required for conception, or viral infection is a condition of influenza. In cooking, bacon, lettuce, and tomato are requirements for the creation of a “BLT”, despite variations in preparation, buns, or sauces (an example of multiple necessary conditions). Successful inter-firm collaboration requires both contracts and trust (Sumo, 2014; van der Valk et al, 2016). A requirement of participatory ergonomics is worker involvement (Burgess-Limerick, 2011). A maxim of human-centred design is that task demands and human capabilities are central to design strategy and, therefore, must be considered (e.g. Horberry et al, 2011; Horberry et al, 2015).

Dul et al (2010) argue that case studies provide rich detail from which to formulate statements of necessary conditions. Paramount learnings are derived when the logical characteristics of necessary conditions have been exhibited. However, bias related to social causation and the presence of natural categories (e.g. humans) may thwart efforts to examine necessary conditions that bring about desired outcomes (McGill, 1998). For example, Dale et al (2017) investigated features of a control strategy that may influence acceptance of the design change. A control (new equipment or re-engineered artefacts, for example) is artificial and readily examined according to covariate factors. In the case of the Pushie (Chapter 5), the industrial push broom was examined because it was a straight-forward case: the control was easy to obtain and use, it was a preferred resolution by workers; it resulted in significant cost benefit, and its use was compatible with prior work practices. When workplaces evaluate ideas related to worker involvement, the worker (an individual or a cohort) represents a natural category upon whom bias may be projected. Despite work health safety legislative framework instructing the practice of worker consultation (e.g. WHS Act, 2011), if management does not believe workers will be useful in their management of risks and productivity goals, they may be unlikely to consider the consultative practice as a critical success factor of good work design. To simplify the example, we can refer to the scenario of a bacon-lettuce-tomato (BLT) sandwich. The successful creation of the BLT may be attributed to a famed chef's artistry (a natural category) more so than the co-variate explanation of all the ingredients assembled in the right quantity and configuration. The bias may lie in a belief that a public persona with fame and fortune belies an artistry that is not easily replicated. McGill (1998) provides another example: early reaction to HIV illness was attributed to social phenomenon and natural categorisation of being a homosexual male without considering biological factors such as viral exposure. There is current bias, also, in attributing acts of violence or terror with religious affiliation, perpetuated by media, before all contributing factors are investigated and disclosed.

McGill (1998) uses social psychology experimentation to argue that people will be less likely to consider necessary information for explanations derived from natural categories. Consequently, people may readily accept natural category explanations (e.g. human error for injury causation) that are poor explanations for an event without examining alternative explanations that are necessary and sufficient. If this is true, because we are dealing with humans and work psychology in human-centred design, it may be difficult to objectively identify the necessary conditions associated with the complex machination required to advance good work design.

7.1.2 Maturity Models

Maturity models provide for benchmarking with guidance for process and outcome improvement. They assist in evolutionary practices to advance a competitive profile of an organisation (Lasrado et al, 2016). A maturity model is typically illustrated in a linear sequence for simplicity to aid communication and comprehension (Lasrado et al, 2016). This is akin to the simplification of a staged design process (e.g. Design for Operability and Maintainability Analysis Technique, d-OMAT, or the Good Work Design guidance documents of SWA, SWA, 2015a).

If one were to explore the vast array of activities that occur in an organisation to launch a program such as good work design, a systems-based approach can be useful. There is a dynamic interplay of events that accommodate the reality of organisational performance (e.g. Waddock et al, 2015). The model can account for equifinality (multiple pathways to an outcome), multiple conjunctural causation (an understanding of multiple causes and avoidance of reductionist, single causation considerations), and case diversity (inclusive of positive and negative outcome cases to derive understanding) (Lasrado et al, 2016).

Maturity Model Classification

Maturity models are generally categorised as a) Fixed-stage capability models, in which process maturity is developed incrementally and skipping levels is not considered a possibility, such as the Capability Maturity Model (Paulk et al, 1993); b) Stage-continuous models in which multiple factors may contribute to performance, and each factor may be rated independently in stage-performance-readiness (rather than a sum rating of all organisational processes) (e.g. Appendix A, Critical Control Management Journey Model, ICCM, 2015); or c) Focus area maturity models in which a functional domain of activity is dissected into components. These are analysed independently by levels of maturity and, thus, there are numerous small steps outlined upon which to focus for performance evaluation. An interdependency of these components is assumed to contribute to the overall domain capacity (van Steenbergen et al, 2013).

Maturity Model Development

The first stage of the six-stage development of a maturity model (Lasrado et al, 2016), involves problem definition: describe the maturity model with conditions (X) and outcomes (Y). For example, in good work design, this may present as:

The outcome, (Y), (Business Value), is defined:

> *Business value: a **significant number of (re)design strategies** are **implemented on a regular basis** to achieve **consequential gains in productivity** and/or **reduced risk.***

The conditions, (X), are highlighted in **bold*.***

Critique of Maturity Models

A limitation of fixed-level models is their simplicity. They can not express interdependencies among processes that contribute to the maturity level (van Steenbergen et al, 2013). However, the simplicity aids communication and provides for concrete understanding of the need for improvement by defined stages (Lasrado et al, 2016). The development of maturity models can be criticised for their lack of foundation in theory (Renken, 2004, cited in Lasrado et al, 2016) or for a lack of empirical validation in the selection of variables (Lahrmann et al, 2011; Wendler, 2012; cited in Lasrado et al, 2016). Further, they can be criticised for their assumption that progression towards maturity occurs through linear stages rather than configurations of multiple complex conditions and pathways (Lasrado et al, 2016).

An Ergonomics Maturity Model

Vidal et al (2012) describe a strategic framework for ergonomics with three aspects of management: process, project, and permanence. Process management refers to the establishment and maintenance of assessment and reporting tools that document project stages. Project management refers to a structured effort to plan, coordinate, secure, and manage resources toward a short-term endeavour that may bring change or value-added benefit to the company. For example, a project within an ergonomics program may be the development of a suite of task analyses to learn about business activities and determine priorities for design intervention. Permanence (or program) management in this framework refers to the sustainability and resilience of an ergonomics program given varied dimensions and integration of business units within the organisation. It refers to the leadership drivers that provide for ongoing support also.

The Ergonomics Maturity Model presented by Vidal et al (2012) was developed with the assumption that ergonomics meant change management per the dimensions of process, project, and permanence. The model was described in 5 stages:

Table 7.1

An Ergonomics Maturity Model (Vidal et al, 2012)

Maturity Level	**Stage Concept**	**Description**
Optimised	Continuous improvement	Everybody is engaged in continuous improvement
Managed	Previsibility and control	Consistent indicators; databased goals planning; aligned processes
Structured	Standardised and consistent	Standard procedures; some control; starting to use indicators
Organised	Disciplined	Main processes defined; balanced resources; structured scheduling
Informal	Imprevisibility (unforeseeable)	Lack of process concept; heroes' place

The ergonomic maturity model was tested with four cases. The authors noted the difficulty in determining successful cases (i.e. organisations with pervasive positive performance) to support the proposed logic-criteria. The model and criteria for assessment were tested with input from practitioners and project managers. The participants were asked to examine a list of problems based upon Crosby's capability grid (a management maturity grid) and translated into operational problems associated with ergonomics and the organisational support systems. The participants were invited to suggest edits to the inclusion criteria. The net result culminated in 14 categories, each with a qualitative aspect (total n = 50), rated by a forced-choice, 4-point Likert scale of “not important at all” to “very important”. It is uncertain whether any category or aspect received differential weighting of importance.

When the four organisations were evaluated, the results included one that was rated as “organised”, two that were “structured”, and one that was “managed”- all mid-tier evaluations (i.e. none received a rating of “1” or “5”, the worst or the best possible scenario). The authors conceded that the differences between organisational performance given the same maturity rating were significant. Further, the organisation that was rated as “managed” (the second-highest rank on the maturity scale) also rated the lowest in team leadership capabilities, and this presented a paradox in terms of the validity of the model. However, the exercise of evaluation proved valuable to furnish guidance for areas of improvement (Vidal et al, 2012).

7.2 Aims

The aim of this chapter is to examine necessary conditions for good work design and, from this, explore the development of a theoretically informed and empirically validated organisational model of maturity or capability. In this way, prescriptive modelling may inform practice. Data will be presented to help the characterisation of modelling, which may include: 1) maturity stage; 2) conditions, 3) boundary conditions, and 4) pathway to maturity (e.g. Lasrado et al, 2016).

7.3 Research Question

What conditions are necessary in organisations to achieve good work design in the opinion of specialists in this field?

7.4 Methods

The methods undertaken included three main parts: development of statements of necessary conditions related to good work design with formulation of hypotheses, examination of the statements and trivialness through questionnaire, and construction of a capability model for good work design with examination of likely boundary conditions.

7.4.1 Statement Construction: Necessary Conditions: Methods

Necessary Condition Analysis: Case Selection: Steps 1 & 2

The method of approach for necessary condition analysis is provided by Dul et al (2010) and the first two steps are highlighted (in bold):

1. **Select cases based upon the presence of outcome desired (e.g. successful design)**
2. **Formulate necessary condition hypotheses**
3. Assess trivialness: e.g. ID cases without the necessary condition
4. Conduct replication studies (or expand the data base)

The findings of the studies presented in this thesis were reviewed to examine critical success factors (n = 3 participatory ergonomics cases; n = 2 human-centred design practices; n = 1 decision making in a participatory ergonomics case; n = 1 program review; or 7 total). These factors were compared and tabulated with findings from narrative literature (Case Review 2) and guidance material. From these findings, statements of necessary conditions were derived (e.g. Dul, 2016a; Dul et al, 2010).

An example of a dichotomous necessary statement is provided below (Table 7.2) (e.g. Dul et al, 2010):

e.g. *Leadership support (X) is necessary to achieve effective outcomes (Y) in participatory ergonomics projects*

Table 7.2

Example of a Dichotomous Necessary Statement for Good Work Design			
Y = Outcome (Effective PE outcome)	1 = Present	Not Possible	Possible
	0 = Absent	Possible	Possible
		0 = Absent	1 = Present
		X = Condition (Leadership Support)	

This statement implies that leadership is necessary but not sufficient. Other activities must accompany the leadership support (a condition of multi-causal phenomena). However, without leadership support, an effective participatory ergonomics project outcome is not possible.

Narrative Literature Review: Key Words

An online literature review was conducted using search terms including “Ergonomics Critical Success” and “Ergonomics Necessary Condition”. Papers were reviewed to determine the link between these terms and study interests. A condition of inclusion was that the cases had to profile successful implementation (e.g. Dul et al, 2010). The investigator extracted propositions from this material.

Statement Construction: Necessary Conditions

Notes were taken detailing common themes found from narrative literature review that met search term criteria (n = 4) and research study case reviews, including workshop exercises (e.g. thesis chapters 3 – 5) (n = 8). The cited methods, approaches, actions, and recommendations, and their frequency of citation were noted and tabulated.

Given case review findings and narrative literature review (n = 12), possible conditions for good work design (sufficiency and/or necessity) were developed and, from these, statements of necessary conditions were constructed (refer to Tables 7.4 and 7.5).

7.4.2 Statement Testing: Necessary Conditions: Methods

Necessary Condition Analysis: Case Selection: Steps 3 & 4

Dul et al (2010) define the last two steps of necessary condition analysis (in bold below):

1. Select cases based upon the presence of outcome desired (e.g. successful design)
2. Formulate necessary condition hypotheses
3. **Assess trivialness: e.g. ID cases without the necessary condition**
4. **Conduct replication studies (or expand the data base)**

To obtain further data about cases, programs, and organisations, a questionnaire was devised and administered to subject matter experts.

Questionnaire: Development and Administration

A questionnaire was developed that included four domains: contextual factors, process maturity, outcome measures, and demographics. Five process levels were investigated: leadership, resources, performance benchmarks, expertise, and outcomes. A range of conditions were included that related to the process levels as derived from Steps 1 & 2 for the development of necessary condition statements.

An iterative process was engaged in the construction of the questionnaire, and verification trials were conducted with academic supervisors (n = 2), a third-party advisor (n = 1), a statistician (n = 1), and colleagues (n = 3). Modifications were made after receiving their feedback. The method of administration was via an on-line questionnaire (SurveyMonkey) with an accessible web-link. Ethics approval was obtained, and consent and disclosures were added to the first page of the survey.

There were 27 main questions: one dichotomous forced-choice nominal question (to determine inclusion criteria); two ratio scales (e.g. “duration”); three ordinal scales with multiple choice (one that provided for outcome “Y”); six multiple-choice nominal questions (e.g. “yes”, “no”, or “do not know”); one multiple-choice nominal question in which more than one factor could have been selected; nine 5-point Likert-style ordinal questions with 37 sub-factors (e.g. to indicate levels of agreement) and option for open-ended comment; and five open-ended questions, including voluntary submission of contact details (Table 7.4).

A snowball sampling technique was used. Participants with experience in advising, supporting, or coordinating good work (re)design were recruited. Participants may have had a background in human factors and ergonomics consulting, coordination, or teaching; regulatory compliance and advisory service; or operations management with sustained integration of good work (re)design practices. The survey remained open for four months. This population was derived by:

1. Direct email to subject matter experts known to the investigator or recommended by colleagues and supervisors (n = 25)
2. Direct email to a voluntary participation list that was displayed at a Musculoskeletal Disorders Symposium 2017 hosted by Workplace Health and Safety Queensland (n = 5)
3. Notice per relevant ergonomics groups on social media: LinkedIn (n = 8 groups collectively with 25,239 group members at the time of notice)
4. Notice per a relevant ergonomics association (HFESA) electronic email newsletter to their subscribers (n = 491) (Bullis, 2018)
5. Participants were invited to nominate a person to whom the questionnaire web-link could be emailed, and these recommendations were pursued (n = 3)

Questionnaire: Statistical Sampling

The investigator examined raw findings and statistical worksheets to determine relationships and derive meaning. A statistician was engaged to conduct data analytics. Data was coded for ease in analysis, clarified to fit with a discrete coding system, and displayed via Excel and Minitab (Minitab, 2010). Pairs of variables were analysed to determine monotonic relationships using Kendall tau(b) rank correlation coefficient (Kendall & Gibbons, 1990) with investigation of high correlation (close to “1”) to examine when observations were of similar rank. Bootstrapping was performed in Excel VBA to estimate two-sided p-values by applying Fisher-Yates shuffles repeatedly to generate distributions of 100,000 tau coefficients for each of the original data pairs (Siller, 2017).

Ordinal logistic and regular regression analyses were conducted using Minitab on Likert values and their sums, as were step-wise regression and general linear models. Specifically, Q10 has been treated as both an independent and dependent variable in various analyses, so the sum of the Likert scores in Q10 allowed for linear regression, whereas Q18 through Q23 required ordinal logistic regression (Siller, 2017). The data included some low counts in some rows/columns, however graphical tables were produced which are suggestive of necessary conditions.

7.4.3 Capability Model: Method

Performance benchmarking was considered through the development of a preliminary capability model for good work design informed by review of literature including standards for human-centred design, case history, program review, and integration of theories-in-use and espoused theories. The model was intended to express the opportunity for continuous improvement through a simple framework of 5 possible performance areas: resistant, complacent, random, resilient, and enterprising. Linear capability models require definition of stage, conditions, and boundaries (specific conditions that must be satisfied to progress to the next stage) (Lasrado et al, 2015, 2016). To validate and verify propositions of this preliminary model, a six-step procedure for data analysis was referred to for guidance and a custom approach was undertaken for some step components to best suit data available (Table 7.3).

Table 7.3

A Six-Step Procedure for Maturity Model Development: Good Work Design (Lasrado et al, 2016)		
PRIMARY STEP	Sub-Step Function(s):	Approach Undertaken
1. Problem Definition	Describe the Maturity Model: Conditions (X) and Outcomes (Y) a. Case Selection & Description	*Conditions of sufficiency and/or necessity were devised. Necessary condition analysis statements were constructed. A framework for a 5-stage maturity model was developed and this was included in questionnaire designed for testing.*
2. Necessary Condition Analysis: Identify Boundary Conditions & Degree of Necessity		*Random sampling was conducted per questionnaire and coded interview data sets. Effect size was plotted and measured.*
3. Iterative Formulation of Maturity Stage Boundary Conditions		*Formulate, or confirm the postulated formulation, of maturity stages and boundary conditions; determine benchmarks*
4. Derive Maturity Configurations	a. Calibrate Set Memberships for each Maturity Stage (X) & (Y) b. Iterative Formulation of Macro Conditions*	*Maturity and capability configurations were derived. Necessary condition analysis was undertaken and data was graphically represented. Statements of sufficiency were made without detailed statistical*

A Six-Step Procedure for Maturity Model Development: Good Work Design (Lasrado et al, 2016)		
PRIMARY STEP	Sub-Step Function(s):	Approach Undertaken
	c. Necessary Condition Analysis d. Qualitative Comparative Analysis (QCA) Solutions: Configuration Stages	*analysis because the data set uniformly rated a level of program success with any project, consistent with theory.*
5. Transfer Concept: Visualise the Maturity Configurations	Visualization of maturity configurations in a format that is easily understood by the target audience	*A hypothetical model was devised (Stage 1) and refined by conditions (Stage 2)*
6. Operationalise Quick Versions of Maturity Measurement	Create and operationalize a condensed version of maturity measurement to serve as a quick diagnostic tool	*Preliminary data was devised and testing in multiple organisations for comparative review is recommended to advance this research*

Capability Model Conditions and Scales

The capability model testing occurred through content analysis provided by the questionnaires (refer to method and results, section 7.4 and 7.5). The questionnaire was structured to examine contextual factors, process maturity, outcome measures, and demographics. Five process levels were investigated: leadership, resources, performance benchmarks, expertise, and outcomes. The outcome “Y”, a level of organisational capability, was investigated across several conditions (Table 7.4).

Capability model conditions and boundaries were used as a basis to develop a Stage 2 model of capacity. The frequency of a positive condition (such as leadership support or practices) was calculated for each category of program capability. Calculations of negative conditions were dismissed (as a minimum entry condition was established; either “resilient” or “enterprising”).

Table 7.4

Capability Model Conditions

Condition (X)		Scale; # of Items
Leadership	Senior management advocates HCD in all facets of operations	Likert 5-point; 8; with option for open answer
	Few barriers exist to HCD practice; barriers are actively removed or diminished	Likert 5-point; 8 with option for open answer
Resources	Resource is strongly committed to advance HCD	Likert 5-point; 3; with option for open answer
Benchmarks	Lead indicators are established to drive HCD practice	Likert 5-point; 6; with option for open answer
	Cost-benefit is engaged to evaluate projects	Nominal scale; 3
	Payback analysis is engaged to evaluate projects	Nominal scale; 3
Expertise	Knowledge, skill, and capability is recruited and developed in support of HCD	Likert 5-point; 6; with option for open answer
	Participant (respondent) role	Multiple choice; 9, with option for open answer

Capability Model Conditions		
Condition (X)		Scale; # of Items
	Methods to generate ideas are multi-faceted: broad in scope and range	Multiple choice; 10, with option for open answer
Outcomes	Effective HCD design outcomes are achieved	Likert 5-point; 6; with option for open answer
	Duration of program operation	Ratio; 4, with option for open answer
	A given project was successful	Nominal scale; 3
	The level of project success was high	Likert 5-point; 1
	Level of impact to morale was high	Likert 5-point; 1
	Level of productivity improvement was high	Likert 5-point; 1

7.5 Results

Results are provided below for three related studies: the statement construction of necessary conditions, the investigation of these statements and trivialness, and the development of a capability model for good work design.

7.5.1 Statement Construction: Necessary Conditions: Results

Narrative Literature Review: Key Words

When the search terms "Ergonomics Critical Success" were used, 138 papers were exhibited with either "ergonomics" or "critical" or "success" in the title or abstract. Each paper was reviewed online to determine linkages with the search terms. Of these, 42 had the words "ergonomics" and "critical" or "success". Fifteen of these were opinion-based articles, non-peer reviewed, and without citations; and were excluded. Three of the documents were thesis-based and, upon further investigation, did not furnish adequate material to constitute a study of critical success factors and ergonomics processes. Three of the studies were considered relevant to the analysis of the success of an ergonomics program. The other papers described the effects of ergonomic practice to change tools, equipment interface, or communication systems and, as such, represented micro-analysis versus macro-analysis of the program in an organisation. When the search terms “Ergonomics Necessary Condition” were used, 63 papers with either “ergonomics” or “necessary” or “condition” were returned. Of these, one had the terms “ergonomics” and “necessary condition”.

The critical statements from each paper (n = 4) are provided below in Table 7.5. The finding of “digital human modelling” was grouped in the statement of “simulation, modelling, and iterative design” that may be a necessary condition for good work design.

Table 7.5

Factors of Ergonomics and Good Work Design Programs Described

Data Source	**Factors**
Search Terms “Ergonomics” and “Critical Success”	
Gauthier, F., Lagacé, D. (2015). Critical success factors in the development and implementation of special purpose industrial tools: An ergonomic perspective. 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015. Procedia Manufacturing, 3, 5639-5646.	1. Worker participation and involvement (voluntary) 2. Appreciation of the ergonomics process (supportive leadership culture) 3. Establishing design goals and objectives, design characteristics and specifications (design philosophy and objectives) 4. Prototype testing and trial (simulation and iterative design process) 5. Evaluating control effectiveness
Koyuncu, G., Kurt, E., & Erensal, Y. C. (2011). Work system design in macro-ergonomics: A	1. Decision support systems are essential to understand the

Factors of Ergonomics and Good Work Design Programs Described	
Data Source	**Factors**
case study related to prioritization of major sociotechnical system components by using the Fuzzy Analytic Network Process. Human Factors and Ergonomics in Manufacturing & Service Industries, 21(1), 89–103.	importance of work system characteristics 2. Production technology is the most important factor affecting work system design: physical characteristics of machinery, tools, equipment, and the degree of automation
Faville, B. A. (1996). One approach for an ergonomics program in a large manufacturing environment. International Journal of Industrial Ergonomics, 18, 373-380.	1. Implementation strategy and schedule 2. Goals and objectives for improvements (design philosophy) 3. Methods and processes to identify and resolve risks 4. Authority to develop and implement the program (leadership) 5. Management commitment 6. Employee involvement 7. Work systems analysis 8. Prevention and control focus 9. Health management integration 10. Training and education 11. Evaluation and documentation
Search Terms “Ergonomics” and “Necessary Conditions”	
Chaffin, D. B. (2005). Improving digital human modelling for proactive ergonomics in design. Ergonomics, 48(5), 478-491.	Simulation (per DHM) is necessary for a proactive ergonomics program

Common Themes and Threads: Results

The approaches, actions, and recommendations derived from the case findings in this thesis were compared with the literature included for study about “critical success” or “necessary conditions”. Trends were tracked per content and frequency of citation. Elements related to safety management systems and activities advised in the legislative framework (e.g. hazard identification and risk determination) were described most typically (> 60%).

Change-readiness and actions such as conveying the value proposition of the work, procuring leadership support, modelling and simulation, and predictive analysis were sometimes described (41 – 59%). Design strategy (e.g. an appreciative approach; or project goal-setting and evaluation; and higher-level organisational activity (e.g. problem-solving and decision making, setting lead indicators, and resource allocation) were not typically described (< 40%).

Statements of Necessary Conditions of Good Work Design

Possible conditions for good work design (sufficiency and/or necessity) were developed (Table 7.6).

Table 7.6

Summary of Possible Conditions for Good Work Design		
No	Function	Statement
1.	Leadership	a. Highly supportive leadership b. Executive remuneration linked to lead indicators for work design
2.	Worker Involvement	a. Worker ideation and collaboration inform projects at all stages
3.	Appreciative Inquiry	a. An appreciative approach encourages workers to nominate tasks for design review
4.	Training	a. Training is necessary and complementary to good work design b. Adequate knowledge, skills, and ability are required (within a design team) to establish effective design philosophy
5.	Task Analysis	a. Traditional hazard management programs are necessary, but not sufficient, for task (re)design b. Effective task-based hazard identification, risk determination, and reporting systems are necessary to substantiate design review c. A case-based task library that illustrates risk and design improvement d. A hierarchical risk-based analytic approach to tasks
6.	Values and Beliefs	a. Evidence of a shared belief in design efficacy among workers and management b. Evidence of a strong value proposition of good work design expressed through tacit knowledge (within a work team, organisation, &/or industry)
7.	Resources	a. Freedom to influence teams and mobilise resources is necessary for a work design coordinator to conduct their work

Summary of Possible Conditions for Good Work Design		
No	Function	Statement
		b. A high degree of autonomy for resource allocation among team leaders
8.	Managing transformation and design implementation	a. The establishment of work (re)design lead indicators b. The articulation of design philosophy and objectives c. Design solutions that are systemic rather than isolated control intervention d. Effective evaluation of controls or (re)design strategies e. Simulation, trials, and iterative design practice f. Predictive design review of capital equipment and work systems
9.	Business unit integration and communication	a. High levels of business unit integration for task (re)design b. Evidence of supply chain integration during project review c. Transparent, broad-range and scope of communication and celebration d. Examination of, and double-loop learning from, design projects

7.5.2 Statement Testing of Conditions: Results

Questionnaire

There were 27 respondents: 11 were project consultants, 9 were program coordinators, 4 were team participants, 4 were safety advisors, and there were 2 respondents each in categories of regulatory advisors, educator/trainers, engineer/designers, and operations managers (it was possible to assign more than one role in response to the question). All respondents had been involved in a task (re)design project employing participatory ergonomics practices.

Eight of the projects considered by the respondents had occurred within the last six months, 3 within the last year to six months, 4 within one to three years, 9 occurred more than three years ago, and 3 were still in progress. However, good work design programs were in existence in the host organisations: 5 for five years or more (41%), 2 for three to five years (7%), 9 between six months and less than three years (33%), and 5 were new under 6 months in operation (19%). Respondents represented diverse industries (Table 7.7).

Table 7.7

Respondents by Industry Type

Industry	Respondents	Percentage
Manufacturing, warehouse, and distribution	9	33%
Mining	5	19%
Health	4	15%
Transportation and logistics	3	11%
Technology	3	11%
Local Government	1	4%
Real Estate Property Management	1	4%
Construction	1	4%

All respondents rated the ergonomics project in which they were involved a success, and the level of success was rated as “moderate” or “high” by 22 respondents (81%). Table 7.8 provides detail of the characterisation of project success.

Table 7.8

Characterisation of Project Success

Industry	**Strongly Agree**	**Agree**
Positive morale	37%; n = 10	44%; n = 12
Productivity and efficiency	37%; n = 10	48%; n = 13
Business improvement	56%; n = 8	30%; n = 15
Risk Reduction	15%; n = 4	70%; n = 19
Health Improvement	11%; n = 3	67%; n = 18
Inclusivity and diversity	15%; n = 4	41%; n = 11
Sustainability	15%; n = 4	44%; n = 12

Respondents predominantly agreed with the statement that there was a high level of executive leadership support for good work (re)design in the host organisation: 66% agreed or strongly agreed (n = 18), 22% neither disagreed or agreed (n = 6), while 11% disagreed (n = 3).

Statements from respondents who disagreed included:

> *“They’re interested but not totally sold yet”*
>
> *“This organisation struggled to see WHS as integrated into business activity”*
>
> *“… CEO ambivalent”*

Of those who disagreed or neither disagreed or agreed (n = 9) that there was high level executive leadership support, all reported that the task (re)design project still had some or more success (however, only 1/9 [11%] at a high level).

- When asked what would have made the project a success, three of these respondents mentioned an aspect of leadership:

  "Management commitment and resources such as time for more staff to participate…"

  "Leadership commitment"

  "Greater senior management ownership and affirmation of the success, wider organisational communication and… change management"

- When evaluating the program of good work design (outcome "Y") within the host organisation, these respondents rated the program on the least prospective end of the spectrum of maturity: random (n = 6), complacent (n = 2), or resistant (n =1) (67% = "random"; and 33% = "complacent or resistant").

Of those who agreed or strongly agreed (n = 18) that there was a high level of executive leadership support for good work (re)design, 100% reported that the task (re)design project was a success; and 11 of these rated this at a high level (61%). When evaluating the program of good work design (outcome "Y"), 10 (56%) rated the program as "resilient" (the more prospective end of the scale), 1 (6%) as "enterprising" (the top end of the spectrum), and 7 (39%) rated the program as "random".

Respondents (n = 20) provided their opinion about what would have contributed to project success. Some of these comments follow (recommendations pertaining to leadership commitment were quoted above):

> *"Greater involvement by operations staff, less control by facilities staff"*
>
> *"More planning in the pre-project stage"*
>
> *"More training to all levels before beginning"*
>
> *"More buy-in/participation from the device manufacturer"*
>
> *"A trial period that allowed introduction of improved iterations during trial…"*

"Communicating better through the business, results failed to disseminate … to all regions"

"Earlier involvement of the employees…"

"…The integration of different areas….: ergonomist, designers, purchase department; … more effective participation of workers, not … a mere source of information but as (co-) 'designers'"

Cost benefit analysis was believed to be useful to evaluate (re)design intervention by 89% of respondents (n = 24); and payback analysis was believed to be of benefit by 85% of respondents (n = 23). Respondents were asked to provide general recommendations for areas of improvement in the respective organisations. Some of the comments are provided below:

"Greater engagement of senior and middle management in marketing and owning the process… "

"Institutionalise PE for all identified hazards"

"Creation of high-level aspirations to use as a touch stone against which to measure … project and design elements"

"Assigning an internal expert to continue managing the process. Initiate an education program on good work design: what it is, how (sic) helps business"

"Better mechanism … for identification of … (re)design opportunities"

"More defined approach to selecting where to intervene"

"… when the project has concluded… the concepts of participatory ergonomics may have been lost…"

"Greater emphasis on highlight and celebrate success"

"… scope of project to be more inclusive of other areas to improve buy-in…"

Data Analytics: Simple Correlations & Regression

Questions 18 and 23 were examined and compared for the significance of the p-values for Kendall's tau-b (**τ_b**) and co-variance with factors arising from other questions. Some demographics questions were omitted from the comparisons (and they did not show statistical significance for either question). Question 18 asked: *How would you rate the level of the participatory ergonomics project success?* (Likert 5-point scale; failure to high). For those questions pertaining to barriers (Q 12), a negative value was obtained so, to rectify interpretation, the question was turned into a positive statement and values made positive. Question 17 was omitted from tables as there was no variation in the responses; a unanimous "yes" was submitted by respondents (Q17: *Was the participatory ergonomics project a success?*).

Question 23 asked respondents to *rate organisational maturity on a scale* of 5 levels: resistant (n = 1 [3.7%]), complacent (n = 2 [7.4%]), random (n = 13 [48.2%]), resilient (n = 10 [37%]), or enterprising (n = 1 [3.7%]). Significance values < 0.05 are highlighted in **bold** font. Co-factors that presented with a statistically significant p-value (<= 0.05) for both questions 18 (project success) AND 23 (program maturity) are highlighted in **blue** - refer to table 7.9 below.

Table 7.9

Level of Project Success (Q18) and Organisational Maturity (Program) Rating (Q23)			
Q.	***Co-Factor***	**Q18**	**Q23**
3.	*How long ago was this project?*	$p = 0.499$ $\tau_b = -0.119$	$p = 0.205$ $\tau_b = -0.216$
4.	*… how long has a good work design program been operating… ?*	$p = 0.131$ $\tau_b = 0.258$	$p = 0.615$ $\tau_b = 0.088$
5.	*What industry best represents this organisation…?*	$p = 0.339$ $\tau_b = 0.163$	$p = 0.769$ $\tau_b = 0.051$
6a.	***There is high-level, executive leadership support …***	**$p = 0.012$** **$\tau_b = 0.432$**	**$p < 0.001$** **$\tau_b = 0.617$**

Level of Project Success (Q18) and Organisational Maturity (Program) Rating (Q23)			
Q.	***Co-Factor***	**Q18**	**Q23**
6b.	***The leadership support is pervasive, as evidenced throughout the business***	**$p = 0.301$ $\tau_b = 0.184$**	**$p = 0.005$ $\tau_b = 0.473$**
6c.	***Good work (re)design is a focal point in multiple … business unit(s)…***	**$p = 0.391$ $\tau_b = 0.149$**	**$p = 0.046$ $\tau_b = 0.340$**
6d.	***There are high levels of supply chain integration …***	**$p = 0.040$ $\tau_b = 0.350$**	**$p = 0.002$ $\tau_b = 0.528$**
6e.	***There are custom policies, procedures, and reporting tools …***	**$p = 0.004$ $\tau_b = 0.486$**	**$p = 0.012$ $\tau_b = 0.423$**
6f.	*The value proposition of the initiatives is regularly communicated in business improvement reports…*	$p = 0.321$ $\tau_b = 0.174$	$p = 0.242$ $\tau_b = 0.204$
6g.	***(Re)design strategies are communicated and celebrated …***	**$p = 0.169$ $\tau_b = 0.244$**	**$p = 0.031$ $\tau_b = 0.371$**
6h.	***There is a harmonized, clear chain of defined responsibilities…***	**$p = 0.035$ $\tau_b = 0.361$**	**$p = 0.002$ $\tau_b = 0.540$**
7a.	*The ratio of resource allocation of good work design to injury management is positive…*	$p = 0.17$ $\tau_b = 0.242$	$p = 0.105$ $\tau_b = 0.286$
7b.	*Discretionary resource is provided to business units to effect good work (re)design…*	$p = 0.390$ $\tau_b = 0.154$	$p = 0.112$ $\tau_b = 0.287$
7c.	*Reporting tools exist that specifically support participatory ergonomics…*	$p = 0.580$ $\tau_b = 0.099$	$p = 0.069$ $\tau_b = 0.317$
8a.	***(Re)design activities are driven by established, quantifiable targets … with ongoing outcome measurement***	**$p = 0.714$ $\tau_b = 0.066$**	**$p = 0.027$ $\tau_b = 0.379$**
8b.	***Predictive design review is conducted*** *…*	**$p = 0.003$ $\tau_b = 0.486$**	**$p = 0.022$ $\tau_b = 0.383$**
8c.	*Supplier agreements require evidence of human-centred design….*	$p = 0.065$ $\tau_b = 0.317$	$p = 0.069$ $\tau_b = 0.315$
8d.	***Contextualised hazard I.D. and risk determination is conducted … in task registers***	**$p = 0.053$ $\tau_b = 0.340$**	**$p = 0.011$ $\tau_b = 0.435$**
8e.	***Projects are tracked to monitor design improvement…***	**$p = 0.039$ $\tau_b = 0.356$**	**$p = 0.001$ $\tau_b = 0.541$**

Level of Project Success (Q18) and Organisational Maturity (Program) Rating (Q23)			
Q.	***Co-Factor***	**Q18**	**Q23**
8f.	***A task-based case library of good work design is maintained***	**$p = 0.093$ $\tau_b = 0.287$**	**$p = 0.005$ $\tau_b = 0.475$**
9a.	***Knowledge and skill is high with evidence-based practice …***	**$p = 0.025$ $\tau_b = 0.381$**	**$p = 0.010$ $\tau_b = 0.429$**
9b.	***Competence is high among key participants to develop effective design strategy***	**$p = 0.020$ $\tau_b = 0.399$**	**$p = 0.023$ $\tau_b = 0.381$**
9c.	***Good work design ideas are solicited in numerous ways throughout the business***	**$p = 0.010$ $\tau_b = 0.458$**	**$p = 0.027$ $\tau_b = 0.386$**
9d.	*Appreciative inquiry is employed to solicit the nomination of tasks…*	$p = 0.785$ $\tau_b = -0.053$	$p = 0.176$ $\tau_b = 0.244$
9e.	***Worker involvement and collaboration is solicited in the design process…***	**$p = 0.076$ $\tau_b = 0.318$**	**$p = 0.032$ $\tau_b = 0.371$**
9f.	*Mature risk and critical event management systems and tools exist…*	$p = 0.230$ $\tau_b = 0.206$	$p = 0.178$ $\tau_b = 0.231$
10a.	***Outcomes have led to significant business improvement***	**$p > 0.001$ $\tau_b = 0.729$**	**$p = 0.005$ $\tau_b = 0.489$**
10b.	***Outcomes have led to significant reduction in risk***	**$p = 0.047$ $\tau_b = 0.351$**	**$p = 0.053$ $\tau_b = 0.348$**
10c.	***Outcomes have led to significant improvements in health***	**$p = 0.008$ $\tau_b = 0.475$**	**$p = 0.058$ $\tau_b = 0.342$**
10d.	***Outcome have led to improvements in inclusivity or diversity***	**$p = 0.004$ $\tau_b = 0.494$**	**$p = 0.233$ $\tau_b = 0.212$**
10e.	*Outcomes have led to improvement in sustainability*	$p = 0.097$ $\tau_b = 0.302$	$p = 0.335$ $\tau_b = 0.174$
10f.	***Outcomes are evaluated along (an occupational perspective of health) spectrum…***	**$p = 0.152$ $\tau_b = 0.251$**	**$p < 0.001$ $\tau_b = 0.599$**
12a.	***Barriers* not likely*…: Lack of interest***	**$p = 0.018$ $\tau_b = 0.412$**	**$p = 0.056$ $\tau_b = 0.331$**
12b.	***Barriers* not likely*…: Lack of skill***	**$p = 0.002$ $\tau_b = 0.513$**	**$p = 0.060$ $\tau_b = 0.316$**

Level of Project Success (Q18) and Organisational Maturity (Program) Rating (Q23)			
Q.	***Co-Factor***	**Q18**	**Q23**
12c.	***Barriers not likely…: Inadequate leadership support***	**$p = 0.014$** **$\tau_b = 0.407$**	**$p < 0.001$** **$\tau_b = 0.584$**
12d.	*Barriers not likely…: Resistance from middle management*	$p = 0.147$ $\tau_b = 0.253$	$p = 0.137$ $\tau_b = 0.258$
12e.	*Barriers not likely…: Resistance from work crew*	$p = 0.203$ $\tau_b = 0.223$	$p = 0.233$ $\tau_b = 0.212$
12f.	*Barriers not likely…: Behavioural safety models outweighing (re)design intervention*	$p = 0.384$ $\tau_b = 0.152$	$p = 0.213$ $\tau_b = 0.216$
12g.	***Barriers not likely…: Inadequate resource commitment***	**$p = 0.061$** **$\tau_b = 0.321$**	**$p = 0.002$** **$\tau_b = 0.502$**
12h.	***Barriers not likely…: A participatory, collaborative process not undertaken***	**$p = 0.102$** **$\tau_b = 0.275$**	**$p = 0.002$** **$\tau_b = 0.507$**
13.	***Cost benefit is used to evaluate (re)design intervention***	**$p = 0.039$** **$\tau_b = 0.379$**	**$p = 0.002$** **$\tau_b = 0.538$**
14.	*Would cost benefit analysis be useful to evaluate (re)design intervention?*	$p = 0.806$ $\tau_b = 0.092$	$p = 0.943$ $\tau_b = -0.008$
15.	*Is Payback Analysis used to evaluate (re)design intervention?*	$p = 0.531$ $\tau_b = 0.116$	$p = 0.279$ $\tau_b = 0.195$
16.	*Would Payback Analysis be useful to evaluate (re)design intervention?*	$p > 0.999$ $\tau_b = -0.007$	$p = 0.903$ $\tau_b = -0.014$
18.	***Level of the participatory ergonomics project success***	**NA**	**$p = 0.004$** **$\tau_b = 0.495$**
19.	***Level of impact to positive morale…***	**$p > 0.001$** **$\tau_b= 0.757$**	**$p = 0.016$** **$\tau_b = 0.425$**
20.	***Level of impact to work productivity …***	**$p = 0.002$** **$\tau_b = 0.531$**	**$p = 0.145$** **$\tau_b = 0.263$**
23.	***Level of organisational maturity…***	**$p = 0.004$** **$\tau_b = 0.495$**	**NA**

Key: **Bold Font =** *statistical significance determined in either Q18 (project success) OR Q20 (program maturity);* ***Blue Colour*** *= necessary conditions determined in both Q18 (project success) and Q20 (program maturity)*

The sum of groups of ordinal factors related to effective (re)design outcomes were used to analyse by regression the sum of the ordinal responses pertaining to outcomes (i.e. Q10; 6 predictors, n = 27). Q6 (leadership support; p-value = 0.007), Q8 (lead indictors; p-value = 0.001), and Q12 (barriers – or lack thereof; p-value = 0.0012) provided the most significant information about the success of intervention, and this was conferred by stepwise regression of Q10 starting with the factors Q6, Q7, Q8, Q9, Q11, Q12 with the criteria F ≥ 4.0 to add or remove a variable) Refer to Table 7.6 for a final best-fitting model. One point to note is that leadership support was positively correlated with Q10 predictors by itself, but negatively correlated in models containing lead indicators (Q8).

Table 7.10

Stepwise Regression: Relationship Among Effective Outcomes and Co-factors

Step	1	2	3	4
Constant	3.525	3.525	3.525	3.525
6sum	-0.35	-0.35	-0.32	-0.34
T-Value (Q6)	-3.01	-3.01	-2.91	-3.11
8sum	0.69	0.67	0.67	0.55
T-Value (Q8)	3.88	3.99	4.02	4.29
12sum	-0.280	-0.266	-0.262	-0.298
T-Value (Q12)	-2.78	-2.83	-2.81	-3.38

An analysis of variance indicated that cost benefit analysis (Q13) was associated with successful outcomes (Q10sum: business improvement, risk reduction, health improvement, improvement in inclusivity or diversity, improvement in sustainability, and outcome evaluation) (F-value = 5.18 and p-value = 0.014), but this effect was not independently significant once 6sum, 8sum and 12sum were taken into consideration. The data also revealed that, after controlling for 6sum, 8sum and 12sum, consultants reported higher levels of success than non-consultants (F=4.26, p=0.051).

Analysis of Conditions of Necessity or Sufficiency

Conditions of necessity were configured by distribution of responses (conditions indicated above the red line that occurred with a contributing factor). Levels of agreement on a Likert Scale were coded numerically with positive integers representing high levels of agreement (note: an outlier was permitted in the data per pragmatic determinism [Dul & Hak, 2008]). **Conditions of necessity** are listed in Tables 7.11 – 7.16:

Table 7.11

Program Capability: High-level Executive Leadership Support							
τ_b = 0.617; p < 0.001							
Q6a: high-level, exec leadership support	Levels of Agreement	**2**	0	0	2	4	1
		1	0	0	5	6	0
		0	0	1	5	0	0
		-1	1	1	1	0	0
		-2	0	0	0	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Table 7.12

Program Capability: Leadership Support is Pervasive							
τ_b = 0.473; p = 0.005							
Q6b: leadership support is pervasive as evidenced throughout the business	Levels of Agreement	**2**	0	0	0	1	1
		1	0	0	7	7	0
		0	1	1	3	1	0
		-1	0	0	3	1	0
		-2	0	1	0	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Table 7.13

Program Capability: Task Registers Used for Hazard Reporting							
t= 0.435; p = 0.010							
Q8d. Task registers are maintained to contextualise hazards/risks	Levels of Agreement	**2**	0	0	2	2	1
		1	1	0	5	7	0
		0	0	0	3	1	0
		-1	0	2	3	0	0
		-2	0	0	0	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Table 7.14

Program Capability: Task Based Case Library of Good Work Design							
τ_b = 0.475; p = 0.004							
Q8f: a task-based case library of good work (re)design is maintained	Levels of Agreement	**2**	0	0	0	2	1
		1	0	1	2	3	0
		0	0	0	6	5	0
		-1	1	1	3	0	0
		-2	0	0	2	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Table 7.15

Program Capability: Outcomes Evaluated Along Spectrum of Health							
τ_b = 0.599; p < 0.001							
Q10f: Outcomes are evaluated along (an occupational perspective of health) spectrum…	Levels of Agreement	**2**	0	0	0	0	1
		1	0	0	3	8	0
		0	1	1	6	2	0
		-1	0	1	4	0	0
		-2	0	0	0	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Table 7.16

Positive Program Capability: Cost Benefit Analysis							
τ_b = 0.538; p = 0.002							
Q13: Cost Benefit Analysis is used to evaluate (re)design intervention	Agreement (yes / no / do not know)	**1**	0	0	7	9	1
		0	1	0	4	1	0
		-1	0	2	2	0	0
Q23: Program Maturity			**-2**	**-1**	**0**	**1**	**2**

Conditions of sufficiency were determined for Q18 (project success) because all projects were considered by respondents to have had *some* level of success. Tables 7.17 – 7.20 represent the success factors.

Table 7.17

Sufficiency of Health Improvement							
τ_b = 0.475; p = 0.007							
Q10c: Outcomes have led to significant improvements in health	Levels of Agreement	**2**	0	0	0	0	3
		1	0	0	2	8	8
		0	0	0	2	2	1
		-1	0	0	1	0	0
		-2	0	0	0	0	0
Q18: Project Success			**-2**	**-1**	**0**	**1**	**2**

Table 7.18

Sufficiency of Risk Reduction							
τ_b = 0.475; p = 0.007							
Q10b: Outcomes have led to significant levels of risk reduction	Levels of Agreement	**2**	0	0	0	0	4
		1	0	0	0	8	7
		0	0	0	4	2	1
		-1	0	0	1		0
		-2	0	0	0	0	0
Q18: Project Success			**-2**	**-1**	**0**	**1**	**2**

Table 7.19

Sufficiency of Productivity/Efficiency							
τ_b = 0.531; p = 0.002							
Q20: Outcomes have significantly impacted productivity / efficiency	Levels of Agreement	**2**	0	0	0	3	7
		1	0	0	2	6	5
		0	0	0	3	1	0
		-1	0	0	0	0	0
		-2	0	0	0	0	0
Q18: Project Success			**-2**	**-1**	**0**	**1**	**2**

Table 7.20

Sufficiency of Business Improvement							
τ_b = 0.729; p < 0.001							
Q10a: Outcomes have led to significant business improvement	Levels of Agreement	**2**	0	0	0	0	8
		1	0	0	2	9	4
		0	0	0	2	1	0
		-1	0	0	1	0	0
		-2	0	0	0	0	0
Q18: Project Success			**-2**	**-1**	**0**	**1**	**2**

General Correlations

Statements that met criteria of high levels of **project success** AND **positive program maturity** (i.e. “resilient” or “enterprising”) (through statistical significance of a low p-value [<= 0.05] by rejecting a null hypothesis of no relationship among co-factors with critical outcomes) included:

- *High levels of executive leadership support*
- *High levels of supply chain integration*
- *Custom policies, procedures, and reporting tools*
- *A harmonized, clear chain of defined responsibilities*
- *Predictive design review is conducted*
- *Task-based registers are used to contextualise hazards and determine risks*
- *Projects are tracked to monitor design improvement*
- *High levels of knowledge and skill of evidence-based practice*
- *High levels of design competence among project team participants*
- *Good work design ideas are solicited in numerous ways throughout the business*
- *Outcomes have led to significant business improvement*
- *Barriers were not evident in areas of: interest levels, skill, or leadership*
- *Cost benefit analysis is used to evaluate design outcomes*
- *Project outcomes led to high levels of morale*

Statements that met criteria of statistical significance for high levels of **project success** ONLY included the following (the relationship to Q23 was omitted because there was no comparison of responses):

- *Outcomes have led to significant reduction in risk*
- *Outcomes have led to significant levels of health, inclusivity / diversity, and productivity*

Statements that met criteria of statistical significance for positive ratings of **program maturity** ONLY included the following (note: the relationship to Q18 was omitted because there was no comparison of responses):

- *The leadership support is pervasive*
- *Good work (re)design is a focal point in multiple… business unit(s)…*
- *(Re)design strategies are communicated and celebrated…*

- *(Re)design activities are driven by established, quantifiable targets … with ongoing outcome measurement*
- *A task-based case library of good work design is maintained*
- *Outcomes are evaluated along a spectrum (e.g. an occupational perspective of health)*
- *Resource commitment is not a barrier*

7.5.3 Capability Model: Results

Good Work Design Capability Model

A five-stage, ordinal capability scale (ReCRREate) for good work design was created to provide performance benchmarks (Table 7.21). The term “capability” was used in place of “maturity” in this model because no significant association was found among program duration (suggesting a level of maturity) and positive outcomes. There were 6 necessary conditions described from the data set.

Table 7.22 shows the developmental process: Stage 1 characteristics represented the bottom-up development of the model, where characteristics where examined and slotted into 5 categories. Stage 2 characteristics of the model reflect testing of the assumptions through questionnaire administration and analysis of conditions (necessary or sufficient). Because the focus of the questionnaire was on success, the stage 2 characteristics are more aligned with positive program features.

Table 7.21: **ReCRRE**ate Capability Model: Necessary Conditions for Good Work Design

Statement of Necessity	**R**esistant (n = 1)	**C**omplacent (n = 2)	**R**andom (n = 13)	**R**esilient (n = 10)	**E**nterprising (n = 1)
	Impenetrable mindsets	Perceived sufficiency in action	Action Quandry	Design Culture and Change-Readiness	Design Prowess; Pioneering
There is high-level executive leadership support			54% (7)	100% (10)	100% (1)
The leadership support is pervasive			44% (4)	80% (8)	100% (1)
Hazards are contextualised to task registers			54% (7)	90% (9)	100% (1)
A task-based library is maintained		50% (1)	15% (2)	50% (5)	100% (1)
Outcomes are evaluated per a spectrum of health			23% (3)	80% (8)	100% (1)
Cost-benefit analysis is used			54% (7)	90% (9)	100% (1)

Table 7.22

Good Work Design: Capability Model Stage Characteristics			
Classification	**Profile**	**Characteristics – Stage 1:**	**Characteristics – Stage 2:**
Enterprising At least 5 years of work (re)design activity that has achieved significant productivity and risk reduction; can provide examples of award-winning or legacy design	**Design Prowess; Pioneering** *We are aware that good begets great and great is derived from our people* *We innovate and articulate; this is our hallmark* *Safety, health, well-being and/or culture surveys indicate positive outcomes* *Our productivity benchmarks are above industry standards*	• **Board-level support and expertise in human-centric design** • **Exec remuneration linked to GWD performance benchmarks (lead indicators)** • **Value proposition expressed in business improvement reports and workforce planning** • **Business Unit Integration: Procurement, Workforce Strategy, Engineering, Legal, Design, Operations, Safety, Environment, Health & Wellness** • **Suppliers require evidence of human-centric design practices** • **Investment in human-centric design education and training: strategic up-skilling of workforce** • **Predictive design review for procurement - ingrained in systems** • **And BLUE characteristics**	**Necessary Conditions** • There is high-level executive leadership support • Senior management advocates HCD in all facets of operations; pervasive leadership support • Hazards are contextualised to task registers • A task-based case library of design is maintained • Cost-benefit is engaged to evaluate projects • Outcomes are evaluated per a continuum of health factors (e.g. an Occupational Perspective of Health model, per Chapter 3) **Simple Correlations & Regression** • *High levels of supply chain integration* • *Custom policies, procedures, and reporting tools* • *A harmonized, clear chain of defined responsibilities* • *Predictive design review is conducted* • *Projects are tracked to monitor design improvement* • *High levels of knowledge and skill of evidence-based practice* • *High levels of design competence among project team participants* • *Good work design ideas are solicited in numerous ways throughout the business*

Good Work Design: Capability Model Stage Characteristics			
Classification	**Profile**	**Characteristics – Stage 1:**	**Characteristics – Stage 2:**
			• *Outcomes lead to significant business improvement* • *Barriers are not evident in areas of: interest levels, skill, or leadership* • *Project outcomes lead to high levels of morale* • *Project outcomes (generally) lead to high levels of success*
Resilient At least 3 years of work (re)design activity that has achieved meritable productivity results and health risk reduction	**Design Culture and Change-Readiness** Our people are a valued asset and we plan for their future We have established solid building blocks for progress Continual improvement and highly competitive business	• **Supportive leadership culture** • **Positive ratio of GWD: IM staff resource** • **Metrics: Lead indicators for design** • **Control implementation evaluated** • **Regular communication and celebration of GWD** • **Simulation and modelling common practice** • **Task-based risk registers** • **JSAs/SWMSs contain distributed SA findings and instruction** • **Case-based library of GWD maintained** • **Worker involvement and collaboration solicited in work design** • **High levels of discretion and responsibility afforded to workers/teams** • **Role clarity and authority harmonized** • **"Double-loop organisational learning" frequently engaged** • **Mature risk management and incident investigation practices with custom tools and approaches** • **Mature critical event management program targeting highest-risk activities** • **Active sustainability practices** • **Appreciative inquiry used to solicit work (re)design**	**Necessary Conditions** • There is high-level executive leadership support • Pervasive leadership support (77% finding) • Hazards are contextualised to task registers (89% finding) • A task-based case library of design is maintained (60% condition) • Cost-benefit is engaged to evaluate projects • Significant levels of improvement in health are achieved (60% condition) **Simple Correlations & Regression** • *Outcomes lead to significant reduction in risk* • *Outcomes lead to significant levels of health, inclusivity / diversity, and productivity* • ***AND:*** *Those listed for an Enterprising Organisation*

Good Work Design: Capability Model Stage Characteristics			
Classification	**Profile**	**Characteristics – Stage 1:**	**Characteristics – Stage 2:**
		Reporting tools, policies, and procedures exist specific to participatory ergonomics practice	
Random At least 6 months of program maturity in a business unit; at least one (re)design project undertaken or ad-hoc projects undertaken	**Action quandary** *Our business strives to recruit and retain talented people and keep them free from harm* *We invest in health and safety* *We meet industry standards for general business performance*	• **Occasional PE / HF project undertaken, driven by incident, industry trend, or random manager interest** • **Workers are encouraged to express views, but management retains the right to act** • **Conduct task analysis w/o strategic intent for design & improvement: inform recruitment and injury management only** • **Prevailing safety metrics: LTIFR, MTI** • **And ORANGE characteristics**	Random projects may have some success
Complacent No internal formal program launch; project(s) may have been attempted with outside hired consultancy service but	**Perceived sufficiency in action** *We need to target hiring practices to attract those who are built for the tasks* *Health and Safety can complicate operational efficiency*	• **Work-design change is mandated: e.g. regulatory body** • **Hazard-based registers common** • **JSAs/SWMSs provide behaviour-based instruction** • **Intervention emphasis: pre-employment screening and injury management: individual** **And RED characteristic**	

Good Work Design: Capability Model Stage Characteristics			
Classification	**Profile**	**Characteristics – Stage 1:**	**Characteristics – Stage 2:**
practices are not sustained	*We focus on production and believe other programs compete with this activity*		
Resistant Work (re)design methods are not engaged; projects are not attempted	**Impenetrable mindsets** *Only the right people for the job can produce the results we need* *Design is an activity of engineering only* *We do what we need to do, and we get by*	• **A solely behavioural-based approach to work investigation, training, and leadership** • **Cases of workplace bullying include deeds of middle management** • **Zero Harm policies espoused with behavioural activity to support practice**	

7.6 Capability Model and Developmental Stages: Discussion

Statement Construction: Necessary Conditions

Reflective case review reveals real-world application of theory and practice. It discloses the theories-in-use, values, and beliefs applied in practice (e.g. Argyris & Schön, 1974; and Dul, J. 2016b). The development of necessary condition statements was a two-stage process involving articulation of theories derived from literature review, examining theories-in-use underpinning case studies, and testing these ideas via expert opinion of questionnaire participants. Statements of necessity provide direction to management for governance, operations, and performance benchmarking (e.g. Argryis & Schön, 1974). Education and training content, industry expectations, and regulation may be enhanced by such clarity. The proposition of necessary conditions provided for the methodology intended in this thesis: an action-research framework with double-loop learning (e.g. Argryis & Schön, 1974). Statements of sufficiency were important also: every project described by a questionnaire participant was rated as having some level of success, regardless of the level of program maturity or capability. It was sufficient to practice participative ergonomics and achieve success through improvement in worker health and productivity/efficiency, and/or risk reduction.

However, those who considered the **executive leadership** support to be the highest were almost six times more likely to rate the level of **project success** as “high” (61%, n = 11/18; versus 11%, n = 1/9). They were more likely to rate **program capability** per constructive terms also (i.e. “resilient” or “enterprising”) (61% of these respondents versus none who rated executive leadership as low). This implies that organisations should promote the values of good work design to leaders in the organisation and strive to design their systems, methods, skillsets, capabilities and resources accordingly (e.g. as per ISO 27500: 2016: A Human-Centred Organisation) should this trend be found to be true when replication studies are undertaken.

Questionnaire Analysis

Simple Correlations & Regression: Discussion

There were different elements that contributed to project versus program success suggesting that skills, resources, tools, capabilities, and management methods to advance specific projects may differ to those required to advance a more comprehensive program. Significant impact in safety and health occurred in projects that were deemed successful. An association was made with business improvement. Advanced organisational processes were reflected in highly capable programs, as was design capability. Task-based reporting of hazards and cost-benefit analysis was prevalent for projects and programs.

Program duration was not significantly associated with success (except for the highest level of capability) and, consequently, “capability” was considered a more appropriate term than “maturity” for benchmarking and modelling of this material. There were no significant differences in industry type either. Worker involvement and collaboration was correlated with program success but not significantly so with project success. This could reflect the nature of the questioning which asked about worker involvement in five stages: hazard identification, risk determination, determination of design philosophy, product procurement or development, and product trials, and involvement through all stages would be more likely in a high capability program. Worker involvement at every stage may not be necessary to achieve a good outcome although the best possible outcome may be more likely.

There was no significant association found between project success or program capability with methods identified or nominated for task (re)design either (data analysed with Q11*sum*). Mature risk and critical event management systems and tools were not significantly associated with a good work design project or program, suggesting that the methods and capabilities to advance effective work (re)design may be different than traditional risk management practice (e.g. Chapters 3, 4, 5, and 6). An association was not found with appreciative inquiry as a driver of positive outcomes (e.g. Chapters 3, 4, and 5). This may be owing to the lack of understanding about the term describing the practices (i.e. the practices could be engaged and the respondent may not recognise them) or there may be rare use of this approach. Use of cost-benefit analysis was supported by the correlation with successful outcomes, *Q10sum*, (F-value = 5.18 and p-value = 0.014).

Necessary Conditions: Discussion

There were five conditions of necessity that were identified for high levels of **program capability**. Two of these were related to leadership (executive and pervasive leadership support), and three were related to practices undertaken (task-based case libraries to contextualise hazards, cost benefit analysis, and outcome review per a spectrum of health indicators). The data for an enterprising organisation (n = 1) was unique so considerations were made for either a resilient or an enterprising organisation. However, the enterprising organisation met all conditions.

Executive and pervasive leadership support was necessary to achieve high levels of program capability: without it, a resilient or enterprising program did not exist. This was not the case for project success, although, as found in the simple correlation studies, the level of success was more likely to be significant with this condition.

Project success related to improvement in health and business, and productivity / efficiency gains. These conditions related to positive gains versus injury risk reduction, suggest practice alignment with business operations, continuous improvement, and wellness programming (or design, engineering, and procurement) more so than risk management and safety systems. Conditions required to achieve success for a random project were different from those required of high levels of program capability. As such, skills, capabilities, resources, methods, tools, and benchmark measures would be different to advance a random project versus operating an effective program.

ReCRREate Capability Model Discussion

A five-stage capability model was used to describe categories, boundaries, and inclusion or exclusion criteria. The model was presented as a continuous-staged model with ordinal categories. The simplicity of this model yields a method to communicate with a measure of ease and explains the need for high performance. However, there was no uniformity in stage progression. The leap from the categories of “complacent” to “random” may be easy to achieve if an operations manager were suddenly influenced to support a random project. In contrast, the leap from “random” to “resilient” may be require substantial effort including changes in culture, values, systems, tools, and leadership at a broad level.

There was only one respondent from an “enterprising” organisation, so comparisons and inferences were difficult to make with this unique example. The most compelling information was derived from identifying conditions that were specific to programs versus projects. Project success was best determined by levels of business improvement, productivity, and health; program capability was best determined by leadership levels, task-focused work descriptions, cost-benefit analysis, and health improvement outcomes

Further investigation is warranted. Not only do we need to know what is necessary, but what is optimum (dose-response, combination of covariate factors, and intervals, or other conditions). Other features derived by simple statistical correlations and regression may be useful (e.g. resource commitment, communication and celebration, or supply chain and business unit integration). Knowing this, action can be focused. The necessary conditions are those which an organisation wishing to advance human-centred design must ensure. Other factors may be interwoven, but not at the expense of a necessary condition.

Research Questions: Chapter 7: Discussion

In the opinion of specialists in this field, what organizational conditions are necessary to achieve good work design?

Statement 1: A high-level of program capability occurs when organisations provide these necessary but insufficient conditions:

a) executive and pervasive leadership that is supportive
b) task-focused work descriptions for hazard identification
c) cost-benefit analysis
d) analysis by health improvement outcomes

Traditional hazard management practice, legislative framework, and health and safety guidance material were not associated with necessity for good work design in this data set. Consquently, the statement of necessity was modified:

Statement 2: Traditional hazard management practice provides insufficient conditions for good work design, including:

a) nomination of tasks for design review
b) effective task (re)design
c) a high volume of design activity

This is important because many organisational activities around health and safety stem from hazard management practice.

Recommendations

Data obtained from a larger set would be useful to examine, and particularly if more enterprising organisations were found. A larger data set will validate findings and may provide for more definitive boundary conditions as well as assist in the determination of stage development and progression. Questions should be targeted to distinguish between project success and program capability: the differences were unexpected, but significant, and warrant discrete examination. However, it is likely that project-based data is more readily available than program-based data because it is rare to find a high-capability program.

Worker involvement should be examined further. Type of involvement by design stage could be considered. Leadership featured significantly in project success and program capability. Exactly what and how this type of leadership support may be expressed should be examined further (e.g. Chapter 6). The multitude of nuances that affect organisational performance warrants further study also.

Limitations

The sample size of questionnaire respondents (n = 27) was small and cases with inclusion criteria categorised as “enterprising” were difficult to find. Only one was identified in this data set. Ten examples were categorised as “resilient” and most (thirteen) were categorised as “random” and project-based. Small data sets are better substantiated by replication, comparative analysis, or experimental design.

7.7 Conclusions

Participatory ergonomics projects will likely achieve some level of success despite the level of leadership support or available resource. It is worthwhile doing *something* rather than nothing. However, projects nested within a highly capable program with executive and pervasive leadership support are far more likely to achieve significant success. The conditions that are necessary to achieve project and program success are positively oriented (i.e. what may be gained) rather than what may be mitigated (risk reduction) and, thus, are different to the orientation of traditional safety management practice. The drivers for successful programs are more akin to salutogenesis than pathogenesis. A distinction was found among conditions that provide for project versus program success, and this can help educators and practitioners target their efforts.

The findings from this chapter provide these key messages:

- *Ergonomics project success is highly likely: it is worth doing **something** rather than nothing*
    - Projects that occur within a well-led, capable design program are far more likely to achieve significant success.
    - Project success is best determined by levels of business improvement, productivity, and health; program capability is best determined by leadership levels, task-focused work descriptions, cost-benefit analysis, and health improvement outcomes.

- *Comfort may be derived from doing “just enough” to meet ethical and legal work obligations; stand-out organisations continually strive to do better*
    - Establishment of lead-indicators, celebration and communication of success, and broad outcome evaluations are suggestive of a highly-capable program.

- The execution of a project requires different skills, resources, tools, capabilities, and activities than the implementation of a sustainable program.

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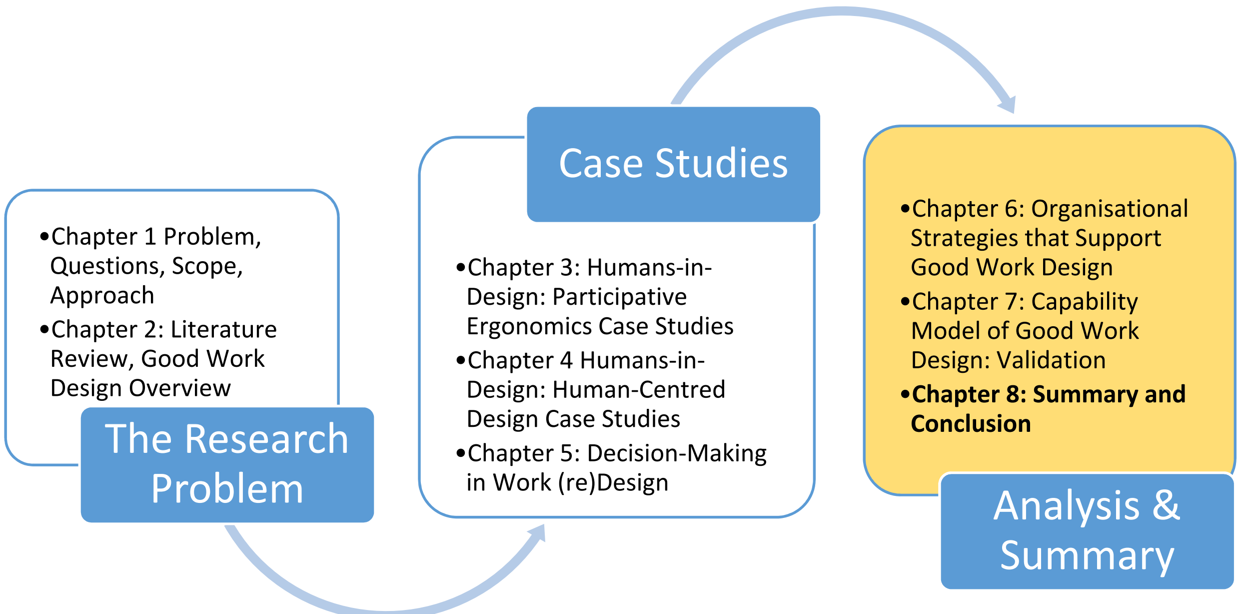
Chapter 8: Overall Discussion, Recommendations, and Conclusion



8.1 Contributions to Knowledge

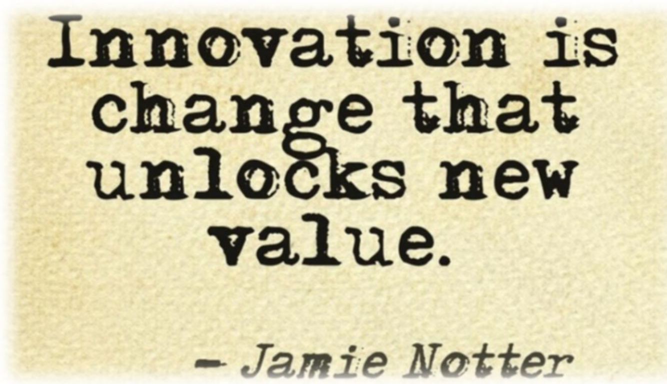


Figure 8.1: Innovation is Change: Source: http://manishjha.net/2015/07/08/innovation-and-creativity-quotes/ (Notter & Grant, 2015).

This thesis investigated how organisations achieved good work design: what tools, practices, activities, structures, systems, conditions, and culture were required to achieve human-centred work. Specifically, what was sufficient and what was necessary? The central question in this thesis was, "How can organisations achieve good work design?".

Project case studies provided a comparative review to test theory and derive new propositions. A program was reviewed to determine features that led to the capability of an organisation to repeatedly implement participative ergonomics solutions. A questionnaire was administered to investigate the opinion of skilled and experienced practitioners, consultants, and managers about how organisations have operationalised and designed successful, human-centred work. Differences were found among the features and methods required to achieve a project as opposed to a program, and a capability model was developed. Key messages were extracted from each study by thematic analysis and the elements were framed within three categories: organisational systems, design processes, and design outcomes (Table 8.1).

Table 8.1: Summary of Key Findings

Summary of Key Findings	Organisational Systems	Design Processes	Design Outcomes
Good work design is vital to organisational (and, likely, industry) performance			
Well-designed work meets worker capability yet challenges new thinking and is physically conditioning. It provides for a productive, healthful, and inspired workforce.			✓
Quality task (re)design conveys social justice; it respects workers			✓ ✓
Worker involvement inspires creativity, innovation, and engagement		✓	
Design-thinking is essential to business improvement			
Design-thinking is opportunity-based		✓	
Traditional risk-based safety management systems do not provide adequate leverage for effective task (re)design	✓	✓	
The challenges to embed design-based thinking in organisations is significant	✓		
Predictive, human-centred design methods can optimise work performance			
Our most expensive capital investments can be costlier without human-centred considerations			✓

Summary of Key Findings	Organisational Systems	Design Processes	Design Outcomes
Hazards can be managed, and productivity enhanced, through design-thinking		✓	✓
Task-based hazard reporting provides meaningful and useful information to leverage work improvement		✓	
A human-centred approach provides for design-based work strategies			
Management practices are an influential factor as to whether structured design processes are undertaken	✓		
Effective design may require flexible approaches		✓	
Decisions reflect belief systems, so it is important to examine them if a human-centred mindset is desired			
Transparent decision making can aid communication, build consensus, and defend actions supporting task (re)design	✓	✓	
Projects that can be addressed by a low-cost, easy solution, and are readily implemented, can simplify the decision-making process, and fortify an early-stage ergonomics program		✓	✓
Without an ergonomics specialist influencing essential (re)design projects, a tactical approach to good work design is unlikely	✓	✓	
Considerable effort must be harnessed, driven by shared beliefs and values, for good work design to prevail in a resilient and systematic manner			
Lead indicators provide metrics to drive task (re)design	✓	✓	

Summary of Key Findings	Organisational Systems	Design Processes	Design Outcomes
Optimum performance requires internal examination and continuous improvement	✓		
Transformational activity (leadership, change-readiness, and design-thinking) is more important to tender innovation than budget, risk management, and reporting systems	✓		
Three pillars for good work design include:			
○ Risk management and business improvement strategy	✓		
○ Action-readiness and decision making	✓	✓	
○ Design thinking, strategy, and practice		✓	✓
Ergonomics project success is highly likely: it is worth doing something rather than nothing			
Projects that occur within a well-led, capable design program are far more likely to achieve significant success	✓	✓	✓
Project success is best determined by levels of business improvement, productivity, and health; program capability is best determined by leadership levels, task-focused work descriptions, cost-benefit analysis, and health improvement outcomes	✓	✓	✓

Summary of Key Findings	Organisational Systems	Design Processes	Design Outcomes
Comfort may be derived from doing "just enough" to meet ethical and legal work obligations; stand-out organisations continually strive to do better			
Establishment of lead-indicators, celebration and communication of success, and broad outcome evaluations is suggestive of a highly-capable program.	✓	✓	
The advancement of a project requires different skills, resources, tools, capabilities, and activities than the advancement of a program; knowing this difference may help target service delivery and inform an educational framework	✓	✓	

8.1.1 Chapter 3: Participatory Ergonomics Case Studies

A new approach for establishing design objectives and evaluating outcomes was demonstrated. The Occupational Perspective of Health model involves: avoidance of catastrophe, fatality, disablement, and impairment or discomfort; as well as attainment of a conditioning effect, social connection, profitability, business unit integration, and industry liaison including supply chain integration. Recommendations were made to include design for sustainability and diversity. These outcomes shift thinking to a salutogenic approach (Antonovsky,1979; Golembiewski, 2010) rather than solely pathogenic. That is, the focus shifts to what can be achieved through design that enables a positive work experience rather than only that which should be avoided.

Design strategy was discussed in detail in relation to the case studies and an appreciative approach was found to be highly effective in encouraging the nomination of tasks for (re)design which subsequently enabled significant risk reduction and productivity improvement. The cases supported the evidence that good work design through participative ergonomics sufficiently achieves these outcomes.

8.1.2 Chapter 4: Human-Centred Design

A systems review was undertaken using a Functional Resonance Analysis Method (FRAM, Hollnagel et al, 2014). The design process assumed in two organisations was determined to be non-linear and non-sequential despite what may seem logical (for example, the d-OMAT 6-step design process and, similarly, good work design guidance material [e.g. SWA, 2015a]). These real cases provide learnings from which guidance and educational material can be enhanced.

Legacy equipment already in use in an organisation can be reviewed to provide for human-centred considerations, compel design modifications, and inform purchasing decisions. This is a function of a capable human-centred organisation (ISO 27500:2016, Human-Centred Organisations). However, readiness among organisations to embrace such practices can vary. For example, in a large multi-national organisation new to human-centred design-thinking, significant activity was undertaken to support the approval process for and communication about the design review of the asphalt job truck. The bitumen trailer was reviewed to support a small to medium enterprise that was change-ready but required structured processes and formal documentation to enable defensible and translatable logic that supported their design ideas.

The learnings, tools, or methods used in one industry can have cross-industry application. Tools and methods used in the mining industry for design of earth moving equipment were found to be useful in the investigation of a job truck and a bitumen trailer in the construction and transportation industries. In the case of the job truck, fifteen hazards were found that had not been previously identified using these methods, leading to a proposition that traditional safety management systems may be important, but not sufficient or necessary to lead to effective, human-centred design changes. These cases supported the proposition that human-centred design sufficiently reduces injury risk, and improves business outcomes. The design tools were necessary but not sufficient to ensure an effective design process was undertaken. Leadership support was also necessary but not sufficient to enable the design process.

8.1.3 Chapter 5: Decision Making in Task (re)Design

The importance of transparency in decision-making was highlighted. A decision-making software application was used and weighted decisions were configured. This process enabled transparent disclosures about the design process to support defensible, compliant, and just approaches.

The Pushie broom case study identified the need to determine tasks suited for (re)design that can provide for a high level of relative advantage, usability, and compatibility with established work practices (e.g. Dale et al, 2017). In this case, the benefit was derived when the program was in an early-adoption phase. Different phases of program maturation can matter. When faced with constrained resources, prioritising task (re)design may be a challenging venture and a compelling business case may be required (Beevis, 2003; Dul & Neumann, 2009; Dul et al, 2012; Stanton & Baber, 2003).

The injury risk reduction and productivity gains achieved in this case reinforced the findings regarding the sufficiency of human-centred design to achieve such outcomes. A level of influence and persuasion was required to ensure support of this project by the management, and a proposition was formed about a continuous condition of necessity for participative ergonomics programs: that is, the more likelihood that benefit can be derived, then the greater the chance that the project will receive support. This may be especially so during the early phase of a program.

8.1.4 Chapter 6: Program Review and Gap Analyses

A resilient participative ergonomics program in which human-centred task (re)design projects were undertaken on a regular basis was reviewed. The conditions in which good work design occurred included a culture of strong leadership that was supportive of task (re)design practices. Lead indicators were built into the reporting system of the business to ensure good work design was accomplished. Communication about, and celebration of, the outcomes were commonplace.

The outstanding features from which to model practices were: the organisation's investment in invention and prevention strategies rather than treatment (ratio of staff resource of 20:1); establishing lead indicators related to design; and pervasive leadership support with enthusiasm for the programs which was found to be shared on the shop floor among the people who do the work, not just among those who conceptualise the work. A design champion trained by an ergonomist was assigned responsibility for the program.

Transformational activity – supportive leadership, a focus on lead indicators, and communication and celebration – were likely the most influential contributors to change management in this organisation. Three pillars of their good work design methods were identified, and those that are often negated in traditional guidance material are in bold:

- **I.** Risk management and **business improvement strategy**
- **II.** **Action-readiness and decision making**
- **III.** **Design thinking, strategy**, and practice

8.1.5 Chapter 7: Necessary Conditions and Maturity Model

It was discovered that ergonomics project success was rated highly likely by questionnaire respondents (n = 27) despite the lack of resource allocation to support a program suggesting that it can be worth doing **something** rather than nothing. Importantly, the results indicated that projects that occurred within a well-led, capable, and effective design program were far more likely (up to six times) to achieve significant success.

Program capability was most strongly associated with supportive leadership and business practices, development of task-focused work descriptions (a task-based library of work), cost-benefit analysis, and outcome evaluation across the spectrum of health - these factors were necessary. The respondents suggested that the advancement of a project required different skills, resources, tools, capabilities, and activities than the advancement of a program. If such a difference exists broadly, the knowledge about these distinctions can help target service delivery and inform an educational framework. Progressive steps can be taken to build program elements but not at the expense of the critical success factors (necessary conditions).

The conditions that were necessary to achieve project and program success were positively oriented (i.e. what can be gained) rather than fashioned around what can be contained (risk reduction) which differs from the orientation of traditional safety management practice. More advanced risk management practice such as critical control management was not significantly associated with good work design projects or programs. This supports the idea that good work design enables transformative design-thinking and strategy and can be positioned best as a stand-alone program or aligned with programs involving these features, e.g. continuous improvement, facilities management and workforce strategy, or design and engineering rather than risk management. In fact, traditional hazard management practices, legislative framework, and health and safety guidance material were not associated with necessity for good work design in this data set: these practices provided insufficient conditions for the nomination of tasks for design review, for example.

A good work design capability model was introduced to provide performance benchmarks – the first known to examine the boundary conditions of top-tier work design program capability and to distinguish between what is necessary versus what is desired.

8.1.6 Overall Contributions

The achievement of good work design was of interest to this study. It was found to be most significant when it occurred within an effective, highly capable program, rather than by measurement of a random project. Results at an organisational level were more pervasive when nested within a constructive ergonomics program. The tools that were effective (though not a necessary condition) included specialised reporting and analysis systems, such as ErgoAnalyst or the Earth Moving Equipment Safety Round Table Design Evaluation for Equipment Procurement (EDEEP). Useful practices involved worker consultation, lead involvement of an ergonomist (at some level, even if to train a work design champion and program coordinator), evaluation of capital equipment for purchase (including legacy equipment to inform modifications or new procurement specifications), an appreciative approach, and "near right" reporting to identify and qualify tasks for (re)design. Also important was the process of task analysis and development of a library of tasks that contextualised hazards and design opportunities, cost benefit analysis to evaluate work, communication and celebration of findings, and work generally that occurred parallel to, rather than integrated within, traditional safety hazard management approaches. Activities that were constructive included the persuasion of leadership to give their support through education; sharing of resources to build tacit knowledge; and to provide training to work teams to understand the connection between ergonomics, productivity, and health. Structures that were agile, such as were found in a small to medium transportation company, enabled swift change because the leadership was supportive of design as a method of work improvement. The flow of communication was rapid and the need to solicit support was not required: actions stemmed from a commitment to change and innovation. Equally, in a global mining company, change was encouraged and built into the lead indicators for high-performance. Targets were established to ensure that human-centred task (re)design occurred. Teams were afforded the opportunity to make change that met the parameters of an established design strategy without seeking higher levels of management permission. The conditions that promoted success related to leadership support, change-readiness, and design strategy. Pervasive elements of organisational culture included values that rewarded design to achieve continually better work conditions and dynamics and creative circumstances to solicit ideas for task (re)design.

These studies supported the idea that good work design was sufficient to achieve injury risk reduction and business improvement. An emerging proposition that arose from the studies was the idea that good work design is opportunity-based and did not have a strong affinity with traditional risk-based safety management systems to escalate the practices – this is important because it can represent a change to guidance material, practice, and teachings. The growth and transformation of continuous improvement, operations, wellness, workforce strategy, and systems design (e.g. engineering practice) could be well-aligned business practices as opposed to the traditional regulatory framework of safety management.

Distinctions were found among the measures for the success of good work design projects versus programs, yet all projects achieved a measure of success leading to the idea that the practices are worth pursuing at any stage of organisational-readiness. The design concepts of a project could be extended beyond traditional measures of prevention. They could include concepts of productivity, business improvement, sustainability, industry liaison, and diversity: a salutogenic approach to work design was presented with the introduction of an Occupational Perspective of Health, a concept model to guide task (re)design projects. The presentation of a capability model for good work design, supported by the findings about conditions of necessity, could serve as a benchmark for organisations wishing to perform competitively.

8.2 Recommendations

Good work design through human-centred practices was beneficial and improved performance. The idea that a project versus a program requires different capabilities and resources should be investigated further. The consideration of management practice through analysis of conditions of necessity or sufficiency was useful and should continue.

The methods to support the nomination of tasks and decision-making in pursuit of good work could be further investigated, particularly when they reveal design strategy, weighting of considerations, and rationale. Modelling, simulation, and immersive technologies may complement these investigations. Investigations should continue for the application of an Occupational Perspective of Health informing design concepts or outcome review. So, too, should the investigations continue to examine capability models about good work design and the boundary conditions among stages.

The messaging about human-centred work design is important: it may sway public opinion and affect leadership support. One may imagine headlines, such as: “ergonomics pays dividends” (e.g. Railey, 2001), or “work as a prescription for health”. The acronyms and language associated with good work design could be explored to determine what makes most sense to industry: is it good work design (GWD), human-centred design (HCD), humans in design (HiD), human factors and ergonomics (HFE), active collaborative ergonomics (ACE), participatory ergonomics (PE), workplace wellness (WW), Total Worker Health® (TWH), or similar? How should the efforts best be described? Investigations should be undertaken, also, as to how best to promote ergonomics in design-centric industries like architecture, engineering, advertising, and industrial or interior design.

Ergonomics could position its work in operations with full embrace of its design capability using design language and parameters (e.g. affordances, constraints, signifiers, and mental models, per Norman, 2013), and, as a secondary measure, translate this to a variety of stakeholders using language for business analysts, safety professionals, health and wellness teams, rehabilitation coordinators, procurement managers, engineers, and workforce strategists. An educational framework and guidance documents would be well served to focus on these aspects also.

To support supply chain integration and performance, it could be useful to interview procurement managers. An industry-wide examination of practices may be insightful too (e.g. the activities of the Earth Moving Equipment Safety Round Table in mining).

The study of accreditation systems could be worthwhile. Rather than penalty-based legislation, something for which to strive could be an accreditation credit per the ReCRREate (resistant-complacent-random-resilient-enterprising) Capability Model for Good Work Design. Similar efforts occur in the corporate white-collar environment with the Well Building Institute® and Green Building or Leadership in Energy and Environmental Design accreditation.

8.3 Conclusion

A range of well-established theories have been explored in real world situations. Emerging theory arose from the work also. Human-centred approaches achieved good work design. A participatory ergonomics or human factors project was highly likely to achieve positive outcomes when nested within a well-led, effective design program. To achieve effective programming, the critical success factors included: leadership support, task-based methods of describing work, cost benefit analysis, and outcome evaluation via a spectrum of indicators.

To elevate and sustain the design of good work, value must be conveyed through business improvement activities. A focus needs to be on change-readiness and decision support systems, and design-thinking and strategies must be well developed. It is anticipated that the research contained in this thesis will help to develop and support good work design.

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Appendix A: Email Communication: Ethics Approval

Vikki Uhlmann <v.uhlmann@uq.edu.au> Mon, Nov 3, 2014 at 2:38 PM
To: Robin Burgess-Limerick <r.burgesslimerick@uq.edu.au>
Cc: Sara Pazell <sara@vivahealthgroup.com.au>

Hi Robin & Sara,

Thanks for sending Sara's revised application.

Sara has now addressed all questions from the Ethics Committee.

The committee is therefore pleased to approve her application for ethics clearance for her research.

We wish her well in her field work.

Vikki Uhlmann

Chair of SMI Ethics Committee

Appendix B: Informed Consent for Study Participants

INFORMED CONSENT FORM	
PROJECT TITLE	Good work design: Strategies to embed human-centred design in organisations
PURPOSE	Given the evidence that there is a design-based assault to productivity, safety, and health in heavy industry (e.g. Horberry, 2011; and Horberry et al, 2011), and there are opportunities to achieve value, health, social connection, workplace engagement, and well-being through good work design, and redesign, (e.g. Burke, 2014; *SWA, 2015a; and Sorensen, 2016)*, the primary aim of this research is to determine how human-centric, good work design strategies may be embedded in the fabric of an organisation.
QUESTIONS RAISED	The overarching question is as follows: *How can organisations achieve good work design?* That is, *What organisational conditions and activities support human-centred practices to provide for good work design?*
EXPECTED DURATION	Questionnaires may take approximately 10 minutes; Interviews may take up to an hour; the study, observation, and measurement of workers with equipment interface may involve several on-site attendances with each task review ranging 30 minutes to 2 hours.
PROCEDURE	The project will occur with consultation with workers or industry representatives and may involve: a) Direct observation of work b) Administration of a questionnaire or guided interview (informal to semi-structured) c) Job and task analysis: physical environment, occupational demand for physical activity, job hazards, physical equipment, supplies and material, staffing allocations, and work rosters. d) Review of vehicle / mobile plant equipment measures such as reaches, forces, repetition rates when using equipment, controls - dimensions, shape, colour, and similar; step heights and type; position, length, and diameter of rails; seating systems; cab layout; hand and foot controls; supplies on the truck; cabinetry; other features and general operational requirements. e) Further consultation with work crew, maintenance staff and safety advisors for the application of risk determination or design strategy,

	review of decision-making processes, or review of organisational activities.
RISKS	The foreseeable risks associated with participation include those which may be inherent in one's job role and may involve working around mobile plant equipment, working within exclusion zones with live traffic, driving and operation of job trucks or plant, ingress and egress, exposure to hazardous manual tasks, work around asphalt and bituminous product or other chemical exposures, and working in variable environments including exposure to heat, cold, wind, rain, or over uneven terrain.
BENEFITS OF PARTICIPATION	The opportunity to engage in collaborative work analysis may benefit the worker and the organization to evaluate and devise effective design strategy measures for productive, safe, healthful work.
CONFIDENTIALITY AND PRIVACY	Voluntary participation: all participants (e.g. interviewees and questionnaire participants) will be invited to participate voluntarily, including the overarching organization through their operations management. Participants should not be rewarded for, or coerced, into participation. Informed consent: all participants will be provided with information about the nature of the research and how the results will be used. They should provide their consent for the information they provide to be used and published in writing. Professional conduct: we shall maintain a courteous and professional relationship with the participants in their study. Confidentiality: any personal information disclosed during interview or survey shall either not reported or not able to be connected to them in any way. Accurate reporting: our raw data shall be reported unchanged and without bias; all reasonable efforts shall be made to reference and correctly site data sources. Right to withdraw: all participants shall maintain the right to withdraw from participating in the research at any time, with the need to give reasons. There should be no consequences for any participant that makes this decision. The general ethical principles, "do no harm" and, "try to do good" shall be considered when aiming to identify hazards, escalate risk, or determine appropriate control measures.

	(Adapted from: https://sites.google.com/site/saceresearchproject/the-folio/ethical-considerations)
DATA SECURITY	Data will be stored on company password protected and secured files with limited-internal access; and on the computer hard drive of the researcher that is password protected.
EMERGENCY MEDICAL TREATMENT & COMPENSATION	Should there arise need for any emergency medical treatment during this research, standard work procedure shall be engaged to ensure the provision of this treatment and compensation to accommodate an injury or illness shall be reviewed according to current workplace practice and WorkCover guidelines.
VOLUNTARY PARTICIPATION / RIGHT TO WITHDRAWAL	As Above, participation is voluntary and as a participant you shall maintain the right to withdraw from participation at any time without ill-consequence.
DATA COLLECTION SHOULD WITHDRAWAL OCCUR	Should you choose to withdraw from participation, data already collected will be considered available for use with your informed consent. Should you wish to withdraw material provided for raw material collection, you may do so without ill consequence and this material shall no longer be used for study.
NAME AND CONTACT DETAILS RE: PROJECT	Sara Pazell, Principal Investigator, sara@vivahealthgroup.com.au , ph 0421 824 644 Supervisors: Prof Robin Burgess Limerick, + 61 7 3346 4084 r.burgesslimerick@uq.edu.au Prof Tim Horberry Timothy Horberry tim.horberry@monash.edu
ACCESS TO FEEDBACK OR RESULTS	At any time, you may request feedback on the results of the study and findings. Feedback shall be provided, also, to management, safety advisors and health and safety representatives. Note: References cited in project aim can be provided upon request.
UNIVERSITY ETHICS AND COMPLAINT RESOLUTION	This study adheres to the Guidelines of the ethical review process of The University of Queensland and the *National Statement on Ethical Conduct in Human Research*. Whilst you are free to discuss your participation in this study with project staff (contactable as above), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 07 3365 3924.

I, (name) ______________________________, have read and understood fully the contents herein about providing consent to my participation in this study. My signature below denotes my full and absolute consent to participate without reservation. I understand that I reserve the right to withdraw from this study at any time without consequence.

Name: ____

Signed: ____ Date: ______________

Witness: _______________________________________ Date: ______________