Regulating safety in adventure activities: Improving the structure of the system with Cognitive Work Analysis.

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Centre for Human Factors and Sociotechnical Systems
Abstract

Led outdoor activities (LOA) allow participants to access a wide range of outdoor activities such as hiking, canoeing, rock climbing. LOA providers include commercial businesses, community organisations, and schools. In providing outdoor activity leadership, expertise, equipment, logistics, and planning, these organisations assume some responsibility for the safety of participants. External efforts to regulate how those organisations assure safety and other aspects of LOA service provision have taken many forms over time and across jurisdictions. These efforts have included statutory regulations, standards, and guidelines. They have included accreditation and licensing of both provider organisations and individual outdoor activity leaders.

The effectiveness and integrity of regulatory mechanisms has often been called into question in the wake of critical incidents and fatalities that have occurred during LOAs. Resulting reviews and reforms of these regulatory mechanisms have consequently occurred around the world. Notwithstanding these developments, there is little evidence to gauge which of these mechanisms, if any, is more or less effective than others. It is therefore perhaps unsurprising to find that some jurisdictions have multiple, sometimes overlapping mechanisms in place to regulate LOA. This proliferation, along with the lack of evidence to gauge the effectiveness of regulatory mechanisms or combinations of them, leaves both providers and community stakeholders uncertain about how best to regulate LOA.

In response, this thesis aims to develop a way to evaluate and design LOA regulatory systems that can provide increased confidence in their effectiveness. Systems thinking provides a theoretical foundation for the thesis, while sociotechnical systems theory principles inform the various analysis and design studies. Components and extensions of the Cognitive Work Analysis (CWA) framework are supported by thematic analysis to provide the methodological, analytical, and design approach. Both the foundational CWA component, Work Domain Analysis (WDA), and the Cognitive Work Analysis Design Toolkit (CWA-DT) are tested in the regulatory system analysis and design context. As a result of the research, WDA is extended in a way that expands its potential range of application.
The findings show that systems thinking improves the capacity to describe, understand and redesign LOA regulatory systems. The application of WDA was able to identify inadequacies in regulatory systems as well as recommendations for improvement. Application of the CWA-DT to a set of overlapping LOA regulatory mechanisms in Victoria, Australia, produced a new, holistic view of LOA regulation in that jurisdiction. In turn, this analysis supported a design process that allowed a disparate group of regulators to generate new, integrated design concepts for the whole regulatory system. Application of WDA to a new national safety standard for LOA in Australia was used to reform the structure of that system.

This research contributes to theory, method and practice in several ways. The successful application of systems theoretic approaches to regulatory system evaluation and design is novel and has wide-reaching potential for further application in other domains. The formal demonstration that the LOA work domain and its subsystems are complex, adaptive systems has wide implications for all aspects of the domain, including management, staff training, and service delivery. The application of WDA and the CWA-DT to regulatory systems represents a new application of these methods. Furthermore, the modification of WDA to recognise cognitive objects in sociotechnical systems extends the potential for application of the method to the design and analysis of new and emerging sociotechnical systems such as those that include global scope, artificial agents, or malevolent purposes. Practically, the thesis provides new ways for designers of regulatory systems in the LOA domain and beyond to design, evaluate, and modify those systems.
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The research presented in this thesis was funded, in parts, by a USC Faculty of Arts, Business and Law HDR Scholarship, and an Australian Government Research Training Program Scholarship.
Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes three original papers published in peer reviewed journals and one submitted for review. The core theme of the thesis is applying systems-based HFE methods to the analysis and design of safety regulations for adventure activities. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the Centre for Human Factors and Sociotechnical Systems under the supervision of Dr. Natassia Goode, Professor Paul Salmon, and Dr Gemma Read of the University of the Sunshine Coast.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of chapters 3, 5, 9, and 10 my contribution to the work involved the following:

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<thead>
<tr>
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<td>3</td>
<td>Not as simple as it looks: led outdoor activities are complex sociotechnical systems</td>
<td>Published</td>
<td>Conceived the idea and study design. Determined the method. Conducted the analysis and interpreted results. Conducted initial drafting of paper and subsequent editing.</td>
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<tr>
<td>5</td>
<td>Sociotechnical systems as a framework for regulatory system design and evaluation: using work domain analysis to examine a new regulatory system</td>
<td>Published</td>
<td>Conceived the idea and study design. Determined the method. Conducted the analysis and interpreted results. Conducted initial drafting of paper and subsequent editing.</td>
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<td>9</td>
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<td>Submitted for publication</td>
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<td>10</td>
<td>Accounting for memes in sociotechnical systems: Extending the abstraction hierarchy to consider cognitive objects</td>
<td>Published</td>
<td>Conceived the idea and study design. Determined the method. Conducted the analysis and literature review. Interpreted results. Conducted initial drafting of paper and subsequent editing.</td>
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I have not renumbered sections of published papers in order to generate a consistent presentation within the thesis.

**Candidate’s Signature**

Date

9 August, 2019

The undersigned hereby certifies that the above declaration correctly reflects the nature and extent of the student and co-authors’ contributions to this work.

**Primary Supervisor’s Signature**

Date

9 August, 2019
Acknowledgements

It is said that it takes a village to raise a child. I now know that it takes many more than that to produce a PhD thesis. There are too many people to name here who have contributed to this work through their support of me. I thank you all but, in particular, wish to acknowledge the following people.

I wish to thank my supervisors for their wonderful advice, support and encouragement.

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Dedication

To my Mum.
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<td>Abstraction hierarchy, a tool for representing output of WDA</td>
</tr>
<tr>
<td>ConTA</td>
<td>Control Task Analysis, a phase of CWA</td>
</tr>
<tr>
<td>CWA</td>
<td>Cognitive Work Analysis, a framework of systems HFE analysis methods</td>
</tr>
<tr>
<td>CWA-DT</td>
<td>Cognitive Work Analysis Design Toolkit, a framework for translating CWA analysis outputs into design proposals</td>
</tr>
<tr>
<td>DL</td>
<td>Decision Ladder, a tool for representing cognitive states and processes in control tasks and strategies</td>
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<tr>
<td>HFE</td>
<td>Human Factors / Ergonomics</td>
</tr>
<tr>
<td>LOA</td>
<td>Led Outdoor Activity</td>
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<tr>
<td>SME</td>
<td>Subject Matter Expert</td>
</tr>
<tr>
<td>SOCA</td>
<td>Social Organisation and Cooperation Analysis, a phase of CWA</td>
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<td>STS</td>
<td>Sociotechnical System</td>
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<td>WCA</td>
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<td>WDA</td>
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Publications arising from this thesis

Peer Reviewed Journal Articles


Peer Reviewed Conference Papers


Peer Reviewed Book Chapters

Preface

Having wandered away from the path of study and scholarship in my teenage years, my early working life consisted of a series of ‘low-skilled’ jobs in construction, security, and waste management. Eventually, dissatisfied and in search of some kind of more satisfying vocation, serendipity and some good friends introduced me to the world of led outdoor activities (LOA). At the time, it was a revelation to me that guiding people on adventures in the outdoors was actually something you could get paid for! I was thenceforth determined to work my way into a job in that field. A traineeship with a small company that ran LOA programs for at-risk young people and groups of corporate managers gave me a foundation of skills and a network of connections in the industry. Casual roles working for recreational adventure guiding companies added to my experience before I eventually landed a full-time role at the largest provider of outdoor education programs in Australia. My work in the LOA sector from then on spanned a range of roles. In the field, I led expeditions and outdoor activities, including rock climbing, hiking, challenge ropes courses, canoeing, and white-water rafting. In the office, I undertook administrative and management roles including program design and planning, client liaison and sales, and later, policy development and strategic planning. Finally, after leaving an executive management role at that same company, I went to work as the Executive Officer at one of the main industry associations.

My experience working in a wide range of jobs in the LOA domain brought me into contact with safety regulations from several angles. During those early roles as an instructor in the field, I was aware of industry standards that informed the policies and procedures of my employers and that were backed by law. Although I was only dimly aware of their specifics, I drew confidence from the belief that my employers were guided by them. This belief supported my confidence that conformance with my employer’s policies would ensure that I was complying with relevant safety law. Later, as a manager, with responsibilities that included planning and designing outdoor activity programs, I came into closer contact with specific aspects of the regulatory environment. These included licensing requirements and the detail of standards that applied to key aspects of program design, such as instructor to participant ratios, equipment provision, and venue selection. I became aware of the existence of several...
different regulatory mechanisms and began to notice what appeared to be inconsistencies between them. Eventually, through working as at the executive management level and finally leading an industry association, I gained a comprehensive view of the range of standards, guidelines, licensing, and accreditation schemes that were intended to influence providers of led outdoor activities. My impression of the resulting regulatory environment was that it lacked coherence and effectiveness. It seemed to me that there was a need for its comprehensive redesign.

When the opportunity arose to undertake post-graduate study in Human Factors, I jumped at the chance to undertake an in-depth study of LOA regulation.
Chapter 1 – Introduction

Introduction

Since the dawn of the industrial era, people have engaged in adventurous outdoor pursuits for recreation, for sport, and in the case of extreme adventures, for personal achievement and social acclaim. While first ascents of iconic peaks and solo expeditions to unexplored wilderness have been beyond the reach of all but a few exceptional individuals, the appeal of such pursuits is broad. Thus, arose the guided outdoor adventure, where experts made it possible for the less experienced to access wild adventures by leading novices, providing them with expert planning, guidance, equipment and support (Ewert, 2014, pp. 16-22).

Adventurous activities outdoors entail inherent risks to safety. For example, canoeing, kayaking, and rafting entail a risk of drowning. Rock climbing, challenge ropes courses, and mountaineering entail a risk of injury through falls from height. Mountaineering, hiking, and ski-touring entail risks of injury through exposure to extremes of weather. The mitigation of these and other risks is a primary obligation of providers of guided or ‘led’ outdoor activities (LOAs).

The relationship between expert activity leaders and dependent participants in adventurous pursuits brings with it expectations and obligations that leaders will keep participants safe. Here lies a fundamental tension, even a paradox, for those who undertake to lead others in risky pursuits. The pursuit is often undertaken in the hope and expectation that the participant will experience some proximity to danger (Fletcher, 2010). Yet, those dependent participants have engaged the services of an expert leader in the expectation that they will keep them from real harm. Furthermore, legal and regulatory frameworks in most jurisdictions require providers to keep participants safe (e.g. State of Victoria, 2004).

The laws that govern such relationships of dependence tend to be quite broad, general, and apply across a wide range of service provision. In Australia, the jurisdiction in which this research occurred, a central principle governing this relationship is to be found in Work Health and Safety laws. The salient clause in such
Chapter 1

laws specifies the obligation that service providers must keep people who may be affected by their service provision, “as safe as reasonably practicable” (e.g. State of Victoria, 2004). It is left to adjudicators in the wake of an adverse event to determine whether or not that obligation was met. To do so, they will examine not only the circumstances surrounding the adverse event, but in order to determine what was ‘reasonably practicable’ in the salient context, will also look to common practice, codes of conduct, standards, and applicable regulations. While legislation is created by government in accord with well-established and relatively transparent tradition, the regulatory mechanisms and instruments that translate the broad intent of law into domain-specific context are not.

In the case of LOA, a broad array of different regulatory mechanisms and instruments have been deployed around the world (Ministry of Business Innovation and Employment, 2010a). These mechanisms are intended to influence leaders of dependent participants in risky outdoor pursuits, to do so in a way that helps to keep those participants as safe as reasonably practicable.

The problem

In Australia, as elsewhere, a disparate array of regulatory instruments has been developed that are intended to influence safety and other aspects of service provision among providers of LOAs. They include standards (e.g. Outdoors Victoria, 2015a; QORF, 2014), guidelines (e.g. Department of Education and Training, 2017; Ministry of Education, 2016), licensing (e.g. Parks Victoria, 2017; U.K. Government, 1995) and accreditation schemes (e.g. ATAP, 2016; NARTA Inc., 2016). They have been developed at different times, impelled by various needs and perceptions. Drivers of their development have included aspirations to minimise insurance costs, underpin consumer and community confidence, provide assurance that public authorities are fulfilling their obligations, and simply to optimise the safety of inherently risky but valuable outdoor activity on moral grounds. Notwithstanding their presence in many jurisdictions around the world (Ministry of Business Innovation and Employment, 2010a), regulatory mechanisms have been criticised during judicial investigations into
fatalities that have occurred during LOAs. For example, a Queensland Coroner investigating the deaths of 5 participants in white water rafting activities in that Australian state made numerous references to the inadequacy of standards (Priestly, 2012). A coronial investigation into the deaths of 6 students and their teacher during a LOA in New Zealand in 2008 recommended that the government consider introducing licensing to ensure minimum standards were met. The Coroner further recommended accreditation audits be conducted by trained auditors (Devonport, 2010). Prompted in part by incidents such as these, governments have, on occasion, required the overhaul of LOA regulatory systems (e.g. Ministry of Business Innovation and Employment, 2010b; U.K. Government, 1995).

National and international private organisations (e.g. Standards Australia, the British Standards Institution, the International Organization for Standardization) provide standards development services to industries (Brunsson, Jacobsson, & Jacobsson, 2000). Often known as Standards Developing Organisations (SDOs), these organisations help industries develop standards by facilitating the process of standards development. This typically includes the formation of technical committees composed of subject matter experts, the development through technical committee meetings of relevant specifications, a process for achieving stakeholder consensus, and implementation of the standard (International Organization for Standardization (ISO), 2019).

The way in which each of these regulatory instruments has been developed seems to conform to a widely used, albeit largely unscrutinised method. This consists of an auspicing authority or organisation consulting with industry experts to determine what constitutes common, acceptable, or best industry practice in a range of service provision activities (e.g. Carden, Salmon, & Goode, 2017b; International Organization for Standardization (ISO), 2019). These are then documented and publicised to providers either in the form of model policies and procedures, guidelines for developing them, or a combination of both.
Notably, little formal guidance is available for auspicing agencies to help guide this process. Similarly, there seems to be scant advice available to support the review, evaluation, and improvement of these regulatory mechanisms following their implementation (Coglianese, 2018). Despite the availability of guidance, such as that offered by standards developing organisations (SDOs; e.g. International Organization for Standardization (ISO), 2019), regulatory research (e.g. Drahos, 2017), and governments (e.g. Australian Government, 2014), these sources offered no specific advice on the nature or structure of effective regulatory systems. Even the most rigorous of these methods, included in the OECD guide to regulatory system evaluation (Coglianese, 2012, pp. 37-47), confines itself to an estimation of system performance while acknowledging its limitations. The OECD guide includes advice that regulatory system designers should collect baseline data on the phenomenon to be regulated, implement the regulation, measure the same phenomenon at a later time, and determine whether change has occurred (Coglianese, 2012, p. 22). However, the guide rightly cautions analysts to avoid concluding causality on the basis of this comparison and offers examples of where a detected change in the measure parameter was traced to a cause other than the regulatory intervention (Viscusi, 1984).

In summary then, the problem identified thus far is that efforts by a range of external stakeholders to influence aspects of LOA service provision, particularly safety, appear to lack a rigorously supported method of development or evaluation. In short, there is little guidance and few structured methods available to support safety regulatory system evaluation and design. This adds to doubts about the effectiveness and efficiency of the resulting regulatory environment which in turn undermines the confidence needed to achieve some of the key purposes of regulation, including consumer and provider confidence.

This PhD research aimed to investigate the use of systems theory and associated systems HFE methods to describe, evaluate, and redesign LOA safety regulations.
Theoretical background

Human Factors and Ergonomics

Research and scholarship in the domain of Human Factors and Ergonomics (HFE) will provide the underpinning methodological foundation for this study. HFE is defined as the “scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance” (International Ergonomics Association (IEA), 2018). HFE is concerned with the study of sociotechnical systems (STS). These are defined as systems ‘composed of technical, psychological, and social elements’ (Vicente, 1999, p. 9). STS include but are not confined to systems of work. Other examples of STS include social systems such as, road transport, sport, and the internet. Along with related theoretic approaches in which it is grounded, including general systems theory and complexity science, HFE offers a novel lens through which the task of regulating safety in led outdoor activities can be viewed. Specifically, the systems-based ecological analysis framework, Cognitive Work Analysis (CWA) and in particular its first phase, Work Domain Analysis (WDA), will serve as the basis for analysis. While more commonly applied to operational and managerial aspects of work systems, CWA appears suited to specific analysis of regulatory systems which are, like the other aspects of work systems, STS. That is, they are composed of technical, psychological, and social elements (Vicente, 1999).

General systems theory

HFE and its methods rely strongly on systems theory. While not all HFE methods are system-focused, to varying extents the discipline of HFE is premised on some core tenets of general systems theory. In particular, notions of holism, interdependence, emergence, and non-linearity are prominent features of the kinds of systems with which HFE is concerned. These notions will be defined and discussed further below. Furthermore, specific aspects of complexity theory, itself a child of general systems theory, have a direct bearing on many HFE methods and on CWA in particular. Complex systems are often characterised by the phrase, ‘the whole is greater than the
sum of its parts’ (attributed to Aristotle). Typically, systems of work and ways of understanding them have been shaped by the mechanistic paradigm of the modern era. Recognition of the limitations of this view have driven the development of general systems theory (von Bertalanffy, 1950). When applied to many areas of enquiry, systems-theoretic approaches have yielded new insights (Thurner, Hanel, & Klimek, 2018). STS appear to exhibit features of the kinds of system that are better described by systems theory than by mechanistic thinking. Therefore, the application of systems-based theory and methods to their analysis and design appears promising.

**Complexity theory**

Complexity theory has emerged from general systems theory as a set of principles, definitions, predictions about systems that conform to a set of criteria that distinguishes them from other types of system. Characteristics of complex systems include dynamic interactions between elements, open system boundaries, large effects of small causes and vice-versa, and the emergence of system behaviour from interactions between elements (Cilliers, 1998). The characteristic of emergence is particularly relevant to the design of regulatory systems. The behaviour of regulatory systems is strongly determined by the interaction of agents (including duty holders and regulators) with each other and with system objects (e.g. rules, safety management systems, and audit requirements). The nature and structure of those objects is therefore of critical importance to the viability and performance of the system.

Another important feature of complex systems is ‘nestedness’ (König, Tessone, & Zenou, 2014). This term refers to the observation that complex systems are composed of sub-systems, some or all of which are themselves complex. Similarly, complex systems are sub-systems of larger complex systems. Recognition of the nestedness of complex systems allows the regulatory sub-system of a work domain to be viewed as a system in its own right. Regulatory systems often include numerous agents and objects interacting in a dynamic environment. These features suggest that regulatory systems exhibit the characteristics of complex systems. Recognising them as such and applying theory and methods that account for complexity to their analysis may, therefore, yield new and useful results.
Control theory
As will be seen in the review of regulatory literature in Chapter 2, systems of social regulation, including safety regulation, rely at minimum upon the presence of three functions. Control theory describes these functions as a sensor, a rule-set, and an actuator. These functions are necessary for any form of regulation (e.g. Doyle, Francis, & Tannenbaum, 2013). The sensor monitors relevant variables, the variables are compared with a tolerance range in the rule-set, and the actuator makes adjustments if the measured variables exceed the tolerance range (Forrester, 1964). A simple example of regulation of a physical system is that of a thermostat. A sensor monitors ambient temperature. A rule-set (often manually set) determines whether the temperature exceeds tolerance. If so, the actuator activates a heating or cooling mechanism. Once the sensor detects that the ambient temperature has returned to within the specified tolerance range, the actuator deactivates the heating or cooling mechanism. Regulation is an ongoing, dynamic process wherein various rules are applied to processes of work at multiple system levels and scales. Viewing regulatory systems through the lens of control theory may help to identify the presence, absence, strength, or weakness, of the three control functions of rules, sensors, and actuators.

Research aim and questions
The overarching aim of this thesis is to investigate the use of systems theory, HFE, and STS methods for describing, evaluating, and designing LOA regulatory frameworks. It has been shown that LOA regulatory systems have been found inadequate and that methods available for their evaluation and design are limited. This research focuses on the domain of LOA; however, the findings are applicable to regulatory design across domains. Within this overarching aim, the following research questions form the basis for the studies undertaken.
Chapter 1

Research questions

1. Does systems theory apply in the LOA domain?
2. Can LOA safety regulatory systems be usefully modelled and analysed with WDA?
3. Does WDA need to be modified for use in the analysis and design of regulatory systems?
4. Can CWA be used to support the design of a LOA regulatory system?
5. Do stakeholders prefer a regulatory system designed using systems theory and CWA to one developed using traditional approaches?

The following section outlines the steps taken during the course of this research project to answer these questions.

Thesis structure

This thesis begins with a review of the literature across the three areas of LOA safety, social regulation, and HFE approaches for regulatory system analysis and design. Chapter Two describes the review and summarises its findings. In summary, the review found that while systems thinking and HFE methods have recently been applied to LOA safety, neither these contemporary applications nor their predecessors have specifically addressed the design or implementation of safety regulation systems (e.g. Dallat, Salmon, & Goode, 2018; Goode & Salmon, 2014; Salmon, Cornelissen, & Trotter, 2012; Salmon, Goode, Lenne, Finch, & Cassell, 2014; Trotter, Salmon, & Lenné, 2014). Further, regulatory scholarship has focused on higher level modes and principles of regulation but not on the actual design of regulatory mechanisms. The body of HFE research revealed little in the way of specific analysis of regulatory systems. While they are prominently identified as important constraints on behaviour in domains of work, a specific focus on the evaluation and design of regulatory systems was not found in the literature.

Before applying systems theory and methods to LOA regulatory systems, confirmation was required that LOAs exhibit the characteristics of complex STSs and consequently
warrant a systems theoretic approach to analysis and design. Chapter Three describes
a study which aimed to compare a relatively simple LOA program with an established
set of criteria that define complex systems. It concludes that even logistically and
experientially simple led outdoor activities meet the formal criteria for complex
adaptive systems and that therefore, the application of systems theory and HFE
methods to this domain, including subsets of work in the domain, is both justified and
necessary.

Having concluded from the literature review that a research gap existed, a set of HFE
methods were selected to address the problem of evaluating and designing safety
regulation systems for LOAs. Chapter Four describes the methods considered, those
selected, and the reasons for that selection. The choice to use a particular ecological
analysis method, CWA, is discussed in Chapter Four, along with the data collection
methods and implicit and explicit theoretical frames underpinning the thesis.

Chapter Five describes a pilot study which was undertaken to investigate the
application of WDA (Vicente, 1999) to a LOA regulatory system. Specifically, WDA was
used to develop a model of the New Zealand Adventure Activities Regulations (NZAAR)
system with a view to analysing its structure and identifying key strengths and
weaknesses. This study demonstrated that WDA could be successfully used to analyse
a system of safety regulation. In addition to revealing inherent structural features of
the NZAAR, WDA facilitated the comparison of this system with some key principles of
good regulation and aspects of control theory.

Chapter Six describes the findings from a study in which WDA was used to analyse one
of several LOA regulatory instruments in Victoria, Australia; the Adventure Activity
Standards (AAS; Outdoors Victoria, 2015a). The analysis showed this regulatory system
to be more limited than the NZAAR system analysed in the previous chapter.
Notwithstanding differences of scale, scope, and structure, the WDA revealed key
structural strengths and weaknesses of this system. These included the lack of a
compliance checking mechanism, the absence of any means of measuring system
performance, and an imbalance between the high number of stated purposes of the
system and the modest set of objects deployed to achieve them. This study thereby demonstrated the versatility of the application of WDA to regulatory systems. Together, the analyses of the NZAAR and the Victorian AAS demonstrated the effective utility of WDA for the analysis of regulatory systems.

Chapters Seven and Eight together describe the application of WDA and the (CWA-DT) to redesign the whole LOA regulatory environment in Victoria. This two-part study involved first building a WDA model of the broad regulatory environment, which consists of several regulatory instruments, each administered by a different agency. The WDA was generated from documentation review and data derived from interviews with subject matter experts (LOA providers). Chapter Seven includes a discussion of this process and the resulting system model. Chapter Eight describes how the model was then used as the basis for workshop attended by representatives of each of the agencies that administer the regulatory instruments identified in the model. In line with guidance offered by the CWA-DT, a set of regulatory system design concepts to improve the system were developed. The product of these two studies was a formative model for a new, integrated LOA regulatory system for Victoria.

Chapter Nine describes a study which applied the analysis and design methods tested in the previous four studies to the structure of a proposed national LOA safety standard for Australia. The study was commissioned by a government backed industry group that was charged with developing the standard. WDA was firstly used to describe the structure of the initially proposed standard. This revealed structural weaknesses and supported the application of a set of design principles to the redesign of the system. The resulting system model was then illustrated using WDA in its formative capacity.

During the course of this research the need to modify WDA to enhance its suitability for regulatory system analysis and design was identified. Chapter Ten presents a proposed methodological extension to the WDA method that involves the inclusion of cognitive objects, as well as physical objects, when developing abstraction hierarchy models. The proposed extension is tested in this chapter via case studies in LOA, road
transport, and terrorism. The findings confirm that the proposed extension is both appropriate and useful.

In the final chapter the findings from the overall program are synthesised along with a discussion of the key theoretical, methodological, and practical contributions. The practical implications are outlined, and important study limitations and recommendations for future research are discussed.
Part 1. Literature and methods
Chapter 2 – Literature review

Introduction

Background

This chapter describes the findings from a review of scholarly literature that provided an overview of contemporary approaches to regulatory system design and practice, particularly as it relates to the design of LOA safety regulation. The aim of the literature review is twofold. First, to understand the recent history of regulation in order to explain the context in which LOA regulatory system design occurs. Second, to describe the existing literature in HFE, LOA, and regulation that might inform and help to address the research questions. Specifically, support will be sought from the literature to discover if gaps exist in prevailing methods for evaluating regulatory systems, if systems-theoretic methods apply to LOA regulation, and if WDA can in principle be used to evaluate regulatory systems.

Literature sources

The search for relevant literature was supported by searches in the ProQuest, Scopus, and Web of Science databases. In addition, searches were undertaken in several journals including Regulation and Governance, Ergonomics, Human Factors, and the Journal of Adventure Education and Outdoor Learning. Search terms included combinations of the words ‘outdoor’, ‘activity’, ‘education’, ‘recreation’, ‘safety’, and ‘regulation’.

Defining regulation

Black (2002) describes regulation as "...a process involving the sustained and focused attempt to alter the behaviour of others according to identified purposes with the intention of producing a broadly identified outcome or outcomes which may involve mechanisms of standard-setting, information-gathering and behaviour-modification. Regulation is thus not seen as an activity performed only by state actors, or as necessarily involving legal mechanisms...". For the purposes of this thesis, regulation refers to efforts exerted by government or other agencies external to an organisation
to protect the public interest from the failures or excesses of the organisation’s activities (Parker & Nielsen, 2011).

While economic regulation consists of controls on prices, trade, and who can enter a business, social regulation includes controls on workplace and public health and safety, environmental protection, and product safety (Litan, 2007). Whether or not it is administered by government, regulation is often guided and driven by legislation (Novak, 1996). LOA regulation, both of safety and other aspects of LOA service provision, is a form of social regulation.

In the context of social regulation, the term ‘regulations’ can be understood in either a narrow or broad sense. The narrow sense tends to refer to rules imposed by governments or their agencies. These are enforceable by authorised agents and there are usually penalties for non-compliance. The specifics of these rules can be enshrined in statutes (e.g. Victorian State Government, 2017). The broader sense of the term refers to a wider range of mechanisms that are intended, like government administered statutory rules, to influence private activity in ways that protect public interest (Black, 2002). These mechanisms can include standards, guidelines, licensing, accreditation, and codes of practice. They are designed and administered, not only by governments and their agencies, but by an array of entities including industry associations, employer groups, trade unions, and public interest groups (e.g. Braithwaite, 2017). Throughout this thesis, unless otherwise specified, the terms regulation and regulations will be used in this latter, broader sense.

Occupational health and safety regulation in Australia (e.g. Victorian State Government, 2017), as elsewhere, is underpinned by laws (e.g. State of Victoria, 2004) that usually include a clause mandating that employers and service providers ensure that their activities affect people in ways that ‘control the risks as far as reasonably practicable’. This broad legal requirement is often given contextual detail by any combination of regulatory mechanisms.
Regulatory mechanisms

These can include statutory (legislated) regulations, standards, guidelines, and codes of practice. These various constraints can be supported or enforced via licensing, registration, or accreditation systems. A wide range of methods for assuring compliance exists. Some domains include rigorous audit processes, while others simply rely on service providers to conform to relevant external constraints. Table 2.1 includes examples of a range of regulatory mechanisms.

Table 2.1. Examples of regulatory mechanisms.

<table>
<thead>
<tr>
<th>Regulatory mechanism type</th>
<th>Example</th>
<th>Overseeing organisation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>Food safety standards (Food Standards Australia &amp; New Zealand, 2015)</td>
<td>Independent statutory agency</td>
</tr>
<tr>
<td>Licensing</td>
<td>Real Estate Agent Licence (Queensland Government, 2018)</td>
<td>State Government</td>
</tr>
<tr>
<td>Accreditation</td>
<td>R&amp;CA Accreditation (Restaurant &amp; Catering Australia, 2019)</td>
<td>Industry peak body</td>
</tr>
<tr>
<td>Code of practice</td>
<td>National Fitness Industry Code of Practice (Fitness Australia, 2019)</td>
<td>Industry association</td>
</tr>
</tbody>
</table>

The primary aims of this review were to discover and describe the methods available and those commonly used to design and develop regulations, and the extent to which those methods incorporate systems thinking. To provide context for those descriptions, the findings section below begins with an overview of the recent history of regulation. To support an understanding of the application of these development methods to the LOA domain searches for relevant literature in the LOA and HFE.
domains were undertaken. Both peer-reviewed and grey literature sources were used. The latter was particularly necessary to build a picture of contemporary practice in regulatory system evaluation and design, much of which is undertaken in the sphere of business rather than academia.

**Findings**

*A brief history of health and safety regulation*

While the regulation of private activity to protect the public interest can be traced back at least as far as the Sumerian Code of Hammurabi (King, 2018), early in the second millennium BCE, the separation of such social constraints from purely legal codes administered by ruling elites and governments, into high level generic laws and subsidiary regulations, gained traction early in the industrial era. The onset of the industrial revolution in the 19th century sparked recognition and concerns about the risks to worker health and safety in the new systems of mass production (Abrams 2001). This led to examination of the nature of those risks by scholars (Sigerist, 1933, pp. 338-340) and responses by governments in an effort to mitigate the risks (Barrow & Lyon, 2018).

*Evolving understandings of work health and safety*

From early, linear understandings of the causes of harm in work, where accidents were seen to have single root causes, transmitted like falling dominoes via linear causal chains (Heinrich, 1959), safety science has progressed through recognition of multiple causes of accidents (Toft, Dell, Klockner, & Hutton, 2012) and layers of prevention (Reason, 1997), to contemporary understandings grounded in complexity science (Dekker, Cilliers, & Hofmeyr, 2011; Pillay, 2015). Policy responses to this developing understanding have been slow to emerge. Throughout the late 19th, and the early to mid-20th centuries, government policy to mitigate risks to worker health and safety took the form of ‘black-letter’ prescriptive rules (Mann & Blunden, 2010) that employers were legally required to follow (Barrow & Lyon, 2018).
Deregulation

In the 1970s, a change in global economic conditions led to a transformative shift in approaches to regulation (Stigler, 1971). Keynesian economic policies had seen governments play a prominent role in markets since the end of the second world war (Coddington, 1976). This period saw unprecedented economic growth around the world, initially boosted by post-war reconstruction and then driven by a boom in lending and consumption in wealthier countries (Sutcliffe, 1977). Simultaneously, new global institutions such as the World Bank and the International Monetary Fund (IMF), sponsored by those wealthier countries, financed economic initiatives in developing countries (Biersteker, 1990). This supported growth, decolonisation and, ultimately, a vibrant global economy. With currency values and interest rates set by national governments, competition in this new global economic system led to runaway inflation in the early ‘70s. The resulting economic crisis, exacerbated by the oil price shock of 1973, gave impetus to emerging neoliberal economic theories, which included the contention that regulation by government was inefficient, stifled growth, and should be minimised (Peltzman, 1989).

The modern history of social regulation has become a history of deregulation. The deregulatory ethos, initiated in the financial sphere, quickly encompassed environmental and safety regulation as well. Deregulation has been supported by both conservative and progressive political parties since its inception in the 1970s and continues to prevail around the world (Peltzman, 1989). Responses to deregulation have included advocacy by community organisations and some political parties, pressuring policy makers and corporations to maintain their legal and moral obligations to protect the public interest. In many domains, responsibility for regulation has been partially or completely transferred to non-government organisations including industry bodies, employer groups, trade unions, and public advocacy groups (Black, 2008). Moreover, deregulation has prompted scholars and researchers in the areas of policy and governance to develop and grow a dynamic body of regulatory research, including a range of novel approaches to regulation that attempt to balance the deregulatory impulse to minimise impediments to economic
activity and growth, with maintaining adequate protection of the public interest. The following section describes some of these approaches (see Table 2.2).

Responses to deregulation

Efforts to reduce the extent to which regulation might impede commercial activity have given rise to a range of regulatory modes that share the common aims of reducing government involvement in rule-making and reducing the costs to business of compliance. Many contemporary regulatory regimes include some of the following features. These modes are not exclusive of each other. Some rely on the inclusion and combination of several other modes.

Table 2. 2. Regulatory modes.

<table>
<thead>
<tr>
<th>Regulatory mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principles-based regulation (Black, 2007)</td>
<td>Regulators set and check high-level, outcome-based requirements.</td>
</tr>
<tr>
<td>Risk-based regulation (Black &amp; Baldwin, 2010)</td>
<td>Regulators focus compliance-checking on highest risk activities of duty holders.</td>
</tr>
<tr>
<td>Meta-regulation (Parker, 2002)</td>
<td>Regulators oversee 3(^{rd})-party administrators of regulatory mechanisms.</td>
</tr>
<tr>
<td>Responsive regulation (Ayres &amp; Braithwaite, 1992)</td>
<td>Regulators maintain flexible approach to compliance strategies, rewarding proactive compliance with a light touch but responding to recalcitrant duty holders with more imposing interventions.</td>
</tr>
<tr>
<td>SMART regulation (Gunningham, 1998)</td>
<td>A combination of responsive and other approaches mentioned above</td>
</tr>
<tr>
<td>Polycentric regulation (Black, 2008)</td>
<td>A regulatory environment with a multiplicity of regulatory mechanisms and administering agencies.</td>
</tr>
</tbody>
</table>

Principles-based regulation

Principles based regulation requires compliance with broadly stated principles rather than detailed rules (Black, 2007). This allows duty-holders flexibility to comply in a way that is appropriate to their specific context. It provides some scope for the regulatory
regime to remain relevant in the face of innovation and change in the regulated domain. Compliance tends to be measured on the basis of outcomes in the regulated domain, rather than on inputs. This reliance on general principles and compliant outcomes shifts both freedom and responsibility for the detail of compliance strategies toward senior management in duty-holding organisations, and away from both regulators and operational workers.

**Risk-based regulation**

Risk-based regulation focuses regulatory efforts on aspects of the regulated activity that are assessed as most risky (Black & Baldwin, 2010). This approach is premised on the notion that limited resources should be targeted toward regulatory activity that offers the best return on the investment of time and money. That return includes the mitigation of both actuarial and reputational risk, the latter applying to both duty holders and regulators (Rothstein, Irving, Walden, & Yearsley, 2006).

**Self-regulation**

Self-regulation is the delegation, without independent oversight, of regulatory functions to regulated industries or organisations. While the viability of this approach was suggested by Ayres and Braithwaite (1992) in their introduction of responsive regulation, experience and research since that time has shown some limitations to the approach. For example, while self-regulation has been found to be effective in the presence of significant reputational or financial risks of non-compliance, both Gunningham (2011b) and Saurwein (2011) found that in the absence of these incentives, pure self-regulation is rarely effective.

**Meta-regulation**

Meta-regulation (Parker, 2002) can be described as ‘regulated self-regulation’. Under this model, government maintains some level of oversight and authority over the regulatory process while allowing the rest of the process - standard-setting, compliance checking, duty-holder education - to be conducted by non-government entities. This approach has the advantage of allowing experts within industry sectors to set the rules and assure compliance while retaining the capacity for government and
its relevant agencies to monitor and intervene if necessary. This regulatory mode runs the risk of regulatory capture (Laffont & Tirole, 1991), wherein regulatory process and structures are shifted to favour industry or organisation special interests, at the cost of objective protection of the public interest.

*Responsive regulation*

Responsive regulation is an approach developed by Ayres and Braithwaite (1992) in which regulators adopt more or less supportive and coercive stances toward duty holders based on several variables including the good faith and demonstrated willingness and capacity of duty-holders to comply. This approach introduced the notion of an ‘enforcement pyramid’ which shows the mild enforcement strategy of persuasion at the lowest, preferred level, but ranges up through a series of more aggressive strategies, including warnings and penalties, up to the enforcement pinnacle of license revocation. Each ascending level of the pyramid is smaller than the one below to indicate the preference for use of enforcement strategies as low as possible within the pyramid.

*SMART regulation*

SMART regulation (Gunningham, 1998) is an evolution of responsive regulation. This approach accounts for a weakness in the earlier formulation of responsive regulation. That weakness can emerge when there are few interactions between regulator and duty-holder. In such cases, there may be no baseline posture of the duty holder for the regulator to ‘respond’ to. Therefore, SMART regulation encourages a pluralist approach which incorporates complementary combinations of actors and methods in the regulatory process. For example, while a responsive regulatory approach might be adopted for interaction with a large, mature duty-holder with a strong history of compliance, a risk-based approach may be adopted toward a less mature duty-holding organisation.
Polycentric regulation

Polycentric regulation occurs when multiple regulatory entities and mechanisms exist in a regulated domain (Black 2008). There may be some connection and coordination between these entities and the regulatory mechanisms they administer or there may be none. The Victorian LOA regulatory system is an example of polycentric regulation, with separate standards, guidelines, accreditation and licensing systems intended to influence the provision of LOAs in various contexts. This will be explored in detail in Chapters Seven and Eight. Questions about the effectiveness of polycentric regulation are not confined to the LOA domain. One example can be seen in the case of flammable cladding. An Australian Senate Committee inquiry, prompted by both the tragic Grenfell Tower fire in the U.K. and an earlier tower fire in Australia, found substantial shortcomings in the polycentric regulatory environment for safety in the construction industry. Of the committee’s 8 recommendations, 5 were directed toward structural changes to the regulatory environment (Parliament of Australia, 2017b). In the concluding chapter of its interim report, the committee noted “there remains a need for a nationally consistent approach to building regulation, inspections and auditing, including licensing and registration.” (Parliament of Australia, 2017a).

The effectiveness of different forms of regulation

The review of regulatory literature yielded rich descriptions and studies explaining the implementation of the various regulatory modes described above. Some of these studies included analyses of the effectiveness of the mode under scrutiny (Braithwaite, 2017; Gunningham & Sinclair, 2017). However, no analysis was found that compared effectiveness across the range of regulatory modes. This represents a significant knowledge gap.

Regulatory system analysis and design

For those charged with the task of developing, reforming, or evaluating regulatory systems, theoretically grounded guidelines or advice appears limited to three aspects of system design or evaluation: principles, cost-benefit analysis, and standards. First, scholarship on the regulatory modes previously discussed, while comprehensive, is
mainly focused at the level of principles, particularly as they related to the posture of regulators in relation to duty-holders. For example, the literature describing risk-based regulation includes reference to cases where it has been applied, such as the environmental policy domain (Rothstein et al., 2006). However, neither these nor any other texts found during this review offered specific examples of how such a regulatory regime would be structured in any given context. It is left to system designers to work this out. Similarly, the literature on responsive regulation is focused on the posture and strategy of regulators rather than on the structure of the regulatory mechanisms they administer (Ayres & Braithwaite, 1992). Finally, the research literature describing polycentric regulatory regimes notes some strengths and weaknesses of such structures (e.g. Black, 2008). However, no advice is provided on any ideal structure of those systems nor on how to formally evaluate their functional effectiveness. This body of research offers very little in the way of specific advice on any detail of system structure or how to create it.

A second body of theoretically based advice centres on cost-benefit analysis (Australian Government, 2014; Coglianese, 2012). This body of advice centres on system performance, rather than system structure. Cost-benefit analysis aims to estimate and compare the costs and benefits of regulatory action. The aim is to ensure that the benefits outweigh the costs. However, both costs and benefits of regulatory action have proven difficult to accurately estimate. Furthermore, estimates of benefit have failed to predict new, emergent risks resulting from the intervention. Viscusi (1984) gives the example of a U.S. regulation requiring manufacturers to create safer packaging for medications and chemicals to protect children. However, because adults also found the modified package harder to open, some of them left the bottles uncapped, neutralising the benefit of the regulation. Coglianese has elsewhere noted (2018) the substantial limitations of the application of cost-benefit analysis, and therefore its actual economic and social utility. While it can be applied prospectively to proposed regulations, as well as retrospectively to existing ones (Coglianese, 2018), like the regulatory modes noted in Table 2.2, cost-benefit analysis offers limited advice on regulatory system structure.
Although no academic research was found in the literature review that focused on it, a third body of knowledge and practice exists in support of standards design and development. This is the methodology that appears to be commonly deployed by Standards Setting Organisations (SSO) such as the International Organization for Standardization (ISO; 2019). This method consists of a facilitated process wherein committees of technical experts develop draft standards that are then shared among stakeholders and iteratively modified until consensus is achieved (International Organization for Standardization (ISO), 2019). While examples of systems developed by this method have been described by scholars (e.g. Cheit, 1990), little evidence was found in the scholarly literature that describes any detail of the methods used nor offers any theoretical foundation for the structure of regulatory systems.

Despite the availability of advice on regulatory modes, cost-benefit analysis, and standards development, none of these avenues of support provide any theoretically grounded, specific, robust guidance to support the design of regulatory mechanisms or systems. This presents a problem for organisations and individuals charged with developing regulatory mechanisms, whether they be standards, guidelines, codes of practice, or licensing and accreditation systems. This problem may be particularly acute for less well-resourced organisations such as industry associations and public interest community groups. As will be shown in the chapters ahead, standards, guidelines, codes of conduct, and licensing and accreditation requirements, tend to be amalgams of policy and procedure from organisations within the domain to be regulated. It will be argued that, just as the level and specificity of constraints inherent in regulations should be different from those in legislation, so too is the level and specificity of constraints inherent in organisational policy and procedure inappropriate for regulations.
Regulating LOA

Constraints on LOA work can emanate from legislation, regulation, policy or procedure. Although many constraints on work are imposed through resourcing and planning processes prior to the work taking place, dynamic decisions and actions of LOA field workers and participants are subject to high degrees of autonomy (Trotter et al., 2014). For a regulatory constraint that is intended to influence the behaviour of workers and participants during LOA work, those agents must somehow be aware of the constraint. For workers, this could come about either through direct awareness of the regulatory constraint or through awareness of a policy, procedure or directive that reflects the regulatory constraint (Zohar & Luria, 2005). For LOA participants, awareness of the regulatory constraint is more likely to come from briefings and instructions provided by the LOA worker in the field or through briefings and instructions received prior to the activity (Dallat, Salmon, & Goode, 2015).

The nature of work in the LOA domain is often characterised by low levels of routinisation and supervision. This could be contrasted, for example, with industrial work on a production line. Workers in that setting are likely to conduct their work in a stable, known and predictable physical environment. The processes they control and the objects they interact with may be complicated and hazardous, but in the absence of component failure, they are not likely to vary over time. While elements of the LOA work system are somewhat predictable in nature, including some of the more obviously hazardous elements (e.g. activities such as rock climbing or white-water paddling), the context in which they occur is highly dynamic. This is due to the presence in the work system of dynamic elements like people, weather, and different physical environments in which the work occurs. Furthermore, the production line worker is likely to work in the presence of a supervisor who can provide feedback in real time. This possibility for immediate feedback is often absent for LOA workers who often work in isolated or remote locations outdoors. These features of the domain present unique challenges for the control of LOA operations, including regulatory controls.
Scholarly literature about the benefits of outdoor adventures has a long tradition, particularly in the U.S. where philosophers and educators such as Muir, Thoreau, and Emerson influenced public policy in the areas of conservation and education (Callicott, 1990; Willson, 1962). Research into LOA safety appears in the literature more recently (Brackenreg, 1999; Brookes, 2011; Davidson, 2007; Goode, Salmon, Lenne, & Finch, 2015a; Meyer, 1979; Priest & Baillie, 1987; Salmon, Williamson, Lenne, Mitsopoulos-Rubens, & Rudin-Brown, 2010). Despite this, no specific literature was found that addressed safety regulation for LOAs. It appears that there is almost no research in this area and so it is not clear how to design LOA regulatory systems, or which forms of regulation work best for LOAs.

Safety in LOAs

Research and scholarship focused on LOA safety has evolved as the variety and popularity of led outdoor activities have grown. Although perhaps accurately characterised as a niche sector, the industry and profession that provide LOAs are faced with the special challenge that the service they provide often includes an intentional engagement with risk. This sets the sector apart from many other safety critical sectors, where risk is an unwanted (although often unavoidable) side effect of the work. Jones (2011) has shown how, while engagement with risk is often directly or indirectly desired by participants in LOAs, safety is certainly also expected. Beyond customer expectation, community, regulators and government also expect and require providers of services to the public to provide those services in a way that minimises harm.

Recently, systems-based HFE methods have been applied to the analysis of LOA safety (Dallat et al., 2018; Goode, Salmon, Lenné, & Finch, 2015b; Salmon, Goode, Lenné, Finch, & Cassell, 2014; Salmon et al., 2017a). This work has consistently found regulatory systems (or the absence of them) to be a contributory factor in LOA injury incidents. Trotter et al. (2014) have shown how regulation plays a role in LOA leader decision making. These findings illustrate the importance of regulation in LOA safety.
Despite the earlier and more recent research on LOA safety, very little scholarly examination of the evaluation or design of regulatory systems in LOAs was found. Given that regulatory systems have been implicated as contributory factors in LOA injury incidents (Priestly, 2012), this is a significant gap.

Human factors and ergonomics (HFE) and regulatory system design and analysis

The HFE literature includes discussion of regulation, particularly as it relates to safety. For example, Rasmussen’s Risk Management Framework (RMF; 1997) includes regulators as one of five social levels (government, regulators, executive management, supervisory management, work) at which activity occurs in systems of work. Based on Rasmussen’s RMF, Leveson’s (2004) STAMP model supports the mapping of controls in STS, including those emanating from the regulatory level of work systems. Accimap, arguably the most popular accident analysis method, includes a regulatory bodies level designed to identify contributory factors relating to regulation. Indeed, the majority of Accimap incident analyses presented in the literature have identified regulatory system inadequacies as contributory factors. These applications span multiple safety critical domains, including LOA, aviation, road and rail transport, process control, healthcare, public health, and emergency response (Hulme, Stanton, Walker, Waterson, & Salmon, 2019).

Despite the recognition in the HFE literature of the importance of regulation for safety in STS, specific methods to support the evaluation or design of systems of safety regulation was not found. For example, a search of academic papers in the U.S. journal, Human Factors, for the term ‘safety regulation’ returned only three results (Evans, 1985; Marquardt, Robelski, & Hoeger, 2010; Rabideau, 1974). None of these research contributions offered a specific focus on safety regulation or the design of systems that support it. A search of academic papers in the U.K. journal, Ergonomics, for the term ‘safety regulation’ was slightly more fruitful, with thirteen results. However, only one of these (Adams, 1988) had a specific focus on safety regulation. This paper centred on how a reappraisal of risk could influence risk targets in road...
safety regulation but offered no systematic advice on regulatory system evaluation or design.

**Summary**

The review of regulatory literature showed that considerable innovation is evident in approaches to regulatory practice (Coglianese, 2017) and to the evaluation of regulatory system performance (Coglianese, 2012). However, little evidence was found of systems-based or theoretically supported approaches to the evaluation or design of regulatory system structure. This literature review showed that various forms of regulation and regulatory mechanisms exist, designed and administered by a diverse array of organisations. However, there is little guidance available on how to design them. Furthermore, the literature review revealed that the development of systems of social regulation has been largely undertaken by academic and research work in the fields of law and governance. There appears to have previously been little contribution from design or systems focused disciplines such as engineering or HFE. This has resulted in a research gap that deprives those charged with evaluating, designing, or reforming regulatory systems of a reliable, specific, and theoretically grounded framework to discharge those duties.

The review of LOA literature revealed a recent but growing body of systems-based HFE approaches to accident analysis (Goode et al., 2015b), risk assessment (Dallat et al., 2018), and operational safety (Trotter et al., 2014). However, while one document was found that listed various approaches to LOA safety regulation around the world (Ministry of Business Innovation and Employment, 2010a), no literature was found that addresses the specifics of regulatory system design or operation for the domain.

The review of HFE literature showed a significant recognition of the role of regulation in safety (Adams, 1988; Leveson, 2004; Rasmussen, 1997). However, no HFE research was found that dealt specifically with regulatory system evaluation or design.

The gaps identified in these three areas of research literature confirm that the application of systems based HFE approaches to LOA regulatory system design and analysis is both warranted and necessary.
Chapter 2
Chapter 3 – Not as Simple as it Looks

Introduction

The application of systems-based methods to LOA safety has, as noted in the previous chapter, produced new approaches to accident analysis, risk assessment, and operational safety planning (e.g. Dallat et al., 2018; Salmon et al., 2012; Trotter et al., 2014). In addition, it was concluded in Chapter 2 that systems HFE potentially provides a useful approach for designing and analysing regulatory systems, both in LOA and other domains. Before testing this assertion further, it is first important to confirm whether a systems HFE approach to LOA regulation is appropriate. This follows questions that have been raised regarding the extent to which this theoretical approach is suited to the domain (A. Brookes, personal communication, May 25, 2015). Systems based HFE methods have been developed within and for complex STS such as aviation, military, and healthcare. At first glance, the LOA domain may seem not to share the complexity of these other domains of work. After all, LOAs often occur in natural settings removed from the complexities and stresses of everyday life and include, or even rely upon, a perception of a simpler environment. If LOAs do not possess the characteristics of complex STS, then a systems HFE approach may not be useful or indeed appropriate in this context.

The aim of this chapter is therefore to answer Research Question 1: Does systems theory apply in the LOA domain? A relational model of a simplistic LOA was developed, identifying system entities across six system levels, along with predictable pathways for interaction between them. The resulting system map is then compared with ten established characteristics of complex systems (Cilliers, 1998) to identify whether they are inherent in LOAs.

Declaration for Thesis Chapter 3

Declaration by candidate

In the case of Chapter 3, the nature and extent of my contribution to the work was the following:

Nature of contribution

Primary author. Conceived the study design, determined the methodology and criteria, conducted literature search and analysis of results. Conducted initial drafting of paper and subsequent editing.

The following co-authors contributed to the work:

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<tr>
<th>Name</th>
<th>Nature of contribution</th>
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<tbody>
<tr>
<td>Natassia Goode</td>
<td>Guidance on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
<tr>
<td>Paul M. Salmon</td>
<td>Guidance on development of the model and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
</tbody>
</table>

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate’s and co-authors’ contribution to this work.

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Not as simple as it looks: led outdoor activities are complex sociotechnical systems

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Not as simple as it looks: led outdoor activities are complex sociotechnical systems

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Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, Queensland, Australia

ABSTRACT
Recent research is providing valuable insights into safety by applying sociotechnical systems (STS) theory to led outdoor activity (LOA) work systems. The LOA domain involves provision of supervised or instructed activities such as kayaking, rock climbing and camping. Despite these successful applications, questions persist regarding the extent to which STS theory and methods are applicable, given the apparently simplistic nature of the domain. This paper seeks to evaluate the validity of systems theoretic approaches by comparing a typical LOA work system with established characteristics of STS and complex systems. Features of the LOA work system are compared with established characteristics of complexity, then considered in relation to STS theory principles. The findings show that this system of work is indeed both complex and sociotechnical. It is concluded that application of STS theory and methods is both appropriate and required to attain improvements in practice and safety in LOA work systems.

Relevance to human factors/ergonomics theory
Perception of the led outdoor activity work domain as linear and deterministic appears prominent among researchers and practitioners. This article uses human factors/ergonomics theory to demonstrate that the domain is in fact a complex sociotechnical system. Implications for practice in regulation, management, supervision and operations are discussed.

Introduction
Led outdoor activities (LOA; defined as facilitated or instructed activities within outdoor education and recreation settings, (Salmon et al. 2010)) represent an important form of active recreation, and include activities such as hiking (also known as bushwalking, trekking or tramping), paddle sports (including rafting, canoeing and kayaking), roped activities (including abseiling, rock climbing and challenge ropes courses) and snow sports (such as skiing, snowboarding and snow shoeing). Programmes of one or more of these activities are commonly run by schools, community clubs or organisations such as Scouts,
and private organisations that offer their services to the public. The aims of such programmes can be educational, recreational or therapeutic (Goode et al. 2014). In educational and therapeutic applications, the activities are often used as metaphors for participants’ life experiences and thereby as a catalyst for learning or personal development (e.g. Priest and Gass 2005, 217).

The led outdoor activity sector experiences adverse events that can cause injury, and in the worst cases, multiple fatalities (e.g. Brookes 2011). Examples of recent major incidents in this sector include the Mangatepopo gorge incident in which six year 12 students and their teacher drowned during a gorge walking activity in the Tongariro National Park, New Zealand (Devonport 2010) and the death of a year 7 student in a pond whilst on school camp in Toolangi, Victoria (White 2014). A large body of research has responded to these events by applying a systems thinking approach in an attempt to understand and prevent injury during led outdoor activities. For example, systems analyses of fatal incidents have identified multiple contributory factors related to various different actors, equipment, processes, and organisations (Salmon et al. 2010; Salmon, Cornelissen, and Trotter 2012; Salmon et al. 2016). Further, research examining more common injury incidents has revealed similar findings, showing that these also involve multiple contributory factors (e.g. Salmon et al. 2014; Salmon et al. 2016). Following these applications, the LOA sector in Australia has developed an industry-wide incident reporting system underpinned by a systems thinking framework (UPLOADS; Goode et al. 2015; Salmon et al. 2016). The systems thinking approach is now firmly embedded in the LOA sector’s approach to injury prevention.

STS theory arose in the context of industrial work settings where the introduction of new technologies was found to be disrupting social foundations of work with adverse effects on productivity (Eason 2014; Trist and Bamforth 1951). It developed further in work settings where the introduction of computer technology became increasingly prominent. Previously stable, tightly constrained systems became more difficult to understand and modify with traditional methods as the introduction of new technologies drove change toward less stability and greater variability of constraints (Vicente and Christoffersen 2006).

Underpinned by complexity theory and STS theory, the systems thinking approach has traditionally been applied in high-risk safety critical systems such as transportation and process control. Part of the justification for such applications is that these systems are highly complex and dynamic, comprising multiple interacting human and technological components. Likewise, recent applications of systems thinking in the led outdoor context are based on the notion that led outdoor activity systems are complex, dynamic systems and exhibit many of the characteristics that are discussed in relation to complexity and sociotechnical systems (Salmon, Cornelissen, and Trotter 2012; Salmon 2014). For some who work in the LOA domain, however, this premise seems counter-intuitive, given the apparent simplicity of their work. Indeed, trekking in a remote wilderness or paddling with a small group along an unspoiled coastline conjures images of a simple life, far removed from the busy-ness of modern, urban living. These examples and many other experiences available for people to spend time in nature do afford a simplification of daily life. Daily routines, ubiquitous technology, noise and pollution can be left behind for a while. The experience afforded to participants by this work domain can indeed be viewed as simple. Upon reviewing accident analysis methods developed and used within the LOA sector, Salmon et al. (2009) concluded that
systems thinking, which could indicate recognition of system complexity, was not evident in the methods reviewed. This suggested a fundamental inadequacy in the prevailing understanding of the nature of the LOA system; however, this is only a fundamental flaw if LOA systems display the characteristics of complex sociotechnical systems.

Complex, non-linear systems can be characterised by the phrase: ‘the system is greater than the sum of its parts’. In contrast, linear, deterministic systems can be characterised by the phrase ‘the system is the sum of its parts’. The former can be best understood by considering all system entities and their interactions together in a process of synthesis, whereas the latter can be satisfactorily understood by decomposing the system into its component parts and subjecting them to analysis (Cilliers 1998).

Differences between the theoretical and analytical approaches required for both perspectives are perhaps best demonstrated through models of accident causation. These have evolved through several distinct stages (Toft et al. 2012). From the 1930s, simple sequential linear models, beginning with Heinrich’s ‘Domino theory’ (as cited in Toft et al. 2012, 4), posited that accidents were a result of a linear sequence of factors. Accidents were seen to be primarily a result of human error or mechanical failure in close proximity to the accident. In the 1960s, more sophisticated complex linear models began to emerge (Toft et al. 2012, 7). Unlike earlier approaches, these models began to account for multiple events in a sequential causal path. Furthermore, they began to account for causal factors at a greater distance in time and space from an accident. Like their predecessors, however, these second generation models assumed and sought to identify a ‘root cause’. From the 1980s, complex non-linear models began to emerge (e.g. Rasmussen’s (1997) Risk Management Framework; STAMP (Leveson 2004); FRAM (Hollnagel 2012)) which could account not only for multiple and non-local causes of accidents, but also for emergent causes which arose as a result of interactions between system elements. This third generation of models offers a more accurate means of understanding complex sociotechnical domains than its predecessors.

It should be noted that the literature on safety and systems theory is inconsistent in the use of terms to describe different system types. The term ‘complex’ in particular has been used to refer both to linear and non-linear systems. The present analysis will follow Kurtz and Snowden (2003) in reserving the term ‘complex’ to refer to complex, dynamic, non-linear systems. It is important to distinguish them from linear systems which may have very many elements and are thereby complicated, but do not exhibit the characteristics of complex systems.

Accurately identifying whether or not the LOA work system is complex by analysing system characteristics has significant implications for how such systems are regulated, managed, supervised and operated. Differences between the nature of complex and non-complex systems mean that misunderstanding the nature of the system will give rise to completely inappropriate regulatory, management and accident prevention strategies, leading to critical safety failures along with structural incapacity to optimise the productive output of the system. Therefore, this study aims to determine whether the LOA work system is a complex STS and if so, to discuss what implications this may have for practice and future research in the LOA domain.

The following section presents a brief overview of the two competing paradigms in LOA research, one that considers the domain as a complex sociotechnical system and another that supports a linear, deterministic view.
Competing paradigms in LOA research

A growing body of research has considered the LOA work domain as a sociotechnical system. This systems-thinking approach has been applied to a number of dimensions of the LOA work system, as illustrated by the following three examples.

First, in their study of accident causation Salmon, Cornelissen, and Trotter (2012) applied a selection of systems-based methods to the analysis of the Mangatepopo Gorge incident (Devonport 2010). This study showed that systems-based methods support the identification of causal factors that occur in close proximity to an accident along with factors at higher system levels and those that result from interactions between entities at different system levels (Salmon, Cornelissen, and Trotter 2012, 1163). This has led to the development of a model of the LOA work domain that includes the regulatory and legislative levels, along with management, supervisory, operational and physical levels. This model acts as a framework, underpinning an incident reporting taxonomy and database (UPLOADS; Salmon et al. 2016).

Second, the sociotechnical systems paradigm has been used to support the evaluation of risk assessment practices in outdoor education programmes (Dallat, Salmon, and Goode 2015). This study found that commonly used risk assessment methods are inadequate for identifying causal factors at higher system levels. Development of a systems-based risk assessment method was recommended.

Finally, the role of improvisation among outdoor leaders in supporting safety has been examined using sociotechnical systems-based analysis methods (Trotter, Salmon, and Lenné 2013). This research identified ways in which outdoor leaders’ decisions when improvising to support safety were influenced by factors across multiple system levels.

Before these applications, other research in the LOA domain had modelled the system of work in a more deterministic, linear way. The following examples demonstrate this approach.

A number of accident causation models have been developed for led outdoor activities (Salmon et al. 2009). Of these, both Brackenreg’s (1999) Accident Potential Model and Meyer’s (1979) Principal Causes model, from which it is adapted, identify causal factors in the immediate proximity of an accident. Hazards are seen to arise from activity leaders, participants, equipment, the environment, or as a result of interactions between any of these system entities. Davidson’s (2007) Root Cause model accommodates identification of a broader range of causal factors by noting the possibility of them arising in safety management systems and senior management. All three of these models account for multiple causes of accidents and the interaction of system entities; however, they offer no guidance for analysis of those interactions nor for the development of associated countermeasures. None of these models account for causal factors that may occur at higher system levels such as the regulatory or legislative. They can therefore be seen to belong to the second generation of accident causation models identified by Toft et al. (2012).

The ChANGeS Framework is a contemporary model which seeks to identify and describe the factors that contribute to the achievement of beneficial outcomes of led outdoor activity programmes (Williams 2012). The model identifies five common components of outdoor programmes (challenge, activity, nature, guided experience and social milieu) in order to rate the extent of the presence of these components. The prominence
of each component in a programme is assessed and an ordinal rating is assigned. This
seems to imply that programme effectiveness is a function of the strength of individual
components. Moreover, the method appears to suggest that the beneficial potential of an
LOA programme can then be expressed as an aggregate sum of these component ratings.
No consideration is given to the interactions between these or other programme compo-
nents, nor to other entities in the broader system. Whilst linear, deterministic systems can
be understood as a sum of their parts, complex, non-linear systems cannot (Cilliers 1998).

Similarly, the extensive literature on outdoor leadership seems to assume that leader-
ship is a product of individual ability, rather than a supportive system (e.g. Crosby and
Benseman 2003, 43; Martin et al. 2006, 56–57; Priest and Gass 2005). This has significant
consequences both for risk management and for the achievement of beneficial programme
aims. For example, although novel developments of leadership attributes and styles are
explored by Smith and Penney (2010), little consideration is given to the context in which
leadership occurs, much less to the effect of that context on leadership itself. This appears
to follow an orthodoxy in the LOA domain that leadership is determined entirely by
the attributes or competencies of the leader (e.g. Priest and Gass 2005, 3). This view stands
in contrast to contemporary models of leadership from other domains which see it as
always embedded within and interdependent with a broader system (e.g. Lichtenstein and
Plowman 2009).

If the LOA system is in fact complex and non-linear, rather than deterministic and lin-
ear, research that seeks to support all of the dimensions of work in the domain, including
safety, effective programme design and staff training, will benefit from adoption of the
systems thinking paradigm.

This article therefore sets out to answer the question of whether LOA systems are com-
plex and sociotechnical in nature. To achieve this, using a case study of a three-day trek
we examine the characteristics of LOA systems and compare them to the core characteris-
tics of complexity theory (Cilliers 1998), sociotechnical systems theory (Trist 1981) and
contemporary models of accident causation (Rasmussen 1997). The aim is to determine
whether led outdoor activity work systems are indeed complex in nature, and thus
whether the growing body of research that adopts a systems approach is warranted.

**What criteria can determine whether a system is sociotechnical and complex?**

Before outlining the case study, it is first worth defining what it is that makes a system
sociotechnical and complex in nature. Sociotechnical systems are defined widely in
Human Factors and Cognitive Ergonomics literature as systems of work that comprise
social subsystems (people) interacting with technical subsystems (devices, interfaces and
work practices) in pursuit of a common goal (e.g. Walker et al. 2008). Klein (2014) has
emphasised that the social and the technical are interdependent aspects of the same sys-
tem in order to avoid any tendency to view either as self-contained. This is important due
to the need for the social and technical aspects of a sociotechnical system to be developed
in conjunction with each other, rather than separately (Jenkins et al. 2009; Trist 1981).

Whether sociotechnical or not, criteria for identifying a complex system are not neces-
sarily obvious or straightforward. Furthermore, a complex system is not the same as a
complicated system. Even though it may have many components, a system is not complex
if the whole system state and the state of the entities of which the system is composed is
reliably predictable. This depends on all system entities and the relationships between them being amenable to complete description. Future states of these linear, deterministic systems can be reliably predicted via accurate analysis of any present state (Cilliers 1998). Components of such systems do not change over time; they do not develop new interactions with other system components or with their environment. The output of such systems generally relies on all system entities continuing to operate and interact in the manner in which the system is initially configured. Such systems may be simple (e.g. a pendulum) or complicated (e.g. a jumbo jet) but they are not complex.

Scholars in the domains of general systems theory and sociotechnical systems theory have identified a wide range of characteristics that are indicative of complexity (e.g. Cilliers 1998; Skyttner 2005; Vicente 1999; von Bertalanffy 1975). Cilliers’ (1998, 15–19) characteristics have been chosen for this study as they appear to incorporate criteria identified by earlier scholars and to be generic enough to suit application across a broad range of work system types. According to Cilliers, complex systems exhibit the following characteristics: a large number of elements; dynamic interactions between elements; elements interact with multiple other elements, interactions between elements are non-linear (small causes lead to large effects and vice versa), information is received primarily from immediate neighbours; recurrent loops in interactions; complex systems are open systems (it is difficult to define the border and the system interacts with its environment); requires constant flow of energy to maintain system organisation; a complex system’s past is co-responsible for its present behaviour; and each element in the system is ignorant of the behaviour of the system as a whole. These characteristics were used as criteria in the case study analysis.

Methods and sources

A case study approach was adopted whereby the work system that supports a typical LOA programme was considered. First, a logistically simple example of an LOA system was analysed to determine the extent to which it aligns with Cilliers’ characteristics of complexity. Second, the system model was compared with five STS design principles which were selected on the basis of their prominence and frequency of appearance in a review of STS literature. The design principles were joint optimisation (Jenkins et al., 2009; Trist, 1981), vertical integration (Rasmussen 1997; Salmon, Cornelissen, and Trotter 2012), flexibility (user finishes the design) (Clegg 2000; Jenkins et al. 2012), simplicity (minimal critical specification) (Cherns 1987; Clegg 2000) and problems can be controlled at the source (Cherns 1987; Clegg 2000).

A subject matter expert (SME) who has over 10 years’ experience leading and managing similar programmes for an Australian organisation was asked to identify and describe a typical and logistically simple LOA. Actors, objects and processes (all considered as ‘entities’ in this analysis) involved in this system were identified from interviews with the SME. The system entities identified for the three-day trek were then allocated to levels of the UPLOADS framework (Goode et al. 2016; Salmon et al. 2016), a representation of the led outdoor activity work domain based on Rasmussen’s (1997) risk management framework. Rasmussen developed his framework to model risk control structures across different social levels in work systems. This allowed a systems view of accident causation whereby causal factors at different system levels could be viewed together and interactions between them identified.
Any system can in principle be decomposed down to ever finer levels of resolution. For example, each raindrop, each tree branch and each hair on the head of a participant could be considered as an individual element in this system. The focus of the present analysis was system effects on participants, both beneficial, intended outcomes and undesirable accidents. Therefore, the level of resolution is that of individual participants and the other people, objects and processes that interact with them within the system boundary.

The system levels represented by the UPLOADS framework are shown in Figure 1. Each system level can be viewed as a subsystem or as an aspect of the whole work domain. Relationships between entities and their placement in the domain hierarchy were identified through discussion between the analyst and the SME. A sociotechnical system map was developed showing the main entities in the system and some examples of...
temporary, emergent entities. A persistent entity exists in this system for the duration of the system’s life; that is, the persistent entities exist throughout the entire activity from commencement to completion of the programme. Examples include the leader, the terrain and land-use restrictions. Temporary or transient entities may emerge from interactions between other entities in response to both planned and unplanned situations. For example, a cooking team is a transient entity with its own unique properties which may form to prepare an evening meal. A temporary rain shelter is an entity that may be spontaneously built in response to an unexpected downpour. The resulting sociotechnical system map was then validated by a second SME with a similar background to the first.

**Case study**

The three-day trek is a walking journey for a single group of 12 new members of a community bushwalking club and one experienced leader in a semi-remote area in south-eastern Australia in October. The goal of the activity is to help participants develop the practical skills of self-contained outdoor living, help group members get to know each other and to create opportunities for a deeper connection with nature. The trek is planned to take three-days and the group are to camp each night, using tents and other equipment carried with them in backpacks. The trek route begins near a carpark and then moves away from roads and other artificial structures. Cell phone reception is only sporadically available in the area.

Sources of drinking water are available at both planned overnight campsites. Each participant carries a backpack containing their sleeping bag, food, water, clothing and personal equipment (e.g. toiletries, medication, mobile phone, GPS device). Group equipment such as tarpaulins, ropes, a shovel and cooking equipment is distributed among group members to be carried in their backpacks. In addition, the leader carries a first aid kit, medical information for all group members, a printed weather forecast, a map, a compass, route notes, a mobile phone and a UHF radio. The trek route is planned to take the group across two mountain ranges and to conclude at a carpark about 40 km from the starting point. Terrain on the planned route includes flat and undulating trails through valleys and plains and steep rocky sections at higher elevations. Flora and fauna in the area include tree ferns, spiky shrubs, eucalyptus trees, kangaroos, wombats, possums, venomous snakes and numerous insects. Weather in this area during October typically includes a temperature range of 4–28 °C with the possibility of strong winds and heavy rain.

The system in which a trek like this takes place includes several classes of interacting entities or elements. Actors are entities in this system that includes participants, leaders and supervisors. Physical objects are entities such as items of camping equipment, route notes and trees. Cognitive objects are conceptual entities including trip objectives, activity standards and learning outcomes. Processes are entities such as compliance checking and route planning.

Each entity is an element within the system and interacts with other elements and is represented as a node on the system map in Figure 2. In order to understand the complexity of the system, the nature, the number and scope of these entities is now considered, along with their relationships with each other.
Figure 2. System map for a three-day trek.
Evaluation: is the LOA work system sociotechnical and complex?

The system map in Figure 2 shows that this led outdoor activity programme does indeed constitute a sociotechnical system according to Klein’s (2014, 138) definition, which identifies interdependence between social and technical system aspects as the defining characteristic of a sociotechnical system. Figure 2 shows social elements and subsystems (e.g. leaders, participants and group), and technical elements and subsystems (e.g. group equipment; map, compass and route notes; standard operating procedures), that interact with each other and with an external environment. A representative example of the interdependence evident in these interactions is that a navigator is dependent on a compass to determine direction and location, and the compass is dependent on its correct use by a navigator to fulfil its purpose. The interaction between social and technical system entities is undertaken to achieve the programme’s stated goals.

There are a number of difficulties associated with any attempt to analyse the characteristics of a domain of work. Two challenges are particularly relevant here. The first is deciding the system boundaries. The second is deciding on the level of granularity or resolution at which the system under examination should be viewed (Naikar, 2013). This decision must be carefully made by the analyst based on the purpose of the analysis. In this case, the purpose is to understand ways in which system entities can act and interact to achieve programme aims or to compromise safety. Both the system boundary and the resolution level were chosen accordingly.

Characteristics of complexity evident in the case study

In Table 1, the led outdoor activity system characteristics are examined against Cilliers’ characteristics of complex systems (Cilliers 1998).

As shown in Table 1, the simplistic three-day trek led outdoor activity system can be viewed as displaying all of Cilliers’ characteristics of complexity. Next, the led outdoor activity system is compared with STS principles.

Sociotechnical systems principles

Whilst a number of sociotechnical systems principles pertain to specific work systems and may not be relevant to analysis of a hypothetical system, the model developed here does allow some conclusions to be drawn about the extent to which this type of system may intrinsically align with STS principles. Table 2 includes a core set of STS principles which are observed in the work system under analysis, their sources in the literature and observations on their relevance to the LOA work system illustrated in Figure 2.

The led outdoor activity system clearly is ‘sociotechnical’, in that it includes a social aspect (e.g. leader, participants, supervisor, emergency responders) and a technical aspect (e.g. group equipment, personal equipment, standard operating procedures). The characteristics noted in Table 1 indicate that this system is complex.

Discussion

The aim of this article was to determine whether led outdoor activity systems are complex and sociotechnical nature. Given the spate of recent systems thinking applications in
This line of inquiry represents an important one for practice and research in this area. Therefore, a case study analysis of a three-day trek was undertaken using the UPLOADS framework. Based on a comparison with accepted characteristics of complexity and sociotechnical systems, the findings suggest that even relatively simplistic LOA systems are indeed complex and sociotechnical in nature. This suggests that not only are systems thinking applications in this area warranted, they are imperative should the desired outcome be safety and efficiency gains (Salmon et al. 2016). The remainder of this discussion now turns to some important implications for practice and research.

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<tr>
<th>Characteristics of complex systems</th>
<th>Examples of characteristic in a three-day trek</th>
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<tr>
<td>Large number of elements</td>
<td>The nodes shown in Figure 2 represent a number of entities: participants, group equipment, personal clothing and equipment are three examples of nodes that represent several elements. Importantly, these elements include human, environmental, technological and non-technological artefacts.</td>
</tr>
<tr>
<td>Dynamic interactions between elements</td>
<td>There are many dynamic interactions between elements. For example, the leader may check participants’ navigation skills and, if required, teach how to navigate with map and compass; all group members interact dynamically with the weather, the terrain, flora and fauna and equipment. For example, participants may put on raincoats if it rains, apply insect repellent if mosquitoes are biting or set up a rope to assist in crossing a fast-flowing stream.</td>
</tr>
<tr>
<td>Elements interact with multiple other elements</td>
<td>Most elements shown in Figure 2 interact with multiple other elements. For example, group members interact with many other system elements; an evening meal can be produced for the group by one or several group members interacting with cooking equipment, the leader, ingredients, etc.; a navigation decision can be made quickly based on prior experience or multiple options can be considered; a temporary rain shelter can be constructed by many or few participants from many or few components.</td>
</tr>
<tr>
<td>Interactions between elements are non-linear: small causes $\Rightarrow$ large effects and vice versa</td>
<td>A few missing words in a weather report can lead to a multiple fatality incident (e.g. as in the Mangatepopo Gorge incident, see Salmon, Cornelissen, and Trotter 2012); a chance close encounter with a soaring eagle on a mountain peak can trigger an epiphany.</td>
</tr>
<tr>
<td>Information is received primarily from immediate neighbours</td>
<td>Aside from phone and radio communications the leader may have, most information enters the system from local sources.</td>
</tr>
<tr>
<td>Recurrent loops in interactions</td>
<td>Cyclic processes of camping, cooking, packing and unpacking constitute recurrent loops; in outdoor education programmes, learning occurs during the trip through recurrent loops of planning, experience and reflection.</td>
</tr>
<tr>
<td>Complex systems are open systems: it is difficult to define the border and the system interacts with its environment</td>
<td>Elements in the physical environment such as rocks, trees, trail declines and inclines are continuously entering and exiting the boundary of this system as the group travels; the system continuously interacts dynamically with the physical environment, including weather, beyond the system boundary at any given moment; temporary entities emerge within the system boundary and then dissolve.</td>
</tr>
<tr>
<td>Requires constant flow of energy to maintain system organisation</td>
<td>Navigation, group discussion, leadership decisions and action all represent energy flows that maintain system organisation. If any one component stops the overall activity cannot proceed effectively.</td>
</tr>
<tr>
<td>A complex system’s past is co-responsible for its present behaviour</td>
<td>Pre-trip preparation will determine resources available during the trip which will, in turn, constrain options available; interactions between participants may influence their relationship and the nature and outcome of subsequent interactions; physical features in the landscape where a programme takes place long precede the programme and shape the nature of the activity and procedures adopted.</td>
</tr>
<tr>
<td>Each element in the system is ignorant of the behaviour of the system as a whole</td>
<td>The activity leader might be able to describe all of the parts and behaviours within a hiking shoe yet would not be able to describe all of the parts, interactions and behaviours that make up the hiking activity system.</td>
</tr>
</tbody>
</table>

LOAs (e.g. Goode et al. 2016; Salmon et al. 2016), this line of inquiry represents an important one for practice and research in this area. Therefore, a case study analysis of a three-day trek was undertaken using the UPLOADS framework.
Implications for practice

The dynamic interactions, non-linearity, openness and component ignorance of total system state in complex systems mean that accurate prediction of all future system states is impossible. This presence of uncertainty as an inherent feature of complex systems is of particular significance for planners and managers. It is important to note that each entity identified here, while a subsystem of the LOA system being considered, can be viewed as a system in its own right, composed of its own component entities and subsystems. Some component entities in the LOA system are themselves complex systems (e.g. the human actors, flora and fauna and weather), while others can properly be viewed as linear, deterministic (and thereby predictable) systems. The presence of complex system components ensures that the overall system is complex in nature at least to the extent that uncertainty will transfer to the larger system from its complex components, by way of their interactions with other system entities. For LOA system designers, this suggests a need to build redundancy into the system in order to support system capacity to self-organise in response to the emergence of unforeseen events (Gilliers 1998, 21–22).

Table 2. Comparison of LOA system model with STS principles.

<table>
<thead>
<tr>
<th>STS principle</th>
<th>Source/description</th>
<th>Relevance to LOA work system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint optimisation</td>
<td>The social and the technical aspects of work systems should be optimised in conjunction with each other (Jenkins et al. 2009; Trist 1981).</td>
<td>The emergent ‘Cooking Team’, shown at the right side of Figure 2 is an example where techniques and tools must align with users’ needs, skills, experience and the relevant rules and goals.</td>
</tr>
<tr>
<td>Vertical integration</td>
<td>Performance depends on effective flow of information up and down the levels of the system (Rasmussen 1997; Salmon, Cornelissen, and Trotter 2012).</td>
<td>The nature of led outdoor activity work system is such that leaders and participants are working in isolation from supervisory and control mechanisms. This means that system performance is critically dependent on effective flow of information about rules and goals from the upper levels to the lower and about work performance from the lower to the upper.</td>
</tr>
<tr>
<td>Flexibility (user finishes the design)</td>
<td>‘…one should not over-specify how a system will work (minimal critical specification). Whilst the ends should be agreed and specified, the means should not!’ (Clegg, 2000).</td>
<td>The open nature of the work system and its uncertainty mean that prescriptive practices and procedures are unlikely to support effective system performance. Goal-based controls which allow users (leaders and participants) to ‘finish the design’ (Read et al. 2015) are more likely to support the achievement of system goals.</td>
</tr>
<tr>
<td>Simplicity (minimal critical specification)</td>
<td>‘This … includes a range of more detailed concerns such as ease of use, ease of understanding, and learnability’ (Clegg 2000).</td>
<td>The multiplicity of known and possible emergent tasks required of leaders mean that system performance will be supported by avoiding over-complication of specific tasks and procedures for leaders, allowing them space to respond effectively to emerging conditions.</td>
</tr>
<tr>
<td>Problems can be controlled at source</td>
<td>‘…variances (un-programmed events) should be controlled at source. …’ (Clegg 2000).</td>
<td>The relative isolation of the locus of work means that emergent problems must be controlled at the source at least initially as external support may not be immediately available.</td>
</tr>
</tbody>
</table>


Management implications

Whilst all of Cilliers’ characteristics of complexity can be seen to have implications for the effective management and operation of complex sociotechnical systems, those that have the greatest effect on possible states of knowledge about the system are of most relevance to system management.

Although it has been described as a characteristic of complex systems (e.g. Jenkins et al. 2009), uncertainty may be more accurately understood as a cognitive state experienced by an observer who may or may not be part of the system. As Storr (2005) identified, this requires actors at all levels of complex sociotechnical systems (e.g. legislators, regulators, managers, supervisors, workers, participants) to contend with four types of system outcomes: predictable and desirable; predictable and undesirable; unpredictable and desirable; unpredictable and undesirable. The pursuit of desirable outcomes in sociotechnical systems of work is usually considered to lie within the realm of productivity while the avoidance of undesirable outcomes prominently includes efforts focused on safety. Figure 3 shows how these categories of management focus interact with system complexity to produce the outcome states noted by Storr, along with his proposed management approaches.

Choice among the four management approaches suggested in Figure 3 (seek, avoid, exploit, accommodate) could be guided by deciding whether or not the management aim under consideration involves system entities that are complex systems in their own right. If not, the direct planning approaches suggested in the top two quadrants may be most appropriate. If so, the more ‘fuzzy’ approach of vigilance shown in the bottom two

Figure 3. Management strategies for complex systems.
quadrants may be more appropriate. In relation to avoiding adverse outcomes, Snowden (2006) refers to this as the creation of ‘safe to fail’ spaces. More recently, safety science scholars have advocated a shift from an ‘anticipatory’ approach to safety management in complex, safety critical domains, to one based on the building of resilience (Macrae 2014). For the LOA domain, this supports the need to build redundant capacity into the system where critical safety and productivity aims are at stake. Furthermore, it supports the need to apply the STS principles of design simplicity and flexibility, along with the concomitant training and empowering of operational workers to ‘finish the design’ (Rasmussen 1997).

On the face of it, led outdoor activity systems may not appear to be similar in nature to the kinds of systems that are typically discussed in the complex sociotechnical systems literature. Take, for example, a large military system (e.g. Jenkins et al. 2012) versus the three-day trek system described earlier. The former is vast, comprising multiple actors, organisations and advanced technologies, and can remain connected whilst spanning entire continents. The latter is logistically simple and affords an experience of simple living for participants. It may be that these appearances of simplicity lead practitioners to reject the suggestion that the system of work within which logistical and experiential simplicity occurs, can itself be complex.

By looking beyond simplistic descriptions of led outdoor recreation, the case study presented in this article has provided evidence that LOA work systems do in fact exhibit the characteristics associated with ‘complex’ and ‘sociotechnical’ systems. Even in the most simplistic of led outdoor activities, the system and emergent behaviours are such that complexity is achieved.

This has significant implications, not only for safety in this domain, but also for other dimensions of work including productivity, programme design, organisational design, work procedures, training and regulation. If the prevailing view of the system is linear and mechanistic, interventions to improve safety or productivity are likely to focus on system components, and are thus likely to be inappropriate and have little impact. Salmon et al. (2014, 2016) report that traditionally, accident analysis in this domain has sought to identify root causes associated with components (e.g. instructors, equipment) and has typically recommended changes to those components as remedies. Initiatives to improve quality or productivity will focus on changing the characteristics of components or introducing new ones, with little consideration of the impacts on overall system functioning. In more conventional complex systems, these approaches to improving safety and efficiency are known to be ineffective (e.g. Dekker and Pruchnicki, 2014; Reason 1997). Viewing led outdoor activity systems through a ‘simple, non-complex and non-sociotechnical’ lens engenders inappropriate approaches for improving them.

By contrast, a systems view of the led outdoor activity work domain will encourage analysts of accidents to be alert for causal factors arising from patterns of interactions between elements within and across system levels. Managers will be encouraged to seek productivity and safety improvements through changes to the relationships between system elements as well as in the elements themselves. Programme designers will be more likely to explore alternative programme designs and options within programmes to achieve aims. Regulatory systems will be designed in ways that support the flexibility and adaptability that a complex system requires for optimal performance. By viewing LOA work systems through the same lenses as we do more traditional complex safety critical systems we will expand our theoretical toolkit, providing the opportunities to gather...
richer data, to exercise more explanatory power, and ultimately to better optimise led outdoor activity systems.

The LOA sector provides an important and growing service around the world. Recognition of the value of meaningful experiences outdoors grows as technological and environmental trajectories place greater stress on many people (e.g. Louv 2008). The economic value of LOAs is increasingly being recognised (e.g. Marsden Jacob Associates 2016). By neglecting contemporary thinking and practice in safety science, including the development of sociotechnical system models of accident causation, LOA research may not have appropriately supported this important sector. Further applications of systems thinking research are encouraged. Whilst these are important for the safety of LOAs (see implications for research section), applications in other areas are also encouraged. These include programme design, training design and regulatory system reform.

A project is currently underway in Australia to amalgamate separate state-based Adventure Activity Standards into a single, national set of standards (Outdoors Victoria 2015). It is hoped that this study may contribute to the growing application of STS approaches in the LOA domain in a way that supports reforms of safety regulation and management. Recognition by reformers of the complex, sociotechnical nature of the domain may be an important foundation for confidence in the further application of STS theory and methods.

As an exploratory case study there are some limitations to acknowledge. The findings of the present study are limited by its hypothetical nature. Analysis of the typical programme studied here is sufficient to clearly identify that led outdoor activity programmes do exhibit most or all of the established characteristics of complex, dynamic sociotechnical systems. Given the logistical simplicity of this example system, we argue that its characteristics discussed here will also be present in more complicated led outdoor activity work systems. However, the application of action research methods to system analyses of actual programmes is likely to yield richer results including revealing how worker understanding of the system of work shapes programme design and outcomes. In addition, other recent analyses also provide evidence in support of the notion that LOA are complex and sociotechnical in nature (e.g. Salmon et al. 2014; 2016).

**Implications for research**

Whilst the opportunities of acknowledging the complex sociotechnical nature of led outdoor activity systems have been discussed, there are some potential pitfalls. For example, it is worth noting a key concern underlying some criticisms of applications of systems thinking to the domain of led outdoor activities (Salmon et al. 2009). Here critics have expressed a fear that by attributing accident causation to factors other than the actions or omissions of leaders, those leaders may become more prone to abrogate their responsibilities for safety and want to blame ‘the system’ for their own failures. This concern has previously been raised in other domains. Dekker and Breakey (2016), for example, cite Sharpe’s (2003) observations about similar concerns in the domain of patient safety. They advocate an approach to worker accountability that takes place within a ‘Just Culture’ where errors and violations by workers are treated by the organisation in a manner designed to constructively address harms, needs and causes. At the same time, deeper,
systemic issues are identified and addressed. Dekker and Breakey also tackle this issue, discussing how accountability is held regardless of whether a systems approach is taken or not as a result of aspects such as professionalism and personal involvement. They also describe second victim syndrome, whereby those involved in adverse events can experience similar levels of trauma as the victims themselves. A systems approach neither removes accountability nor prevents accountability from being held by those involved in incidents.

Future research initiatives may benefit the led outdoor activities sector by examining how approaches like Dekker’s ‘Just Culture’ (Dekker and Breakey 2016) might address concerns about abrogation of responsibility. Whilst systems theoretical approaches are supporting a growing body of research on safety, great potential also exists to apply systems thinking to the analysis of productivity in the LOA domain. Despite any concerns that may remain among LOA practitioners, the results of this study show that the continuing application of STS methods in this domain is both appropriate and necessary.

Are all work systems complex and sociotechnical in nature?

Given that the primary finding of this article was a confirmation that the apparently simplistic system of led outdoor activities is complex and sociotechnical in nature, it is worth touching briefly on the notion that this is true of every system involving humans interacting with human and non-human entities. Certainly such systems would qualify as sociotechnical in nature; however, the relevance of complexity is dependent specifically on the nature of the activity being undertaken, the role of complex system components (such as people) in the activity and the impact of unpredictability on system objectives.

Conclusion

This case study demonstrates that the system of work that supports even a logistically simple led outdoor activity programme displays all of the hallmarks of so-called complex sociotechnical systems. The simplistic nature of the work system analysed supports the proposition that most or all led outdoor activity programmes occur within complex, dynamic sociotechnical systems. The findings therefore suggest that, not only is a sociotechnical systems approach warranted in this domain, it is required should research achieve its aims of optimising safety and efficiency.

This recognition provides analysts and designers with a firm theoretical foundation, previously missing from accident analyses, work design and system development in this domain. The improved objectivity and analytic tools afforded by this foundation offer unprecedented opportunity to enhance the safety, performance and resilience of led outdoor activity programmes.

It is hoped that the case study analysis presented acts as a call to arms for researchers in the area of led outdoor activities. In order to explore the benefits available from the application of systems thinking to the led outdoor activity domain, further research is required. A useful starting point would be to look at perceptions of the work system within the sector to build a picture of how it is understood by people in key roles such as regulators, programme designers, managers and leaders. Studies examining how sociotechnical systems theory could be usefully applied to safety regulation,
organisational structure, programme design, staff training and achieving programme aims could follow.

Disclosure statement
No potential conflict of interest was reported by the authors.

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Professor Paul Salmon holds a chair in Human Factors and is creator and director of the Centre for Human Factors and Sociotechnical Systems at the University of the Sunshine Coast. He currently holds a prestigious Australian Research Council Future Fellowship and has over 15 years experience in applied Human Factors research in a number of areas, including defence, transportation, workplace safety, sports and outdoor recreation, and disaster management. Paul has co-authored 10 books, over 120 peer reviewed journal articles, and numerous conference articles and book chapters.

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References


Summary

The aim of this chapter was to determine whether the work domain supporting LOAs, including its subsystems, meets formal criteria for complex systems and therefore whether the application of systems-based HFE methods in the LOA context is warranted. Doing so addressed the first research question posed in Chapter One: Does systems theory apply in the LOA domain? The study showed that even a relatively simplistic LOA does exhibit all of the characteristics of a complex, adaptive STS thereby demonstrating the need for application of systems theory and systems based HFE methods.

LOAs can be conducted across a broad range of physical settings, activity types, time spans, and group sizes and numbers. The case considered in this study of a single group undertaking a single adventure activity (hiking) over a modest time span represents a relatively simplistic LOA.

The rationale for recognition of the formal complexity of this system was discussed along with some implications for LOA regulation, management, and operations. Furthermore, it was shown that previous approaches to LOA safety and operations have not accounted for the complexity of the system and that therefore, new, systems-based approaches are warranted. Finally, a key criteria of STS complexity was identified, confirming the necessity of applying systems-based methods to LOA subsystems such as regulation.

The finding that the presence in STS of complex subsystems is a key determinant of the complexity of the broader system implies that any STS with a sufficiently prominent set of complex subsystems is itself complex. Therefore, the finding that this LOA meets formal criteria for complexity can be extended to all larger scale and more complicated LOA. Furthermore, this central criteria for STS complexity applies to each of the subsystems identified as system levels in the system map, including the regulatory subsystem.
The regulatory system for LOAs can be systematically viewed from at least two perspectives. The first is from the perspective of a particular LOA work system, as described in this chapter. From this perspective, the regulatory system that applies to the LOA described here must account for, and include within it, a model of that specific LOA. Furthermore, the regulatory processes of attaining and demonstrating (if necessary) compliance with regulatory requirements includes complex subsystems (at minimum, people). On both of these accounts, the regulatory subsystem constitutes a complex STS.

A second perspective from which the LOA regulatory system can be viewed is that of the regulatory system itself. This perspective includes all LOAs to which the regulatory system applies. While the previous view of the regulatory system considers it as a subsystem of a specific LOA, from this alternative angle, each LOA is a subsystem of the regulatory system. It could perhaps be argued that in some edge cases, regulatory processes involved in some specific LOAs might not exhibit all of the characteristics of complexity. However, the view of the regulatory system as it applies to all LOAs is not vulnerable to such arguments due to its inevitable size, scope and required variability of application (see Corbett, 2017).

Having established the complexity of both LOAs and the systems that may regulate them, a set of consequently suitable analysis, design and data collection methods were selected. The following chapter describes these methods and the basis for their selection.
Chapter 4 – Methods

Introduction
In the study described in Chapter Three it was established that the LOA domain can be characterised as a complex STS. Therefore, the analysis and design of such systems requires the application of methods suited to such systems. This suggests that the ecological analysis framework, Cognitive Work Analysis (CWA; Vicente, 1999), can be usefully applied to the domain. The aim of this chapter is to explain the choice, central to this thesis, of CWA and its associated methods for application to regulatory system analysis and design. A rationale for choosing the CWA suite of methods is followed by descriptions of each of the CWA-related analysis and design methods used throughout this thesis. This is followed by a description of the data collection methods used.

As noted in Chapter One, the discipline of HFE is concerned with the analysis and design of STS. HFE methods are tools that support evaluation and design of STS (Stanton et al., 2017). They include techniques to support analysis of many aspects of STS, including tasks, errors, processes, teams, situation awareness, and mental workload. They also include system design methods, integrated methods, and frameworks of methods (Stanton et al., 2017). Among these methods, the CWA framework appears particularly well-suited for adaptation to the analysis and design of regulatory systems. A comparison with other HFE methods, along with non-HFE methods currently used for regulatory system analysis, illustrates the advantages of CWA.

Methods selection
The choice of analysis and data collection methods for this research was influenced by several factors. As the research is focussed on applying systems thinking to regulatory system analysis and design, a number of factors relating to both the theoretical underpinning of the methods available as well as their capacity to support systems
design were considered. These factors informed the criteria used to evaluate analysis method. The first criterion, that the method be underpinned by systems theory, is based on the recognition that the LOA domain and its subsystems are complex (as described in Chapter Three). Second, the need for capacity to describe the system at different levels of abstraction is premised upon the preliminary observation that there appears to be some disjuncture between the purposes of LOA regulatory systems and the means deployed to achieve them. Identifying components of these systems at different levels of abstraction will shed light on such disjuncture. The third criterion is used to estimate the reliability of the method based on previous performance. The final criterion seeks an integrated approach to addressing the research questions listed in Chapter One: an integrated approach to analysis and design will better support the whole process of system analysis and design than the application of unrelated design and evaluation methods. These criteria are outlined in Table 4.1, below. A set of analysis methods are evaluated against these criteria. The first two are existing methods currently used to support regulatory system evaluation and/or design (see Chapter Two). The remainder are HFE methods for the analysis of STS and their emergent behaviours (Salmon, Walker, M. Read, Goode, & Stanton, 2017b).
Table 4.1. Analysis methods compared with evaluation criteria for analysis and design of regulatory systems.

<table>
<thead>
<tr>
<th></th>
<th>Underpinned by systems theory</th>
<th>Capacity to describe regulatory system at different levels of abstraction</th>
<th>Previous systems thinking-based design applications</th>
<th>Link to specific design framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Government (2014) Guide to Regulation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cost-benefit analysis (Coglianese, 2012)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hierarchical Task Analysis (HTA; Embrey, 2000)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Event Analysis of Systemic Teamwork (EAST; Walker et al., 2006)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>MacroErgonomic Analysis and Design method (MEAD; Kleiner, 2006)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Functional Resonance Analysis Method (FRAM; Hollnagel, 2012)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cognitive Work Analysis (CWA; Vicente, 1999)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Among the array of systems HFE methods, the CWA framework was the only one that met all four selection criteria. It was therefore considered to be the approach best suited for adaptation to the analysis and design of regulatory systems. In particular, the first phase of CWA, Work Domain Analysis (WDA), was the main method used to
support both analysis and design in this research project. CWA and WDA are described in detail in the following sections, along with data collection methods, some other components of the CWA framework that appear in a later chapter in this study, and some underpinning theory. Design components of this thesis were supported by the CWA-DT (Read, Salmon, Lenné, & Jenkins, 2015). Based on the CWA framework, the CWA-DT has been used to design various systems or components of systems including rail ticketing, road intersections, rail level crossings, and safety interventions (Read, Salmon, Goode, & Lenné, 2018).

The literature review, discussed in chapter 2, revealed that, while WDA had previously been applied to STS that included regulatory components, it had not been applied exclusively to the system of work that constitutes the regulatory process. Moreover, the literature review revealed no method for analysing the structure of regulatory systems. Therefore, the choice of WDA here is exploratory and the testing of the fitness of WDA for regulatory system evaluation and design is a central aim of this thesis.

Analysis methods

Cognitive Work Analysis (CWA)

CWA is a framework of methods that are used to model cognitive work in STS (Vicente, 1999). Methods within the framework support the modelling of the functional structure of the system, tasks required to achieve the purposes of the system, strategies that can be used to undertake those tasks, the cognitive states and processes associated with decision making during task performance, allocation of tasks to teams and individuals, and the competencies required of workers in the system. CWA can be used to analyse systems as they actually are (descriptive analysis), as they were intended to be (normative analysis), or as they could be (formative analysis; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999).

Typically (e.g. Vicente, 1999), the CWA framework consists of five phases (although others have been developed; see Lintern, 2009), with each phase building upon products of the earlier phases. WDA, the foundational phase of the CWA framework, is
used to model the agent- and event-independent functional structure of an STS. The second phase, control task analysis (ConTA), is used to model tasks that can be undertaken to serve system functions identified in the WDA. The third phase, strategies analysis (StrA), is used to identify various possible ways of carrying out the different control tasks identified in ConTA. The fourth phase, social organisation and cooperation analysis (SOCA), is used to show which human and non-human agents and combinations of agents in the system can enact strategies identified in StrA and how they may be able to cooperate in doing so. The final phase, worker competencies analysis (WCA), is used to identify the skills, rules and knowledge that agents require to undertake the work represented in the earlier CWA phases (Vicente, 1999). Table 4.2 shows five phases of CWA, the constraints modelled by each phase, and the modelling tools used to display results for each phase.
Table 4.2. CWA phases (adapted from Barge, 2019).

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Constraints</th>
<th>Modelling tools</th>
<th>Example applications in regulatory system design and analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Domain Analysis (WDA)</td>
<td>Physical, social, or cultural environment, including purposes and physical resources</td>
<td>Abstraction-decomposition space (ADS), abstraction hierarchy (AH)</td>
<td>Evaluating regulatory system structure</td>
</tr>
<tr>
<td>Control Task Analysis (ConTA)</td>
<td>Work situations, work functions, or control tasks</td>
<td>Contextual activity template (CAT), decision ladder (DL)</td>
<td>Identifying tasks required to undertake regulation</td>
</tr>
<tr>
<td>Strategies Analysis (StrA)</td>
<td>Strategies to enact control tasks</td>
<td>Information flow map, decision ladder</td>
<td>Identifying strategies for meeting, checking and enforcing compliance</td>
</tr>
<tr>
<td>Social Organisation &amp; Cooperation Analysis (SOCA)</td>
<td>Allocation, distribution, or coordination of work</td>
<td>All of the above</td>
<td>Identifying which agents can best perform regulatory functions, tasks or strategies</td>
</tr>
<tr>
<td>Worker Competencies Analysis (WCA)</td>
<td>Human cognitive capabilities and limitations</td>
<td>Skills, rules, and knowledge taxonomy</td>
<td>Identifying competencies required of all roles in regulatory systems</td>
</tr>
</tbody>
</table>

CWA has previously been applied in a wide range of domains including transport (e.g. Cornelissen, Salmon, McClure, & Stanton, 2013; Salmon et al., 2016b), military (e.g. Jenkins, Stanton, Salmon, Walker, & Young, 2008a; McIlroy & Stanton, 2011; Stanton & Bessell, 2014; Stanton & McIlroy, 2012), process control (e.g. Jamieson, Miller, Ho, & Vicente, 2007), and social networking (e.g. Euerby & Burns, 2012). In particular, as noted above, CWA has been shown to support STS system design (e.g. Ahlstrom, 2005; Jenkins, Stanton, Walker, Salmon, & Young, 2008b; Naikar, Pearce, Drumm, & Sanderson, 2003; Read, Salmon, & Lenné, 2016; Read et al., 2015; Read, Salmon, Lenné, & Stanton, 2016; Watson & Sanderson, 2007).

Work Domain Analysis (WDA) WDA (Naikar, 2013; Vicente, 1999) is the analysis method primarily used throughout this thesis. The first phase of CWA, WDA uses an ecological approach to work analysis and, as its foundational phase, confers this
Chapter 4

approach upon the rest of the CWA framework. This means that WDA is used to identify and depict the affordances and constraints that exist to allow and limit agent behaviour in the system. These affordances and constraints, along with links between them, represent the ‘ecology’ within which system agents can act. The primary tool used to elicit and represent this ecology is the abstraction hierarchy (AH).

The AH models constraints as nodes in what is usually a 5-level hierarchy of abstraction (the CWA framework and its phases are flexible, allowing for different numbers of AH levels if the analysis requires it). The least abstract entities in the system are shown as nodes at the lowest level, commonly labelled as Physical Objects. The second lowest level shows processes that emerge from objects shown at the lowest level. Entities shown at this level are commonly labelled as Object-related Processes. In the level above object-related processes, purpose-related functions are shown. These are the general functions required for a system’s purposes to be achieved. Above the purpose-related functions are shown the set of values and priority measures that both modulate and can be used to measure the achievement of the systems functional purposes. The functional purposes of the system are modelled as nodes at the top layer of the AH. Just as entities represented at the lowest level of the AH are held to be the least abstract or most tangible system entities, those at the top level are held to be the most abstract constraints in the system.

The AH supports WDA by illustrating several key features of the functional structure of STS. One system feature illustrated by the AH is the means-ends links between entities at adjacent levels in the model. A link upward from any node to a node in the level above represents a relationship wherein the lower-level node is the means for achieving the higher-level node. Conversely, the higher-level node is the end toward which the lower-level node is directed. For example, in an AH representing an automobile (Figure 4.1), the physical object ‘brakes’ may be linked to an object-related process in the level above, ‘stopping’. The process, ‘stopping’, may be linked upward to a purpose-related function, ‘speed control’. In this example, brakes are the means by which stopping is achieved. Stopping is both the end for which brakes have been included in the system and a means by which speed control may be achieved. These
means-ends relationships can be characterised by ‘how?’ and ‘why?’ questions. How is stopping achieved? Brakes. Why is stopping included in the system? Speed control. Figure 4.1 shows an example of a simplified AH for a car, with labels overlaid at the right to indicate means-ends links.

![Simplified abstraction hierarchy for a car](image)

**Figure 4.1. Simplified abstraction hierarchy for a car (adapted from Bessell et al., 2007).**

**Control Task Analysis (ConTA)**

Control Task Analysis (ConTA) models tasks that must be undertaken in order to fulfil the functions or processes identified in WDA. Typically, the ConTA phase is undertaken using either the decision ladder method (DL; Rasmussen, 1976) or the Contextual Activity Template (CAT; Naikar, Moylan, & Pearce, 2006). The CAT is used to model when and where functions and processes are currently performed, and when and where they could potentially be performed. The output is a table that shows the situations, within that STS, in which activities are typically performed or where they could be performed to serve each function or process. For each cell in the CAT that indicates that an activity is or could be performed, a decision ladder (see below) can be constructed to show the typical set of cognitive states, processes and trajectories that
are involved in the performance of that activity. ConTA shows what needs to be done without specifying how. ConTA was used in this thesis only to support the case for modification of the AH, discussed in Chapter Ten. However, ConTA could be used in regulatory analysis and design to identify tasks required to communicate and assure regulatory compliance.

![Figure 4.2](image-url)  
*Figure 4.2. Example information contextual activity template, output of Control Task Analysis (adapted from Bessell et al., 2007).*

**Decision Ladders (DL)**

Decision Ladders (DL) model alternating cognitive states and cognitive processes in decision making, allowing analysts to describe possible cognitive trajectories associated with tasks. They can be applied both to activities represented in ConTA contextual activity templates and to strategies in StrA information flow diagrams. A DL template including labels for each of the progressive cognitive states and processes is shown in Figure 4.3. While DLs, like ConTA, were only used in this thesis to support the case for methodological modification proposed in Chapter Ten, they too could be usefully deployed for full analysis and design of regulatory systems. This could include applications to help design optimal strategies for task performance or to support the introduction of artificial decision-making technology in regulatory systems.
Figure 4.3. Decision ladder template (adapted from Bessell et al., 2007).

Strategies Analysis (StrA)

Strategies Analysis (StrA) is used to model multiple possible sequences of actions that can be performed in order to complete each of the tasks identified in the previous phase (ConTA). The aim is to show the different ways in which functions and processes can be achieved. Strategy options are typically shown in an Information flow map (Jenkins et al., 2008b). An example information flow diagram is presented in Figure 4.4. Like ConTA and DLs, StrA was not applied in this thesis to regulatory system analysis or design but was used in Chapter Ten to support the case for adaptation of the AH. As
will be seen, all phases of the CWA framework could be applied to regulatory system evaluation and design.

Figure 4.4 Example information flow diagram, output of Strategies analysis (adapted from Bessell et al., 2007).

*Strategies Analysis Diagram (SAD)*

The Strategies Analysis Diagram (SAD) was developed by Cornellisen, Salmon, Jenkins, and Lenné (2013) to augment and combine WDA and StrA. SAD supports the construction of natural language sentences that can describe available strategies for action within the system. It does this by adding a layer of verbs below the objects level of the AH one of which can then be used in combination with entity descriptions from the levels above to create sentences that describe strategies. For example, using the car example, the verbs ‘turn’, ‘press’, and ‘release’ could be added below the objects shown in the AH in Figure 4.1. This would allow the construction of sentences describing strategies such as ‘Turn the steering wheel to cause steering, maintaining safe directional control to achieve vehicle mobility’.

As with the previous three methods, SAD is used in Chapter Ten to support the case study analysis which argues for the inclusion of a new category of entities in WDA abstraction hierarchies.
**Design methods**

*Cognitive Work Analysis Design Toolkit (CWA-DT)*

While the CWA framework provides useful tools for the analysis and evaluation of a progressive set of STS features, its support for system design is limited. Therefore, a method that can translate analyses into design concepts and requirements was needed. The Cognitive Work Analysis Design Toolkit (CWA-DT; Read et al., 2018) was developed to address this gap. The CWA-DT is a suite of guidelines and tools that supports the application of CWA to design. It includes 11 stages. It was selected for this thesis to help translate LOA regulatory system analyses into design concepts and requirements. The CWA-DT is an intentionally flexible framework. Components can be selected and applied based on the needs of analysis (Read et al., 2018). As will be seen in Chapters Seven and Eight, a set of components from the CWA-DT were selected to suit the aims of this thesis: namely, to address research questions posed in Chapter One.
Figure 4.5. The Cognitive Work Analysis Design Toolkit (CWA-DT; adapted from Read et al., 2018).
All but the last four stages of the toolkit were used to guide the analysis and design process described in Chapters Seven and Eight. While the planning and evaluation processes were undertaken by the author, specific tools from the ‘Insights’ and ‘Concept design’ stages were used to support the engagement of SME knowledge described in Chapters Seven and Eight. These included the use of ‘Scenario features’, ‘Leverage points’, ‘Pain points’ and ‘Design solutions’ in the study described in Chapter Seven. ‘Assumption crushing’, ‘Impossible challenge exercise’, ‘Rapid prototyping’, ‘Design concept template’, and ‘Design concept shortlist’ were used in support of the study described in Chapter Eight.

Figure 4.6 shows the chapters of this thesis in which each of the analysis and design methods were used.

Data collection methods

Interviews

Semi-structured interviews were used to collect data for the first of two studies that supported the analysis of the Victorian LOA regulatory environment, described in Chapter Seven. This mode of data collection was chosen because it was important both to gain a sense of how the system was perceived by those whose work was the target...
of regulation, and to gain a picture of what LOA regulatory mechanisms existed in order to guide a subsequent document review. A set of prompting questions (see Table 4.3) guides interviewees to provide data that will help both to populate a WDA AH and guide analysts to source documents. The flexibility of an open approach encourages the provision of rich contextual information and potential links to further data sources.

Table 4.3. Questions for the semi-structured interviews, described in Chapter Seven.

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<th>Interview questions</th>
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<tr>
<td>What regulations, standards or guidelines apply to the provision of led outdoor activities in Victoria?</td>
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<td>What is the purpose or purposes of these regulations, standards or guidelines?</td>
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<td>In what way do these regulations, standards or guidelines influence your decision making and actions when managing, supervising or leading led outdoor activities?</td>
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<tr>
<td>Do you believe that these regulations, standards or guidelines are effective in achieving their purposes?</td>
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<td>Do you believe that these regulations, standards or guidelines are efficient in achieving their purposes?</td>
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<td>How could these regulations, standards or guidelines be made more effective?</td>
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<td>How could these regulations, standards or guidelines be made more efficient?</td>
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**Workshop**

A workshop was conducted to elicit the views of representatives of agencies that administer LOA regulatory instruments in Victoria. The workshop, described in Chapter Eight, was structured in accordance with guidance provided in the CWA-DT and elements of the World Café method (World Café, 2019). This mode of data collection was chosen in accordance with guidelines from the CWA-DT. It allowed people with a stake in different parts of an interconnected system to share a common picture of the system, brainstorm with each other, and collaboratively generate design concepts.
These were then used in accord with CWA-DT guidelines to develop a formative AH of the modified system. This was in turn used to generate specific design recommendations.

**Document review**

For all of the regulatory mechanisms and systems analysed in the course of this research, reviews of documentation associated with each system provided rich data on purposes, values, functions, processes, and objects associated with each system. This data was used to populate initial versions of each AH which were then subject to multiple iterations of SME review and modification.

**Summary**

The methods selected to support the research described in this thesis represent a set of systems-based tools and data collection methods with the capability of supporting analysis and design of complex, adaptive STS. As shown in Chapter Three, despite regulatory systems being identified as exhibiting these characteristics (e.g. Corbett, 2017) such methods have not previously been applied to this domain. WDA provides a holistic model of the functional structure of the system, showing systems properties at several levels of abstraction. Along with the means-ends links between them, this allows analysts to discern the extent to which the system may be functionally capable of achieving its purposes. The CWA-DT supports a collaborative design process which offers the possibility of domain stakeholders and SMEs contributing to the design or reform of the system. Semi-structured interviews and workshops allow for both guided and open responses to prompts by analysts, thereby supporting a rich, informed contribution to both the analysis and design processes.

While the success of the methods described in this chapter has previously been demonstrated in application to aspects of work within STS and to whole work systems, it has not previously been applied exclusively to the regulatory level of a work domain. The following chapter describes the first such application.
Part 2. Regulatory system analysis
Chapter 5 – Application of Work Domain Analysis to Led Outdoor Activity Regulation

Introduction

Chapter Three described why systems based HFE methods are appropriate tools for the analysis and design of LOA work systems. In Chapter Four, WDA was identified as a suitable method for describing and analysing the structure of a regulatory system. The present chapter describes the findings from a study that was undertaken to test that proposition. The study involved applying WDA to describe and analyse a recently developed LOA regulatory system, the New Zealand Adventure Activity Regulations (NZAAR). The NZAAR constitutes a regulatory system for LOAs that was developed and introduced in 2011 following a series of critical and fatal incidents in the New Zealand LOA domain. At the time of this study, the NZAAR had not been subject to any formal analysis in terms of its structure and likely effectiveness.

The aim of the study was to test the utility of WDA as a means of analysing regulatory systems by applying it to the NZAAR (see Research Question 2, in Chapter One). The criteria for success was whether the method could produce a model of the functional structure of the system that showed key strengths and weaknesses, as verified by high-level subject matter experts (SMEs). This analysis included iterative review of the system model by 2 HFE SMEs who between them have authored 50 papers on CWA, and one of whom has authored over 20 papers on LOA. Importantly, all iterations of the model in its development were reviewed by a high-level SME who was closely involved in the development of the NZAAR and a related ISO standard. Further details of the credentials and identity of this SME have been excluded from this manuscript at the request of the SME. In the process of this analysis, the possibility of a novel construct, the cognitive object, was identified. While this entity is noted in the course of Chapter Five, a full exploration of the concept is included in Chapter Ten.
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Declaration for Thesis Chapter 5

Declaration by candidate

In the case of Chapter Five, the nature and extent of my contribution to the work was the following:

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<th>Nature of contribution</th>
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<tr>
<td>Primary author. Conceived the study design, determined the methodology and criteria, conducted literature search and analysis of results. Conducted initial drafting of paper and subsequent editing.</td>
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The following co-authors contributed to the work:

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<th>Name</th>
<th>Nature of contribution</th>
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<tr>
<td>Natassia Goode</td>
<td>Refinement of AH; feedback on coding; guidance on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
<tr>
<td>Gemma J. M. Read</td>
<td>Guidance on application of model and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
<tr>
<td>Paul M. Salmon</td>
<td>Guidance on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
</tbody>
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The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate’s and co-authors’ contribution to this work.

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Sociotechnical systems as a framework for regulatory system design and evaluation: Using Work Domain Analysis to examine a new regulatory system

Tony Carden*, Natassia Goode, Gemma J.M. Read, Paul M. Salmon
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Abstract
Like most work systems, the domain of adventure activities has seen a series of serious incidents and subsequent calls to improve regulation. Safety regulation systems aim to promote safety and reduce accidents. However, there is scant evidence they have led to improved safety outcomes. In fact, there is some evidence that the poor integration of regulatory system components has led to adverse safety outcomes in some contexts. Despite this, there is an absence of methods for evaluating regulatory and compliance systems. This article argues that sociotechnical systems theory and methods provide a suitable framework for evaluating regulatory systems. This is demonstrated through an analysis of a recently introduced set of adventure activity regulations. Work Domain Analysis (WDA) was used to describe the regulatory system in terms of its functional purposes, values and priority measures, purpose-related functions, object-related processes and cognitive objects. This allowed judgment to be made on the nature of the new regulatory system and on the constraints that may impact its efficacy following implementation. Importantly, the analysis suggests that the new system’s functional purpose of ensuring safe activities is not fully supported in terms of the functions and objects available to fulfill them. Potential improvements to the design of the system are discussed along with the implications for regulatory system design and evaluation across the safety critical domains generally.

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1. Introduction

Adventure activities provide a wide range of benefits to a wide range of people in a wide range of settings (e.g., Dickson et al., 2008). From iconic individual pursuits like surfing, through the familiar rite of passage of school and holiday camps, to the more targeted and deliberate applications of Bush Adventure Therapy and Corporate Outdoor Training, adventure activities are central features of pursuits that are familiar to people in affluent societies around the world. While the motivations and goals of participation in adventure activities are diverse, a feature they tend to share—and indeed the basis of much of their value—is that they pose a risk of harm to participants. In adventure recreation, engaging with risk is a key motivation for participation and provides participants with a sense of autonomy and enjoyment (Lynch and Dibben, 2016). In outdoor education and adventure therapy, participant perception of risk is used as a means of facilitating learning and developmental aims (Mortlock, 1994; Russell, 2001).

When people depend on the support of a leader to undertake adventure activities, there is generally an expectation on their part and under the law that they can depend on the activity provider to mitigate the risk of serious harm that might result from participation. Regulatory systems have been developed in many jurisdictions to encourage, specify or mandate the deployment of policies, procedures and practices that adventure activity providers should comply with in order to minimise the risk of serious harm to participants (e.g., Ministry of Business Innovation and Employment, 2010a). Regulation has been identified as a key contributory factor in a number of critical incidents in adventure activities. For example, in his report on an inquest into the deaths of five people during white water rafting activities over a period of five years, a Queensland (a
state in Australia) Coroner was critical both of weaknesses in the prevailing regulatory environment and of previous efforts to reform it (Coroners Court of Queensland, 2012). Similarly, in a 2014 report on the inquest into the death of a twelve-year-old student during a swimming activity on a school camp, a Victorian Coroner commented on the lack of awareness of the existing regulatory system among organisers and supervisors of the activity. He also noted several ways in which compliance with the guidance provided by that regulatory system may have prevented the student’s death. Three of the six recommendations of that report are directed toward extending regulatory compliance (Coroners Court of Victoria, 2014). Finally, a New Zealand Coroner conducted an investigation into the deaths of six school students and their teacher during a canyoning activity at Mangatepopo Gorge, Tongariro on the 18th of April 2008. He recommended that Government consider the introduction of licensing for adventure activity operators to ensure compliance with minimum safety standards. The Coroner commented on a number of failures of the safety accreditation system which may have contributed to this incident (Coroners Court of Victoria, 2010).

Although promising initiatives are now underway to collect comprehensive data on incident and accident rates (Salmon et al., 2016a), previous efforts to gather data have produced insufficient evidence to draw conclusions about the effectiveness of regulation (e.g., Bentley et al., 2001). Indeed, there is currently no formal approach for assessing the quality or effectiveness of regulatory systems in led outdoor activities. This article argues that sociotechnical systems (STS) theory provides a suitable framework with which to assess, and indeed design, regulatory systems.

Accordingly, we present a sociotechnical systems-based analysis of an activity regulatory system, the New Zealand Adventure Activity Regulations (NZAAR). The analysis aimed to identify aspects of the NZAAR that could be used to inform the design of regulatory systems in other jurisdictions and to identify issues and lessons learned to inform future reform of adventure activity regulation. A secondary aim of the analysis was to test the extent to which cognitive work analysis, a sociotechnical systems theory-based approach, provided a useful methodology for examining regulatory systems.

1.1. Regulatory systems

While regulation of private activity to protect the public interest has always been a central activity of government, regulatory reform in recent decades has seen a range of ‘governance’ based strategies employed to spread regulatory functions beyond the direct control of government and its agencies (Baldwin et al., 2012). The impetus and direction for this reform has been influenced by economic theories which call for the minimisation of government interference in economic activity in order to optimise economic (and thereby social) outcomes (e.g., Hayek, 2012). Social and political pressure for governments to ‘deregulate’ is periodically punctuated by social demands and political responses to increase elements of regulation in response to disasters (e.g., Haines, 2011). The interplay between these forces results in a continuing cycle of reform wherein regulatory measures are progressively removed to meet aspirations to deregulate and then added in reaction to crisis.

Governance based strategies have emerged along a spectrum beyond the traditional ‘command and control’ (CAC) regulation imposed by government. These strategies include elements of self-regulation and rely on regulated organisations, industries or third parties to provide some or all of the functions of regulatory principles, rules and compliance mechanisms. Various combinations between punitive and accommodative compliance strategies and between prescriptive rules and outcome-based principles have been applied across this spectrum (Black, 2012).

A number of ‘co-regulatory’ approaches that combine elements of government and self-regulation are prominent in the literature. They have been applied in the regulatory domains of financial, social (including health and safety) and environmental regulation around the world (Baldwin et al., 2012). These include ‘enrolment’ regulation, where third parties such as unions or industry associations take on some or all of the tasks of the regulator, with government providing some level of support. ‘Meta-regulation’ is another co-regulatory approach, in which a government agency enforces an organisation or industry’s internally developed regulatory rules or principles (Parker, 2002).

Another strategic approach to regulation is known as risk-based or risk management regulation. This approach seeks to identify and focus regulatory efforts at the highest risk areas of a regulated activity (Black, 2012). Advice to designers and reformers of regulatory systems is offered both by governments (e.g., Commonwealth of Australia, 2014) and scholars of regulation (e.g., Black, 2012; Cunningham, 2011; Haines, 2009; Saurwein, 2011). In particular, these sources offer guidance on principles for identifying choices from among regulatory approaches depending on the nature and context of the activity being regulated (Saurwein, 2011); on cost benefit analysis (Cunningham, 2011); and on identifying regulatory impacts (Commonwealth of Australia, 2014). Whilst this guidance appears to be firmly grounded in economic theory (Hayek, 2012) and deterrence theory (Pearce and Tombs, 1990), and has indeed informed and shaped important regulatory reforms, it’s focus appears mainly to be at the level of principles rather than having any predictive value.

1.2. The NZAAR

In June 2010, the New Zealand Government’s Department of Labour released its findings following a comprehensive review of risk management and safety in the adventure and outdoor commercial sectors in New Zealand (Ministry of Business Innovation and Employment, 2010c). The review had been launched at the request of New Zealand’s Prime Minister following 31 reported fatalities and 297 reported workplace serious harm injuries in the sector in the space of five years (Ministry of Business Innovation and Employment, 2010b; 2010c). The findings noted the rapid recent growth of the sector in New Zealand, its significance to the national economy and some shortfalls in the prevailing system of self-regulation (Ministry of Business Innovation and Employment, 2010c). The implementation of a mandatory system of audit and registration was recommended for commercial providers of adventure activities deemed to exceed a defined threshold of inherent risk (New Zealand Parliament, 2013). The New Zealand Adventure Activity Regulations (NZAAR) were developed as a result of those recommendations.

A range of agencies were engaged to facilitate the implementation of the NZAAR. With government support, the Tourism Industry Association NZ (TIA) in partnership with Outdoors NZ developed the SupportAdventure website to provide guidance material for adventure activity providers (OutdoorsNZ & Tourism Industry Association NZ, 2014b). In order to comply with the NZAAR, commercial providers of adventure activities (as defined in the regulations (New Zealand Parliament, 2013)) must pass regular audits by certified auditors in order to attain certification of compliance and thereby become registered. WorkSafe NZ established an audit standard and oversight of auditor accreditation and operator certification (OutdoorsNZ & Tourism Industry Association NZ, 2014c). Several auditing organisations were accredited to undertake assessments of operator compliance.
The theoretical framework evident in the regulatory literature seems to rely heavily on retrospective analysis of regulatory systems to shape system reform. Comprehensive methods for assessing the structural integrity of regulatory systems in their formative stage appear to be lacking. By analysing weaknesses of existing and previous regulatory approaches, new combinations or variations are proposed that may reduce the weaknesses identified potentially resulting in a novel approach to reform. Furthermore, opportunities for system improvements rely on adverse events to occur in regulated domains. This may take an amount of time to occur. The detail of how to structure specific regulatory systems is left to system designers, reformers and technical experts who may benefit from development of specific methods to assist design.

Although reference is made in the literature to ‘systems-based’ regulation (Cunningham, 2011), this appears to refer to a co-regulatory strategy relying on application of management systems within an organisation to regulate risk, and not to any systems theoretic approach to regulation. This study will test whether an approach based on STS theory may have some potential to contribute to the theory and practice of regulation.

1.3. NZAAR evaluation

The following analysis does not aim to evaluate the effectiveness of the NZAAR in terms of its outcomes. Rather, it aims to examine the structure of the system in a way that will identify its affordances and constraints, that is, its capabilities and limitations. It is hoped that this approach of analysing the structural foundations of the regulatory system may represent a novel and useful way of evaluating regulatory systems that may offer a theoretically founded means of evolution beyond the reactive cycle described by Haines (2009), of the prevailing process-based analysis methods which cyclically add new, specifically focused, regulatory measures in reaction to incidents, and then remove regulatory measures in reaction to commercial, economic or political pressures.

2. Method

2.1. A systems approach to regulatory assessment

STS theory contends that systems of work are complex, dynamic systems consisting of social sub systems composed of people, interacting with technical systems composed of techniques and technologies, interacting together in relationship with an external environment (Trist, 1981). Regulatory systems comprise social and technical elements as most other systems. They involve the interaction of actors such as auditors, registrars and the regulated parties (i.e. operators). Regulation is supported by technologies and artefacts such as legislation, audit systems and databases and regulation occurs in a wider political, economic and social context.

STS theory has conceptual roots in General Systems Theory which includes the powerful observation that each element of a system can itself be viewed as a system in its own right (Skyttner, 2005). For example, a human can be considered as an element of a social system but each individual human can be viewed as a system composed of elements which are organs. Each organ itself in turn can be considered as a system in its own right composed of cells. The terms system, sub system, and macro system (alternatively, supra system or super system) can be used to denote respectively the system under examination, the components of that system and the system of which that system is a component. In the present context, it is possible to view the regulatory system as a system that is composed of sub systems and that is a sub system of the work domain it is intended to regulate. It is precisely these features that create possibilities for design and evaluation with STS methods. One such method is Work Domain Analysis (WDA; Naikar, 2013), the first phase of Cognitive Work Analysis (Naikar, 2013; Vicente, 1999).

2.2. Work Domain Analysis

WDA is the first phase of Cognitive Work Analysis (CWA), CWA provides a framework for analysing systems of work (Vicente, 1999). As the first of five analysis phases, WDA involves building a functional representation of the system under analysis. The output, an Abstraction Hierarchy (AH) (Jenkins et al., 2009) describes the system across five levels:

1. Functional purposes: the reasons why the system exists (e.g. a regulatory system may exist to control safety within the regulated domain)
2. Values and priority measures: ways of guiding or measuring the achievement of the functional purposes (e.g. to determine whether a regulatory system is working one measure may be the proportion of accredited bodies within a given system)
3. Purpose-related functions: the things the system needs to do to achieve its purposes (e.g. one function of a regulatory system may be registration of compliant organisations)
4. Object-related processes: things that the objects can do to support the functions (e.g. a physical process that supports registration may be compliance checking)
5. Cognitive and physical objects: the actual objects deployed to serve the system's purposes (e.g. a physical object that supports compliance checking may be a compliance auditing app for a mobile device)

The nodes at each of these levels are then linked together based on means-ends relationships. For each node in the system, an upward link shows why that node is in the system and a downward link shows how it is supported in the system. For example, the link upwards from ‘Auditing’ in the AH shown in Fig. 1, connects to ‘Number of Compliant Operators’, which is an end served by ‘Auditing’. The upward link shows why ‘Auditing’ exists in the system. The links downwards from ‘Auditing’ connect to the nodes ‘Evidence that an Operator is Compliant’ and ‘Compliance checks’. These two nodes represent two means within this system of supporting ‘Auditing’. The downward links shows how Auditing is supported in the system.

The resulting map allows examination of the functional structure of a system. What are its purposes? What are the objects, processes and functions deployed to serve those purposes? What are the measures that can indicate the effectiveness of the system? Are there gaps? Are the functions required to achieve the purposes supported by appropriate objects and processes? Based on this utility WDA has previously been used for many purposes, including to design new training systems (Naikar and Sanderson, 1999), energy efficiency (Hillard and Jamieson, 2015), system modelling (Hadjukiewicz et al., 2001), system analysis (Stanton and Bessell, 2014), system design (e.g. Bisantz et al., 2003), automation (Mazaeva and Bisantz, 2007) system evaluation (Salmon et al., 2016b) and hazard identification (Walker et al., 2014). However, WDA does not appear yet to have been applied to regulation. In the regulatory system context, it is these authors opinion that the AH can be used for both regulatory system design and evaluation. In the case of existing regulatory systems, it can be used to identify strengths (e.g. redundancy in the system), weaknesses (e.g. where particular purposes or functions are not supported) and the extent to which the regulatory system is capable of achieving its purposes. This potentially provides a powerful tool for assessing and refining
regulatory systems throughout their design and implementation.

2.3. Data sources

This analysis included examination of publicly available documentation from the New Zealand Ministry of Business, Innovation and Employment (formerly the Department of Labour) (Ministry of Business Innovation and Employment, 2012), Worksafe New Zealand (e.g. WorkSafe NZ, 2014a) and the Support Adventure website (OutdoorsNZ & Tourism Industry Association NZ, 2014a). The documents were reviewed and the text coded firstly to each level of the AH and secondly aggregated into nodes, using the qualitative analysis software Nvivo 10. A total of 431 phrases or sentences were coded from 28 documents. For example, the following sentence concluded the Minister of Labour’s Foreword in the document. ‘Health and Safety in Employment (Adventure Activities) Regulations 2011: Guidance for Operators’ (Ministry of Business Innovation and Employment, 2012): “These new requirements will give foreign visitors and New Zealanders confidence that appropriate steps have been taken to keep them safe and ensure our adventure industry’s excellent international reputation is maintained.” From that sentence, the nodes ‘Safety’ and ‘Industry and National Reputation’ were coded and placed at the functional purpose level.

Based on this an NZAAR regulatory system AH was constructed. The draft AH was reviewed by two of this paper’s co-authors, who are analysts with significant experience in applying WDA to describe and analyse complex systems. Paul Salmon has 11 years’ experience in applying the method, with 25 peer reviewed journal articles describing applications of the method and 4 books relating to the method. Gemma Read has 5 years’ experience in applying the method and is an author of 7 peer reviewed journal articles describing applications of the method.

The AH was discussed in detail with a subject matter expert with significant experience as a leader, a manager and an auditor in the led outdoor activity domain in New Zealand. Differences of opinion on exclusions and inclusions of nodes and links were discussed and modifications made until consensus was reached.

3. Results

Fig. 2 shows the AH representing the functional structure of the NZAAR.

3.1. Functional purposes

The analysis identified five core functional purposes of the NZAAR. These are to ensure safe adventure activities, legislative compliance, consumer confidence, industry and national reputation, and economic sustainability (Ministry of Business Innovation and Employment, 2012).

Whilst safe activities might seem to be the primary functional purpose of the NZAAR, the legal imperatives built into the system mean that legislative compliance is the functional purpose most strongly and directly supported by this system. The key actors working within the system, adventure activity operators, auditors (certification bodies) and registrars, all carry legal compliance obligations (WorkSafe NZ, 2014a).

Consumer confidence, industry and national reputation, and economic sustainability could be viewed as external to the regulatory system. They have been included here as functional purposes because of their prominence in the documents describing the NZAAR system and the processes that developed it. For example:

Consumer confidence: “These new requirements will give foreign visitors and New Zealanders confidence that appropriate steps have been taken to keep them safe and ensure our adventure industry’s excellent international reputation is maintained.” (Minister of Labour, Hon Kate Wilkinson in Ministry of Business
Fig. 2. Abstraction Hierarchy of the New Zealand adventure Activity regulations.
Innovation and Employment, 2012, p. 5).

Industry and national reputation: “Such accidents could result in harm to individuals and their families as well as damage to New Zealand’s reputation as an international visitor destination.” (Ministry of Business Innovation and Employment, 2010c, p. 6).

Economic sustainability: “Our number one goal is to protect everyone who undertakes an adventure activity, but also to protect the international reputation of New Zealand’s tourism sector — which earns about $10 billion of exports annually.” (Worksafe NZ, 2014b).

3.2. Values and priority measures

The values and priority measures level describes the measures that can be taken to assess the extent to which the system is achieving its functional purposes. It is important to note here that values and priorities were only included in the AH if mechanisms were found to be deployed within the NZAAR system to support their measurement. For example, whilst consumer confidence is a functional purpose of the regulatory system, there are currently no formal processes in place to measure consumer confidence and so the level of consumer confidence was not included as a value and priority measure. Based on this, the analysis identified only two values and priority measures supported by the system: accident rate and registered operators.

The number of registered operators is measured directly by the registration process with that number recorded in the operator register database and published on the WorkSafe NZ website (Worksafe NZ, 2014c). The accident rate appears to be measured only indirectly via operator self-reporting to auditors and via Worksafe New Zealand’s requirement for mandatory reporting of ‘notifiable events’. This data does not seem to be systematically collected or correlated with participation data. It is not made directly available to operators or the public through the objects and processes of the NZAAR system. Although WorkSafe NZ publish data by industry sector on workplace fatalities and serious harm incidents (Worksafe NZ, 2016b), no indication is provided of which of these incidents occurred during activities mandated under the NZAAR.

The absence of values and priority measures to support the purposes of consumer confidence, industry and national reputation, and economic sustainability, and the lack of a direct way of measuring the accident rate are key findings of this analysis. They raise an important question of the extent to which a regulatory system should incorporate or provide the measures required to understand whether it is achieving its own purposes.

3.3. Purpose-related functions

Nine purpose-related functions were identified. These main functions are shown in the AH from left to right in order of their relevance to the three main classes of actor in this system: operators, auditors and registrars. Industry education and operator safety management are the functions of most relevance to adventure activity operators. Verifcation, surveillance, auditing and certification are of most relevance to certification bodies and the auditors they employ. Maintenance of the operator register, enforcement of the regulations and ensuring that auditors meet requirements are the primary concerns of registrars.

The range of functions deployed in this system, as illustrated in the AH, indicate a regulatory system that is capable of supporting operators to understand and meet their compliance obligations. The functions include a mix of accommodative (e.g. industry education) and deterrent (e.g. enforcement) strategies to support compliance. The prominent role of the auditing function, as indicated by the high number of links to supporting processes below it, indicates a strong reliance on this function.

Industry education and facilitation of operator safety management appear well supported. This is indicated by the numerous links to processes and objects below them in the AH. The content of these components also links them strongly to the actual measure of registered operators and the potential measure of accident rate in the tier above. In contrast, the surveillance and enforcement functions each appear to be supported by only one object-related process. This suggests that these functions are not heavily relied upon to ensure compliance.

Links to processes and objects at the lower two levels that are shared by the auditing and operator safety management functions suggest a high level of consistency between compliance requirements and resources to support operator understanding of those requirements. These shared links also suggest the system’s capacity for multiple strategies to ensure operator understanding of compliance obligations: auditor conversations with operators can check, reinforce or if necessary replicate strategies that support operator understanding of safety management requirements. This apparent redundancy may be a useful strength of the system, given the likely diversity of experience of operators. More experienced operators who are familiar with compliance requirements are likely to require less support than those less experienced.

3.4. Object-related processes

A number of object-related processes were identified in this analysis. Some (including, provision of guidance about compliance; provision of guidance for standard operating procedures; documentation of standard operating procedures requirements) are mainly relevant to adventure activity operators. Others (including demonstration of compliance; compliance assessment; support for audit process and enforcement of compliance) are processes that support the work of auditors. A third group of processes are those relied on by registrars (registration; inter-audit compliance checks; storage of info on registered operators and official recognition of auditors).

The number of objects that support the process of providing guidance about compliance shows that operator education is a strong feature of this system. Whilst this process could be seen to include several other processes, such as provision of guidance for SOP’s or safety management system requirements, these latter processes are quite specific. The former includes a lot of important generic information. Examples of this can be found at the SupportAdventure.co.nz website (OutdoorsNZ & Tourism Industry Association NZ, 2014a) and in the New Zealand Department of Labour’s ‘Guidance for Operators’ (Ministry of Business Innovation and Employment, 2012).

An interesting observation of this analysis is that some of the objects that afford processes in this system are in fact independent of a particular physical object. For example, the object ‘activity guidelines’ is a set of ideas which supports four object-related processes. It is not any property of the physical container of those ideas (e.g. words on paper or an electronic file) that affords or constrains any of the four processes they support. It is the properties of the ideas themselves. To distinguish these objects from physical objects such as ‘internet connected device’, the relevant affordances and constraints of which arise from the physical object itself, the term ‘cognitive objects’ is introduced below.

3.5. Cognitive and physical objects

A range of objects were found including operator guidance resources (Support Adventure NZ website; WorkSafe NZ website and
Dept. Labour operator guides), standards and guidelines (activity guidelines; adventure activity regulations; auditing standards; auditor surveillance procedures and auditor accreditation requirements), compliance evidence (instructor training and qualification records; activity equipment; activity environment; standard operating procedures; drug and alcohol policy; safety management plan and safety management system); audit consequences (safety audit certification and safety management system), audit compliance evidence (instructor training and quality assurance, auditor surveillance procedures and auditor accreditation records); and audit software applications (internet; internet connected device; audit software app and operator register).

Like the processes they support, some of the physical and cognitive objects in this system are of most significance to one class of actor. Others are useful to more than one class of actor. For example, the Support Adventure and WorkSafe websites provide advice and guidance to adventure activity operators. Safety audit certificates are significant to the operators who receive them, the auditors who issue them and the registrars who require them to authorise operator registration. The NZ Safety Audit Standard and audit software applications are of primary relevance to auditors. Safety management plans and a drug and alcohol policy are used by auditors in assessing compliance, and by operators in achieving it.

The detail of some important constraints on actors in the system is not shown in the AH but becomes clear upon examination of some of these objects. For example, the definition of what kind of Operator is bound by these regulations in contained within the Adventure Activity Regulations (New Zealand Parliament, 2013).

4. Discussion

The aim of this article was to attempt to understand whether a sociotechnical systems analysis method, WDA, could provide useful insights into the structural strengths and weaknesses of a regulatory system. This discussion now focuses on three central questions: first, the strengths and weaknesses found in the NZAAR system; second, the extent to which STS and CWA provide useful frameworks for examining regulatory systems, and third, the implications for regulatory system design and evaluation.

4.1. Regulatory system strengths and weaknesses

The analysis shows that the NZAAR regulatory system is a complex one comprising multiple objects, a range of core functions and ultimately attempting to fulfil different and potentially competing purposes. The following discussion outlines some of the key issues identified and attempts to draw out some key lessons that could inform development of adventure activity regulatory systems elsewhere.

On the basis of this analysis, several key strengths of the NZAAR are apparent. Industry education appears strongly supported by the information made available online and by the auditing process. Verification that operators are meeting requirements is provided by the processes that support the auditing function. An accreditation body (JAS-ANZ) checks that auditors comply with standards. Regular checking by skilled auditors allows operators flexibility in adapting principles-based safety requirements to suit their specific context. A key feature of the NZAAR is that compliance is compulsory for mandated operators. According to scholars of regulation, this means it is more likely to be effective (Gunningham, 2011; Haines, 2009; Hale et al., 2015; Parker, 2002).

Several potential weaknesses are also evident. The absence of any direct function to measure accident rates means that safe activities can only be measured by indirect means. Although audits require operators to demonstrate capacity to manage and review incidents (Ministry of Business Innovation and Employment, 2013, p.15) there is no audit requirement to report them. While Worksafe NZ requires reporting of ‘notifiable incidents’ (Worksafe NZ, 2016c), only aggregate fatality data is published (Worksafe NZ, 2016a) and this does not specify whether or not the adventure activity was led. Neither of these processes for recording incidents and accidents have any capacity for comparison with participation data nor therefore to calculate incident and accident rates. In turn, this means it may not be possible to understand whether the system is achieving one of its core functions: it may be worth exploring options for deploying automated systems to support functions like verification of compliance, surveillance and accreditation. Such systems might also incorporate support for functions to measure and aggregate participation and incident data. If reports on this data were published, for example via the SupportAdventure and WorkSafe NZ websites, the system purposes of consumer confidence, and industry and national reputation could be more directly supported.

4.2. Do STS and CWA provide useful frameworks for examining regulatory systems?

As Eason (2014) pointed out, STS theory has traditionally been applied to analysis and design of whole work systems, new technologies and control interfaces. The present study has shown that WDA can be successfully applied to a wider array of sociotechnical sub systems, including those at the more abstract upper system levels.

Whilst the regulation of adventure activities constitutes a subsystem of the domain of adventure activity safety (Salmon et al., 2014), it must be remembered that this regulatory subsystem can be viewed and analysed as a sociotechnical system in its own right. Regulation is a sociotechnical system in which system effectiveness is critically dependent upon both its social and technological aspects. In this case the technical subsystem primarily consists of the regulatory rules or principles. The social subsystem includes regulators and compliance auditors, both of whom must have a good understanding both of the activity being regulated and of the purpose and requirements of the regulation (Black, 2012).

In order to apply Work Domain Analysis to this regulatory system, the WDA standard model was adapted by reframing the bottom level of the Abstraction Hierarchy as describing both cognitive and physical objects. Cognitive objects in this context are tools for thinking, such as guidelines and standards. While they may be encoded on physical media, this analysis shows that some objects
which afford processes described in the AH level above, are indeed intangible thinking tools: cognitive objects. When it is considered that cognitive objects of different scales can be seen to include ideas, beliefs, ideologies and belief systems, it is evident that this adaptation suggests a new array of potential applications for STS analysis and design methods.

These insights, revealed by the application of Work Domain Analysis, show that the method can offer useful guidance to reformers and designers of regulatory systems for adventure activity safety and other domains.

4.3. Implications for regulatory system design and evaluation

This analysis shows the NZAAR to be an example of the co-regulatory approach described above. It can be viewed as an example of a meta-regulatory system – regulated self-regulation. Government mandates registration of operators. Operators develop their own context-appropriate safety management plans with support of resources provided by the NZAAR system and with the assistance of their own technical experts. Independent organisations are enrolled to undertake certification audits. Certification requires operators to demonstrate that their safety management plans and operations conform to the principles-based requirements of the Safety Audit Standard for Adventure Activities (Ministry of Business Innovation and Employment, 2013).

This demonstration of WDA as a method for analysing the structural features, strengths and weaknesses of a regulatory system provides confidence for further development. Recent innovation in the application of Cognitive Work Analysis (the STS framework of which WDA is the first phase) as a design methodology (Read et al., 2016), could offer further potential benefit by applying WDA to the design of regulatory systems.

In her description of the challenges faced by Australian regulators of maritime and air transport security following the September 11th, 2001 terrorist attacks in the U.S., Haines identifies a key difficulty for any designer or reformer of regulation: how can you know if the regulatory system is effective? Even in the light of an adverse event in the regulated domain, reliable methods for attributing causality to regulatory failure (or success) are lacking (Haines, 2011).

WDA can extend existing approaches to regulatory reform by offering a method of analysis and design that is not dependent on system performance data but instead constructs a map of the functional structure of the system. This allows system capability and structural integrity to be gauged ahead of time, potentially an advantage over methods that rely on trial and error to test the effectiveness of system reforms or designs. WDA and the broader CWA framework offer strategies which could augment current approaches to regulatory reform by providing tools to develop the detail of not only system structure, but organisational, work task and decision making dimensions of regulatory systems.

By providing a means to analyse and design the functional structure of a regulatory system, WDA may provide a means of breaking out of the regulatory reform cycle described above where forces of deregulation and reaction to crises keep regulatory systems in flux. A regulatory system designed in a collaborative, transparent and comprehensive manner in accord with WDA design principles may prove more resilient and less subject to the aforementioned flux.

4.4. Study limitations

The limitations of this study should be acknowledged and its observations and conclusions viewed with commensurate caution. The analysis presented here was of one regulatory system only and one that was quite recently developed. The publicly available documentation accessed as source material to develop the AH presented here, whilst providing a good picture of the structure of the NZAAR, provided limited information on the process used to develop the system following the release of the findings of the Government Review (Ministry of Business Innovation and Employment, 2010c). Although one subject matter expert with exceptional credentials and familiarity with the NZAAR reviewed the AH, future analyses would benefit from review by a greater number of SMEs who represent a wider range of system actors. WDA provides an actor and event independent model of the functional structure of a system. As such, it offers a picture of what the structure of a system allows and what it does not. It cannot in isolation predict with any accuracy how a system will perform in action. Therefore, in order to evaluate the effect of system changes suggested by this analysis, further study is required. This could include analysis with other CWA methods (Vicente, 1999) or pilot testing of recommended system reforms. Given that a number of objects in this system are cognitive rather than physical objects, detailed analysis of the structure of such objects and their effectiveness in reliably affording cognitive processes would be valuable.

5. Conclusion

This study demonstrates that WDA can be successfully used to analyse the structural integrity of a regulatory system. In the absence of adequate performance data, by assessing the system’s structural ability to serve its purpose, this method may represent a novel and effective way of evaluating regulatory systems. Whilst only one regulatory system was assessed, the conclusions suggest that important elements for regulatory system design include complementary purposes and the provision of appropriate systems for measuring the extent to which the functional purposes are being achieved. By offering a method of modelling connections between purposes, measures, functions processes and objects, WDA may be an economical way to optimise and integrate regulatory system design and reform proposals prior to deployment.

Future research collaboration is recommended between scholars of regulation and of STS to enhance the capacity of theory to support practice in the design and evaluation of regulatory systems across a range of domains.

This study provides a basis for future research on the relationship between regulation and practice in the adventure activity domain and beyond. The detailed understanding of the functional structure of the regulatory system offered here could combine with results of WDA of other sub systems within the same work domain. The resulting data could underpin a meso-ergonomic analysis (Karkh et al., 2014) which could produce useful guidance on improved design of sub systems and their inter-relationship.

In modifying a construct within the method in order to successfully apply WDA to a novel sub system type, this study offers encouragement to apply STS methods to a broader array of work domain sub systems and a broader array sociotechnical systems, including those beyond the domains of work.

References

Summary
The aim of this chapter was to test the utility of WDA as a means of analysing regulatory systems by applying it to the NZAAR. The criteria for success was whether the method could produce a model of the functional structure of the system showing key strengths and weaknesses, as verified by high-level subject matter experts (SMEs).

The findings demonstrate that WDA was able to support the description and analysis of the NZAAR. The analysis identified several key strengths and weaknesses of the system and these were verified by high-level LOA SMEs. Means-ends links offered an indication of the extent to which various system functions and purposes are supported. For example, the value & priority measure Registered Operators is supported by all identified purpose-related functions. These functions are, in turn, supported by many linked processes and objects. This allows Registered Operators to serve as a measure of the achievement of the functional purposes to which it is linked. Several further benefits of the analysis were found. First, the WDA AH model allowed analysts to see which system objects were of relevance to various system actors. Second, the AH model supported a higher-level functional view of the system by grouping system elements according to high-level functions such as duty-holder education, compliance, auditing, and registration. This has the useful effect of clarifying which aspects of the system are relevant to which types of user. For example, duty holders will mostly interact with the educative and compliance aspects, auditors with the auditing and registration components, and system administrators with the whole system. If one or another of these areas is over or under supported, it is likely to be easily evident in the AH. Furthermore, the groupings allow analysts to compare system elements with basic control functions such as sensors, actuators, and rules (see Chapter One). Finally, in the process of analysis, it was found that some system objects did not require actors to interact with a physical object but rather, with an idea or concept. This represents an important extension of the AH method, with previous applications not specifically incorporating such ‘cognitive objects’. The nature and validity of these cognitive objects will be considered further in Chapter Ten.
Having initially confirmed the utility of WDA on this recently developed, large and comprehensive LOA regulatory system, the next task was to test the versatility of the application of WDA to regulatory system analysis. While the NZAAR is a self-contained, Government-led regulatory system that has recently been designed and implemented, many other kinds of regulatory system and mechanism exist. Unlike the NZAAR, many of them have evolved over time, are combined with other regulatory mechanisms, and may have been designed and implemented by any of a range of organisations (see Chapter Two). For WDA to be most useful as a means of evaluating LOA or other regulatory systems, it must be capable of application to the types of systems that commonly exist. The following chapter describes the application of WDA to a smaller LOA regulatory mechanism that, unlike the NZAAR, was developed by an industry association. The Victorian Adventure Activity Standards (AAS) were initially developed in response to rising insurance costs for LOA providers. These standards were introduced in Victoria in 2004 and eventually became the basis for similar standards in other Australian states. The AAS in each state were eventually linked to other regulatory mechanisms within those jurisdictions. The capacity of WDA to produce a useful analysis of such a system is an important step toward determining the overall strength of WDA as a method for regulatory system evaluation.
Chapter 6 – Setting the standard: Evaluation of a regulatory mechanism with WDA

Introduction

Study context

Chapter Five described the application of WDA to the NZAAR, a full-scale regulatory system in New Zealand that includes duty-holder education, auditing, registration, and compliance enforcement. That application of WDA produced a rich set of analytic outputs including identification of some strengths and weaknesses of the system. However, if it is to be considered as a reliable method for the analysis of a wide range of regulatory systems, it is necessary to test the application of WDA to a diverse set of system types. This chapter describes a study in which WDA was applied to a regulatory system of smaller-scale than the NZAAR, the Victorian Adventure Activity Standards (AAS; Outdoors Victoria, 2015a).

The NZAAR, described in Chapter Five, included objects intended to support a wide array of compliance-related activity by a range of actors. These actors included operators, auditors, and administrators of a registration scheme. In contrast, the Victorian AAS is more narrowly focused on providing guidance to operators for good LOA practice. It includes no auditing or registration functions. It therefore constitutes a regulatory mechanism at a different scale and degree of complexity from the NZAAR. The application of WDA to the Victorian AAS represents in initial test of the versatility of WDA when applied to regulatory systems of different scope. The aim of this study was to evaluate the capacity of the Victorian AAS to achieve its purposes and identify any structural weaknesses that may prevent it from doing so.

Following the collapse in 2001 of major Australian insurance company, HIH Insurance (Haines, 2011, p. 125), steep rises in the price of liability insurance threatened the viability of LOA providers (Barnett, 2002). In response, with the support of Government, the Outdoor Recreation Centre (ORC) in Victoria, Australia, began working to develop a code of practice, in the form of a set of standards, for LOA providers. The purposes of these standards were to promote safety for participants
and providers, provide protection for providers against legal liability claims, and provide assistance in obtaining insurance cover (Outdoors Victoria, 2006, p. 4). Activity standards drafts were developed by volunteer committees, comprising experts in the relevant activity. The drafts were published for public comment. After a few iterations of this process, the Victorian AAS were launched in 2004, with an initial set of standards published as downloadable documents on the ORC website.

From 2005, projects commenced in other Australian States to develop similar standards (ORIC, 2014; Outdoors WA, 2014; QORF, 2014; Recreation SA, 2016; Tasmanian Government, 2009). These development projects were supported by various private organisations and government agencies. Following concerns and criticisms raised within the LOA sector, a project commenced in 2015 to reform and integrate all of Australia’s state-based AAS into a single national set of AAS (Outdoors Victoria, 2015b). While this process aimed to improve efficiency by eliminating interstate duplication and reducing unnecessary duplication within standards by consolidating common content into a single location, the development process was similar to that used in the development of the original Victorian AAS, relying exclusively on expert opinion (Outdoors Victoria, 2015c). No systematic evaluation of the AAS has been undertaken to support the current reform process. A close examination of the functional structure of the Victorian AAS therefore appears warranted.

Recent research has applied systems thinking methods to understand the LOA work system (Salmon, Williamson, Lenné, Mitsopoulos-Rubens, & Rudin-Brown, 2010; Salmon et al., 2012; Salmon et al., 2017a). Subsequent research has confirmed the validity of systems theory for describing and understanding LOA work systems (Carden, Goode, & Salmon, 2017a) and for analysing the functional structure of LOA regulatory systems (Carden, Goode, Read, & Salmon, 2019). This study is a continuation of this research, outlining the findings from a study in which Work Domain Analysis (WDA) was used to describe and analyse the Victorian AAS. The aim was to evaluate the capacity of the Victorian AAS to achieve its purposes and identify
any structural weaknesses that may prevent it from doing so. This could inform the development of the new Australian standard.

Methodology

As described in section 2.2 of Chapter Five, WDA is the first phase of Cognitive Work Analysis (CWA), a framework of STS methods designed to analyse the cognitive tasks associated with systems of work (Vicente, 1999). WDA involves building a functional representation of the system under analysis. The output, an Abstraction Hierarchy (AH; Jenkins, Stanton, Salmon, & Walker, 2009), describes the system across five levels:

1. Functional purposes
2. Values and priority measures
3. Purpose-related functions
4. Object-related processes
5. Cognitive and physical objects

The nodes at each of these levels are then linked together based on means-ends relationships. The example in Figure 1 shows a limited AH for a vehicle. The functional purpose of the vehicle is transportation. The engine and brakes afford the processes of propulsion and stopping. These processes in turn afford the system function of responsive vehicle mobility. This function is guided and could be measured by safety and speed, affording the system purpose of transportation. For any node in the AH, a link to a node above indicates why the first node exists in the system. A link to a node below indicates how the first node is supported in the system.
Figure 6.1. An example Abstraction Hierarchy (adapted from Carden et al., 2019).

Although the application of WDA to regulatory systems is novel, it has been used in many areas for many purposes ranging from training system design (Naikar & Sanderson, 1999), to hazard identification (Walker, Cooper, Thompson, & Jenkins, 2014).

Data analysis

The WDA was conducted based on a review of documentation describing the history and purpose of the AAS, collected from the AAS pages on the Outdoors Victoria website (http://outdoorsvictoria.org.au/). Naikar’s (2005) 9-step method was used to construct an AH model of the system (see Table 6.1). The documentation was analysed using the qualitative analysis software Nvivo 10. This involved coding the text to each level of the AH, and then aggregating the specific quotes into higher level themes. For example, “minimize the risk of injury” (Outdoors Victoria, 2006, p. 6) was coded to the AH level ‘Functional Purpose’, and then aggregated into the theme “Safety”. Based on this, a Victorian AAS AH was constructed. The draft AH was reviewed by two analysts with significant experience in applying WDA to describe and analyse complex systems and two subject matter experts in the development and application of the Victorian
AAS. Differences of opinion on exclusions and inclusions of nodes and links were discussed and modifications made until consensus was reached. Nodes that were clearly identified as present in the system were outlined in black. Nodes that were required for system integrity but not identified as clearly present were outlined in grey.

Means-ends links that were clearly identified as present were shown as solid lines while those identified as weak were shown as dotted lines.
Table 6.1. Naikar’s (2005) 9-step method applied to the Victorian AAS.

<table>
<thead>
<tr>
<th>WDA method steps</th>
<th>How this step was addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish the purpose of the WDA</td>
<td>To identify strengths, weaknesses, and limitations of the Victorian AAS; to test WDA on a smaller regulatory mechanism</td>
</tr>
<tr>
<td>Identify project constraints</td>
<td>Limited time; limited access to SMEs</td>
</tr>
<tr>
<td>Determine boundaries of analysis</td>
<td>This analysis considered only the Victorian AAS system itself. It did not extend to operational systems of LOA providers, nor did it consider other regulatory or legal mechanisms</td>
</tr>
<tr>
<td>Identify the nature of constraints</td>
<td>The constraints on actors in this system were mostly intentional rather than causal (Naikar 2013)</td>
</tr>
<tr>
<td>Identify information sources</td>
<td>Information sources for this analysis consisted of publicly available, online documentation</td>
</tr>
<tr>
<td>Construct AH</td>
<td>Based on description of system at official AAS website</td>
</tr>
<tr>
<td>Refine analysis</td>
<td>Based on supporting and ancillary documentation</td>
</tr>
<tr>
<td>SME review</td>
<td>2 LOA SMEs and 2 HFE SMEs confirmed the accuracy of the included nodes and means-ends links</td>
</tr>
<tr>
<td>Validate</td>
<td>The AH was considered by the LOA SMEs in relation to known work scenarios and confirmed as accurate</td>
</tr>
</tbody>
</table>
Results

Figure 6.2 shows the AH representing the functional structure of the Victorian AAS.

![Abstraction Hierarchy of the Victorian AAS](image)

**Figure 6.2. Abstraction Hierarchy of the Victorian AAS. Values and priority measures are outlined in grey and links to functions below are dotted to show that no mechanisms exist within the system to measure these criteria.**

**Functional purposes**

The seven functional purposes identified in the resource documentation relate to the interests of multiple stakeholders. While activity providers (denoted in the AH as ‘operators’) are served by assistance in obtaining insurance and protection from legal liability, other purposes serve the interests of consumers and Government. It appears that the purpose of safety, toward which much of the content of each activity standard is directed, is closely related to the purposes of obtaining insurance and protection from liability.
Values and priority measures

The values and priority measures shown represent the criteria identified during this analysis as necessary for the purpose-related functions to achieve the functional purposes. While some of the elements at this level could perhaps, in principle, adequately serve as unmeasured values to guide achievement of system purposes, most would work best as tangible measures.

Such measures would need to be well supported by functions, processes and objects (e.g. accident rate could be measured by an incident reporting system to guide system performance and reform). The values and priority measures identified in this system are shown in grey and the means-ends links to the functions below are shown as dotted lines. This is to illustrate that the values and potential priority measures are only indirectly and weakly supported by the objects deployed within the system and by the processes and functions that they afford.

Purpose-related functions

The sole purpose-related function afforded directly by this system appears to be the provision of management guidance for LOA providers. Assuming that providers follow this guidance, the additional functions of safety and environmental management become system functions. However, the absence of a compliance checking function places the control of these two critical system functions beyond the scope of this system.

Object-related processes

One of the four object-related processes, documentation of standard operating procedures, is supported by objects within this system, but dependent also on the action of providers. The other three processes identified are afforded directly by objects deployed within the AAS system.

Physical and cognitive objects

In addition to the static objects deployed by the AAS system, and the technical objects required to access them, this level also shows the dynamic objects, AAS updates and
review committee. These two objects indicate a capacity for the AAS to adapt to changes in the operating environment.

Discussion
The aim of this chapter was to use WDA to describe and analyse the Victorian AAS. The analysis provides several important findings regarding the functional structure of the Victorian AAS. These are discussed below.

High number of functional purposes
There appear to be a high number of functional purposes in relation to the number of objects deployed in their service. It could be argued that this is an effect of the incorrect identification of elements such as ‘confidence in operators’ and ‘consistency of quality’ at the functional purposes level rather than the values and priority measures level. However, it was clear from source documents that these were indeed primary purposes of the system for some stakeholders (e.g. Barnett, 2002). Further consultation among stakeholders could support a reduction of the number and variety of aspirations for this system that could in turn enhance its functional integrity.

Mechanisms to measure performance are absent.
While the Victorian AAS is not, and does not purport to be, a complete regulatory system for LOA safety, the absence of the capacity to objectively measure its performance is a significant weakness. Each of the seven identified functional purposes and the associated six values and priority measures could in theory be associated with a performance measure, however, currently they are not. For example, as shown in figure 6.2, a mechanism to measure the accident rate could provide a measure for at least four of the identified functional purposes.

No compliance checking mechanism
Not only is there no mechanism to measure the effectiveness of the AAS, no compliance mechanism was identified by the analysis. While even the best regulatory systems have limitations on the capacity for compliance auditing and enforcement (Coglianese, 2015), the existence of a compliance mechanism can be sufficient to
influence the majority to comply without regulator intervention (Gunningham, 2016). As a corollary, it is not possible to determine whether LOA providers are complying with the AAS.

**Objects are insufficient to support stated purposes**

There are limited processes and objects that afford each function. For example, in the absence of compliance auditing, performance measurement or any means of communicating with all stakeholders, the mere existence of activity standards seems insufficient to reliably achieve any of the identified system purposes. This suggests that either the system purposes or the objects deployed to serve them, need to be changed.

**Regulatory capture or creep?**

The earliest references confine the original purposes of the AAS to improving safety, limiting operator liability and reducing insurance costs (Adventure Victoria, 2006; Barnett, 2002; Outdoors Victoria, 2006). The purpose of limiting environmental impacts only appears in later references (Outdoors Victoria, 2015c). No rationale for this extension is provided. It is therefore reasonable to ask whether this development was a case of ‘regulatory capture’ (Carrigan & Coglianese, 2016), whereby a regulating body expands its reach beyond its original remit, in order to serve special interests. Alternatively, it may be concluded that this is a case of regulatory creep. This is defined by the UK Government’s Better Regulation Taskforce as “the process by which regulation is developed or enforced in a less than transparent fashion...” (Better Regulation Task Force, 2004).

**Self-regulation**

As the AAS documentation makes clear, it is a set of voluntary standards. As such, it is a system intended to support self-regulation. However, other entities have mandated requirements for LOAs in Victoria. These include government agencies such as the Department of Education and Training, WorkSafe Victoria, Parks Victoria and Maritime Safety Victoria. In addition, two independent accreditation systems for outdoor activity providers are available, each of which requires that accredited organisations comply
with the AAS. The design of the AAS as a system of voluntary self-regulation may not support its adoption by other agencies as a set of mandated rules. Although the AAS documents themselves emphasise that compliance with them is optional, for providers bound by other agencies’ adoption of the AAS, this is not the case. Furthermore, regulatory literature suggests that systems of industry self-regulation are rarely effective because of inherent economic incentives to minimise, manipulate or ignore requirements (e.g. Gunningham, 2011a).

**Practical implications for enhancing the AAS**

This analysis suggests that there is a gap between the stated purposes of the Victorian AAS and the objects deployed to serve them. Therefore, a better alignment could be achieved by modifying the purposes or the objects deployed to serve them. The current purposes of the AAS could be better served with the introduction of a compliance checking function and mechanisms to measure values and priority measures. For example, an incident reporting system could be introduced in order to measure the accident rate.

**Limitations of this research**

While this analysis provides a view of the functional structure of the Victorian AAS, illustrating structural weaknesses in the system’s capacity to fulfil its purposes, analysis of how the system is used in practice would provide a more complete evaluation.

**Conclusions**

This case study has allowed the identification of several ways in which the structure of the Victorian AAS limits its capacity to achieve its purposes. The absence of compliance checking and performance measurement casts doubt upon the system’s value. It is the hope of the author that this illustration will support the efforts of those charged with implementing improvements to Adventure Activity Standards and other regulatory systems, by providing guidance for system reform. A final conclusion is that this study has provided further evidence that WDA provides a usable and useful approach for evaluating regulatory systems. Further applications are encouraged, as are design
applications in which methods such as CWA (Vicente, 1999) and the CWA-DT (Read et al., 2018) are used to design new or modified regulatory systems.
Chapter 7 – Analysing the Victorian LOA Regulatory Environment

Introduction

The studies described in Chapters Four and Five produced accurate models of the functional structure of the system under scrutiny as confirmed by SMEs. Furthermore, both studies produced important insights into structural features of the system that could be modified to improve system integrity. These results showed that WDA can be successfully applied to regulatory systems of different size and scope. As discussed in Chapter Two, a wide variety of configurations of regulatory systems exist. These include regulatory regimes composed of multiple mechanisms administered by different organisations. These polycentric regulatory systems have evolved as deregulatory trends have distributed regulation beyond government and into a range of industry and community organisations (Black, 2001).

The next step in the quest to determine whether LOA safety regulatory systems can be usefully modelled and analysed with WDA (Research Question 2, described in Chapter One), is to apply the method to a more complex regulatory configuration. If successful, this would provide a new way to analyse these whole systems composed of multiple regulatory mechanisms, all of which may have similar or overlapping aims, but which have evolved or been designed separately from each other. This would allow stakeholders to, perhaps for the first time, recognise opportunities to reconcile redundancies and gaps across whole regulatory systems and thereby find ways to improve system efficiency and effectiveness. This chapter describes the first of a pair of linked studies of the Victorian LOA regulatory system. This first study engaged key system stakeholders in semi-structured interviews to identify structural features and weaknesses in the system.

LOA as a Polycentric Regulatory Environment

As noted in previous chapters, LOAs include a range of adventurous activities in which people engage for recreational, educational and therapeutic purposes. However, many of these activities are risky. LOA providers are, therefore, obliged to manage those risk in order to keep participants safe so far as is reasonably practicable (e.g.
State of Victoria, 2004). An array of Government and non-Government agencies administer regulatory instruments that seek to influence the safe management of led outdoor activities in Victoria. The resulting system constitutes a polycentric regulatory environment (Black, 2008), as described in Chapter Two. Confusion among activity providers about their regulatory obligations to manage safety has been implicated in Australian led outdoor activity fatalities (e.g. Priestly, 2012; White, 2014). Reducing this confusion through improved system design has the potential to improve safety.

**Regulatory System Evaluation and Design**

Contemporary methods for evaluating regulatory systems tend to focus on how well a regulatory system is administered, the extent of compliance with its requirements, or outcome performance (for which reliable causal evidence is difficult to attain; Coglianese, 2012, pp. 14-15). Chapters Five and Six described studies in which LOA regulatory systems were evaluated using documentary sources to populate WDA AHs. The study of the regulatory environment described in this chapter was focused on both user perceptions and designer intentions. Therefore, interviews with providers were used along with document searches to both build a picture of the designed structure of the system, and how it was perceived by key user groups.

The primary aims of this study were to develop an accurate model of the functional structure of the Victorian LOA regulatory environment and a set of design insights generated by key users of that system. A secondary aim was to use those insights as inputs for a design workshop which will be described in Chapter Eight. The successful modelling of a polycentric regulatory regime with WDA would further confirm both the utility and versatility of WDA in its application to regulatory systems. Furthermore, this study, in tandem with the study described in Chapter Eight, will address the research question posed in Chapter One: Can CWA be used to design regulatory systems?
Method

Study design

Data collection for this study was undertaken using semi-structured interviews with subject matter experts (SMEs) from three different levels of the work system, across seven different LOA provider organisation types. Each of the organisation types are subject to several different regulatory instruments. 20 SMEs were sought who had significant experience in either management, supervisory, or operational roles. A representative distribution of SMEs was sought across the three organisational levels and the seven organisation types. Table 7.1 shows the organisation types that were targeted for SME recruitment. The target number of 20 interviewees was determined based on three considerations. First, time, resources, and SME availability were limited. Second, guided by the findings of Guest, Bunce, and Johnson (2006) on data saturation and variability in interview-based thematic analysis, a minimum number of 12 interviewees was set. Interview participants were recruited by sending email invitations to approximately 50 candidates in organisations of the types listed in Table 7.1.

Table 7.1. LOA Organisation Types

<table>
<thead>
<tr>
<th>LOA Organisation types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity provider</td>
</tr>
<tr>
<td>Residential activity provider</td>
</tr>
<tr>
<td>Residential program provider</td>
</tr>
<tr>
<td>State School</td>
</tr>
<tr>
<td>Independent or Catholic School</td>
</tr>
<tr>
<td>TAFE &amp; University</td>
</tr>
<tr>
<td>Outdoor recreation club</td>
</tr>
</tbody>
</table>
Interviews were conducted either at the SMEs workplace or at an alternative location nominated by the SME. All interviews were guided by the prompting questions listed in Table 7.2 and all were audio recorded.

**Table 7.2. Semi-structured interview questions.**

<table>
<thead>
<tr>
<th>Interview questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What regulations, standards or guidelines apply to the provision of led outdoor activities in Victoria?</td>
</tr>
<tr>
<td>What is the purpose or purposes of these regulations, standards or guidelines?</td>
</tr>
<tr>
<td>In what way do these regulations, standards or guidelines influence your decision making and actions when managing, supervising or leading led outdoor activities?</td>
</tr>
<tr>
<td>Do you believe that these regulations, standards or guidelines are effective in achieving their purposes?</td>
</tr>
<tr>
<td>Do you believe that these regulations, standards or guidelines are efficient in achieving their purposes?</td>
</tr>
<tr>
<td>How could these regulations, standards or guidelines be made more effective?</td>
</tr>
<tr>
<td>How could these regulations, standards or guidelines be made more efficient?</td>
</tr>
</tbody>
</table>

**Analysis methods**

Two CWA-based methods were used in this study. First, WDA (Naikar, 2013; Vicente, 1999) was used as a partial guide to the coding of interview data, and to populate an AH model of system structure along with features identified for reform. In contrast to its application to the stand-alone regulatory systems described in Chapters Five and Six, this study will use WDA and the AH to form a composite model of several regulatory mechanisms. Second, to identify system features for reform, elements of the CWA-DT (Read et al., 2018) were used (see Figure 7.1). As described in Chapter Four, Stages 2 to 7 of the CWA-DT (Analysis planning, Analysis process & outputs, Requirements specification, Design planning, Concept design, and High level evaluation & design
concepts selection) were used to guide both the overall analysis process described in this chapter and the design process described in Chapter Eight. The following specific ‘Insight’ tools from Stage 3 were used in the present study: ‘Scenario features’, ‘Leverage points’, ‘Pain points’ and ‘Design solutions’ (see Figure 7.1).
Figure 7.1. The Cognitive Work Analysis Design Toolkit (CWA-DT; adapted from Read et al. 2018) with the Stage 3 tools that were used in this study highlighted.
Materials

Materials used in support of this study included a Phillips DVT 1400 Voice Recorder, the set of interview questions shown in Table 7.2, the websites for each of the main regulatory mechanisms identified in interviews, and the venues for each interview, each of which was nominated by the interviewee. In addition, the qualitative analysis software Nvivo 11 was used to thematically code interview data.

Procedure

SME participants were recruited, and provided with a Research Project Information Sheet, describing the nature and purpose of the interviews. Appointments were then made, and interviews conducted across a period of five months from July 2017 to November 2017. In each interview, SMEs were reminded that their responses would be de-identified and were encouraged to speak freely. The prompting questions shown in table 7.2 were put to SMEs by the interview in the course of free-flowing conversation. With the permission of participants, all interviews were audio recorded. Audio recordings of the interviews were subsequently transcribed. The research methodology was approved by the Ethics Committee of the University of the Sunshine Coast.

Interviews and a document review were used to support the construction of a WDA abstraction hierarchy (AH), modelling the functional structure of the regulatory. The AH models system entities across a range of abstraction, with the least abstract entities (physical objects) shown at the lowest level and the most abstract entities (functional purposes) at the highest level. Object-related processes, purpose-related functions, and value and priority measures are shown at successive levels in between (see Fig. 1). Means-ends links between two entities at adjacent levels show that the upper entity is why the lower entity is in the system, and the lower entity is how the upper entity is achieved.
Data analysis

An initial review of interview transcripts identified key regulatory mechanisms that applied in the Victorian LOA domain. A document review was then conducted to identify the scope of application, purposes, and objects associates with each regulatory mechanism. Data from interview transcriptions and the document review were then thematically coded against a coding taxonomy based on WDA AH level descriptors (purposes, measures, functions, processes and objects) and CWA-DT insights (pain points, leverage points, and scenario features) using the qualitative analysis software Nvivo 11.

The coded data were then used to populate an AH and a Design Insights table. First, a WDA AH model was constructed using Naikar’s (2005) 9-step method, based on the coded interview data and the results of the document review. The resulting model was reviewed by 2 analysts with extensive experience in applying WDA to describe and analyse complex systems and by 2 LOA practitioners, each with over 10 years’ experience in the Victorian domain. Secondly, a Design Insights table was populated based on pain points, leverage points, and scenario features (Read et al. 2018). Insights were identified during the initial coding sweep of interview transcripts. A second coding sweep was undertaken to ensure all comments relevant to the final insights taxonomy were identified. Identified insights were recorded in an Insights Table (Read et al. 2018). The Insights Table was then reviewed by two HFE analysts, each with extensive experience in thematic coding.

Results

Interviews

Semi-structured interviews were conducted with fifteen SMEs who worked at three levels of the Victorian LOA work system: management, supervisory, and operational (levels based on Rasmussen’s (1997) Risk Management Framework). Interviewees were recruited from 7 distinct types of provider organization (see Table 7.3). The resultant sample (n = 15) represented a broad cross-section of actors constrained by the regulatory system. Interview duration ranged from 35 to 60 minutes.
Table 7.3. Interviewee job roles and organisation types.

<table>
<thead>
<tr>
<th>Organization type</th>
<th>System level *</th>
<th>Job role</th>
<th>Age</th>
<th>Years of experience in LOA provision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential activity provider</td>
<td>Management</td>
<td>Facility manager</td>
<td>&gt;40</td>
<td>10-20</td>
</tr>
<tr>
<td></td>
<td>Supervisory/operational</td>
<td>Program designer/Staff supervisor</td>
<td>25-30</td>
<td>5-10</td>
</tr>
<tr>
<td>Residential program provider</td>
<td>Management</td>
<td>Facility manager</td>
<td>&gt;40</td>
<td>10-20</td>
</tr>
<tr>
<td></td>
<td>Management</td>
<td>Owner</td>
<td>&gt;40</td>
<td>10-20</td>
</tr>
<tr>
<td></td>
<td>Supervisory</td>
<td>Program manager</td>
<td>25-30</td>
<td>5-10</td>
</tr>
<tr>
<td></td>
<td>Operational</td>
<td>Activity instructor</td>
<td>20-25</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Large non-profit activity provider</td>
<td>Management</td>
<td>CEO</td>
<td>&gt;40</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td>Management/supervisory</td>
<td>Head of Department</td>
<td>&gt;40</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td>Management/supervisory/operational</td>
<td>Head of Department</td>
<td>&gt;40</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Small commercial activity provider</td>
<td>Management/supervisory/operational</td>
<td>Business owner</td>
<td>&gt;40</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Organization type</td>
<td>Level of responsibility</td>
<td>Training role</td>
<td>Approx duration (years)</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td>Community recreation club</td>
<td>Supervisory/operational</td>
<td>Outdoor leader training instructor</td>
<td>&gt;40</td>
<td></td>
</tr>
<tr>
<td>Tertiary education course provider</td>
<td>Supervisory/operational</td>
<td>Outdoor leader training coordinator</td>
<td>&gt;40</td>
<td></td>
</tr>
<tr>
<td>Secondary school</td>
<td>Supervisory/operational</td>
<td>Outdoor program coordinator</td>
<td>&gt;40</td>
<td></td>
</tr>
</tbody>
</table>

*Based on Rasmussen’s (1997) Risk Management Framework*

Organization size varied from a small commercial provider with 2 full-time staff to a large non-profit activity provider with around 300 staff. Some interviewees held responsibilities at more than one system level. 8 held management responsibilities (including budgeting and statutory compliance), 9 held supervisory responsibilities (including staff supervision and program design), and 9 held operational responsibilities (including leading adventure activities). All were notionally subject to the intent of one or more regulatory instruments. The experience level of this group, as a whole, was very high in a domain with high levels of transience and staff turnover (Skills Hub, 2011, p. 8).

Interviews included questions designed to elicit perceptions of the structure of the regulatory environment and design insights in line with CWA-DT insight categories (see Table 7.3). Once interviews were complete and the audio recordings transcribed, the resulting raw interview data was coded according to the following procedure. An initial coding sweep identified regulatory mechanisms, along with some of their objects, functions, processes, measures, and purposes, and comments that may constitute design...
insights within any of the three CWA-DT insight categories, Pain points, Leverage points, or Scenario features. For example, the following comment from an interviewee identified 2 regulatory mechanisms, “...our core business is primary schools and school-based students. Often, we are balanced between the Department of Education guidelines and the AAS for activity standards”. In response to the question, “What would you say are just the very top-level purposes of the standards? What are they trying to influence?”, another SME’s response identified a functional purpose of one of the regulatory mechanisms, “Oh, safety is probably the key word”. The Pain point, ‘Lack of compliance checking’ was identified from several SME comments such as the one in the following exchange:

SME: [Some] operators probably tick the box without actually reading things and there’s no compliance checks. No one ever comes out and actually has a bit of a look and see what you’re doing.

Interviewer: Do you feel that’s a problem?

SME: I think it is.

The identification of specific design insights during the first coding sweep was progressive. Therefore, to ensure that comments from earlier transcripts of relevance to insights that were identified in later transcripts were not missed, a second, coding sweep was undertaken to ensure that all relevant comments were coded according to the complete insight taxonomy.

Once a core set of regulatory mechanisms was identified, websites associated with each of them were reviewed to identify purposes, measures, functions, processes, and objects associated with each. These aligned with SME perceptions, in particular, the perception common to all SMEs interviewed that the primary functional purpose of all of the regulatory mechanisms was safety.
Interview data identified 5 main regulatory mechanisms for LOAs in Victoria. They were the Victorian Adventure Activity Standards (AAS; Outdoors Victoria, 2015a), the Department of Education and Training’s Safety Guidelines for Education Outdoors (SGEO; Department of Education and Training, 2017), the Australian Tourism Accreditation Program’s Camp and Adventure Activity Accreditation Program (ATAP; ATAP, 2016), and Parks Victoria’s Tour Operators Licensing system (TOL; Parks Victoria, 2017). The fifth instrument was the reporting requirements of the Government work health and safety regulator, WorkSafe Victoria (WSV; 2018).

A review of web-based documentation associated with each of these regulatory mechanisms revealed the intended scope and purposes of each system. The AAS is a voluntary set of standards that describe how to safely conduct a range of adventure activities. The SGEO is a set of guidelines for Victorian Government schools that describe how to safely conduct a range of adventure activities, along with a mandatory approval process. ATAP is one of two national accreditation schemes available for LOA providers. Commercial LOA providers who operate on public land are required to hold a Tour Operators License.

The regulatory environment comprised of these instruments is represented in the AH shown in Figure 7.2. The document review revealed various objects and processes associated with each mechanism. While some mechanisms had several stated purposes, their one common purpose was safety. These system features were used to construct an AH in accordance with Naikar’s (2005) 9-step method.

Once all 5 regulatory mechanisms were represented together in the AH, the following structural problems became evident.

The AAS and SGEO provide specific advice on how to safely conduct a range of adventure activities. The SGEO includes guidelines for 21 activities. The AAS includes standards for...
15 activities that are included in the SGEO and 4 that are not. The content of the guidelines and standards for identical activities is similar but not identical. For example, some supervisory ratios for the same activity are different. Some provider organisations that are subject to both of these regulatory mechanisms. Which activity guidelines should they follow?

The AAS, SGEO, TOL, and ATAP websites each provide both general and specific advice on safety management. The content and emphasis of each of these sets of advice varies. Is any one of them definitive?

Both the ATAP accreditation and TOL licensing instruments rely heavily on periodic (once every 1, 3, 5, or 10 years) desktop audits. In neither of these systems are field audits mandatory. Audits appear not to be conducted in line with a recognised auditing standard. ATAP accreditation requires documentation of risk management plans. The TOL requires compliance with the AAS as a condition of licensing. However, no mechanism for regular checking of operational compliance appears to exist for either ATAP or TOL. Furthermore, the AAS were designed as a set of voluntary standards. This suggests the possibility that their content or structure may be unsuited to a mandated compliance requirement.

While compliance with the SGEO is required only for Government schools, a 2014 Coroner’s report on the death of a school student on camp (White, 2014) recommended that all Victorian schools should follow the SGEO.

In summary, the structural picture of the Victorian LOA regulatory environment suggests a high potential for confusion for some providers. For example, an organisation that provides LOA programs for both state school students and others, on both public and private land (many such organisations exist; see Skills Hub 2011) is bound by all 5 regulatory instruments. Moreover, weak compliance checking processes cast doubt on the system’s capacity to achieve its purposes.
The following section shows that the perceptions of LOA providers align with the systemic problems identified through WDA.
Figure 7.2. Abstraction Hierarchy representing the composite Victorian LOA regulatory environment.
Design Insights

Insights based on CWA-DT insight categories (Read et al. 2018, p.333) were coded from comments in interviews. They were ‘Leverage points’ (“Aspects within a system that, if changed in a small way, could produce larger changes across the system.”), ‘Pain points’ (“Problems or issues identified during the analysis.”), and ‘Scenario features’ (“rich contextual information about the domain being analysed”). Table 3 shows insight categories, insights, the number of references to each insight in interviews, and one example of the comments upon which each insight was based. These insights suggest the inadequacy of several nodes and links shown in the AH. Nodes most directly affected by insights are shown with grey background, with affected links shown as bold lines in Figure 7.3.

Table 7.4. System design insights.

<table>
<thead>
<tr>
<th>Insight category</th>
<th>Insight</th>
<th>References</th>
<th>Example quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain points</td>
<td>Financial cost</td>
<td>9</td>
<td>And I ... said, “That’s why our camp is a little bit more expensive, because you are, we are adhering to all those standards” and then they finally understood that.</td>
</tr>
<tr>
<td></td>
<td>Need for better updates</td>
<td>1</td>
<td>One of the things they do need to change is how they effectively communicate changes and upgrades and updates.</td>
</tr>
<tr>
<td></td>
<td>Lack of compliance checking</td>
<td>21</td>
<td>There’s no... there’s no inspection regime, there’s no accreditation that sits alongside it. So, anybody can ignore it or they can adopt it.</td>
</tr>
<tr>
<td></td>
<td>Compliance obligations unclear</td>
<td>12</td>
<td>Readability and usability. Things like do we use the word &quot;should&quot; or &quot;shall&quot; or &quot;must&quot;? Just tell</td>
</tr>
</tbody>
</table>
them what you want them to do and make it clear and concise.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System lacks credibility</td>
<td>6</td>
<td>What regulatory bodies are there really? They’re not really regulatory bodies. I mean you can’t really count on them.</td>
</tr>
<tr>
<td>System too complicated</td>
<td>34</td>
<td>I feel like there’s several benchmarks: it’s hard to say which one do you go with at times. It can be quite confusing.</td>
</tr>
<tr>
<td>Unsure if safety is improved</td>
<td>6</td>
<td>I know regulations and a lot of the paperwork we do here is for if something goes wrong, we’re covered. And that sometimes might come in conflict with actually keeping people safe.</td>
</tr>
<tr>
<td>Leverage points</td>
<td>2</td>
<td>I think there would be an advantage to have some outdoor people working for ...[the]...regulator coming out doing a bit of stuff.</td>
</tr>
<tr>
<td>Better use of information technology</td>
<td>7</td>
<td>They’re not using modern technologies like ... not that that is always the perfect way to manage things, but quite often the systems are fairly old.</td>
</tr>
<tr>
<td>Scenario features</td>
<td>6</td>
<td>Just whatever needs to happen to actually make these things happen and everyone stick to the same standards because you know as well as helping out with the safety aspect ... it also helps out with the commercial side of things where everyone has similar costings because no one can do it cheaper.</td>
</tr>
</tbody>
</table>
Each of the insights included in Table 7.4 is explained in more detail in the following sections.

**Pain points**

**Financial cost**
This pain point included concern about the cost of compliance with regulations, particularly in light of the prospect that competitors could offer lower prices as they were not compelled to comply. It was compounded by concern about the lack of clarity about compliance obligations resulting in money wasted on unnecessary compliance activities.

**Need for better updates**
Frustration at a lack of communication from regulatory mechanism administrators about system updates was expressed directly by one SME and indirectly by others.
Lack of compliance checking
Perhaps surprisingly, most SMEs expressed a feeling that the lack of compliance checking was a negative system feature. This was tied both to concerns about the consequent damage to a ‘level playing field’ due to non-compliant operators undercutting market prices, and to a desire for affirmation that their own compliance was satisfactory.

Compliance obligations unclear
This pain point was associated with several system features. They included uncertainty about which mechanism or combination of mechanisms applied to the SME’s organisation, poorly worded regulatory documents, and uncertainty about providers’ legal obligations in relation to compliance.

System lacks credibility
This pain point included perceptions that regulations were ineffective, that regulatory mechanism administrators had no real regulatory power, and that many LOA providers claimed to be aware of or compliant with standards but did not, in fact, take them seriously.

System too complicated
SMEs noted several factors that they felt made the overall regulatory system overly complicated. These included the multiplicity of benchmarks across the different regulatory mechanisms, contradictions between mechanisms, the various regimes of forms and paperwork, and the high volume of documentation.

Unsure if safety is improved
SME comments that were summarised in this pain point include, “What’s the purpose of them? I’ve got no idea”, “I don’t think that in reality any standards or regulations have much impact on us.”, and “I know regulations and a lot of the paperwork we do here is for if something goes wrong, we’re covered. And that sometimes might come in conflict with actually keeping people safe.”
Leverage points

Community of practice
This insight suggests that SMEs felt that the collective expertise of providers could be better utilised by those in charge of regulatory mechanisms to support regulatory compliance. This included suggestions of peer review of safety management practices and engagement of providers in regulatory review.

Better use of information technology
This leverage point suggested that understanding of and compliance with regulatory requirements could be improved through better use of information technology by administrators of the regulatory mechanisms. Comments supporting this leverage point included the observation that, “...quite often the systems are fairly old”.

Scenario features

Need for level playing field
Although similar to and overlapping with the pain point ‘Financial cost’, this scenario feature captured the idea, expressed in various ways by 6 SMEs that the regulatory regime had the potential to create a more level playing field in which providers could compete fairly. However, these comments included the condition that improved compliance checking would be required to achieve this.

Need for flexibility in standards
Many comments from SMEs emphasised a need for regulation to avoid being too specific. Examples were given of the dynamic variables that LOA providers must routinely adapt to and the caution that overly rigid or specific regulatory requirements could not account for this dynamism.

Guidance for recruitment & training
This scenario feature was based on the observation that the regulatory system provided guidance for staff training both in terms of the design and provision of instructor training courses and to guide employment policy and practice.
Regulations provide reassurance
This strongly supported design insight expressed the perceived positive value of the regulatory system in providing assurance or reassurance to both providers and their clients that LOA service provision was being conducted in an acceptably safe manner.

Discussion
This study aimed to develop a model of the functional structure of the Victorian LOA safety regulation system using WDA and to develop a set of design insights generated by key users of that system with a view to using the structural model and insights to inform a subsequent design process. In doing so, the application of WDA to a polycentric LOA regulatory system constituted a further test of the application of systems-based methods to regulatory systems.

By including the five main regulatory instruments at the physical objects level, the AH shown in Figure 7.2 affords a holistic view of the functional structure of the regulatory environment. Insights showed a strong sense among providers that the regulatory system is too complicated, that weak compliance checking was problematic, that compliance obligations were unclear, and that compliance standards should be flexible. Figure 7.3 combines the AH with the design insights. Highlighted nodes and links in the AH reflect several pain points and scenario features. Multiple guidance webpage objects make the compliance guidance process confusing and expensive. The duplication of activity standards objects confuses the processes of safety management system requirements and guidance for standard operating procedures. The functions of provider education, surveillance, and compliance enforcement are all compromised by weak support from processes indicated by bold links. These functional weaknesses, in turn compromise the capacity to measure and to achieve safety.

It is important to note that not all LOA providers are bound by all five regulatory instruments (shown in light-grey text, below the physical objects in Fig. 7.2). Only
Government schools are bound by the Department of Education and Training (DET) to follow the SGEO. The AAS are offered as voluntary standards. ATAP accreditation is not mandated for all LOA providers, however the SGEO requires Government schools only to use accredited external providers. The TOL is only required by commercial LOA providers to operate on public land but is conditional on compliance with the AAS. Interview data suggested that many provider types are bound by more than one regulatory instrument. Many, including the largest providers, are bound by all. To provide effective influence on safety for the full range of provider types, the instruments that compose the system must have the structural capacity to function alone or in combination with others.

Practical Implications
This study and its findings constitute a preliminary analysis of the Victorian LOA safety regulatory system. These findings indicate a need for structural reform of the system. The outputs of this study (the AH in Figure 7.3 and the design insights in Table 3) can support subsequent steps in a design process, which should include participation of regulatory agencies identified in this study. The shading of object nodes in Figure 7.3 indicates that they represent elements of the system that could be changed to address the design insights shown in Table 7.4. Shaded means-ends links indicate that these altered objects could affect system elements at higher levels of abstraction. Affected higher-level nodes are also shaded in Figure 7.3.
Figure 7.3. Abstraction Hierarchy showing the Victorian LOA regulatory environment with Design Insights.
Study Limitations

The limitations of this study should be acknowledged, and its observations and conclusions viewed with commensurate caution. The WDA represents only a preliminary analysis of the functional structure of the system. Furthermore, while design insights developed in this study were derived from a cross-section of provider types and job roles, the modest sample size may be limited in its representation of broader opinion. Further analysis, perhaps including the application of other CWA phases (Vicente, 1999) and CWA-DT tools (Read et al., 2018), is required to determine optimal strategies for practical system reform.

Conclusion

This analysis showed that the regulatory environment for LOA safety in Victoria consists of several loosely coupled instruments that are independently administered. The resulting system includes redundancies, gaps and contradictions which appear likely to limit achievement of the collective functional purpose of safety. The weakness and inconsistency of any compliance checking function and the absence of a safety evaluation function mean that the success or failure of the system is currently unknowable. The structural view of the system afforded by the WDA aligned with SME perceptions as revealed in the Design Insights table. The resulting picture is that of a convoluted and confusing system.

While regulatory research has offered notional support for the application of systems thinking to the evaluation of regulatory systems (Corbett, 2017), the literature review described in Chapter Two suggested that systems-based evaluation methods have not yet been developed.

CWA provided a useful framework for this initial analysis of a polycentric safety regulation environment by guiding data collection to support model construction and eliciting insights from system users that can underpin future design initiatives. The following chapter describes a study in which the AH and Design Insights described in this chapter were used as inputs for a design process, guided by the CWA-DT.
Part 3. Regulatory system design
Chapter 8 – Redesigning the Victorian LOA Regulatory Environment

Introduction

This chapter describes the second of two linked studies of the Victorian LOA regulatory environment. The previous chapter described the first study and the overall framework for the two studies, based on guidance from the CWA-DT (Read et al. 2018). The outputs of the first study were an AH model of the multi-instrument (polycentric) regulatory environment and a set of design insights. Those descriptive analytic outputs were used as inputs for the workshop described in this chapter. The aims of the workshop were to generate design concepts and a formative AH model that could be used to guide system re-design.

Limitations on existing methods for evaluating and designing regulatory systems were discussed in detail in Chapter Two. Contemporary methods for evaluating regulatory systems tend to focus on how well a regulatory system is administered, the extent of compliance with its requirements, or an estimation of costs versus benefits (for which reliable causal evidence is difficult to attain; Coglianese, 2012, pp. 14-15). Chapter Two concluded that a research gap exists that deprives those charged with evaluating, designing, or reforming regulatory systems of a reliable, specific, and theoretically grounded framework to evaluate the system’s functional structure.

Some advice is available in the public domain to support the design of systems of social regulation. This includes model codes of practice (e.g. Safe Work Australia, 2018), support by non-government organisations to develop standards (International Organization for Standardization (ISO), 2019), and admonitions to minimise any impediment to productivity (Australian Government, 2014). However, little advice is available to guide the design of regulatory system structure or on processes that might support developing such structures. This is especially problematic given that diverse non-government agencies are among the designers and administrators of standards, guidelines, licensing and accreditation requirements.
The increasing reliance on private organisations to participate in the design and administration of regulatory mechanisms means that many such organisations are developing standards, guidelines and other regulatory instruments without the benefit of reliable guidance (Carden et al., 2017b). The present study brought together representatives of several mostly non-government organisations, each of which administered a different instrument for regulating LOAs in Victoria. The organisations and their regulatory instruments were identified in the study described in Chapter Seven, as illustrated in the AH shown in Figure 7.2.

This study set out to translate regulatory system design insights generated by regulated LOA providers into design concepts. The primary aim of the study was to address the fourth research question posed in Chapter One: Can CWA be used to design regulatory systems? However, from a practical standpoint, the study also aimed to generate a design concept short list that could support reforms to improve regulatory effectiveness and efficiency in a complex, polycentric environment.

Method

Study design

This study involved a participatory design workshop, structured using the Cognitive Work Analysis Design Toolkit (CWA-DT; Read et al. 2018) and the World Café Method (World Café 2019). In order to generate meaningful design concepts for the LOA regulatory system, SME participants were needed for the workshop from each of the organisations responsible for administering the regulatory mechanisms identified in Chapter Seven (see Figure 7.2). For the remainder of this chapter, these SMEs will be referred to as regulators. In addition, a small number of the LOA provider SMEs who had been interviewed for the study described in Chapter Seven were invited to the workshop, primarily to allow regulators to hear their perspectives directly. These SMEs will be referred to as providers.
Recruitment and participants

Invitations to participate in the workshop were sent by email to each of the regulator organisations along with a research project information sheet explaining the nature and purpose of the workshop. To ensure some diversity of representation, one provider SME was invited from each of the three system levels of management, supervisory and operational.

Table 8.1 shows the regulatory mechanisms and associated organisations identified in the study described in Chapter Seven. Representatives of each of these organisations were invited to participate in the design workshop.

Table 8.1. Victorian LOA regulatory mechanisms.

<table>
<thead>
<tr>
<th>Regulatory mechanism *</th>
<th>Organisation name</th>
<th>Organisation type</th>
<th>Regulatory instrument type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adventure Activity Standards</td>
<td>Outdoors Victoria</td>
<td>LOA Sector State peak body</td>
<td>Activity Standards</td>
</tr>
<tr>
<td>Safety Guidelines for Education Outdoors</td>
<td>Department of Education and Training</td>
<td>State Education Department</td>
<td>Activity guidelines</td>
</tr>
<tr>
<td>Tour Operators License</td>
<td>Parks Victoria</td>
<td>State public land manager</td>
<td>Licence to operate</td>
</tr>
<tr>
<td>Camps and Adventure Activity Provider Accreditation</td>
<td>Australian Tourism Accreditation Program (ATAP)</td>
<td>Accreditation provider Accreditation</td>
<td></td>
</tr>
<tr>
<td>Occupational Health &amp; Safety Regulations</td>
<td>WorkSafe Victoria</td>
<td>State Work Health and Legislative Safety Authority</td>
<td>Legislative compliance</td>
</tr>
</tbody>
</table>

*As identified in Chapter Seven. See Figure 7.2.

Analysis methods

The Cognitive Work Analysis Design Toolkit (CWA-DT)

The study described in Chapter Seven used elements of the CWA-DT (Read et al. 2018) and WDA to produce both the AH shown in Figure 7.2 and a set of design insights, derived from interviews with LOA providers (Table 8.2). The study described in the present chapter used a selection of tools from the CWA-DT to design a new structure for the
system. These included ‘Assumption crushing’, the ‘Impossible challenge exercise’, ‘Rapid prototyping’, the ‘Design concept template’, and the ‘Design concept shortlist’ (Read et al. 2018; see Figure 8.1).

Table 8.2. Summary of system design insights derived from interviews with LOA providers, as described in Chapter Seven.

<table>
<thead>
<tr>
<th>Insight category</th>
<th>Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pain points</strong></td>
<td>Financial cost</td>
</tr>
<tr>
<td></td>
<td>Need for better updates</td>
</tr>
<tr>
<td></td>
<td>Lack of compliance checking</td>
</tr>
<tr>
<td></td>
<td>Compliance obligations unclear</td>
</tr>
<tr>
<td></td>
<td>System lacks credibility</td>
</tr>
<tr>
<td></td>
<td>System too complicated</td>
</tr>
<tr>
<td></td>
<td>Unsure if safety is improved</td>
</tr>
<tr>
<td><strong>Leverage points</strong></td>
<td>Community of practice</td>
</tr>
<tr>
<td></td>
<td>Better use of information technology</td>
</tr>
<tr>
<td><strong>Scenario features</strong></td>
<td>Need for level playing field</td>
</tr>
<tr>
<td></td>
<td>Need for flexibility in standards</td>
</tr>
<tr>
<td></td>
<td>Guidance for recruitment &amp; training</td>
</tr>
<tr>
<td></td>
<td>Regulations provide reassurance</td>
</tr>
</tbody>
</table>

The CWA-DT is a suite of guidelines and tools that supports the application of CWA to design. As shown in Figure 8.1, it includes 11 stages. It was selected for this and the previous study due to its close integration with CWA and its capacity to help translate WDA analytic outputs into design concepts and requirements. As described in Chapter Four, the planning and analysis processes of the CWA-DT (‘Analysis planning’, ‘Requirements specification’, ‘Design planning’, and ‘High level evaluation & design concept/s selection’) were conducted by the author. The ‘Insights’ stage of the CWA-DT guided the analysis process and its outputs described in Chapter Seven. The workshop and associated concept design processes described in this chapter were based on guidance.
from the ‘Concept design’ stage of the CWA-DT. In particular, several strategies from the ‘Idea generation’ and ‘Design concept definition’ components of the concept design stage were used. These included ‘assumption crushing’, ‘impossible challenge exercise’, ‘rapid prototyping’, ‘design concept template’, and ‘design concept shortlist’ (see Figure 8.1).
Figure 8.1. Strategies from the Idea Generation and Design concept definition steps in the Concept Design stage of the CWA-DT (Read et al., 2018) were used to guide the design workshop.
The aim of the workshop was to generate a design concept shortlist. As indicated by the left-pointing arrows across the bottom of Figure 8.1, these design concepts were then subject to high level evaluation and a set of final design concepts selected. These design concepts were used to convert the descriptive AH shown in the previous chapter (Figure 7.2) into a formative AH which models the functional structure of the modified system.

The World Cafe Method
The format of the workshop was influenced by the World Cafe Method (World Café 2019). This method provides a flexible format for hosting group discussions. It includes 5 components: setting the environment, welcome and introduction, small group rounds of conversation, questions to prompt each round of conversation, and a ‘harvest’, where small groups report back to the whole group. This format was chosen due to its capacity to support groups to address multiple questions in a short space of time and the strong alignment of the method with the CWA-DT and its associated principles (Read et al. 2018, 328-331).

Procedure
A selection of concept design and evaluation tools from the CWA-DT were used. These included the use of a WDA analysis (generated in the previous CWA-DT stage, as described in Chapter Seven) as the basis for concept design, the strategies of ‘assumption crushing’ and an ‘impossible challenge exercise’ to stimulate idea generation, and the ‘Design concept evaluation’ and ‘Concept summary’ tables to support evaluation and outcome summary.

Participants were introduced to the AH and the model it represented of the polycentric regulatory regime (Figure 7.2). Participants were provided with a summary of the abstraction hierarchy and how it models objects, processes, functions, values, and purposes in a system. Gaps and redundancies identified in the earlier system analysis were discussed along with the design insights identified through interviews with providers (see Table 8.2). Following this overview participants were invited to participate in an
assumption crushing exercise. This consisted of participant being invited to identify any pre-existing ideas for solving system shortcomings or roadblocks to reform. Facilitators then invited the group to identify potential solutions to assumed roadblocks.

In accordance with the advice provided by the CWA-DT and guided by the outputs of the WDA discussed in Chapter Seven, participants were provided with a design brief to develop design proposals for part or all of the regulatory system that would reduce the redundancies or weaknesses identified through both the descriptive AH of the system and the design insights generated by provider interviews. These design improvement needs were selected from the design insights (Table 8.3) based on the highest number of mentions in the coded interview data discussed in Chapter Seven. Filtering and prioritisation were conducted in order to suit the time constraints of the workshop and associated study. If real-world application of this study’s findings were its primary purpose, all identified design concepts might be selected. However, the primary purpose of this study was to test the method, and application of any identified design recommendations beyond its scope. Other filtering or prioritisation processes and the final four stages of the CWA-DT could be used if the scope and primary purpose of the study included implementation of its design recommendations. The filtered ‘Design improvement needs’ categories which would serve as the focus for workshop discussion are shown in Table 8.3.

Table 8.3. Design improvement needs categories.

<table>
<thead>
<tr>
<th>Design improvement needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance education</td>
</tr>
<tr>
<td>Compliance checking</td>
</tr>
<tr>
<td>System performance evaluation</td>
</tr>
<tr>
<td>Holistic system integration</td>
</tr>
</tbody>
</table>

Following an assumption crushing exercise, four brainstorming sessions were conducted. Each session centred on one of four system design improvement needs identified in the
earlier analysis. These needs were compliance education, compliance checking, system performance evaluation, and holistic system integration.

Each problem was defined and clarified at the outset of the brainstorming session. Groups then spent 25 minutes addressing that problem in relation to each of five prompting questions. The questions were, ‘How?’ (how can this problem be addressed?), ‘Who?’ (who will enact the solution?), ‘Resourcing?’ (where will funding come from?), ‘Integration?’ (how can this solution be integrated with the broader system?), and ‘Tech Solutions?’ (how could technology contribute to this solution?). These prompting questions were chosen to prompt and encourage the brainstorming and design concept generation processes described in the CWA-DT (Read et al. 2018, 334). The overall aim was to develop design concepts, in light of the design insights from LOA providers and AH model of the system, that could improve the efficiency and effectiveness of the system.

Each group’s ideas were recorded on a large sheet of paper. At the end of each 25-minute session a spokesperson from each group reported back on their group’s ideas. Participants completed an evaluation form at the end of the workshop.

Following the workshop, each group’s notes were transcribed by the lead HF analyst from the large sheets of paper into electronic format. The resulting transcripts were then thematically coded to identify design concepts and recorded in a design suggestions table (Table 8.5, displayed in the results section, below). These design concepts were then evaluated using the CWA-DT Design Concept Evaluation Table. Given sufficient time, resources, and engagement by regulators, their participation in an iterative evaluation process using the final 4 stages of the CWA-DT would be preferred. However, such a collaborative and iterative process was beyond the scope of this academic study. Instead, the design concept evaluation was conducted by analysts using criteria based on extensive knowledge and experience of the domain.

The ‘Design concept evaluation table’ allows changes to nodes at multiple levels of the AH to be identified. A comparison of the evaluation tables supported an estimation of which
design concepts offered the optimal mix of key benefits, minimum potential negative
effects, and realistic costs. These were recorded in a ‘Final design concepts’ table and a
formative AH constructed to model the effect of the final design reforms on the functional
structure of the system.
Results

A single-day workshop was facilitated by 3 human factors analysts in Melbourne, Victoria. Two of the analysts had extensive experience in the LOA sector having each worked for over 15 years for a major LOA provider. Workshop participants included 7 representatives of organisations identified in the study described in Chapter Seven as stewards of key regulatory instruments for the Victorian LOA domain. In addition, 3 LOA providers who had been interviewed for the study described in Chapter Seven participated in the workshop. Their work roles, approximate age, and experience levels are listed in Table 8.4.

Table 8.4. Victorian LOA regulatory workshop participants.

<table>
<thead>
<tr>
<th>Organisation type</th>
<th>SME organisational role</th>
<th>Age</th>
<th>Years of regulatory experience*</th>
<th>Regulatory instrument type</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA Sector State peak body</td>
<td>Board member</td>
<td>&gt;40</td>
<td>&gt;20</td>
<td>Activity Standards</td>
</tr>
<tr>
<td>State Education Department</td>
<td>Senior Policy Officer</td>
<td>&gt;40</td>
<td>10-20</td>
<td>Activity guidelines</td>
</tr>
<tr>
<td>State Environment Department</td>
<td>Policy and Strategy Manager</td>
<td>30-40</td>
<td>&lt;5</td>
<td>Licence to operate</td>
</tr>
<tr>
<td>State public land manager</td>
<td>Tour Operator Liaison Officer</td>
<td>&gt;40</td>
<td>5-10</td>
<td>Licence to operate</td>
</tr>
<tr>
<td>State public land manager</td>
<td>Statewide Leader Recreation, Park Planning Directorate</td>
<td>&gt;40</td>
<td>10-20</td>
<td>Licence to operate</td>
</tr>
<tr>
<td>Accreditation provider</td>
<td>Program Manager</td>
<td>&gt;40</td>
<td>&lt;5</td>
<td>Accreditation</td>
</tr>
<tr>
<td>State Work Health and Senior Ergonomist Safety Authority</td>
<td>Senior Ergonomist</td>
<td>&gt;40</td>
<td>10-20</td>
<td>Legislative compliance</td>
</tr>
<tr>
<td>Private LOA provider</td>
<td>CEO</td>
<td>&gt;40</td>
<td>10-20</td>
<td>Multiple</td>
</tr>
<tr>
<td>Private LOA provider</td>
<td>Manager</td>
<td>&gt;40</td>
<td>10-20</td>
<td>Multiple</td>
</tr>
<tr>
<td>Private LOA provider</td>
<td>Instructor</td>
<td>&gt;40</td>
<td>5-10</td>
<td>Multiple</td>
</tr>
</tbody>
</table>

*For regulators this refers to time spent administering regulations, for providers, time spent working in roles of which regulatory compliance was a part.

The workshop was conducted in line with an agenda based on the World Café method (World Café 2019). After a welcome and introductions, the whole group was presented
with the AH of the whole Victorian LOA regulatory environment (as shown in Figure 7.2), and the design insights arising from the study described in Chapter Seven (see Table 8.2). A large copy of the AH was displayed on a wall throughout the workshop and SMEs were encouraged to refer to it. The process for the workshop was outlined and the shortlisted Design improvements needs described (see Table 8.3). Each of these was the topic of deliberation for each of four 25 minute-long ‘Café rounds’ in which small groups discussed the design improvement need and ways in which it could be addressed. Five prompting questions were suggested to guide and stimulate design suggestions. These were ‘How?’ (how would the design suggestion work?); ‘Who?’ (what people or roles would be needed to implement the suggestion?); ‘Resourcing?’ (what were the resource requirements for implementation and how might they be met?); ‘Integration?’ (would the suggestion integrate well with existing system features?); and ‘Tech solutions?’ (could technology help to implement the design suggestion?).

Four groups were formed of 2 or 3 SMEs. They were invited and encouraged to change groups throughout the day. Four Café rounds were conducted throughout the day. Prior to each Café round, an exercise was conducted to stimulate creative thought. These included Assumption crushing and Impossible challenge exercises (Read et al. 2018).

At the end of each Café round, a 15 minute ‘harvest’ session was held, where a representative of each small group would report back to the whole group on their design suggestions. These suggestions and explanations were recorded electronically in written notes by the facilitating analysts. Following the workshop, design suggestions recorded in the workshop notes were summarised and are shown in Table 8.5. The numbers in brackets following each suggestion indicate the number of times that suggestion was identified in the summary of workshop notes.
Table 8.5. Design suggestions to improve efficiency and effectiveness of the LOA regulatory system in Victoria.

<table>
<thead>
<tr>
<th>Design improvement need</th>
<th>How</th>
<th>Who</th>
<th>Resourcing</th>
<th>Integration</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compliance education</strong></td>
<td>Single source (8)</td>
<td>Single trusted source (3)</td>
<td>Existing government programs (3)</td>
<td>National system (2)</td>
<td>Provided via online &amp; offline for multiple devices (3)</td>
</tr>
<tr>
<td></td>
<td>Must be clear &amp; current (2)</td>
<td>Multiple integrated sources (2)</td>
<td>Larger providers pay more (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tailored for each provider-type (2)</td>
<td>Peak body (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Compliance checking</strong></td>
<td>Self-audit (5)</td>
<td>Trained auditors (5)</td>
<td>Government funds (2)</td>
<td>Single compliance checking mechanism (4)</td>
<td>Online submission of compliance evidence (2)</td>
</tr>
<tr>
<td></td>
<td>Independent/ external audit (3)</td>
<td>Existing regulatory agency (4)</td>
<td>Industry pays (2)</td>
<td>Integrate compliance checking with compliance education (2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed audit methods (2)</td>
<td>Existing peak body (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Virtual audits (2)</td>
<td>Independent standards body (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Random audits (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System performance evaluation</strong></td>
<td>Measure incidents/ injuries (7)</td>
<td>Government (2)</td>
<td>User/license fee (4)</td>
<td>Regulatory agencies to share compliance &amp; incident data (2)</td>
<td>Online access to incident/participation data (4)</td>
</tr>
<tr>
<td></td>
<td>Measure compliance achievement (2)</td>
<td>Regulatory bodies (2)</td>
<td>Government (3)</td>
<td>Automated upload of provider incident data to central register (2)</td>
<td>Online incident data collection (2)</td>
</tr>
<tr>
<td></td>
<td>Measure insurance claims (2)</td>
<td>Operators (2)</td>
<td>Industry task force (2)</td>
<td>In-kind resourcing from sector (2)</td>
<td>Incident reporting &amp; trend info available online, offline, web &amp; apps (2)</td>
</tr>
<tr>
<td></td>
<td>Measure growth of compliance activity (2)</td>
<td>Independent review body (2)</td>
<td>Independent review body (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Client representative group (2)</td>
<td>Client representative group (2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


| Holistic system integration | Single regulatory body with representatives from all current regulators (4) | Representatives from all current regulators (4) | Industry (3) | - | Use technology to maintain currency & communicate compliance requirements (2) Use technology to engage stakeholders (2) |
Evaluation of design concepts

Design concepts generated by the SMEs during the workshop (shown in Table 8.5) were evaluated using the Design Concept Evaluation table, a tool from the CWA-DT (for examples, see Tables 8.6 and 8.7). The resulting evaluations were ranked in order of the analyst’s assessment of likely benefit and likelihood of implementation, given resource and political constraints. The top 4 ranked design concepts were selected as final design recommendations. An example of a design concept evaluation for a concept that was included in the final set of recommendations is shown in Table 8.6. An example of a design concept evaluation for a concept that was not included in the final set of recommendations is shown in Table 8.7.

Table 8.6 shows the design evaluation table for the concept, ‘Measure Incidents/Injuries’ (see Table 8.5 in the ‘How’ column of the ‘System performance evaluation’ row). This table shows that this design concept could be incorporated into the system by adding a new physical object, ‘Incident database’. This would support a new object-related process, ‘Collect and share incident data’ which would in turn support the new purpose-related function, ‘Safety evaluation’. Analysis suggests that introduction of this new object would enhance two other proposed new objects (offline-capable compliance app and online compliance portal) thereby supporting three existing functions (provider education, surveillance, and compliance enforcement) which in turn improves support for a reduced accident rate and increased safety. The introduction of an incident database appeared to require no removal or modification of existing nodes. On the basis of this evaluation and in comparison with evaluations of the other concepts shown in Table 8.5, this design concept was selected for inclusion.

Table 8.7 shows the design concept evaluation table for the concept, ‘Self-audit’ (see table 8.5 in the ‘How’ column of the ‘Compliance checking’ row). This table shows that this design concept could be incorporated into the system by adding a new physical object, ‘Audit training for operators’. This would support the existing process of
compliance checking, in turn supporting the existing function of safety evaluation. However, concerns based on findings from regulatory research about the limitations of self-regulation (see Chapter Two) cast doubt upon the extent to which this might support the system’s values and purposes. The introduction of self-auditing could in-fact undermine the limited existing surveillance, accreditation and compliance enforcement functions by influencing regulating agencies to reduce or abandon their own efforts in this area. The potential negative impacts noted in Table 8.7, along with a comparison of benefits with other evaluated concepts, led to this design concept being excluded from the final set.

Table 8.6. Design concept evaluation: Measure incidents/injuries (included in final design concepts).

<table>
<thead>
<tr>
<th>Effects on WDA</th>
<th>New nodes</th>
<th>Enhanced nodes</th>
<th>Nodes removed</th>
<th>Appropriately restricted nodes</th>
<th>Inappropriately restricted nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects</td>
<td>Incident database</td>
<td>Offline-capable compliance app; Online compliance portal</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Processes</td>
<td>Collect &amp; share incident data</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Functions</td>
<td>Safety evaluation</td>
<td>Provider education, Surveillance, Compliance enforcement</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Values</td>
<td>-</td>
<td>Accident rate</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Purposes</td>
<td>-</td>
<td>Safety</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Assumptions</td>
<td>Requires appropriately trained and resourced staff to undertake data analysis and interpretation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key benefits</td>
<td>Allow evaluation of system performance; Support guideline evolution &amp; provider education via safety lessons learnt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential negative impacts</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Further research required</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential refinements</td>
<td>May require incentives and education support for LOA providers to report</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8.7. Design concept evaluation: Self audit (excluded from final design concepts).

<table>
<thead>
<tr>
<th>Effects on WDA</th>
<th>New nodes</th>
<th>Enhanced nodes</th>
<th>Nodes removed</th>
<th>Appropriately restricted nodes</th>
<th>Inappropriately restricted nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects</td>
<td>Audit training for operators</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Processes</td>
<td>Compliance checking</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Functions</td>
<td>-</td>
<td>Safety evaluation</td>
<td>-</td>
<td>-</td>
<td>Safety management, Surveillance, Accreditation, Compliance enforcement</td>
</tr>
</tbody>
</table>
Following application of the Design concept evaluation process to the set of Design concept suggestions generated by the workshop (as shown in Table 8.5), a comparison of the results led to the selection of four final design concepts.

**Online compliance portal**
This was conceived by workshop participants as an online ‘one-stop-shop’ where all compliance requirements, associated forms and processes could be accessed. Access to specific advice should be quickly available either via online chat or a ticketing-based compliance help system. This would eliminate the current need to access compliance advice and information from multiple sources and reduce the consequent confusion.

**Compliance audits**
Workshop participants proposed a random audit regime conducted by appropriately trained auditors. This recommendation was buoyed by the expectation that awareness
among the provider community of the possibility of random audits would improve compliance even among providers not audited.

Incident database
This recommended reform was strongly influenced by recognition among workshop participants of the importance of measurement of the performance of the regulatory system in order to identify needs for improvement and to justify its existence.

Synthesise compliance requirements
The elimination of unnecessary duplication of compliance requirements was identified as an important way of improving compliance by improving the simplicity, clarity and credibility of the regulatory system.

Details relating to each of these four final design concepts are included in Table 8.8 below.
Table 8.8. Final design concepts for improved efficiency and effectiveness of the LOA regulatory system in Victoria.

<table>
<thead>
<tr>
<th>Concept name</th>
<th>Online compliance portal</th>
<th>Compliance audits</th>
<th>Incident database</th>
<th>Synthesise compliance requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key needs addressed</td>
<td>Combines and streamlines provision of compliance guidance and education</td>
<td>Checks and encourages compliance</td>
<td>Measures achievement of system purpose</td>
<td>Ensures simplicity, and clarity of compliance requirements</td>
</tr>
<tr>
<td>Approach</td>
<td>Reform compliance requirements then build online platform to support context-optimised access</td>
<td>Random audit regime</td>
<td>Incident reporting to UPLOADS (Clacy, van Mulken, Goode, &amp; Salmon, 2016) a compliance condition</td>
<td>Create single generic compliance standard, convert separate detailed standards to good-practice guides; Establish multi agency committee to monitor &amp; review</td>
</tr>
<tr>
<td>Benefits</td>
<td>Central source of compliance info exchange reduces time cost &amp; potential for confusion</td>
<td>Encourages compliance thereby improving safety including among those not audited</td>
<td>Establish and grow incident knowledge base; share safety learning</td>
<td>Consistent high-level compliance requirements, improved contextual flexibility; Reforms &amp; updates filtered for whole-system coherence &amp; integrity</td>
</tr>
<tr>
<td>Estimated costs</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Contributions-in-kind from regulatory agencies</td>
</tr>
<tr>
<td>Potential negative effects</td>
<td>-</td>
<td>If user pays, cost may challenge some providers</td>
<td>-</td>
<td>Potential for regulatory creep must be managed</td>
</tr>
<tr>
<td>Assumptions</td>
<td>Reform of requirements to include generic safety management system standard supported by context-specific ‘good practice’</td>
<td>Sustainable availability of sufficient numbers of appropriately trained and experienced auditors</td>
<td>Sustainable availability of appropriately trained and resourced staff to undertake data analysis and interpretation</td>
<td>Relies on executive and political support</td>
</tr>
</tbody>
</table>
The ultimate step in this design process was to use the final design concepts shown in Table 8.8 to convert the descriptive AH of the polycentric Victorian LOA regulatory system (see Figure 7.2) into a formative AH of a new, integrated Victorian LOA regulatory system.

Reforming the functional structure of the system

Figure 8.2 shows a formative AH representing the functional structure of the Victorian LOA safety regulatory system following the implementation of the final design concepts. New nodes were added, and others removed to reflect the changes resulting from the design concept recommendations in Table 8.8.

The four separate agencies’ operator guidance webpages were replaced by the single node ‘Online compliance portal’. Along with the new object ‘Offline-capable compliance app’, the new ‘Online compliance portal’ provides a central source of compliance guidance. The two sets of ‘Activity standards’ were replaced by a ‘Safety management standard’ (a principles-based set of compliance requirements), ‘Adventure activity good practice guides’, and ‘DET-specific requirements’. These changes simplify and strengthen the affordance of ‘Safety management system requirements’, ‘Guidance for SOPs’, and ‘Documentation of SOPs’. ‘Audit procedures’ and ‘Auditing standard’ were added to strengthen the affordance of ‘Compliance checking’. Finally, an ‘Incident database’ was added to afford the process, ‘Collect & share incident data’. This new process supports the new purpose-related function, ‘Safety evaluation’.

The enhancement of the review committee to include representation from all current regulatory agencies supports the synthesis of current, separate compliance requirements. The introduction of a generic safety management standard and associated restriction of
agency specific requirements to good practice guides supports context specific yet clear compliance action. The introduction of a single online compliance portal was intended to reduce the replication of compliance education material. The introduction of an incident database supports the process of collection and sharing of incident data. The introduction of an audit capability is likely to improve compliance checking. These two processes both support the newly introduced safety evaluation function which in turn offers significant new support for the critical measure, accident rate, which strengthens support for the functional purpose of safety.

The reduction in duplication of objects suggests that these changes, if implemented, are likely to improve system efficiency. The introduction of a safety evaluation function and the improved support for provider education and safety management are all likely to strengthen this system’s capacity to achieve its functional purpose of safety. This would represent an improvement in system effectiveness.
Figure 8.2. Formative abstraction hierarchy of the Victorian LOA regulatory system showing proposed design modifications (new nodes are shown with dark outlines).
Application of the final design concepts to the AH included the removal of duplicated objects and the addition of new objects to better support existing and needed processes and functions.

**Discussion**

This study aimed to identify design proposals which, if implemented, were likely to lead to improvements in the efficiency and effectiveness of the Victorian LOA regulatory system. The design workshop brought together representatives of each regulating organisation identified during the WDA of the system, described in Chapter Seven, along with 3 representative LOA providers. Several themes emerged from the design concept suggestions. Agreement was unanimous among participants that the system model shown in the WDA AH (Figure 7.2) indicated the need for improved system integration, performance measurement, compliance checking and compliance education.

The workshop process, as described above, resulted in a rich set of design suggestions. These are shown in Table 8.5 with a number following each suggestion to indicate the number of times it appeared in the workshop transcripts.

Some suggestion sets were diverse and potentially contradictory, for example ‘Compliance checking – Resourcing’ where ‘government funding’ and ‘industry pays’ were both mentioned twice. However, other suggestion sets show a clear preference for a specific strategy, such as ‘Reps from all current regulators’ proposed as the sole suggestion for ‘who’ should be involved in ‘holistic system integration’.

In accordance with advice from workshop participants, it was decided to limit the extent of proposed system changes, to a number that would not overwhelm stakeholders but instead be likely to be deemed realistic. The number of final design concepts was therefore limited to four.

Following the evaluation process described above, the four final design concept recommendations were to implement an online compliance portal, introduce an
incident reporting requirement, introduce compliance audits, and to synthesise existing compliance requirements, as shown in Table 8.8.

The design evaluation concept process helped identify the specific changes required to implement these design concepts. These changes consisted of the addition, removal, or modification of physical and cognitive objects within the system.

This application of the CWA-DT allowed the rapid prototyping of design concepts that aim to improve efficiency and effectiveness of this regulatory system. It allowed stakeholder engagement, input and confidence in reform directions. STS principles and values that underpin the CWA-DT ensured the presence in the workshop not only of representatives of all of the regulating organisations but of representatives of different levels of the duty-holding work system. In particular, this shared responsibility for design with a wide range of stakeholders, helped promote respect for individual differences in both the design process and outcome, and sought to capitalise on humans as assets rather than viewing them as liabilities in the system (Read et al. 2018, 331). This novel application of STS principles to regulatory system design embodies them in the resulting system.

The presence during workshop discussions of the descriptive AH of the system, along with the design insights generated from provider interviews served as a consistent reference point for the workshop groups during brainstorming sessions. The design concept evaluation process compared and helped to prioritise reform suggestions and revealed redundancy among them (for example, most suggestions in the technology column in Table 8.5 are variations on the introduction of a central online compliance portal).

Finally, the versatile utility of WDA allowed the descriptive AH to form a central reference point for thinking about design needs and then for the final design concepts to be represented in a formative AH. This transition from a holistic picture of the original state of the system to a holistic picture of the modified system served as a useful and satisfying way to gauge the effect of this CWA-DT process.
Practical Implications

This study and its findings constitute a preliminary analysis of the Victorian LOA safety regulatory system. These findings indicate a need for structural reform of the system. The outputs of this study (the AH in Figure 8.2 and the final design concepts in Table 8.8) can support subsequent steps in a design process, which should include participation of regulatory agencies identified in this study.

Both within and beyond the LOA domain, the paired studies described in this and the previous chapter demonstrate the viability of a new method for regulatory system evaluation and design. In doing so, they address the gap in regulatory research literature, identified in Chapter Two, that has, to date, left regulatory system designers and reformers with little guidance to support the structural specifics of system design. This has the potential for application the broad range of not only health and safety regulation, but other modes of social regulation such as environmental and financial regulation. Given the diverse array of people and organisations charged with developing and administering regulatory instruments and systems, these new methods are both warranted and needed.

Study Limitations

The limitations of this study should be acknowledged, and its observations and conclusions viewed with commensurate caution. The workshop inputs included the AH model (Figure 7.2) and design insights (Table 8.2) that were based on interviews with LOA providers, as described in Chapter Seven. The AH model represents only a preliminary analysis of the functional structure of the system. Furthermore, while the design insights were derived from a cross-section of provider types and job roles, the modest sample size may be limited in its representation of broader opinion.

Other limitations included constraints on consultation time with both LOA providers (as described in Chapter Seven) and regulators (as described in the present chapter) and the coarse granularity of the representation of the system. The limitation on available consultation time, in particular, precluded the reiteration of process encouraged in the CWA-DT, thereby limiting its potential utility in this application.
However, these findings support further analysis and design which could include staged decomposition for analysis of several system elements represented by nodes in the WDA AH models (Figs. 7.2 & 8.2). In addition, the latter phases of CWA (Vicente, 1999) could be applied in line with CWA-DT guidelines to support a refinement of the reforms proposed here. This was, however, beyond both the scope of the present study and its limited access to SMEs.

**Conclusion**

While far more detailed design work has been undertaken with WDA and CWA elsewhere, those applications have required considerable investment of time and money. This new, customised application of the CWA-DT to regulatory system reform supported a rapid evaluation of a complex domain, allowing stakeholders to gain trust in the method while participating economically in the design process. Despite the selective application of CWA-DT tools and the limitations on data collection and validation, this study demonstrated that the CWA-DT when paired with WDA, offers an effective method for the structural evaluation and reform of regulatory systems.

Taken together, Chapters Seven and Eight showed that WDA can be applied to regulatory systems as both a descriptive analytic tool and a formative one. Furthermore, these two linked studies demonstrated both the effectiveness and flexibility of the CWA-DT when applied to a complex regulatory environment. These studies build upon the findings described in earlier chapters, namely, that the application of systems-based HFE methods (and, specifically, the CWA framework) are warranted for regulatory system analysis and design. Finally, this application of the CWA-DT to a polycentric regulatory regime represents a novel approach to regulatory reform. It is the author’s hope that this approach may be further developed and applied in a wide range of regulatory settings.

In contrast to the studies described earlier in this thesis, the studies described in Chapters Seven and Eight engaged and involved a range of stakeholders in analysis and design processes for the regulation of the LOA domain. However, all of the studies described so far in this thesis have been academic exercises: they were conducted
with no immediate prospect of their findings influencing the shape of their subject systems. The following chapter describes the application of WDA to a review of a national set of LOA safety standards for Australia. The review was commissioned by the organisation charged with developing the standard. Unlike, the earlier studies that demonstrated on paper that WDA could be used for the analysis and design of regulatory systems, this one held the potential to influence the shape of a regulatory system in the real world.
Chapter 9 – Reforming the Structure of the Australian Adventure

Activity Standards

Introduction

This chapter describes a final study in which the CWA-based analysis and design methods described in earlier chapters were applied to a national set of safety standards for LOA in Australia. The study was undertaken as part of a review commissioned by an industry-based committee charged with developing the new standard.

At the time of thesis submission, this chapter had been submitted to the peer-reviewed journal, ‘Regulation and Governance’ and was awaiting review.

Declaration for Thesis Chapter 9

Declaration by candidate

In the case of Chapter Nine, the nature and extent of my contribution to the work was the following:

Nature of contribution

Primary author. Conceived the study design, determined the methodology and criteria, conducted literature search and analysis of results. Conducted initial drafting of paper and subsequent editing.

The following co-authors contributed to the work:

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natassia Goode</td>
<td>Collaboration on engagement with SMES. Advice on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
<tr>
<td>Paul M. Salmon</td>
<td>Guidance on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
</tr>
</tbody>
</table>

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate’s and co-authors’ contribution to this work.

Candidate’s signature | Date
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| | 19 July 2019

Co-author’s signature | Date
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| | 19 July 2019

Co-author’s signature | Date
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| | 19 July 2019
### Regulation and Governance

**Simplifying Safety Standards: Using Work Domain Analysis to Guide Regulatory Restructure**

<table>
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<tr>
<td>Keywords:</td>
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Simplifying Safety Standards: Using Work Domain Analysis to Guide Regulatory Restructure

Abstract

This article describes a study in which a popular systems analysis method was used to inform the design of a safety standard. Specifically, Work Domain Analysis was used to analyze and reorganise the structure of a safety standard for organisations providing adventure activities in Australia. Work Domain Analysis allowed for the identification of system objects, processes, functions, measures, and purposes, revealing limitations in the capacity of the proposed structure to achieve the safety standard’s intended purposes. Limitations included a high number of compliance requirements, a confusion between mandatory and optional requirements, a lack of educational support material, and no reliable means to measure system performance. The analysis was used to design an “ideal” structure for the safety standard. Key recommendations of the ideal structure were accepted for implementation, while others were not. The potential for future applications of Work Domain Analysis for regulatory system evaluation, reform, and design are discussed.

Keywords: work domain analysis, regulation, regulatory system evaluation, safety standards, systems thinking
**Introduction**

Regulation and safety standards play an important role in accident and injury prevention (e.g. Kahane 2004). By exerting social, moral and financial influence on providers of goods and services, the intention is to minimise harm arising from work activities. However, designing regulatory standards that are efficient and effective, while also simple enough for duty holders to understand, is a significant challenge (Coglianese 2012, 13, Adams 2013). In order to be efficient, standards should be designed in a way that minimises the cost, both in time and money, required to achieve compliance (Coglianese 2012, 16). In order to be effective, standards should be demonstrably capable of influencing duty holders in ways that achieve the standards’ purposes (Kagan et al. 2011, Coglianese 2012). Both efficiency and effectiveness are supported by ‘user-friendliness’: this requires user-centred design of the standards, including any educational and administrative systems supporting them (Coglianese 2017).

Human Factors and Ergonomics (HFE) is defined as ‘the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance’ (International Ergonomics Association (IEA) 2018). HFE is a broad discipline that is concerned with both the physical and cognitive dimensions of human action and interaction.

Approaches in cognitive ergonomics include those that focus on team and individual performance (e.g. Hollnagel et al. 1981), task analysis (e.g. Crandall et al. 2006), situation awareness (e.g. Endsley 1995), and error prediction (e.g. Embrey 1986). While these methods are useful in the analysis of micro and meso views of sociotechnical systems (STS: systems that include ‘technical, psychological, and social elements’; Vicente, 1999, 9), systems-based approaches offer advantages in the analysis of these systems at the macro scale (Salmon et al. 2017b).

Grounded in systems thinking (von Bertalanffy 1950), systems HFE methods have been put forward as suitable approaches to support the design of regulation and standards...
Early (retrospective analysis) work shows promise (Carden et al. 2018), however, prior to the work described in this paper, such approaches have not actually been applied in regulatory or standard design projects.

This paper describes a process in which HFE methods were applied to the evaluation and redesign of a national adventure activity standard for Australia. Some background on the domain of application and proposed standards is first outlined, then a description of the analysis process and its resulting recommendations, followed by an account of the response to those recommendations. Finally, the broader implications for regulatory system analysis and design in other contexts are discussed.

**Adventure activities**

Adventure activities include a range of activities in which people engage for recreational, educational and therapeutic purposes. Typical examples include canoeing, rock climbing, hiking and camping.

An inherent value of many of these activities is the presence of risk (Dallat et al. 2015). Risk contributes to the excitement of recreational outdoor activities and provides personal challenges that often form a necessary component of learning and personal growth processes in outdoor education and adventure therapy (Lynch & Dibben 2016). Injuries, both minor and fatal, occur in this domain (Brookes 2011, McArdle 2011, Salmon et al. 2012, Salmon et al. 2017a).

In Australia, these activities are provided by a many different types of not-for-profit, volunteer and commercial organisations, including schools, youth groups, community clubs, and businesses (Goode et al. 2014).

Adventure activity providers facilitate activities by providing skilled staff, support specialised equipment, along with logistical and planning support. In providing this kind of service, providers are obliged to eliminate or minimize health and safety risks so far as is reasonably practicable under the occupational health and safety legislation of the state or territory in which they are operating (e.g. State of Victoria 2004).
Adventure Activity Regulation

In addition to the Occupational Health and Safety Acts and regulations, the Australian adventure activities sector is subject to a range of regulations (e.g. accreditation, licensing, guidelines and standards) each administered by different government and non-government agencies (Carden et al. 2018). Together, they constitute a polycentric regulatory regime, where multiple regulators seek to influence the same duty holders (Black 2008). From 2001, standards to guide the conduct of led outdoor activities were developed in most of Australia’s 6 states and 2 territories (Carden et al. 2017c). First developed in the state of Victoria in response to a steep rise in insurance costs, the Victorian Adventure Activity Standards (AAS) were adapted to suit the context in other Australian states and territories over the following years. This has resulted in some confusion in the sector, particularly for organisations operating in multiple states, or with adventure activity programs that cross borders (Outdoors Victoria 2018). In 2015, a project commenced to harmonize and streamline the state-based adventure activity standards in Australia to create the Australian Adventure Activity Standards (AAAS; Outdoors Victoria 2018a). This mirrors other efforts in Australian to harmonize the Occupational Safety Act and regulations in each state in territory.

Case background: development of the Australian Adventure Activity Standards

The initial development of the AAAS was undertaken by a consortium of peak bodies for the adventure activities sector, backed by state government departments, and led by a project group known as the AAAS Presentation Working Party. The AAAS Presentation Working Party set about combining the content of the state-based standards for each adventure activity into a single version and extracting all the content that was common to all activity standards into a single core standard. It was intended that the core standard would include guidance on generic activities such as risk management, leadership and program planning. Individual standards for each adventure activity would then only include material specific to that activity. Technical working groups were formed from volunteer subject matter experts (SMEs) for each adventure activity, along with a technical working group to draft the core standard.
The work of the technical working groups was overseen by a steering committee (Outdoors Victoria 2018b).

Development of the core standard was undertaken during the first 12-18 months of the project. The draft core standard consisted of a 65-page document including sections on risk management, planning, participants, environment, equipment & logistics, leadership, a glossary of terms, and appendices. Following completion of the initial draft, it was released for public comment via stakeholder surveys. Along with approval of aspects of the proposed core standard, some concerns were raised by stakeholders.

In response to the stakeholder feedback, the AAAS Presentation Working Party invited HFE researchers to undertake an analysis of the draft standard to evaluate the structure of the proposed standard. The aims of the analysis were to use HFE methods to develop a model of the draft AAAS based on the draft core standard; use the model to identify potential problems in the draft standard; and propose a simplified model to address the identified problems.

**Method**

Human Factors research is grounded in systems theory. Emerging in the early to mid-20th century, general systems theory seeks to explain phenomena that arise from the interactions among components of a system (von Bertalanffy 1950). This perspective contrasted with reductionist science which had, until that time, dominated many scientific disciplines and driven great progress in human understanding and technological development. Systems thinking has since been applied in many scientific fields, notably including biology (e.g. Coffey 1998), ecology (e.g. Lovelock 2000), and psychology (De Greene & Alluisi 1970). In the social sciences, some disciplines such as anthropology have matured since the advent of systems theory and incorporated its principles in their foundations (e.g. Boas 1982). Others, such as economics, retain strong reductionist roots and continue to evolve with the application of systems thinking (e.g. Forrester 1964).
The continuing study of systems principles has given rise to a science of complex systems (Thurner et al. 2018), which has identified a set of characteristics of complex systems. These include several attributes that characterize systems of safety regulation. First, such systems are dynamic and include non-linear interactions between system elements. Non-linearity means that small effects can have large causes, and vice-versa. Secondly, complex systems have open boundaries. This means that elements can and regularly do enter and leave the system and influence behaviour as they do so. It can also mean that interactions between the complex system and its surrounding environment can change the structure or content of the complex system. A third characteristic of complex systems is that they include many elements. A final characteristic of complex systems, especially relevant to standards and regulations, is emergence. This term refers to the phenomenon of whole-system behavior emerging from interactions between system elements rather than from individual elements (Cilliers 1998). For regulation this means that regulatory outcomes will depend, not only upon individual components of regulations or standards, but upon the whole system and the interactions between multiple system components and people who use the system.

While general systems theory, and more recently complexity theory, are well-established foundations of the scientific discipline of Human Factors, their application in regulatory research and scholarship is less widespread (Corbett 2017, Clark-Ginsberg & Slayton 2018). These recent examples of systems thinking in regulatory scholarship acknowledge the complex nature of regulated entities and the importance of regulators incorporating understanding of that complexity in their work. However, the application of systems-based methods to the evaluation and design of broader regulatory systems (including the tools and techniques used by both regulators and regulated to achieve compliance) remains in its infancy (Carden et al. 2017a, Carden et al. 2017c, Carden et al. 2018).
Work Domain Analysis

Cognitive Work Analysis (CWA; Vicente 1999) is a systems analysis and design framework that has become a popular method for understanding and optimising complex systems (Bisantz & Burns 2008, Stanton et al. 2017). The framework provides a series of modelling approaches that focus on identifying the constraints imposed on behaviour within the system under analysis (Vicente 1999). The first phase, WDA, is used to construct an event- and actor-independent model of the system under analysis, known as an abstraction hierarchy (AH; Naikar 2013). This means it is not focused specifically on any event (e.g. a road crash) and does not include actors who operate within the system (e.g. a driver, a pedestrian, a cyclist). Rather, the aim is to describe the functional structure of the system as well as the purposes of the system and the functions, process and object-related constraints imposed on the actions of any actor performing activities within that system (Vicente 1999). The abstraction hierarchy method is used to describe systems according to the following five conceptual levels:

1. Functional purpose – The overall purposes of the system;
2. Values and priority measures – The values that are assessed and used to measure the system’s progress towards the functional purposes;
3. Purpose-related functions – The general functions of the system that must be undertaken within the system so that the functional purposes are achieved;
4. Object-related processes – The functional capabilities of the physical objects within the system that enable the purpose-related functions; and
5. Physical and cognitive objects – The physical and cognitive objects within the system that are used to undertake object-related processes.

AH models use means-ends links to show the relationships between nodes across the five levels of abstraction. This means that the linked nodes at the level above a node in the hierarchy relate to ‘why’ that node is required, and the linked nodes at the level below the node relate to ‘how’ the node is achieved. For example, in the simplified safety standard model shown in Figure 1, the function ‘Duty holder education’ has

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links to values and priorities above it such as ‘Accidents’ and ‘Accredited operators’. This is because reducing the number of accidents and increasing the number of accredited operators are reasons why duty holder education is present as a function of the system. At the level below, ‘Duty holder education’ has links to the object-related process ‘Compliance guidance’. This shows how the system supports the function of duty holder education. The process of ‘Compliance guidance’ is in turn supported by the objects ‘Standards’ and ‘Website’ shown at the lowest level, because user interaction with these objects is ‘how’ compliance guidance is achieved.

Figure 1. Example Abstraction Hierarchy of a simplified set of safety standards.

The AH shows how all the parts work together to enable key functions to be achieved, and then how these functions allow the system to achieve its main purposes. Specifically, the method supports analysis of the purposes of a system (e.g. why the system exists), and determines whether the measures, functions, processes and objects within the system adequately support the stated purposes. WDA is often used to determine whether a system can achieve its purposes, given the available resources. It is also often used as an approach for identifying how systems can be optimised.
Key principles for redesigning regulatory systems

Both sociotechnical systems (STS) and regulatory research literature were reviewed to identify key principles of good practice regulation, which were used as a basis for simplifying and addressing the problems identified with the draft AAAS.

STS are defined as systems composed of technical, psychological and social elements (Vicente 1999). The AAAS and adventure activities are examples of STS (Carden et al., 2017) (Carden et al. 2017b). The STS literature provides important guidance in the form of design principles that support system performance and human wellbeing. These principles include the need to avoid specifying no more than is essential, to control variance as near to the point of origin as possible (i.e. workers should be empowered to adapt to emergent conditions), to deploy multi-functional mechanisms, and to incorporate mechanisms for reiterative design (Cherns 1976).

The review also included an examination of international standards for outdoor activities, and Australian workplace health and safety (WHS) regulations, shown in Table 1.
<table>
<thead>
<tr>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Work Health and Safety Regulations (Safe Work Australia 2016)</td>
</tr>
<tr>
<td>International Standard for Adventure Tourism (International Organization for Standardization (ISO) 2014)</td>
</tr>
<tr>
<td>New Zealand Adventure Activities Certification Scheme:</td>
</tr>
<tr>
<td>● Adventure Activities Regulations (New Zealand Parliament 2016)</td>
</tr>
<tr>
<td>● Safety Audit Standards (Ministry of Business Innovation and Employment 2013)</td>
</tr>
<tr>
<td>● Activity Guidelines (OutdoorsNZ &amp; Tourism Industry Association NZ 2014a)</td>
</tr>
<tr>
<td>● Operator guide (Ministry of Business Innovation and Employment 2012)</td>
</tr>
<tr>
<td>U.K. Adventure Activities Licensing Regulations (Health and Safety Executive 2004)</td>
</tr>
<tr>
<td>Education Department Safety Guidelines for Education Outdoors (Department of Education and Training 2017)</td>
</tr>
</tbody>
</table>
Based on the review, a set of key principles of good practice in regulatory system design was identified. These are listed in Table 2 and described below.

**Table 2. Key principles of good practice in regulatory system design.**

<table>
<thead>
<tr>
<th>Systems based regulatory design principles</th>
<th>Supporting references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulations should be modular to reduce complexity for users</td>
<td>Bruder et al. 2009, Patterson et al. 2001</td>
</tr>
<tr>
<td>Regulations should primarily influence management</td>
<td>Leveson 2004, Rasmussen 1997</td>
</tr>
<tr>
<td>Regulatory requirements should support the core purposes of the system</td>
<td>Better Regulation Task Force 2004, Jones 2004</td>
</tr>
<tr>
<td>Regulation should be generic and avoid over-specification</td>
<td>Black 2007, Cherns 1976, Corbett 2017</td>
</tr>
<tr>
<td>Regulation should be flexible and adaptable to different organizations</td>
<td>Parker &amp; Nielsen 2011, Corbett 2017</td>
</tr>
</tbody>
</table>

**Regulations should be modular to reduce complexity for users**

Modular design is a way of making complex systems manageable (Bruder et al. 2009). Modularity makes complex and complicated systems with large numbers of components and subsystems more accessible and usable by simplifying the way we interact with them (Patterson et al. 2001). This is achieved by decomposing the system into a hierarchically organized structure. For example, in a smart phone, users access apps, based on their specific, current need. Each app only contains a small sub-set of the smart phone’s functions that are relevant to the task. This avoids confusion and inefficiency by ensuring that users only access the functions that are relevant to their specific task.

**Regulations should primarily influence management**

Rasmussen’s Risk Management Framework (fig. 2; Rasmussen 1997) shows where standards, guidelines, rules and regulations fit into the broader scheme of a system of work. The labels under the arrows show the controls each level uses to influence the level below.
Broad constraints specified in legislation (e.g. health and safety law) at the
government level often apply across multiple sectors. Industry sector compliance with
these laws can be contextualized by regulators in the form of regulations, standards
and guidelines, to provide more specific constraints for companies. In turn, companies
develop policies and procedures that further contextualize the more general
regulations and laws into constraints appropriate to their context. This further
contextualized specification of constraints occurs at each subsequent lower level
transition in Rasmussen’s framework.

While controls imposed at higher system levels can and do constrain behaviour at
multiple lower levels, not just the adjacent one (e.g. Leveson 2004), these increments
of specificity mean that controls from non-adjacent levels are likely to be too general
to guide specific behaviour. Furthermore, methods to (at least prospectively) enforce
controls tend to be confined to adjacent levels. For example, just as managers, not
regulators, will guide and monitor the compliance of workers with policy and
procedures, regulators, not legislators will guide and monitor the compliance of
organizations with regulations. Therefore, the design of regulatory mechanisms should
embody an appropriate balance of specificity and generality necessary to support
senior managers to develop and implement compliant management systems
appropriate for their organizational context.
Avoid reliance on self-regulation

Findings of contemporary regulatory research in safety critical domains has shown that self-regulation of safety is largely ineffective (Gunningham 2011). The oil industry provides some stark examples. The Piper Alpha oil rig disaster in 1988 killed 167 workers (Woolfson & Beck 2000). The more recent Deepwater Horizon tragedy killed 11 workers and spilt around four million barrels of oil into the Gulf of Mexico (Environmental Protection Authority 2017). In both incidents a convoluted regulatory environment and a reliance on self-regulation were found to have contributed to these catastrophic failures (Woolfson 2013). Self-regulation of safety only appears to be effective where a clear and profound commercial incentive exists (Saurwein 2011, Drahos 2017, 124). No such incentive exists in the outdoor activity domain. This

Figure 2. Rasmussen’s (1997) Risk Management Framework.
indicates that the AAAS should be designed to support the implementation of compliance checking and education.

**Regulatory requirements should support the core purposes of the system**
A common problem in many regulatory systems is regulatory creep, where requirements accumulate over time which are increasingly associated with the core purpose of the system (Better Regulation Task Force 2004, Jones 2004). This has the effects of reducing clarity and clouding priorities. Similar criticism has been levelled at some approaches to risk management, where the distinction between degrees of harm and the importance of prioritizing prevention of the worst harms can be diluted and lost. To address these issues, regulatory systems should always be designed specifically to support the core purposes of the system in which they will be enacted.

**Regulation should be generic and avoid over-specification**
Research in both systems and regulation show that over-specification of work requirements by regulators and managers is counter-productive (Black 2007). There are three main reasons for this. First, too much specificity inhibits adaptation and even effective action: people will work around rules that are too specific or too numerous (Cherns 1976). Second, attempting to control the detail of what people do disempowers and de-motivates them (Read et al. 2015). Finally, it is impossible for standard operating procedures or regulations to predict the detail of how events will unfold in the complex dynamic reality of work-as-done (Corbett 2017). This means that regulation needs to be generic and avoid over-specifying requirements to allow for variation in any setting.

**Regulation should be flexible and adaptable to different organizations**
Regulated domains can include a diverse array of organizations and often, organization types. For example, commercial businesses, not-for-profit businesses and charities, health and education service providers, and community clubs may all be bound by food handling regulations. Duty-holding organizations may vary greatly in size, scope, and resourcing. To account for this variability, the structure and the content of regulatory mechanisms must provide sufficient detail of advice on good practice in a
way that avoids placing inappropriate constraints on providers. Key features of such a system should be flexibility and adaptability (Parker & Nielsen 2011, Corbett 2017).

AAAS analysis method

The next phase of the study involved analysing the draft standard using work domain analysis and the regulatory design principles described above. Data sources for this analysis were provided by Outdoors Victoria and included a draft of the ‘core standard’, a draft camping standard, a draft bushwalking (hiking) standard, and a summary of stakeholder feedback on the draft core standard. The core standard was intended to capture common compliance requirements that applied to a set of adventure activities ranging from bushwalking (hiking), camping and canoeing, to rock climbing, white water rafting and horse trail riding. The compliance requirements compiled in the core standard had previously been replicated in each separate activity standard in each state. These related to components of activity provision that are common to all adventure activities, such as program planning, leadership, and emergency response. The camping and bushwalking standards drafts were examples of new individual activity standards that had been reduced in length and streamlined by the removal of the generic ‘core’ compliance requirements.

Naikar’s (2013) nine-step WDA methodology was applied across an initial draft abstraction hierarchy development phase and a subsequent consultation with SMEs in order to create a descriptive AH model of the draft core standard.

Initially the aims and purpose of the analysis were established (as expressed earlier) and any relevant project constraints were identified. Next, the analysis boundary was defined as the proposed core Australian Adventure Activity Standard which included provisions to influence the behaviour of adventure activity providers and the administrators of the AAAS.

The draft AAAS core abstraction hierarchy (Figures 3a and 3b) was then developed by the authors, all of whom have extensive experience in applying WDA in a range of domains including defence, aviation, rail, disaster management, sport, and process
control (e.g. Carden et al. 2017a, Salmon et al. 2018). Development of the abstraction hierarchy involved systematically working through each abstraction hierarchy level using Naikar’s (2013) prompts to identify relevant nodes (see Table 3 for examples of the prompts used). Publicly available documentation regarding the AAAS development process (e.g. the AAAS website; Outdoors Victoria 2015) and existing analyses previously undertaken by the authors were used to support this process. Discussion continued until the three authors were in agreement regarding the nodes identified. Once the nodes were finalised the authors discussed the means-ends links, again agreeing on appropriate means-ends links to include in this initial, descriptive abstraction hierarchy.

Table 3. Abstraction hierarchy prompts (adapted from Naikar 2013).

<table>
<thead>
<tr>
<th>Functional Purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>For what reasons does the AAAS exist?</td>
</tr>
<tr>
<td>What are the highest-level objectives or ultimate purposes of the AAAS system?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Values and Priority Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>What criteria can be used to judge whether the AAAS is achieving its purposes?</td>
</tr>
<tr>
<td>How is the performance of various functions within the AAAS system evaluated?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purpose-related Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What functions are required to achieve the purposes of the AAAS?</td>
</tr>
<tr>
<td>What are the functions of individuals, teams and agencies?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Object-related Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>What can the objects in the AAAS system do or afford?</td>
</tr>
<tr>
<td>What processes are the objects in the AAAS system used for?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical and Cognitive Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the objects within the AAAS – discrete entities with which an actor interacts?</td>
</tr>
<tr>
<td>What objects or resources are necessary to enable the processes and functions of the AAAS?</td>
</tr>
</tbody>
</table>
The abstraction hierarchy was then reviewed and refined with two SMEs who were members of the AAAS Presentation Working Party. During this review process, the nodes at each level were systematically reviewed and verified, followed by the means-ends links. Nodes and means-ends links were either agreed upon, modified, or removed if all authors did not agree that they should be included. In addition, where new nodes or means-ends links were identified, they were discussed and if agreed upon, were added to the model. This process continued until there was agreement regarding the abstraction hierarchy’s content.

*Using the abstraction hierarchy to redesign the core standard*

Once the abstraction hierarchy was finalised, two of the authors worked through each level and applied the key principles for redesigning regulatory systems to each level, node, and means-ends link in the AH. Where system elements were found to be in conflict with the key principles, nodes were, modified, removed or combined with other nodes. Means-ends links were considered with respect to their estimated strength (i.e. the extent to which each element was capable of supporting the elements to which it was linked). The resulting draft formative AH was then reviewed by the third author and any disagreements discussed between the three authors until agreement was reached. The resulting formative AH, representing the proposed new structure for the AAAS was then used as the basis for a report to the AAAS Presentation Working Party including a summary of recommended system reforms. This report was circulated to a broader group that included Chairs of AAAS Technical Working Groups (volunteer experts developing the content of each activity standard) and representatives of State Government departments (sponsors of the project). A date was set for the authors to meet with this broader group of stakeholders in a workshop setting to present and discuss the report.
Results

The descriptive AH of the draft core AAAS is presented in Figures 3a and 3b. Due to the number of elements identified, the model is large and therefore presented in two halves. Following the AH are 5 tables that list, respectively, the (functional) purposes, (values and priority) measures, (purpose related) functions, (object related) processes, and (physical and cognitive) objects that were represented in the AH.
Work Domain Analysis of the AAAS Core

Figure 3a. AAAS Core draft abstraction hierarchy left-hand side.
Figure 3b. AAAS Core draft abstraction hierarchy right-hand side.
Table 4. Purposes identified in the current structure of the draft AAAS (i.e. why the AAAS exists).

<table>
<thead>
<tr>
<th>Purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Safety</td>
</tr>
<tr>
<td>2. Legal compliance</td>
</tr>
<tr>
<td>3. Responsible delivery</td>
</tr>
<tr>
<td>4. Environmental and cultural protection</td>
</tr>
</tbody>
</table>

Table 5. Measures identified in the draft AAAS to evaluate whether the purposes are achieved.

<table>
<thead>
<tr>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Risk management (RM) integrated into all organisational processes</td>
</tr>
<tr>
<td>2. RM avoids excess risk aversion</td>
</tr>
<tr>
<td>3. Adaptable, responsive safety management</td>
</tr>
<tr>
<td>4. All adventure activities covered</td>
</tr>
<tr>
<td>5. Ensuring safety systems are implemented</td>
</tr>
<tr>
<td>6. Cost of legal non-compliance</td>
</tr>
<tr>
<td>7. Land manager requirements compliance</td>
</tr>
</tbody>
</table>
Table 6. Functions identified in the structure of the draft AAAS.

<table>
<thead>
<tr>
<th>Functions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Resource allocation to support RM</td>
<td>23. Manage alcohol, smoking, drug use</td>
</tr>
<tr>
<td>3. Supervision &amp; management of activities</td>
<td>24. Address all relevant environmental conditions</td>
</tr>
<tr>
<td>4. Understand participant restrictions</td>
<td>25. Identify trigger points</td>
</tr>
<tr>
<td>5. Identify vulnerable participants</td>
<td>26. Monitoring of weather conditions</td>
</tr>
<tr>
<td>6. Identify health, medical &amp; other personal conditions</td>
<td>27. Provide severe weather sites</td>
</tr>
<tr>
<td>7. Identify allergies &amp; anaphylaxis safety for minors</td>
<td>28. Comply with fire danger restrictions</td>
</tr>
<tr>
<td>8. Determine maximum &amp; minimum group size</td>
<td>29. Manage tree safety</td>
</tr>
<tr>
<td>10. Ensure privacy of information</td>
<td>31. Manage drinking water safety (pollution)</td>
</tr>
<tr>
<td>11. Determine equipment requirements</td>
<td>32. Provide sufficient water</td>
</tr>
<tr>
<td>12. Provide activity equipment</td>
<td>33. Ensure food safety</td>
</tr>
<tr>
<td>13. Equipment maintenance</td>
<td>34. Manage effects of medication</td>
</tr>
<tr>
<td>14. Equipment storage</td>
<td>35. Manage effects of fatigue</td>
</tr>
<tr>
<td>15. Provide first aid equipment</td>
<td>36. Ensure compliance with sex discrimination laws</td>
</tr>
<tr>
<td>16. Provide communication equipment</td>
<td>37. Address cultural &amp; religious factors in activity delivery</td>
</tr>
<tr>
<td>17. Provide appropriate transport</td>
<td>38. Ensure environmental sustainability</td>
</tr>
<tr>
<td>18. Ensure availability of necessary medication</td>
<td></td>
</tr>
<tr>
<td>19. Verification of leader competencies</td>
<td></td>
</tr>
<tr>
<td>20. Allocation of leadership roles and responsibilities</td>
<td></td>
</tr>
<tr>
<td>21. Provision of activity briefings</td>
<td></td>
</tr>
</tbody>
</table>
### Table 7. Processes afforded by objects within the structure of the draft AAAS core document.

<table>
<thead>
<tr>
<th>Processes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Documentation of RM framework</td>
<td></td>
</tr>
<tr>
<td>2. Embed RM in operations</td>
<td></td>
</tr>
<tr>
<td>3. Periodic review of RM framework &amp; process</td>
<td></td>
</tr>
<tr>
<td>4. Risk identification</td>
<td></td>
</tr>
<tr>
<td>5. Risk analysis</td>
<td></td>
</tr>
<tr>
<td>6. Risk evaluation</td>
<td></td>
</tr>
<tr>
<td>7. Risk treatment</td>
<td></td>
</tr>
<tr>
<td>8. Documentation of RM plans</td>
<td></td>
</tr>
<tr>
<td>9. Periodic review &amp; assessment of AAAS</td>
<td></td>
</tr>
<tr>
<td>10. Monitoring &amp; review of RM framework, process, &amp; plans</td>
<td></td>
</tr>
<tr>
<td>11. Accountability for RM</td>
<td></td>
</tr>
<tr>
<td>12. RM reporting &amp; review processes</td>
<td></td>
</tr>
<tr>
<td>13. Establish internal RM communication mechanisms</td>
<td></td>
</tr>
<tr>
<td>14. Establish external RM communication mechanisms</td>
<td></td>
</tr>
<tr>
<td>15. Ensuring appropriate leader competence</td>
<td></td>
</tr>
<tr>
<td>16. Program / activity design suitable for context</td>
<td></td>
</tr>
<tr>
<td>17. Third party provider compliance</td>
<td></td>
</tr>
<tr>
<td>18. Emergency management planning</td>
<td></td>
</tr>
<tr>
<td>19. Pre-activity communication</td>
<td></td>
</tr>
<tr>
<td>20. Planning for everyday activities &amp; contingencies</td>
<td></td>
</tr>
<tr>
<td>21. Management &amp; approval of activities</td>
<td></td>
</tr>
<tr>
<td>22. Informed consent</td>
<td></td>
</tr>
<tr>
<td>23. Adequate participant screening</td>
<td></td>
</tr>
<tr>
<td>24. Ensure leaders have required documentation</td>
<td></td>
</tr>
<tr>
<td>25. Fulfilment of duty of care</td>
<td></td>
</tr>
<tr>
<td>26. Dynamic risk assessment</td>
<td></td>
</tr>
<tr>
<td>27. Ensuring safety systems are implemented</td>
<td></td>
</tr>
<tr>
<td>28. Ensuring systems &amp; processes are followed</td>
<td></td>
</tr>
<tr>
<td>29. Modification or cancellation of activities</td>
<td></td>
</tr>
<tr>
<td>30. Activity leadership &amp; supervision</td>
<td></td>
</tr>
<tr>
<td>31. Activity briefing</td>
<td></td>
</tr>
<tr>
<td>32. Sun safety</td>
<td></td>
</tr>
<tr>
<td>33. Bushfire safety</td>
<td></td>
</tr>
<tr>
<td>34. Tree safety</td>
<td></td>
</tr>
<tr>
<td>35. Wildlife safety</td>
<td></td>
</tr>
<tr>
<td>36. Drinking water safety</td>
<td></td>
</tr>
<tr>
<td>37. Water purification</td>
<td></td>
</tr>
<tr>
<td>38. Food safety</td>
<td></td>
</tr>
<tr>
<td>39. Prompt correction of identified problems</td>
<td></td>
</tr>
<tr>
<td>40. Incident reporting</td>
<td></td>
</tr>
<tr>
<td>41. Notifiable incident reporting</td>
<td></td>
</tr>
<tr>
<td>42. Incident site preservation</td>
<td></td>
</tr>
<tr>
<td>43. Compliance with legislation</td>
<td></td>
</tr>
<tr>
<td>44. Minimum environmental impact practices</td>
<td></td>
</tr>
<tr>
<td>45. Protecting natural and cultural heritage</td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Objects that a user could interact with identified in the structure of the draft AAAS.

<table>
<thead>
<tr>
<th>Objects</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. AAAS Part 1 - Core standards</td>
<td>25. O.R. Training Package - Competencies Units</td>
</tr>
<tr>
<td>2. AAAS Part 2 - Activity standards</td>
<td>26. Equipment checklist</td>
</tr>
<tr>
<td>3. Website</td>
<td>27. Equipment procedures</td>
</tr>
<tr>
<td>4. Risk management (RM) framework</td>
<td>28. Food safety procedures</td>
</tr>
<tr>
<td>5. RM process</td>
<td>29. Bushfire safety procedures</td>
</tr>
<tr>
<td>6. RM plan</td>
<td>30. Emergency management plan</td>
</tr>
<tr>
<td>7. RM Int / Aus standard ISO 31000</td>
<td>31. Incident reports</td>
</tr>
<tr>
<td>8. Specific external requirements (laws)</td>
<td>32. Incident reporting mechanism</td>
</tr>
<tr>
<td>9. Specific requirements of internal stakeholders</td>
<td>33. UPLOADS project</td>
</tr>
<tr>
<td>10. RM policy</td>
<td>34. WHS law &amp; regulations</td>
</tr>
<tr>
<td>11. RM performance measurement methods</td>
<td>35. Food handling safety law &amp; regulations</td>
</tr>
<tr>
<td>12. Risk communication objects</td>
<td>36. Drinking water safety law &amp; regulations</td>
</tr>
<tr>
<td>13. Group size</td>
<td>37. Allergy &amp; anaphylaxis safety law &amp; regulations</td>
</tr>
<tr>
<td>15. Weather forecasts</td>
<td>39. Vulnerable person standards</td>
</tr>
<tr>
<td>16. Severe weather site plans</td>
<td>40. Privacy law</td>
</tr>
<tr>
<td>17. Activity plans</td>
<td>41. Sex discrimination law &amp; regulations</td>
</tr>
<tr>
<td>18. Pre-activity information</td>
<td>42. Fire danger laws &amp; regulations</td>
</tr>
<tr>
<td>19. Medical practitioner approval of participation</td>
<td>43. Transport law &amp; regulations</td>
</tr>
<tr>
<td>20. Participant health &amp; medical information</td>
<td>44. First aid kit standard, AS 2675-1983</td>
</tr>
<tr>
<td>21. Activity documentation required by leaders</td>
<td>45. Land manager requirements, law &amp; regulations</td>
</tr>
<tr>
<td>22. Activity leader roles &amp; responsibilities</td>
<td>46. Environmental sustainability procedures</td>
</tr>
<tr>
<td>23. Activity leader skills &amp; knowledge</td>
<td>47. Cultural &amp; religious policies &amp; procedures</td>
</tr>
<tr>
<td>24. First aid competencies training</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Issues identified

Based on the analysis, the following five key problems were identified with the AAAS.

1. Irrelevant objects. Not all the objects are relevant to all types of outdoor activity providers. For example, providers of tertiary outdoor training courses have no need for child protection law, while most camp operators have no need for land manager law & regulations.

2. A high number of objects and processes. Not all objects are relevant to all users, and the mixture of mandatory and optional requirements, all combine to make it unlikely that the AAAS would be used as intended. It is simply too big and convoluted. It is not ‘user-friendly’.

3. Education. The capacity to support user understanding of their obligations is not supported by anything other than the standards documents themselves. Experience in other domains shows that education to support user understanding is critical and improves compliance (e.g. Coglianese 2017, 46). For example, statutory regulations for adventure activity safety in New Zealand are supported by a wide range of user guides, educational support material and compliance advice (Ministry of Business Innovation and Employment 2012, OutdoorsNZ & Tourism Industry Association NZ 2014b).

4. Measurement capacity. The capacity to assess or measure users’ compliance with the standards is absent from the draft AAAS. This undermines any basis for confidence that the system is working. Research shows that self-regulation of safety is ineffective (Gunningham 2011) but that most people will comply if they’re confident that non-compliers will be sanctioned (Kagan et al. 2011, 37-58).

5. Vague measures. The measures proposed to determine whether the AAAS is achieving its purposes are vague and not easy to objectively measure. This will make it difficult to periodically review and assess the performance of the AAAS as proposed in the AAAS Core document.
Recommended structure

Based on the principles described above and the analysis of the proposed AAAS core, a new structure for the AAAS was proposed (see Figure 4). The proposed structure is based on a synthesis of the elements in the AAAS core document, plus some additional elements required to address the identified gaps. The aims of improved system efficiency, comprehensiveness and user-friendliness are addressed in the following ways. The radically reduced length and number of objects of the core standards (64 pages with 47 objects reduced to approximately 10 pages with 10 objects) means that duty holders can gain a broad understanding of their compliance requirements far more quickly.

The modularization of the core standard (splitting it into a concise core, applicable to all duty holders along with a suite of good practice guides, each applicable to some) improves the user-friendliness of the system, both by improving efficiency for users as described above, and by reducing uncertainty about compliance requirements.

While the AH model of the reformed AAAS shown in Figure 4 is far simpler that that shown in the originally proposed system model in Figure 3, this is not due to any change in the granularity of the models. Instead, it represents a proposed change in the level of detail included in the system itself. The intentional removal of detail from the core standard is intended to make the core compliance requirement simpler and more user-friendly. The exporting of finer detail to proposed ancillary instruments, such as good practice guides, requires only those actors who need that detailed information to access it.

The recommendations to implement incident reporting and learning requirements and a compliance checking mechanism support the important system value of incident rate measurement, and the function of compliance assurance. These modifications make the proposed structure more comprehensive by adding a means of gathering information on the effect of the system, in turn supporting the possibility of ongoing system improvement.
Figure 4. Work Domain Analysis showing the revised AAAS structure.
How the key principles were applied

Modularity
The current scope of the AAAS makes it a large, complex system. Like a smart phone, it has lots of parts, lots of functions, and lots of ways a user may need to interact with it. It was recommended that the AAAS should be redesigned in a modular way to ensure that users are able to engage only with the content relevant to them. This user-centred design approach would make the AAAS not only more user-friendly, but more customizable. Several other, comparable systems of safety guidance use a modular design. These include the New Zealand Adventure Activities Certification Scheme, the U.K. Adventure Activities Licensing Regulations, the International Standard for Adventure Tourism (ISO 21101), and the Victorian Education Department Safety Guidelines for Education Outdoors. The New Zealand regulations were illustrative. The regulations themselves are confined to defining terms and describing the structure of the system. A separate safety audit standards document describes in general terms the compliance requirements for outdoor activity providers. Separate activity guidelines provide advice on how compliance could be achieved. Extensive education material is provided separately by the industry peak bodies.

Influence on management
The AAAS fits into the broad category of ‘regulations’, shown in Rasmussen’s Risk Management Framework (Figure 2). This means that, while lower level actors still need to understand the regulations and how they apply to them, it was recommended that the AAAS should primarily aim to support and influence outdoor activity managers to develop policy appropriate to their own context. This in turn would support and influence effective plans and actions in activity planning and operation. Any mandatory compliance requirements should therefore be directed toward the management level of provider organizations and avoid over-specifying. It was further recommended that detailed guidance (including any examples or templates for procedures and policies) for specific use-cases be included in separate guidance documents.
Self-Regulation
The analysis revealed that there was no mechanism outside of duty-holder organisations to check for compliance with the AAAS. In addition to supporting anti-competitive behaviour (service providers can freely ignore the standards and undercut the prices of compliant competitors), the absence of objective compliance checking precludes the measurement of the effectiveness of the standards. This in turn prevents reliable system review, improvement, and evolution. The development and implementation of a compliance checking mechanism was therefore recommended.

Regulations should support core purposes
In the draft AAAS Core document, the purposes of the system were unclear. To avoid regulatory creep and dilution, it was recommended that the purposes of the AAAS should remain clear and its content should prioritize prevention of harm appropriately. While document analysis and discussion with SMEs revealed historical sources for the functional purposes of ‘Safety’ and ‘Legal compliance’ (e.g. Carden et al. 2017c), the origin of the functional purpose, ‘Environmental and Cultural Protection’, was unclear. Furthermore, this apparently dual purpose was not clearly defined, nor was it well supported by objects, processes or functions within the system. Therefore, additional work to determine the most appropriate way of measuring environmental protection and cultural protection was recommended.

Avoid over-specification
For reasons noted in the Key Principles section above, regulation needs to be generic and avoid over-specifying requirements to allow for variation across the domains to which it applies. The level of detail specified in the draft core standard was found to be of a level of detail more appropriate to organisational policy and procedures than to regulatory standards. Moreover, although framed and intended as a ‘core standard’ that applied to all providers of led outdoor activities, the proposed standard included details of requirements of relevance only to some providers. For example, the inclusion of requirements around child safety protection law & regulations was not relevant to adventure activity providers who did not work with children; requirements around transport law & regulations were not relevant to providers whose service did
not include transport. This finding led to the recommendation to generalize and simplify the core standard and relocate more specific detail that was deemed necessary, to separate good practice guides.

**Flexibility and adaptability**

Adventure activities, organizational provision of them, and efforts to regulate them, all constitute complex, dynamic sociotechnical systems (Carden et al. 2017b). A key characteristic of complex systems is that events in such systems emerge, sometimes unpredictably, from interactions between components within and beyond the system boundary. To cope with this complexity, actors in the system must be afforded the latitude to deal flexibly and adaptively, within the minimal necessary set of constraints, with events as they emerge. Both the structure and content of regulatory constraints, including standards, should reflect this need. It was recommended that the core standard should specify what outdoor activity providers need to do to meet their obligations under the standard, but not how to do it. Guidance on how to undertake particular tasks (e.g. risk management) should be provided separately from the core standard.

**Summary of recommendations**

Based on the principles described above and the analysis of the AAAS, the following structure for the AAAS was proposed:

- The core standard: Clear, brief description of compliance requirements. Describes what providers need to do to comply.
- Good practice guides: Detailed advice on how to comply with the standard which include detailed advice from technical experts.
- Links to useful external resources: These include non-outdoor-specific advice that may be relevant for some outdoor providers.
- Education and training material: Resources to help providers understand and fulfil their compliance requirements.

It was recommended that the core standard should be a brief document of around 10 pages (1 section per page), with the following sections:
1. Introduction;
2. Risk management requirements;
3. Activity & program planning requirements;
4. Equipment & environment requirements;
5. Outdoor leadership requirements;
6. Emergency management requirements;
7. Environmental & cultural protection requirements;
8. Incident reporting and learning requirements;
9. Review & continuous improvement of the AAAS; and
10. Links to good practice guides & external resources.

In addition to these core, structural recommendations, the following further recommendations were made, based on the analysis.

There was no proposed means of measuring the performance or impact of the AAAS. It was therefore recommended that compliance checking, and the reporting of incident rates be included in the AAAS to support the continuous review and improvement of the AAAS. Furthermore, insufficient details were provided in the draft core standard document or elsewhere to determine the compliance requirements for ‘cultural protection’. It was therefore recommended that additional work was required to determine the most appropriate way of measuring stakeholder satisfaction, environmental protection and cultural protection.

SME Response

The findings and recommendations outlined above were presented at a workshop in June 2018. The workshop was attended by 19 stakeholders involved in the development of the AAAS, including the Chairs of the AAAS Technical Working Groups, members of the AAAS project steering committee, and representatives of state government departments. The report was presented by its authors and questions and comments invited.
Discussion and questions ensued, including consideration of how the proposed structure might work for different organisation types (e.g. community clubs vs. commercial operators; large vs. small), whether the proposed 10 section standard was too general, and what categories of operation would need to be covered by good practice guides (e.g. activities, environmental practices, transport, food handling).

The response from workshop participants to the analysis and recommendations was overwhelmingly positive. However, it was evident during the workshop discussion that some participants were quite wary of the suggestion to improve compliance checking. They felt that any such change exceeded the scope of their reform project, while others feared a backlash from duty-holders. Although the lack of clarity about compliance obligations in relation to cultural and environmental protection was acknowledged, as was the suggestion that perhaps these requirements may have entered the standards via a process akin to regulatory creep, the recommendation to improve clarity around these requirements was met with some ambivalence.

Reactions from workshop participants to the presentation of the report included approval of simplification of the structure (e.g. ‘I think the ten requirements are great because anyone can comply regardless of whether there are two people or a thousand’), questions about compliance checking (e.g. ‘Sometimes there’s three separate things people need to comply with – but we don’t know how many people are complying’), and comment on the need to clarify the requirements for cultural and environmental protection (e.g. ‘how do we craft environment and cultural protection so we can measure them?’).

Prior to the end of the workshop, participants were each invited in turn to provide summary comments on their impressions of the proposed structural changes. Their responses are summarized in Table 9. They key themes were satisfaction with the simplified structure, the collaborative process, and the extent to which the recommended changes would address stakeholder feedback.
Table 9. Workshop participant reactions to the analysis and recommendations.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Illustrating quotes from workshop participants</th>
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<tbody>
<tr>
<td>Structure</td>
<td>“…it’s a relief as I think we have a better structure.”</td>
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<tr>
<td></td>
<td>“I like the new structure, I’m very comfortable. I think less is more.”</td>
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<tr>
<td></td>
<td>“I really liked the structure…This is a radical shift…”</td>
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<tr>
<td></td>
<td>“I think the compliance and accountability needs to be really clearly addressed. My feeling is that people are very resistant to giving up their information to unknown people....I agree [that] the ten points are great.”</td>
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<tr>
<td>Clarity</td>
<td>“… clarity around who the standard is for is really important.”</td>
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<tr>
<td></td>
<td>“I really like the analysis that was done. That helped create a lot of clarity for me…”</td>
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<tr>
<td></td>
<td>“I like it being simple and I think getting clarity for the good practice guides is going to be interesting.”</td>
</tr>
<tr>
<td>Simplification</td>
<td>“I’m very warm about simplification of the process. I think we need to clarify [who] the audience [is] as well.”</td>
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<td></td>
<td>“I think it’s not only simplification but it’s necessary. I think if we don’t do this, we can still create an AAAS but it won’t get used by all parts of the sector.”</td>
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<tr>
<td></td>
<td>“I think the simplification is good.”</td>
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<tr>
<td>Addresses feedback</td>
<td>“I think for me that if I [were] to report against the feedback – where we’re moving towards will meet much of the negative feedback from the initial core.”</td>
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<tr>
<td></td>
<td>“The fact that people went to the trouble that people gave us that feedback – we can show that we are addressing that feedback.”</td>
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<tr>
<td>Collaborative design</td>
<td>“A moment of praise [for] collaborative interrogation of a topic – there’s been a lot of progress that has been made. This process has worked.”</td>
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<td>“I commend the industry taking it on – it’s really great to see a group of people from industry, government and academia address a problem that people are genuinely interested in seeing progress on.”</td>
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<tr>
<td>General</td>
<td>“Well done everyone…I think we’re in a good place with some really pragmatic actions.”</td>
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<td></td>
<td>“I think it’s great – a really good bit of work.”</td>
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The outcome

In September 2018, Outdoors Victoria issued a public communiqué announcing that a revised structure for the AAAS was to be implemented (Outdoors Victoria 2015). In line with our recommendations the revised structure consists of:

- The AAAS (the Standard) – this addresses the common ‘requirements’ for all types of adventure activities
- A Core Good Practice Guide (GPG) – this provides additional information to help support implementing the AAAS
- Various activity GPGs – these provide guidance specific to the various adventure activities.

In December 2018, the revised AAAS (‘the Standard’), a core GPG, and 7 activity based GPGs were publicly ‘pre-released’, confirming the implementation of the new structure.

The aim of this article was to present the findings from a study that involved the evaluation and redesign of a national adventure activity standard for Australia. The findings show that Work Domain Analysis was a useful approach to support the analysis and redesign of the standard. The modelling approach provided a means of reducing 111 elements down to 25. Using principles of good practice regulation alongside the method, provided an effective way of integrating human factors methods with guidance from the regulatory literature. Most importantly, the decision by the developers of the AAAS to implement our key structural recommendations demonstrates that this method is more than merely academically interesting, it is practically useful. It is our recommendation that the approach described in this article should form the basis for a new framework for the design of standards and other regulatory instruments, such as licensing and accreditation schemes.

Implications for regulatory system evaluation and design

Our review of the regulatory literature revealed an abundance of advice on the higher-level design features of regulatory systems (e.g. risk-based approaches where
regulatory approaches focus on the riskiest activities of duty holders; Black & Baldwin 2010). Regulatory design advice from government agencies often reflects a deregulatory agenda and includes a strong emphasis on minimising regulation (e.g. Australian Government 2014). Moreover, a rich array of advice is available for regulators on how they can best structure and conduct their compliance-support organisations and activities (e.g. Coglianese 2017). However, theoretically grounded advice on the systematic evaluation and design of the fundamental regulatory mechanisms including standards, licensing, registration, and accreditation systems appears lacking.

The extent to which the approach described here can be successfully applied in other regulatory settings requires further testing. However, the success evidenced by the adoption of the key recommendations resulting in the restructure of a national safety standard is encouraging. Indeed, further application and extension of this method could serve as a basis to develop other analytic tools for regulatory systems. For example, one prominent challenge for regulatory system evaluation centers on prospective and retrospective cost-benefit analysis (Coglianese 2018). By adding methods for quantifying financial costs associated with objects and processes and financial benefits associated with achievement of measures and purposes, WDA may serve as a useful foundation for more accurate and reliable methods of holistic cost-benefit analysis. This could in turn improve public and political confidence in regulatory systems.

While this demonstration of the utility of WDA in the evaluation and design of a safety regulation system is encouraging, it should be recognized as a first-of-its-kind application of a human factors framework in the regulatory domain. As well as applications in other regulatory contexts, the other phases of CWA (the ecological analysis framework of which WDA is the first phase) could also be applied to regulatory system analysis and design. These could help to identify and improve the efficiency and effectiveness of tasks, strategies, and skills required of both duty holders and regulators.
Study limitations

The wider application of the methods described in this study will depend on further development and testing. While this application addressed stakeholder concerns and resulted in a restructure that appears likely to improve usability, evaluation of both of those outcomes has yet to be completed. Further, measurement of the effectiveness of any regulatory system and indeed of safety, is difficult to achieve. Therefore, further exploration of the development and application of human factors methods, including WDA and other CWA phases to support regulatory system analysis is warranted.

Conclusion

The novel application of WDA to the evaluation and redesign of the AAAS revealed ways in which these standards could be restructured to improve their user-friendliness and efficiency. The acceptance and implementation of the majority of this study’s recommendations by the developers of this system of national safety standards offer confidence that these methods can be further developed, refined, and applied to regulatory system evaluation and design. It is the hope of the authors that future research, including collaboration between Human Factors and Regulatory scholars, will include wider application and testing of human factors methods and systems theoretic principles to regulatory system evaluation and design.

References


Carden T, Goode N, Read GJM and Salmon PM (2017a) Sociotechnical systems as a framework for regulatory system design and evaluation: Using Work Domain Analysis to examine a new regulatory system. *Applied Ergonomics*.


Chapter 9


Chapter 10 - Accounting for memes in sociotechnical systems: extending the abstraction hierarchy to consider cognitive objects

Introduction
During the study of the NZ Adventure Activity Regulations, described in Chapter Five, it was observed that system users may interact with some elements of the system without the need for interaction with any physical object. It was proposed that perhaps some systems include cognitive objects, as well as physical ones. This chapter explores that proposition by considering three case studies.

AH models for each case are reviewed and the possible benefits of including cognitive objects considered. The inclusion of cognitive objects in WDA is considered in light of theoretic considerations and the implications for other phases of CWA discussed.

It is concluded that the adaptation of WDA to include cognitive objects is warranted and potential applications are discussed. The results of this study represent an expansion of the range of application of WDA and, by extension, CWA.

For ease of reading, larger copies of Figures 3, 5, and 7 from this article are reproduced in Appendix A, at the end of this thesis.

Declaration for Thesis Chapter 10

Declaration by candidate

In the case of Chapter Ten, the nature and extent of my contribution to the work was the following:

**Nature of contribution**

Primary author. Conceived the study design, formulated the methodological adaptation, determined the methodology and criteria, conducted literature search and analysis of results. Conducted initial drafting of paper and subsequent editing.

The following co-authors contributed to the work:

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<th>Name</th>
<th>Nature of contribution</th>
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<tr>
<td>Natassia Goode</td>
<td>Contributed to case study reviews. Provided critical review of draft version of the paper.</td>
</tr>
<tr>
<td>Paul M. Salmon</td>
<td>Advice on choice of case studies, guidance on interpretations and presentation of results. Provided critical review of draft version of the paper.</td>
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The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate’s and co-authors’ contribution to this work.

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Accounting for memes in sociotechnical systems: extending the abstraction hierarchy to consider cognitive objects

Tony Carden, Natassia Goode & Paul M. Salmon

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Accounting for memes in sociotechnical systems: extending the abstraction hierarchy to consider cognitive objects

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Centre for Human Factors and Sociotechnical Systems, University of the Sunshine Coast, Sippy Downs, Australia

ABSTRACT

Work domain analysis (WDA) is used to model the functional structure of sociotechnical systems (STS) through the abstraction hierarchy (AH). By identifying objects, processes, functions and measures that support system purposes, WDA reveals constraints within the system. Traditionally, the AH describes system elements at the lowest level of abstraction as physical objects. Multiple analyses of complex systems reveal that many include objects that exist only at a conceptual level. This paper argues that, by extending the AH to include cognitive objects, the analytical power of WDA is extended, and novel areas of application are enabled. Three case studies are used to demonstrate the role that cognitive objects play within STS. It is concluded that cognitive objects are a valid construct that offer a significant enhancement of WDA and enable its application to some of the world’s most pressing problems. Implications for future applications of WDA and the AH are discussed.

Practitioner summary: Some sociotechnical systems include memes as part of their functional structure. Three case studies were used to evaluate the utility of introducing cognitive objects alongside physical ones in work domain analysis, the first phase of cognitive work analysis. Including cognitive objects increases the scope and accuracy of work domain analysis.

Abbreviations: WDA: work domain analysis; STS: sociotechnical systems; AH: abstraction hierarchy; CWA: cognitive work analysis; StrA: strategies analysis; WCA: worker competencies analysis; SAD: strategies analysis diagram; CAT: contextual activity template; SOP: standard operating procedure

Introduction

The accelerating pace of social and technological change is giving rise to increasingly complex sociotechnical systems (STS; Dekker, Hancock, and Wilkin 2013; Grote, Weyer, and Stanton 2014; Salmon et al. 2017). This includes the increasing mobility of people across international borders, advances in automation, communication, and data processing, and the increasing role of artificial intelligence in STS (Hancock 2014; Walker et al. 2017). With increasing complexity comes the need to adopt Ergonomics analysis methods to cope with the evolving problem space (Salmon et al. 2017). As complexity of STS increases, so does the need for appropriate methods to understand, control, and optimise them.

Cognitive work analysis (CWA; Vicente 1999) is a currently popular tool for understanding and attempting to optimise STS (Bisantz and Burns 2008; Stanton et al. 2017). The first phase, work domain analysis (WDA; Naikar 2013) involves using the abstraction hierarchy (AH) to develop a model of the STS in question. This resulting model describes system elements at the lowest level of abstraction as physical objects. Processes emerge from agent interactions with these objects that support system functions, values, and purposes. The development of CWA originated in the domains of industrial process control (Naikar 2013, 53; Rasmussen 1979). In those and many subsequent applications in manufacturing, healthcare, and aviation, objects at the lowest level of abstraction were deemed to be exclusively physical. In the words of Rasmussen (1986, 17), ‘The lowest, most concrete level of abstraction is the representation of physical form, i.e. the physical appearance and configuration of the system and its parts’. For example, an agent interacting with a light switch in a house can give rise to the process of illuminating a room. This, in turn, supports the function of visibility, that in turn supports one purpose of the house, comfort.
However, it is apparent that the functional structure of some systems includes objects that are not physical, but ideational. For example, in a blues jam session, user interaction with the 12-bar blues pattern might support the process of remaining in tune and in time, which in turn supports the function of synchronised melody, which in turn supports the purpose of playing the blues. In this example, musicians did not need to interact with a physical object to interact with the 12-bar blues pattern. Rather, the 12-bar blues pattern is a cognitive object in the sense that the musicians each have their own internal representation of it. We argue that for accurate representation of this system in WDA, the 12-bar blues pattern can be accurately represented as a ‘cognitive object’. The existence of written representations of the pattern in sheet music does not necessarily negate the need to independently represent it as a cognitive object, as agents may never actually interact with the physical sheet music.

As we will show, complex STS can include cognitive objects along with physical objects as components of their functional structure. These cognitive objects are no less real than any physical object. They are constructed by people and represent important design and analysis considerations for ergonomists. For analysts to ignore these artefacts as though they were beyond the control or influence of system designers could potentially represent a failure to recognise the full complexity of systems. We argue that it is important to recognise cognitive objects as system components that can, and must, like physical objects, be recognised, understood and modified to optimise system performance and human wellbeing.

An epistemological foundation for cognitive objects lies in the recognition of memes. Memes were first defined by the biologist Dawkins (2006, 217) as ‘unit[s] of cultural transmission’ in his attempt to note that genes were not the only kind of possible replicator that can give rise to evolution. Other definitions include ‘unit[s] of imitation’ (Dawkins 2006, 217), ‘synaptic patterns that code cultural traits’ (Delius 1991, 83), and ‘a kind of way of behaving (roughly) that can be copied, transmitted, remembered, taught, shunned, denounced, brandished, ridiculed, parodied, censored, hallowed’ (Dennett 2017, 192). Just as only some explicit, enduring and transmissible ideas qualify as memes, only some memes qualify as cognitive objects. We argue that cognitive objects are memes that give rise to unique affordances and constraints in some STS, distinct from physical objects with which they may be associated. They exist at the lowest functional level of abstraction in those systems and their explicit identification in WDA gives rise to unique analytic outputs and design implications.

The continual evolution and enhancement of our analytical toolkit is required for Ergonomics to remain both useful and relevant (Salmon et al. 2017). The aim of this article is to show that a modification of WDA can improve that framework’s utility for application to increasingly complex STS. This involves extending the abstraction hierarchy to support the identification of cognitive objects alongside physical objects. CWA has been used widely for the analysis and design of STS. Its latter phases are well suited to identify some cognitive constructs (e.g. skills, rules, knowledge; Vicente 1999) that reside in the minds of users of the system under analysis. However, we argue that CWA can currently overlook canonical or fixed ideas that exist independently of system agents and physical objects, and yet form part of the system’s functional structure. We argue that such ideas play an increasingly prominent role in emerging, complex STS, and must be considered as objects and included in WDA, alongside physical objects.

Work analysis and sociotechnical systems

STS have been variously described as those systems which include social, technical, and psychological components or aspects (Klein 2014; Trist 1981; Vicente 1999). STS theory emerged in the mid-20th century (e.g. Trist 1981; Trist and Bamforth 1951) as a response to the increasing emergence of technology in work and a recognition of the need to understand the changing nature of work. STS is a work design approach concerned with both the performance of the work system and the experience and well-being of workers (Clegg 2000). A key tenet of STS theory is that systems require adaptive capacity; one of the primary means to achieve this is to analyse social, psychological and technical elements of the system and their interactions together. This holistic approach to analysis supports the joint optimisation of human and technical elements across the system of interest.

Although it originated in the domains of industrial work (Trist and Bamforth 1951), STS theory has become a popular means of both understanding and designing STS. In addition to typical systems of work, it has been applied beyond the workplace to social systems such as road and rail transport (Read, Salmon, and Lenné 2016; Salmon et al. 2018b), house design (Naikar 2013), home carpentry (Lintern 2009) and sport (Hulme et al. 2017; McLean et al. 2017).
CWA (Vicente 1999) is a framework for analysing the physical and social environmental constraints and affordances in STS. CWA originated from the pioneering work of Jens Rasmussen at the Risø National Laboratory in Denmark (e.g. Rasmussen and Timmerman 1962). Beginning in the early 1960s, Rasmussen’s aim was to provide a framework to help understand the human and technical factors that combined to determine the safety and performance of nuclear reactor systems (Vicente 1999). CWA provides a set of conceptual tools for modelling several nested dimensions of the physical and social environments within which STS occur (See Vicente 1999 for an overview of the framework).

The abstraction hierarchy (AH) is the foundational construct for WDA and therefore, for CWA. It consists of a five-tier model where the lowest level represents the least abstract view of the system and the highest level represents the most abstract view (Rasmussen, Pejtersen, and Goodstein 1994, 44). During the evolution of WDA, the labels for each level have been modified and adapted as scholars and analysts refined the method (Naikar 2013, 51–75; Rasmussen, Pejtersen, and Goodstein 1994, 45–48; Vicente 1999, 166). The highest level of abstraction in the hierarchy represents system elements that Rasmussen framed as ‘reasons’ for the system’s existence, while the lowest level represents system elements that act as ‘causes’ to control the physical functions of the system (Rasmussen 1979, 3). Synthesising the work of foregoing scholars and noting the need for flexibility in both the number and labels of AH levels, Naikar (2013, 67–75) described a standard set of labels for an abstraction hierarchy, as represented in Figure 1.

At the lowest level, the AH identifies the physical objects that are or could be deployed to serve a system’s purpose. The second level represents object-related processes that can arise from agent interactions with the objects. The third level shows general functions that serve the system’s purposes. At the level above, there are values and measures that can guide and monitor system performance. Finally, the functional purposes of the system are represented at the top level.

This method produces a comprehensive, holistic picture of a system’s structure, allowing analysts to discern what it is capable of achieving. Vicente (1999) describes how, while a task analysis describes a set of directions for a worker, WDA describes the functional environment within which the work takes place (157). The later phases of CWA introduce tasks and agents into the functional structure identified in WDA to offer a progressively rich analysis of the detail of actual or possible system performance.

The accuracy, and therefore the utility, of the latter phases of CWA is often influenced by the accuracy of WDA. Furthermore, the scope of application of CWA will be limited by the range of application of its foundational phase, WDA. If the description of the work domain provided by WDA is incomplete, so too will be the products of all other CWA phases. We argue that, in addition to physical objects, some STS also include cognitive objects. For the purposes of CWA, WDA, and the AH, these non-physical objects share many of the same attributes as physical objects. They are components of the system prior to their interaction with agents in the system. That is, the system does not rely on agents bringing these objects into the system. Agents may encounter them on every new interaction with the system. They are thus agent and event independent components of the system’s functional structure. Most importantly, processes can uniquely emerge from agent interactions with cognitive objects that serve important system functions.

Two objections to the inclusion of cognitive objects alongside physical objects at the lowest level of the AH arise from traditional formulations of CWA (Naikar 2013; Rasmussen, Pejtersen, and Goodstein 1994; Vicente 1999). The first is that all cognition is abstract, and that the higher levels of the AH, along with latter phases and products of CWA (e.g. strA, decision ladders, WCA; Jenkins et al. 2009) already account for memes. Cognitive objects as we will describe them are indeed in a global sense ‘abstractions’, as defined by Deutsch (Deutsch 2011, 114–119). That is, a cognitive object emerges originally from a physical

**Figure 1.** Abstraction hierarchy standard labels (Naikar 2013).
substrate, such as a group of neurons in a brain. However, once the object exists, it can be transmitted to other brains. Its existence is not confined to the brain in which it emerged. Indeed, some cognitive objects will replicate and evolve independently of their origin in a process of cultural selection (Dawkins 2006, 214–218). Their subsequent instantiation consists of interaction between a cognising entity (i.e. a human or non-human agent) and the persistent cognitive object (i.e. the meme). We argue that in some specific STS, their functional role can best be located at the least abstract level of that system. We argue that where their omission from an abstraction hierarchy would diminish the utility of the analysis, cognitive objects should instead be identified and included. Therefore, we propose that the possibility of the existence of cognitive objects, along with a careful definition, should be added to the taxonomy of entities to be considered for inclusion in WDA.

A second related objection is that ideas are neither agent nor event independent. They can surely only exist in the flow of time within the mind of an agent. This should rule them out as candidates for inclusion in WDA’s models of the agent and event independent functional structure of STS. We argue, however, that ideas are commonly transmitted from external sources into minds as described by Deutsch (2011, 93) and others (e.g. Dawkins 2006; Delius 1991). Theories of distributed and embodied cognition also offer an explanation of how ideas, along with other components of cognition, can be distributed among a set of agents, physical entities, and processes. These observations show that cognitive objects can be, and often are, independent of agents within an STS. We will draw on these theories in the sections below to support our proposal to include cognitive objects, where useful, at the lowest level of the AH. To qualify as event independent, physical or cognitive objects do not need to be timeless. After all, few physical objects described in WDA have existed since the beginning of time. Instead, to qualify as event independent for the purposes of WDA, an object merely needs to have existed as part of the system prior to the system’s activation (triggered by agent interaction).

Following Rasmussen (1985, 4–5), Naikar (2013, 25–27) distinguishes between ‘causal’ and ‘intentional’ STS. The former are defined as those where actor behaviour in the system is primarily constrained by physical or natural laws while in the latter, behaviour is constrained more by social conventions, individual values, and internal goals. It is initially tempting to suspect that STS that include cognitive objects must be more intentional than causal. However, this may not be the case. The conventions, values, and goals noted by Rasmussen and Naikar are generally represented in AH at higher levels of abstraction, particularly at the values and priority measures level (e.g. health, pleasure, conservation; Naikar 2013, 26). There is a reliance in these systems upon the a-priori intentions of actors. In contrast, cognitive objects are truly actor independent and can have the selfish, self-replicating characteristics of memes, as described by Blackmore (2000, 27–32). Therefore, the presence or absence of cognitive objects in STS is not a predictor of the position of that STS along the spectrum from causal to intentional systems (Naikar 2013, 39).

The claim that cognitive objects can form part of the agent and event independent functional structure of an STS relies on the possibility that these non-physical entities can reside somewhere other than the minds of system agents.

**Distributed cognition and schema theory**

Recently, the theory of distributed cognition has become an important lens to analyse STS (Chatzimichailidou and Dokas 2016; Plant and Stanton 2016; Salmon, Read, and Stevens 2016; Salmon et al. 2008; 2014; Stanton 2016; Stanton et al. 2009). This fundamentally changes the understanding of cognition from that which underpinned the early development of CWA. As a result, the manner in which WDA incorporates objects that underpin cognition requires an update.

Both distributed cognition theory (Hutchins 1995) and the related exploration of distributed situation awareness (Stanton et al. 2006) describe how cognition can be distributed among agents and objects in STS. From the perspective of an agent, this means that some aspects of cognition can be externally represented (Zhang and Norman 1994). Schema theory (Bartlett 1932) provides a foundation to explain how stored frameworks of contextual concepts filter perception. A schema is a mental template that modifies information and influences behaviour (Stanton et al. 2009). While initially conceived as a phenomenon within individual minds, schemata may be distributed among groups. For example, Daft and Weick (1984) describe how assumptions about the environment among managers in organisations congregate into a shared model that informs collective decisions and action. Moreover, distributed cognition theory reveals the possibility that behaviour-shaping schemata may include or consist of external representations.
More recently, ergonomics researchers have shown how schemata filter and shape individual agents’ interpretation of perceived data in STS and thereby influence decision-making and action (Salmon et al. 2014). Stanton et al. (2009) discuss two levels of schemata held by individuals in STS: genotypic and phenotypic. A genotypic schema is a passive set of situational assumptions. When activated in a relevant situation, it is modified by perceived data and instantiates in a situational phenotypic schema which in turn influences decisions and actions in real time. This instantiation of the genotypic schema via a phenotypic ‘child’ schema can, in turn, modify the genotypic schema through internal feedback. CWA can currently support the modelling of these individual schemata in the upper levels of the AH, in decision ladders, and in WCA. However, some collective schemata and their affordances are so critical to STS performance, that system design either does not or should not rely on their importation to the system by agents.

Furthermore, unlike schemata held within the minds of individuals, externally represented schemata are unable to be quickly modified through any automatic feedback mechanism. Instead, we argue that they are fundamental, incorrigible objects that form part of those systems’ functional structure.

In summary, this paper examines the proposition that STS rely upon powerful ideas or concepts to the extent that these ideas constitute fundamental elements of the system’s functional structure. In such cases, where these critical concepts are independent of their physical representations, of system users, or any particular instantiation of the system, we explore the validity of including them and explicitly identifying their cognitive nature at the objects level within an AH.

Method

Case studies

Case study 1

A regulatory system for adventure activity safety. The New Zealand Adventure Activity Regulations (NZAAR; Mateparae 2016) were implemented in 2011 after an extensive review and reform process, facilitated by the New Zealand Government. The scheme requires commercial providers of outdoor adventure activities to comply with regulatory requirements. (WorkSafe 2014).

While regulation has been more commonly viewed by ergonomists as a component of a work domain (e.g. Rasmussen 1997), Carden et al. (2017) analysed the New Zealand Adventure Activity Regulations (NZAAR; Mateparae 2016) as a STS in its own right. This analysis identified cognitive and physical objects at the lowest level of the AH (see Figure 2).

The AH for the NZAAR shows 22 objects at the lowest level, many of which are unambiguously physical objects and several of which could be considered as cognitive objects. For example, ‘activity guidelines’ is one object that may be considered as either a physical or a cognitive object. If the system reliably supports agents to interact with the physical object (e.g. a physical document, handbook, or webpage), it may be
sufficient to identify the objects solely as physical. This would mean any desired changes to the object revealed by WDA could be enacted upon those physical objects. However, if agents are likely to gain their understanding of the activity guidelines by other means, the object’s identification as physical may be insufficient.

An agent developing standard operating procedures (SOPs) for the first time is likely to read the authorised, current version of the activity guidelines. However, some agents may rely on their previous experience with writing SOPs for adventure activities, common industry knowledge, or memory of their previous reading of the official activity guidelines. These alternative means of accessing information show that the physical object may not actually be used in all cases and that the cognitive processes that support the development of SOPs are distributed across the system. In the former case, the agent relied on an external representation of relevant information while the agent in the latter case called upon an internal representation of the relevant information (Zhang and Norman 1994).

While a novice agent may be more likely to interact with a physical object (e.g. read the written guidelines to gain an understanding of their compliance obligations), they may for future compliance activity rely on their memory of the requirements. This memory will form the basis of that agent’s own iteration of the cognitive object, modifiable by their internal schemata and experience, with which they may subsequently interact to afford understanding of compliance requirements. This iteration of the cognitive object may also become a source for other agents who may gain their own understanding of the guidelines from the first agent, rather than by reading the written guidelines. The second agent will then have interacted only with a cognitive version of the object and not the physical version. The second agent then becomes another node for the distributed external representation of the cognitive object for future agents.

An important distinction comes into view here between the intent of system designers and how the system is actually used. A growing body of ergonomics literature refers to this distinction as ‘work-as-imagined’ versus ‘work-as-done’ (Hollnagel 2017; Hysong et al. 2005). This research reveals gaps between STS design and STS operation. Reasons for these gaps include time and resource pressures, leading agents to find and normalise shortcuts to achieve goals. In the case of activity guidelines, it seems reasonable to predict that agents would prefer to interact with a cognitive rather than a physical version if it saves time and money but still achieves the goal of affording sufficient understanding to meet compliance requirements.

The explicit inclusion of cognitive objects in descriptive WDA improves the likelihood of detecting gaps between work-as-imagined and work-as-done. Their inclusion in formative applications of WDA supports designers’ capacity to close such gaps.

Figure 3 shows 4 diagrams arising from the application of the second and third phases of CWA, Control Task Analysis and Strategies Analysis to a selection of processes afforded by the object, ‘activity guidelines’. The four object related processes linked to activity guidelines in the AH (Figure 2) show that it is a means of affording compliance guidance, guidance for
developing standard operating procedures (SOP), the documentation of SOPs, and safety management system requirements. Three of these are shown in the Contextual Activity Template (CAT; Jenkins et al. 2009, 185–187) at the top-left of Figure 3.

Applying Cornelissen et al.'s (2013) strategies analysis diagram (SAD) formulation to the two strategies shown in the strategy flow diagram (top-right of Figure 3) and the two decision ladders (Jenkins et al. 2009, 187–189) below guides us to refer to object and function nodes linked to the object-related process, ‘safety management system requirements’, in the AH (Figure 2). We can then add a verb to describe how a user would interact with the relevant object under each of the two conditions shown in the strategy flow diagram and the two decision ladders. This results in two descriptive sentences. First ‘Reading Activity Guidelines leads to an understanding of Safety Management System requirements which supports Operator Safety Management’. Secondly, ‘Recollection of Activity Guidelines guides the application of Safety Management System Requirements to Operator Safety Management’. If the activity guidelines change, ensuring that the change has the desired effect on the purpose-related function of operator safety management would require only a change to the content of the physical object if users could be relied upon to read it.

If it is likely that users will not refer to the official version of the activity guidelines on a regular basis to maintain a compliant safety management system, other strategies will be required to enact the desired system change. These strategies would need to affect the cognitive version of the activity guidelines object. They could include training, awareness campaigns, or the introduction of new technologies to update users.

Case study 2

Queensland road transport system. The AH shown in Figure 4 represents the functional structure of the road transport system in Queensland, Australia (Salmon et al. 2018a). This AH was developed initially using publicly available documentation about the Qld road transport system (e.g. National and state road safety strategies, road rules and regulations, standards) and existing systems analyses previously undertaken by the authors (e.g. Salmon, Read, and Stevens 2016). The draft AH was then reviewed and refined in a subject matter expert workshop involving researchers with extensive experience in road safety research as well as applied systems thinking research across a range of domains.

Naikar’s (2013) nine-step WDA methodology was applied across the draft AH development phase and subsequent workshop. This involved initially...
establishing the aims and purpose of the analysis (as expressed earlier) and discussing any relevant project constraints. Next, the analysis boundary was defined as the Qld road transport system incorporating the activities of the agents and organisations described by Salmon, Read, and Stevens (2016) in their Qld road transport system control structure model. Salmon et al.'s (2016) control structure model included all of the agents and organisations who play a role in the design and operation of the road transport system in Qld. This included agents across the following six levels: international context; parliament and legislatures, government agencies, industry associations, user groups, insurance companies, courts and universities; operational delivery and management; local management and supervision; and the operating process and environment.

While most of the objects shown in Figure 4 are unambiguously physical (e.g. cars, motorcycles, heavy goods vehicles, bicycles, buses), several are not. For example, the object ‘Road rules and regulations’, like the ‘Activity Guidelines’ in case 1, affords processes that directly rely on the content of the rules and regulations, rather than the properties of any physical document or display.

The CAT at the top-left of Figure 5 shows 3 object-related processes that rely upon the object, ‘Road rules and regulations’. As with the object ‘activity guidelines’ considered in case 1, the strategy flow diagram and decision ladders in Figure 5 show that ‘road rules and regulations’ when considered as a physical object yields different analytic results than when it is considered as a cognitive object. Once again, the decision process is shown to be shorter when no reading of a document is included. As with the previous case, the analytic value in this case of separate consideration of the object as cognitive should be determined by an estimation of how likely it is that agents will access the object in its physical form. In the case of road rules and regulations, while some drivers may be relied upon to have read the road rules when studying for their driver’s licence, it seems quite unlikely that most will read them again (Li and Tay 2014). As a result, external representations of the rules are distributed across the system in the form of additional physical objects (e.g. speed limit signs, warning signs) and cognitive objects (e.g. popular opinion). In practice, drivers use skill-based behaviour (Vicente 1999, 292–308) supported by their internal correlate (Zhang and Norman 1994, 90) of an external representation of the road rules. This suggests that, for a change of the road rules to be understood and internalised by drivers and thereby influence the linked system processes, functions, and purposes, modification of the physical object alone (e.g. the official road rules manual) is likely to be insufficient. Rather, road user education campaigns (World Health Organization 2004, 137) or other strategies (e.g. in-car warning systems) are required.

The strategy sentences generated by application of the SAD method support the suggestion that reading of any physical object representing road rules is quite unlikely when cognition occurs in real time: ‘Reading the road rules clarifies which vehicle has priority, thereby controlling traffic behaviour’. This seems less likely to occur than the alternative strategy that arises from identification of road rules and regulations as a cognitive object: ‘Recollection of the road rules...’

Figure 5. Contextual activity template, strategy flow diagram, and decision ladders for the QLD road transport system.
indicates which vehicle has priority, thereby controlling traffic behaviour. However, the enactment and enforcement of any change in the road rules would require a physical reference point both for driver education and to support enforcement. To successfully change system outcomes by modifying road rules would, therefore, seem to require modification of both a cognitive and a physical iteration of the ‘road rules and regulations’ object. Both object types should, therefore, be included in the AH.

Case study 3

Jihadi Islamist terrorist group. The AH shown in Figure 6 represents the functional structure of the STS of a Jihadi Islamist terrorist group, such as Islamic State (Wood 2016). The analysis of this system (Salmon, Carden, and Stevens 2018) was based on data sourced from journalistic, academic and jihadi sources. Contrary to traditional applications of CWA and its components, this novel application of WDA seeks to produce analytic insights that support disruption of the system and its purposes.

The 19 objects shown at the lowest AH level include several that could be considered as cognitive objects. ‘Islamic scripture’, the ‘doctrine of redemption of sin via jihad’ (e.g. Quran 4:74), the ‘doctrine of eternal afterlife’ (e.g. Quran 30:40), the ‘doctrine of manifest destiny’ (e.g. Quran 8:39), and ‘manifesto’ are all objects that impose cognitive constraints upon system users. However, the objects ‘Islamic scripture’ and ‘manifesto’ may adequately be described as physical objects. ‘Islamic scripture’ is a broadly descriptive object which includes a wide array of material with varying degrees of authority and influence. It seems sufficient to consider this as a broadly described physical object which affords processes at higher levels of abstraction that impose more specific constraints on system users. ‘Manifesto’ can be considered as the set of operating rules or constitution of the terror group. Its content is, at least in principle, amenable to change by system users. In contrast, the three doctrines shown provide specific constraints and affordances for system users. As specific, canonical doctrines (Cook 2000, 28), these objects are not amenable to modification by system users. They can, therefore, be considered as components of the physical and social environment which forms the functional structure of this system (Vicente 1999, 50–51).

Like the physical objects identified, these three cognitive objects both constrain and afford a range of possibilities for action within this system (Vicente 1999, 119). No particular physical container or conduit for these doctrines is required. It is the meme itself – the cognitive object – which has the most concrete level of form that is relevant to these objects in this system. It may be noted that for the devout, these doctrines are held to be even less malleable than the laws of nature (Quran 35:43; Cook 2000, 60). Furthermore, none of them exists as a distinct, bounded component of a specific text. Instead, they
are distributed widely across the canon of, not only Islamic scripture but many religious traditions.

The object-related process ‘murder and martyrdom motivation’ is supported by the three doctrines. The strategy flow diagram and decision ladders in Figure 7 show alternative strategies available to agents to allow them to find the motivation to overcome the fear of killing and dying. Both strategies rely on acceptance of one or more of the doctrines. However, the decision ladders illustrate a more deliberate and less certain decision pathway if the agent relies on the reading of scripture, compared with the pathway that relies instead on a pre-existing acceptance of these externally represented, shared memes.

As with cases 1 and 2, modifying the processes and functions that depend on the doctrine objects in this system look quite different if the objects are considered to be cognitive objects rather than physical objects. If the aim of the analysis is to disrupt this malevolent system, analysis showing the doctrines as physical objects suggest modifying the content of the canonical texts may achieve this aim. When analysis identifies these doctrines as cognitive objects, the necessity for a different range of disruption strategies appears. These might include, for example, existing and novel de-radicalisation strategies, along with other re-education and influence efforts (e.g. as cited in http://www.abdullahx.com/; Moonshot CVE 2018).

The divergent outputs of analysis are supported by the sentences that arise from application of the SAD method. For the strategy relying on the physical version of a doctrine object, the following sentence applies: ‘Reading the doctrine of redemption of sin via jihad provides murder and martyrdom motivation allowing the jihadi to execute attacks’. The process and function being supported here appear to require a psychological force that seems unlikely to be attained by a simple reading of doctrine. A deeper, more enduring commitment appears more likely to achieve the necessary impetus: ‘Recalling the doctrine of redemption of sin via jihad provides murder and martyrdom motivation allowing the jihadi to execute attacks’.

**Discussion**

This article aimed to justify an extension to WDA, a method that is currently popular in systems ergonomics applications, to include cognitive objects. Three case studies were used to show that, in some STS, some of the cognitive and behavioural affordances arise, not from the interaction of agents with any physical object, but from interaction with a cognitive object – an ideational representation or meme (Dawkins 2006) that exists independently of the agent. Accordingly, it is these authors’ contention that the AH method should be extended to incorporate both physical and cognitive objects at its lowest level.

In case 1, the usefulness of identifying the object ‘activity guidelines’ as cognitive as well as or instead of physical was marginal and would depend on the purpose of analysis. Any such utility depended on the likelihood of relevant agents in the system rarely accessing the physical version of the object but instead relying on externally represented versions of the information it contained (e.g. word-of-mouth, observation of others).

In case 2, identifying ‘road rules and regulations’ as a cognitive as well as a physical object seemed more necessary, as most relevant system agents were
unlikely to interact with the physical version of the object to give rise to the linked object-related processes identified in the AH. Explicit identification of road rules and regulations as a cognitive object as well as a physical one supports better-targeted interventions where analysis shows a need for change in that object.

In case 3, the identification of the three ‘doctrine’ objects as cognitive rather than physical was critical to the accuracy and utility of the analysis. These objects are widely distributed, are not confined to any specific physical objects, and to the extent that they are represented in physical objects, these objects (e.g. the Koran, the Hadith, the Bible) are beyond the scope of analysts or disrupters of the Jihadi STS to modify.

Our findings suggest that it is important to identify both physical and cognitive objects when developing AHs as part of a WDA. A cognitive object is an externally represented synaptic pattern that is a foundational component of the functional structure of an STS. To qualify as a cognitive object for inclusion in the AH, a cognitive object must meet the following criteria:

- It must afford processes that support functional purposes;
- Its affordances must differ from any analogous physical object;
- The inclusion of the cognitive object must preserve the local agent and event independence of the AH;
- Memes must have sufficient endurance and stability to qualify as a cognitive object (i.e. the cognitive object must be capable of consistent recognition and use by novice agents);
- A cognitive object must uniquely support processes that support system functions in ways that cannot be fully ascribed to any particular container or conduit.

To offset the possibility that including cognitive objects may further complicate CWA, the current AH level labels could each be replaced with a single word: Purposes, Measures, Functions, Processes and Objects.

Whilst we have argued that the inclusion of cognitive objects is a novel extension to WDA and the abstraction hierarchy method, it is worth noting that previous analyses have included what appear to be cognitive objects. These analyses have either followed the orthodox level-labelling convention by conflating them with associated physical objects or locating them at a higher level of abstraction. For example, in his WDA of the management of microsystems design, Durugbo (2012) identifies ‘virtual prototype’ at the lowest level of abstraction, linked upward to the physical function (object-related process), ‘model testing’. All other elements shown at the lowest level are unambiguously physical objects linked upward to affordances that would emerge from user interaction. However, the virtual prototype is not itself a physical object. Unlike the ‘physical prototype’ alongside it that affords the same physical function (object-related process), the virtual prototype is an ephemeral construct: a cognitive object. The author makes this explicit, noting ‘Prototypes can be described as quickly created samples or replicas for analysis by physical means or abstract representation. Abstract representations or virtual prototypes for MST may be computer databases or CAD files generated by CAD software’ (Durugbo 2012, 613). Although an abstract representation, the virtual prototype is actor and event independent and unambiguously belongs at the objects level in the AH.

Lintern (2008) explicitly includes facts, ideas, and opinions as lower level entities in an abstraction hierarchy for a reasoning space. However, these entities are identified as physical functions (object-related processes) at the second lowest level of the AH rather than as objects. The objects level in Lintern’s model is populated by physical sources of those ideational entities. Identifying facts, ideas, and opinions as processes emerging from user interaction with a selection of source objects such as sensors, maps, and spreadsheets may be appropriate for the military planning system Lintern describes. However, in some systems including those described in our three case studies, data is neither reliably available to users from such sources in real time nor do these systems rely upon such physical source objects. Sources of cognitive objects can include not only physical objects like rule-books, web pages and scripture, but an imitation of the behaviour of others, and memory of culturally entrenched tropes. It may be the case that, if Lintern’s Reasoning Space were to be generalised beyond the military context, the entities in the physical functions level of his AH might better be dropped down to the lowest level of abstraction replacing the now somewhat arbitrary list of physical source objects. The physical functions (object-related processes) level could then be populated with the cognitive filtering processes (e.g. comparing new data with existing data, interpretation of data) that provide the means to support the general functions of insight and understanding.
Cognitive objects need only be included in an AH where achievement of the purpose of analysis requires modification of processes and functions that depend uniquely on the cognitive object. Therefore, where a physical object supports the same affordance as a cognitive object and system users can be relied upon to interact with the physical object, identification of an analogous cognitive object that supports the same affordance may be unnecessary.

When cognitive objects and analogous physical objects provide different affordances that are found to require a change to achieve the aims of analysis, different strategies will be required to change each. In these cases, it is important to identify cognitive objects in the AH. In contrast, if the affordances linked to a cognitive object are not found by the analysis to require change, or if they are identical to the affordances of a physical analogue, it may be adequate to represent the object simply as physical, as no strategy development is required to achieve desired changes.

For each of the case studies, non-physical objects were identified which afforded object-related processes. While these objects could be found in various physical containers or conduits, their affordances differed from those of their containers and conduits. Although the container too should be included in the AH if its properties mean that it imposes constraints and affords actions that are relevant to purpose-specific functions, these should not be confused with the constraints and affordances provided by the cognitive object it contains. In each of the three cases, the analyses demonstrated how, were the cognitive objects to be conflated with their physical container, important system design requirements would be overlooked.

Indeed, if the relevant process is afforded by the content rather than the container, for some systems and some analyses it may be important to distinguish between the two. While the design and modification of books and webpages can be achieved with one set of actions, the design and modification of enduring concepts may require another. The examples provided by these case studies show three different outcomes of the separate identification of cognitive objects and their physical containers. They illustrate that in some systems where cognition is distributed, the explicit recognition of cognitive objects in WDA adds analytic value.

**Future applications**

Part of the impetus for the proposed modification to WDA and the AH comes from the fact that the ergonomics problem space is shifting. These changes are likely to bring about new and emergent problems that require the intervention of ergonomics. Examples include autonomous vehicles, advanced automation, and artificial intelligence. The identification and analysis of cognitive objects will be paramount when attempting to design or evaluate such systems. In the case of AI, for example, ideas will enter machine cognition post their engagement in the system. Like their human analogues, AI will bring some prior ‘knowledge’ to their role in the system. They will acquire more knowledge within the system from their interaction with other system entities. However, unlike their human counterparts, AI agents cannot be relied upon by system designers to bring a standard set of common-sense or cultural background knowledge to the system. Systems will need to include specific and reliable means to convey cognitive objects upon which they rely to AI agents. By supporting the understanding and modelling of units of knowledge as modifiable objects, the inclusion of cognitive objects in the AH will improve the utility of WDA and in turn CWA for evaluating and improving the design of STS in which AI agents play an increasingly prominent role. Furthermore, efforts by AI safety researchers to improve transparency of AI decision making (e.g. Wachter, Mittelstadt, and Floridi 2017) may be supported by this adaptation of WDA due to its enhanced capacity to make cognitive constraints and affordances more explicit.

In addition, it may be that adding this capacity opens up further areas of analysis for CWA and systems ergonomics. While it has traditionally been used to improve the performance of sociotechnical systems with desirable purposes, the application of CWA to the disruption of systems that are designed to achieve illicit ends may have potential beyond the terror cell (Salmon, Carden, and Stevens 2018). Other examples may include systems with damaging outcomes that emerge from the functional structure of the system, regardless of whether those outcomes reflect intended functional purposes. One example may be institutional child abuse where many entities at the bottom level of a WDA would seem likely to be cognitive objects. These could include international laws and cultural beliefs. Another example may be climate change. It may be that the inclusion of cognitive objects in an analysis of the functional structure of the global STS that causes environmental damage offers valuable insight for policy makers. For example, specific, canonical memes may underpin economic ideologies which are drivers of climate change. These memes might
include widespread beliefs such as ‘economic growth is necessary’, ‘local actions only have local effects’, and ‘the unregulated free market is the best means to meet all needs’.

Conclusion
This study has shown that some sociotechnical systems include cognitive objects as part of their functional structure. The constraints afforded by these objects independently precede the cognitive constraints brought to the system by agents acting within it. On the basis of three case studies, it is concluded that WDA, and specifically the AH, should be modified to include both physical and cognitive objects. The findings from the case studies indicate that a richer, more valid, and more useful analysis is constructed when identifying both physical and cognitive objects. Therefore, in systems such as these, specific recognition in WDA of cognitive objects as components of a system’s functional structure improves the analytic accuracy and utility of CWA. It is proposed that extending WDA and the AH in this manner will improve its capacity to cope with emergent systems such as autonomous vehicles and AI. Further applications are encouraged.

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References


Summary

The study described in this chapter set out to examine the validity and necessity of modifying the objects level of the WDA AH to include cognitive objects alongside physical objects. This is a novel extension to the CWA framework that has been identified through the research conducted in this thesis. Three case studies were considered. First, a system for regulating safety in LOAs. Second, a road transport system. Third, a terrorist cell. In each of these STS, a small number of objects were identified that supported important system processes and functions but did not require agents to interact with a physical entity. Instead, it was found that these processes and functions were likely, at least some of the time, to be supported by user interaction with a persistent idea or meme.

The research literature supported the identification of these ideas or memes as cognitive objects in STS. ConTA, StrA, and SAD were used to demonstrate the functional differences between cognitive objects and their physical counterparts. Five criteria were proposed to guide the identification of cognitive objects in the analysis of STS. Future applications of the modified AH taxonomy were discussed.

The inclusion of cognitive objects within the AH represents an important methodological extension. It makes CWA even more useful for the analysis of future systems, particularly those that include artificial intelligence (AI). While many aspects of human cognition, including assumptions about commonly held beliefs and values (i.e. memes), may be taken for granted, the same is not true for AI. Specifying these aspects of cognition as cognitive objects at the design stage of an STS may help address the challenge of AI decision-making transparency (Wachter, Mittelstadt, & Floridi, 2017). Recognising cognitive objects in analysis of STS that include AI may prove very useful in troubleshooting undesirable system outcomes. This capacity may be most useful if and when Artificial General Intelligence emerges (Tegmark, 2017).

The study presented in this chapter concludes the task of addressing the question of whether the application of systems theory and STS methods can produce design proposals for LOA regulatory systems. The modification of the WDA AH described here
consolidated the adaptation of CWA-based methods to the analysis and design of regulatory systems, described and tested in studies described in earlier chapters. It remains now only to summarise and synthesise these findings in the following, final chapter.
Chapter 11 – Discussion

This chapter recaps and summarises the overall thesis findings, discusses the limitations of the studies described, and suggests the broader relevance and future applications of this work.

Overview of findings

The purpose of this thesis was to test several linked propositions. Firstly, that the LOA domain is a complex system and that, therefore, systems-thinking is needed, not only to support regulation in the domain, but also to understand all aspects of LOA system safety and performance management. Secondly, that STS theory and methods provide a suitable approach for evaluating regulatory systems. Thirdly, that STS theory and methods, and specifically the CWA-DT, can usefully support regulatory system design. Finally, that extensions can be made to existing STS methods to make them even more useful for regulatory system evaluation and design. The findings of the overall body of work will now be discussed and each of the research questions posed in Chapter One will then be revisited.

To begin with, it was necessary to describe in Chapter One the unique challenge in LOA safety involving the need to balance intentional engagement with risk with the obligation to ensure safety is paramount. It was also important to recognise that various applications of regulatory mechanisms by government, industry and independent agencies to regulate LOA safety lacked coherence. This was evidenced by criticisms of LOA regulation found in judicial findings (e.g. Priestly 2012; Devonport 2010; White 2014).

In Chapter Two, a review of three relevant domains of scholarly literature revealed gaps in the research that could hinder efforts to evaluate and design systems of LOA safety regulation. Before proceeding further and prompted by concerns among some members of the LOA community, it was confirmed in the study described in Chapter Three that the application of complexity theory and systems-based methods was appropriate for the analysis and design of LOA work systems. This was important for the present research; however, it also has important ramifications for other LOA
research. For example, confirmation that systems thinking approaches are appropriate in this context opens up a series of new application area such as LOA program design and evaluation, risk assessment and accident analysis, and training program design. Such applications are important as many previous approaches have been reductionist in nature. Based on this and a review of systems HFE methods, the Cognitive Work Analysis framework was identified as potentially useful in regulatory system evaluation and design.

To test this assertion, an initial study was undertaken to investigate the utility of WDA for evaluating regulatory systems. This involved using WDA to describe and evaluate the NZAAR, a recently developed system of statutory safety regulations for LOAs in New Zealand. This study, described in Chapter Five, identified the strengths and weaknesses of the NZAAR system, suggesting areas for structural improvement. Strengths included comprehensive education material for duty-holders and effective compliance checking. Weaknesses included high costs both for LOA providers and for government. WDA was particularly useful for several reasons. Firstly, it allowed the various deployed components of the system to be compared with the functional purposes of the system, thereby indicating the extent to which those purposes could be achieved. Secondly, the holistic model afforded by the WDA AH provided a quick snapshot of the functional areas of the system that were more or less supported (e.g. duty-holder education, compliance checking, and registration). Thirdly, the AH showed how some stated system purposes were poorly supported, thereby directing attention to areas for system improvement. This constituted an initial demonstration that WDA could be successfully applied to the analysis of a regulatory system, not only in the LOA domain, but in any domain.

A smaller scale system of LOA safety regulation was then analysed. A WDA of the Victorian AAS revealed inherent structural weaknesses in the system and conflicts with principles of effective regulation described in the regulatory literature. Described in Chapter Six, this study found that the Victorian AAS were developed by an industry association with no prior experience in developing regulatory mechanisms, in reaction to a steep insurance price rise. The resulting system was found to have an
unrealistically large number of functional purposes, apparently representing the aspirations of stakeholders. However, the system was found to lack the objects, processes and functions necessary to support attainment of its functional purposes. No evidence was found of any formal structural analysis or guidance used in the process of creating the Victorian AAS. This second application of WDA to a smaller-scale LOA regulatory system built upon the previous study by providing an initial demonstration of the flexibility of the method’s application to LOA regulation.

Chapters Seven and Eight described two studies conducted in line with guidance from the CWA-DT to first model a complex regulatory environment and then to redesign it in a way that improved its efficiency and effectiveness. Chapter Seven described the first study and its two aims. The first aim was to generate a model of the broad LOA regulatory environment in Victoria which included the Victorian AAS, described in Chapter Six, and several other regulatory instruments. The second aim was to use tools from the CWA-DT to generate design insights which could support the redesign of the Victorian LOA regulatory system. The study produced an AH model of the system and showed that LOA providers found the system to be convoluted, confusing and less effective than they would like. These findings supported the design process outlined in the following chapter. In doing so, they provided initial affirmation of the proposition, central to this thesis, that STS theory and methods, and specifically the CWA-DT, can usefully support regulatory system design.

Chapter Eight described the second of the two studies of the Victorian LOA regulatory environment. The aims of this second study were to use the inputs of the previous study to support regulators to generate design concepts to support a new, integrated regulatory system. Using a selection of strategies from the CWA-DT, the aims of this study were realised with the generation of a set of system design concepts that were then used to develop a formative model for an integrated regulatory system for LOAs in Victoria. The two linked studies described in this and the previous chapter confirmed that STS theory and methods, and specifically the CWA-DT, can usefully support regulatory system design. In this case, the type of system analysed was more
complicated than those examined in earlier chapters due to its polycentric nature. Furthermore, while all the applications of WDA in previous chapters were descriptive analyses of existing systems, the study described in Chapter Eight produced a formative analysis of how a new regulatory system could be structured.

Chapter Nine described a project in which WDA was used to evaluate and redesign a set of national LOA standards. Unlike the applications of CWA-based methods described in the earlier chapters, this one was not an academic exercise. The approach that was developed and refined through the earlier phases of this research were applied here to regulatory reform in the real world. The study was commissioned by an industry-based group charged with combining separate state-based standards into a single national standard. A structural analysis of a proposed ‘core’ national LOA standard was undertaken using CWA. The resulting AH model supported identification of several structural weaknesses. These included a high number of objects and processes, inclusion of objects that were irrelevant to many providers, poor duty holder education, and no capacity to gauge compliance. In addition, a set of regulatory system design principles were synthesised from regulatory research findings, sociotechnical design principles and ecological interface design principles (e.g. Black, 2007; Bruder, Rademacher, Schaub, & Geiss, 2009; Cherns, 1987; Clegg, 2000; Corbett, 2017; Leveson, 2004). With guidance from these principles, the identified structural weaknesses were addressed, and the resulting reformed, simplified system structure was represented in a formative AH model. This was in turn used as the basis to develop a series of design recommendations. The main structural recommendations were accepted and implemented, fundamentally reshaping this national regulatory system. The success of this project provided affirmative answers to all five of the research questions articulated in Chapter One.

An important contribution of this research has been to test the utility of CWA when used to evaluate and design regulatory systems. Based on the studies undertaken, an important methodological extension to WDA was developed. This enhances the utility and suitability of WDA, both for regulatory system analysis and design, and for
applications in other areas such as emerging autonomous systems, malevolent STS (e.g. criminal and terrorist activities), and global ecological problems.

During the analysis of the NZAAR, described in Chapter Five, it was noticed that some objects identified during analysis may not require any physical manifestation in order for agents to interact with them. These included guidelines, regulations, and procedures. To test this observation, a case study analysis was conducted to test the proposal that STS can include cognitive objects at the lowest level of abstraction in their functional structures. Chapter Ten describes this analysis. The AH of the NZAAR was used, along with AHs from studies of a road transport system and a terrorist group. Foundational concepts that underpin CWA and WDA were considered. The second and third phases of CWA; ConTA, and StrA were used, along with a CWA extension, SAD, to test the difference in analytic outputs when cognitive objects were explicitly identified, compared with when they were not. It was found that recognition of cognitive objects did enrich analytic outputs and that their inclusion in WDA as a new category of object was warranted. A set of criteria for determining the identification and inclusion of cognitive objects was developed.

This modification of CWA, discovered through its application to regulatory systems, improves its utility for the analysis and design of those systems. Earlier applications of CWA may have produced richer results had cognitive objects been recognised previously (Lintern, 2008; McLean, Salmon, Gorman, Read, & Solomon, 2017; Salmon et al., 2016b).
Research questions revisited

In Chapter One, the following questions were posed that have formed the basis for this inquiry.

1. Does systems theory apply in LOA?
2. Can LOA safety regulatory systems be usefully modelled and analysed with WDA?
3. Does WDA need to be modified for use in the analysis and design of regulatory systems?
4. Can CWA be used to design a LOA regulatory system?
5. Do stakeholders prefer a regulatory system designed using systems theory and CWA to one that is not?

Each of these questions will now be revisited in turn and answered based on the findings described in the foregoing chapters.

Does systems theory apply in LOA?

In Chapter Three it was shown that the LOA work domain meets all of a set of established criteria for complex systems. The dynamic nature of the work in the domain and the presence in the system of several complex sub-systems including people, weather, and natural environments, was found to confer many of the characteristics of complexity to the whole work domain. Furthermore, the work of Corbett (2017) in identifying all regulated domains as complex systems supported the proposal that systems theory applies in LOA regulation. Finally, the successful application of systems-based analysis methods to LOA regulation, described throughout this thesis, confirmed that systems theory does indeed apply in LOA.

Can LOA safety regulatory systems be usefully modelled and analysed with WDA?

This question has been answered unequivocally in the affirmative. Chapters Five, Six, Seven, Eight, and Nine describe studies in which a diverse array of LOA regulatory systems was successfully analysed with WDA. In each case, a rich set of analytic
outputs was produced and verified by SMEs. In each of the last two cases, the analysis was successfully used as the basis for a subsequent design process which produced recommendations to optimise the regulatory systems in question. This confirms and amplifies the success of these analyses. The research described in this thesis has demonstrated that WDA can be used to provide a structured and theoretically underpinned approach to regulatory system evaluation and design. In doing so, it provides a significant contribution given the absence of such approaches identified in the literature review described in Chapter Two.

**Does WDA need to be modified for use in the analysis and design of regulatory systems?**

This possibility was identified during the first application of WDA to a regulatory system, described in Chapter Five. It was found that some objects in the system did not necessarily require system users to interact with a physical object. Instead, in some cases, it seemed that users could instead interact with a cognitive object in order to generate the system processes and functions that addressed the system’s purposes. This idea was examined in detail in Chapter Ten. It was concluded that modification of the AH to account for cognitive objects in STS alongside physical objects was both theoretically and practically justified. This modification improves the suitability of WDA for regulatory system analysis and design.

**Can CWA be used to design a LOA regulatory system?**

The study described in Chapter Eight provided the first demonstration that the CWA can be successfully used to design a LOA regulatory system. In that case, the CWA-DT was used in conjunction with WDA to transform a set of loosely connected LOA regulatory mechanisms into an integrated LOA regulatory system. The study described in Chapter Nine was a culminating test for both the analysis and design potential of CWA as it applies to LOA regulatory systems. In that case, WDA was used in both its descriptive and formative capacities to first analyse and then to design the structure of a new LOA national standard for Australia. Unlike the previous studies described in this thesis, this final application of WDA to LOA regulatory system design proved the efficacy of the method by shaping a national regulatory system which has been
implemented. This provides strong confirmation that CWA can be used to design LOA regulatory systems.

*Do stakeholders prefer a regulatory system designed using systems theory and CWA to one that is not?*

While the evidence collected throughout this thesis that can be used to address this question is limited, it can still be answered affirmatively with some confidence. The evidence includes the consistently positive feedback provided by participants in the design workshop described in Chapter Eight and the presentation workshop described in Chapter Nine. However, the strongest evidence that some stakeholders prefer a regulatory system designed using systems theory and CWA to one that is not is found in Chapter Nine. In that case, stakeholders relinquished a design that they themselves had devised in favour of one designed using systems theory and CWA. Further research grounded in a wider sample of stakeholders could clarify the extent to which stakeholders prefer regulatory systems designed with the methods described in this thesis.

In summary, all five of the research questions posed at the outset of this thesis have been answered in the affirmative. This paves the way, not only for adoption of the methods tested here for application to the design and evaluation of LOA regulatory systems, but to all kinds of systems of social regulation. In doing so, this work helps to narrow the highly consequential research gap identified in Chapter Two.
Theoretical, Methodological, and Practical contributions

This thesis contributes to theory, method and practice in the areas of regulation, LOA, and HFE in several ways. These contributions are summarised in Table 11.1, below.

Table 11. 1. Contributions made by this thesis to theory, method, and practice.

<table>
<thead>
<tr>
<th>Contributions to...</th>
<th>Theory</th>
<th>Method</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory</td>
<td>Application of systems theory to regulatory system evaluation &amp; design</td>
<td>Application of WDA to a regulatory system</td>
<td>New method for regulatory system evaluation &amp; design</td>
</tr>
<tr>
<td></td>
<td>Formal demonstration that the LOA domain &amp; its subsystems are complex systems</td>
<td>Extension of WDA to consider cognitive objects in the evaluation and design of complex sociotechnical systems</td>
<td>Improved structure of a National set of standards for LOA (the AAAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Application of the CWA-DT to a multi-agency regulatory system</td>
<td>Development of a set of regulatory system design principles</td>
</tr>
</tbody>
</table>

Limitations

The proof or disproof of the central proposition of this thesis can be considered as either a binary question or a scalar one. If the former, then the positive results described throughout this thesis lead to the unequivocal conclusion that the proposition is proved: CWA can be used, and indeed now has been used as described in Chapter Nine, to understand and improve the structure of the LOA safety regulation system in Australia. While this thesis has described a novel and successful application of systems-based methods to the analysis and design of regulatory systems, the scale of this success is limited, and further work is required to realise the full potential of the approach. Consideration of some limitations of both the method and the result may help guide future research efforts that could extend this application.
One difficulty in determining the degree of success of this application of CWA is that there are neither pre-existing structural (or other) evaluations of the systems analysed nor any obvious alternative methods. Until such work is done, it is difficult to draw direct comparisons between the system evaluations described in this thesis and evaluation arrived by other methods. However, the methods found and described in the literature review in Chapter Two are clearly incapable of providing the kind of structural analyses demonstrated here with CWA. Another difficulty is inherent in the main aim of this kind of regulation: safety. How can safety be measured? (Hopkins, 2009) Does it require the measurement of the absence of harm (Macrae, 2014; Reason, 2000)? And even if safety could be reliably measured, how could the effect of regulation on operational safety be measured? How much of safety was attributable to which aspects of the work system, including the actors at all levels? Therefore, the structural analyses presented in this thesis can offer no direct insight into system performance. However, they can be used to predict system failure in general terms by their identification of structural barriers to system performance.

The relatively static nature of the view provided by CWA is a further limitation to these results. This may be best explained though the notions of ‘work-as-imagined’ versus ‘work-as-done’. The former represents abstract notions of how work is intended to be shaped and conducted. It is characterised by the limitations of modelling and the inevitable absence of some of the detail of how the ‘work-as-done’ will actually play out. In operation, the detail of events that occur in STS is shaped not only by the system’s structure, which WDA can map, nor only by the activities, strategies, roles, and competencies that other phases of CWA can represent. As discussed in Chapter Three, complex systems are characterised by open system boundaries and unpredictable emergence of new phenomena from interactions between entities. This inherently limits the predictive capacity of a modelling framework like CWA.

CWA does offers greater predictive power than some other HFE methods, for example, Hierarchic Task Analysis (HTA) which models known tasks, in the sense that by modelling constraints on behaviour, WDA reveals the possibility of a range of
affordances that may in principle be infinite. However, it is subject to the same kind of teleology as HTA in the sense that it is only likely to specifically represent positive affordances that support intended system functions and purposes. While the CWA framework and its phases allow it, it would require the judicious efforts of an insightful analyst, probably supported by significant computing power, to model the full range of incidental and undesirable affordances. This limitation should not be held to detract from the significant analytic power of CWA which can indeed reveal critically important holistic functional and structural features of STS. If used in combination with more dynamic systems-based analysis methods such as Agent Based Modelling (ABM; Bonabeau, 2002) and Systems Dynamics (SD; Sterman, 2001), the full power of CWA may be realised.

The analyses presented in Chapters Five, Six, Seven, Eight, and Nine, were all constrained by limitations of time and resources. In the absence of such constraints, the application of the full CWA suite of methods, including ConTA, StrA, SOCA, and WCA could have provided a deeper set of design guidance to improve the operation of regulatory systems. However, this was not needed to confirm the central proposition of this thesis that CWA is suited to regulatory system analysis and design. WDA and the CWA-DT were sufficient to identify issues and provide design recommendations.

Considering these limitations, it is the hope of the authors of all of the studies presented here that this work may inspire more comprehensive and deeper future studies of regulatory systems, using and developing the methods described. Notably, the approach developed and applied in this thesis is generic and so could be applied in any domain in which formal regulatory systems are used. As such, there are many areas in which this approach could be applied. Given recent safety issues, pertinent areas for future applications include driverless cars, carbon emissions, and social media. Each of these three areas are, at the time of writing, subject to highly contentious discussions around how to regulate them in order to protect public safety. Driverless cars represent only one early example of an artificially intelligent system that, along with its benefits, poses threats to public safety.
Areas for further research

During the initial review of literature, no reference was found in the regulatory literature to systems theory or to the complex nature of regulatory systems. However, more recently, an essay by Corbett (2017) has identified and emphasised the complex, dynamic, adaptive nature of systems that are subject to regulation. He therefore advocates the recognition by regulators of that complexity, and outlines ways in which regulators and regulatory methods should change to account for it. Corbett urges regulators to adopt a systems approach and proposes a set of stances which can shift the posture of regulators toward systems thinking. However, this advice does not extend to the design of regulatory mechanisms such as standards, guidelines, licensing requirements or audit procedures.

Corbett’s recognition of complexity in regulation, particularly given its publication in a prominent anthology of leading regulatory thought, suggests an encouraging convergence between regulatory scholarship and the systems thinking and HFE-based research presented in this thesis. Further collaboration between regulatory and HFE scholars is encouraged to develop an enhanced, cross-disciplinary effort to improve regulation. This thesis provides a starting point for these efforts.

The use of WDA as a versatile, adaptable method for fast evaluation of regulatory mechanism or system design could be further refined, validated, and streamlined to support its use as a practical tool for non-HFE-trained regulators. This could include adoption of the simplified AH level labels proposed in Chapter Ten and would require the development and distribution of a customised training package for regulators.

Further research could extend upon the studies described here by applying the latter phases of CWA to regulatory system design and reform. As previously noted, more extensive stakeholder surveys or interviews could be used to evaluate stakeholder satisfaction with systems-based design outcomes. In collaboration with regulators from across a polycentric regulatory system, the full suite of CWA-DT stages could be used to go beyond its application described in Chapters Seven and Eight, to facilitate the integrated reform of that system. Based on the functions identified in the AH of
the redesigned Victorian LOA regulatory system described in Chapter Eight, application of the latter phases of CWA could underpin a detailed plan for reform. ConTA could be used to identify the tasks that must be undertaken to enact the functions. StrA could then be used to identify and evaluate possible strategies for addressing those tasks in a range of situations. SOCA could be used to build a picture of optimal team and role structure to run the system, and WCA could be used to specify the competencies required of those team members. A multi-tiered and integrated approach of this nature would be particularly useful for agencies with limited resources to develop or reform a regulatory system with confidence.

The regulatory system design principles discussed in Chapter Nine were developed through a synthesis of tenets and principles from STS, ecological interface design, and regulatory research. These could be further developed, validated, and made available to individuals and organisations who may be charged with designing or reforming regulatory systems to guide those processes.

The extension of WDA and CWA to consider cognitive objects opens up various areas for further research. For example, further work on identifying and developing ways to engineer cognitive objects could be useful for several new applications both within and beyond regulation. Just as identifying the processes and functions afforded and constrained by physical object can guide modification of those objects to alter system performance, the same is true for cognitive objects. However, while physical objects can be engineered using familiar physical processes, the engineering and reengineering of cognitive objects requires different methods. The identification of these objects as memes suggests a range of engineering techniques including education, advertising, and behavioural modelling. Applications beyond regulation that may be amenable to this approach could include the analysis and design of systems that include non-human (AI) agents, large-scale STS where belief plays a prominent role (e.g. global food or energy production), and ‘oppositional human factors’ applications, where the aim is not the traditional one of optimising performance of desirable systems, but disrupting the performance of undesirable ones, such as criminal or terrorist activities (Salmon,
Carden, & Stevens, 2018). Just as the affordances of physical objects in a STS can be altered by modifying, removing or replacing the object, so too with cognitive objects. Concerted education, advertising, or propaganda initiatives can target specific memes, guided by CWA, in the pursuit of specific functional purposes.

This initial success in the application of CWA to regulatory systems encourages research that applies CWA and other HFE and systems-theoretic approaches to other dimensions of regulation. For example, challenges abound in the accurate comparison of costs versus benefits in regulation. It may be that, by explicitly identifying the full range of objects and activities included in a regulatory system, both cost centres and functional benefits may be more accurately identified and measured using HFE approaches to analysis. Large-scale regulatory challenges, including those of global scale like climate change, have so far exceeded the capacities of prevailing approaches to social regulation. The holistic nature of CWA, including its capacity to account for emergence by identifying affordances and constraints rather than know tasks and activities, may help to develop regulatory approaches capable of addressing these large-scale challenges. Similarly, the need to control and regulate emergent systems that include non-human agents is becoming more urgent as these systems proliferate. Public discussion and academic exploration of the regulatory challenges posed by autonomous vehicles provide an early insight into this looming problem. Current approaches to regulation might be augmented in ways that help meet these challenges by including some of the principles and methods outlined here and those that can be developed along similar lines. Future research should build on this work by continuing to explore the application of CWA and other HFE methods to regulatory system design and operation in ways that can help meet emerging sociotechnical, cultural, and environmental challenges.

This thesis began with the observation that systems of safety regulation for LOAs lacked coherence, leading to concerns about their effectiveness and also the approaches that are used to design them. A review of the literature and exploration of the development of some of those systems showed that little theoretically based
support for the design and development of such systems existed. The application of elements and extensions of the CWA framework to the evaluation and design of the structure of LOA regulatory systems produced new insights and design concepts. It was shown that, enhanced by the adaptation that recognises cognitive objects, WDA and the CWA-DT provide a new and effective way to understand and design regulatory systems. The application of these methods at different scales to different types of LOA regulatory system demonstrates the versatility of the approach.

The combination of STS and EID principles with findings from regulatory research led to the development of a set of principles to guide regulatory design. The novel and successful application of these methods and principles to the evaluation of LOA safety regulation systems has made explicit the structure of these systems. Rasmussen’s Risk Management Framework, the review of regulatory scholarship, principles from control theory, and the studies described throughout this thesis all support the contention that systems of social regulation all share some common structural features.

This offers confidence that the methods developed here can be applied more broadly to other kinds of regulatory system including health and safety regulation in other domains, and other forms of social regulation such as environmental and financial regulation.

**Conclusion**

STS have their own structure, their own logic, their own momentum. Despite the needs and wishes of people in the system, bad structure can lead to bad outcomes. We need look no further than the economic system to find an example of a large-scale system which, due to aspects of its structure, produces adverse outcomes such as inequality and pollution in pursuit of its intended purposes. The need to regulate systems that are capable of producing bad outcomes is widely accepted and evident in many areas of modern life: work health and safety, transport, finance, and environmental protection are all subject to regulation around the world. As has been shown in this thesis, and as is frequently evident in news reports, the prevailing methods of optimising regulatory systems have been found lacking. The methods tested and
demonstrated in this thesis offer a new approach; one that may produce wide-scale benefits if widely applied to regulatory system evaluation and reform into the future.


References


Jones, M. L. (2011). *The influence of perceived risk on participation in outdoor education activities by pre-teen age schoolchildren in New Zealand*. (Master of Philosophy), AUT University, Auckland, NZ.


Appendix A – Figures from Chapter 10

Figures 3, 5, and 7 from the journal article included in this thesis as Chapter Ten are included in this appendix for ease of reading. They include contextual activity templates, strategy flow diagrams, and decision ladders. Large versions of these analytic outputs are shown on the following pages for each of the case studies considered in Chapter Ten.
Figure 3 from Chapter 10. Contextual activity template, strategy flow diagram, and decision ladders for the NZAAR.
Figure 5 from Chapter 10. Contextual activity template, strategy flow diagram, and decision ladders for the QLD road transport system.
Appendix A

Figure 7 from Chapter 10. Contextual activity template, strategy flow diagram, and decision ladders for the terrorist group system.