Integrating Human Factors Methods and Systems Thinking for Transport Analysis and Design

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Dedication

For our colleagues Tom and Eric, and for all those who have been affected by crashes at rail level crossings

Preface

In April 2006, a truck carrying a 14-tonne slab of granite was struck by a passenger train as it traversed a rail level crossing in the rural area of Trawalla, Victoria, Australia. Signage at the crossing required road users to stop and give way to trains, but there were no flashing lights or boom barriers installed. As a result of the collision, the train driver and two train passengers were killed. Just over a year later in June 2007, approximately 230 km from the site of the Trawalla collision, the driver of a loaded articulated truck was travelling at 100 km/h along a familiar rural highway near Kerang. Apparently not noticing the flashing lights or approaching train, the truck driver continued towards the crossing with the intention of driving through. Although the driver eventually saw the train and attempted evasive action, the truck struck the second carriage of the train, resulting in the deaths of 11 train passengers.

These tragic events represented a wake-up call for the Australian rail industry. Previously, crashes at rail level crossings were viewed as a road transport problem, but the emergence of significant numbers of train casualties in level crossing collisions gave rise to renewed concern. It was clear that existing rail level crossing designs were unable to ensure safety, and that human factors considerations were not well integrated into the design, assessment and operation of these legacy systems.

The design of warnings and technologies at rail level crossings has a strong historical basis. For example, the flashing red lights provided to warn of approaching trains were designed to resemble a red lantern being swung from side to side, as this is how signalmen or station masters warned the road users of that time, such as horse-drawn cart drivers, of approaching trains prior to the introduction of electric track circuits (Green 2002). Similarly, modern train horns were designed to emulate the sound of steam train whistles (Transportation Safety Board of Canada 1996), rather than purposefully designed to provide an optimal auditory warning to road users. The continuing relevance of these designs to modern transportation systems has rarely been questioned, even though the context of their use has changed considerably with increased rail and road traffic, increasing trends towards active transport modes, changes to surrounding road infrastructure and improvements to vehicle design and capabilities. Whereas road and rail systems have evolved and become far more complex, rail level crossing infrastructure and warning systems have not necessarily kept up.

With heightened concerns over safety issues at rail level crossings, it was recognised by government and industry that a collaborative approach was required. Human factors professionals and behavioural scientists employed in road authorities, rail authorities and rail operators formed a committee to coordinate human factors research initiatives, review data trends and investigation findings and provide expertise into research and development of new technologies. This committee commissioned a literature review into human factors issues at level crossings and, when the review was completed, it was evident that answers would not be found in the existing literature (Edquist et al. 2009).

Indeed, it was clear that a new approach was required. In response, the project leaders proposed *systems thinking* as a promising way forward to address this intractable problem. In particular, Cognitive Work Analysis, a systems analysis and design approach that members of the research team had used previously to redesign other complex systems, was identified as a suitable methodological framework. Accordingly, it was proposed as a key methodology for evaluating the current rail level crossing system and generating new designs to reduce the risk of collisions and subsequent fatalities and injuries. Such an approach was highly novel and innovative at the time, as it had not previously been applied in the rail level crossing context.

The research proceeded with funding from the Australian Research Council and our industry partners through a Linkage Project grant (LP100200387). A project management committee was established in 2011 to oversee the research programme, comprising representatives from the key Victorian government agencies and industry organisations. The first-of-its-kind research programme was completed in 2016, creating new insights into behaviour at rail level crossings along with new knowledge on how rail level crossing safety can be improved.

The purpose of this book is to share the approach taken over the multi-year research programme and to communicate the key findings around rail level crossing safety and behaviour. Accordingly, the book covers the data we collected, the methods we applied and how we engaged with our government and industry stakeholders, along with the key findings from each stage of the research. We also provide suggestions on how such approaches could be adopted or adapted in future research to address other transport and wider societal problems.

WHO SHOULD READ THIS BOOK?

This book is intended to be of interest to academic and industry researchers, postgraduate students and human factors practitioners who are faced with solving complex issues and problems in the transportation industries. We believe that the approaches are useful for transportation systems generally for optimising the interactions of humans and technology across the system life cycle – from design, construction and commissioning, to operation, maintenance and decommissioning.

We hope that experienced human factors researchers and practitioners will find some new methods, insights and learnings from reading the material and that researchers new to human factors and/or systems thinking will find useful guidance and advice.

Naturally, the book also outlines our findings in relation to rail level crossings. We expect that these will be of interest to those working in this area, and we hope that all readers will find the research findings as interesting and thought-provoking as we have while undertaking this work.

WHY SHOULD YOU READ THIS BOOK?

There are a number of excellent books available that provide guidance on the use of human factors and systems thinking methods (e.g. Crandall, Klein and Hoffman 2006, Naikar 2013, Stanton et al. 2013, Vicente 1999). Further, it is widely acknowledged that multi-method approaches are needed to understand and address complex problems such as accidents in transportation systems. Despite this, there is little guidance on how to select appropriate methods and to integrate them within a single research project that spans analysis, design and evaluation. This book intends to address this gap and to provide you with tools and advice for taking a similar approach to solve other problems in transportation and beyond.

HOW TO READ THIS BOOK

We expect that some readers will be highly familiar with the methods and approaches discussed, whereas for others there will be much new information. We have tried to achieve a balance in the level of detail provided and, where possible, refer the novice reader to other texts that they may find useful for further guidance and exemplars.

We use examples from our work in rail level crossing analysis, design and evaluation to illustrate the approach throughout the book. However, you will find other examples discussed throughout the book and general principles highlighted that can be applied to broader transport issues as well as domains outside of transportation.

This book is divided into five main sections:

I. *Introduction to the Research Approach*
   - Chapters 1 and 2 provide an introduction to the key human factors and systems thinking philosophies, theories and methods adopted throughout the research programme. Chapter 3 then outlines the integrated framework of methods we applied.

II. *Rail Level Crossing Data Collection and Analysis*
   - Chapter 4 describes the data collection activities we undertook to understand road user behaviour at rail level crossings. The findings reported in this chapter draw on traditional human factors analysis methods.
   - Chapter 5 describes how the data were used to develop systems-based models that describe the functioning of rail level crossings.

III. *Design of New Rail Level Crossing Environments*
   - Chapters 6 through 8 describe the process undertaken to generate novel designs for rail level crossings, to conduct an initial desktop evaluation using the systems thinking models described in Chapter 5 and to subsequently refine the designs.

IV. *Evaluation of Design Concepts*
- Chapter 9 describes a suite of driving simulator studies that were used to measure driver responses to the new designs.
- Chapter 10 presents the findings of a survey undertaken to elicit feedback from all road user types (i.e. car drivers, heavy vehicle drivers, motorcyclists, cyclists and pedestrians) on the proposed designs.

V. *Conclusions and Future Applications*
- Chapter 11 outlines the recommendations arising from the research, identifies future research directions relevant to rail level crossing safety and reflects upon the extent to which the research programme met its overall aims.
- Chapter 12 discusses potential future applications of the research approach to other transport and non-transport domains.

We hope that this book might inspire new applications of human factors and systems thinking that continue to extend the methods and approaches adopted as well as to provide practical recommendations that can help to address real-world problems.

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Neville A. Stanton, PhD, DSc, is a chartered psychologist, chartered ergonomist and chartered engineer. He holds the chair in human factors engineering in the Faculty of Engineering and the Environment at the University of Southampton, Southampton. He possesses degrees in occupational psychology, applied psychology and human factors engineering. His research interests include modelling, predicting, analysing and evaluating human performance in systems as well as designing the interfaces and interaction between humans and technology. Neville has worked on the design of automobiles, aircraft, ships and control rooms over the past 30 years, on a variety of automation projects. He has published 35 books and over 270 journal papers on ergonomics and human factors. His work has been recognised through numerous

awards, including the Hodgson Prize, awarded to him and his colleagues in 2006 by the Royal Aeronautical Society, London, for research on design-induced, flight-deck error. He has also received numerous awards from the Chartered Institute of Ergonomics and Human Factors in the United Kingdom and in 2014 the University of Southampton, Southampton, awarded him a Doctor of Science for his sustained contribution to the development and validation of human factors methods.

Paul M. Salmon, PhD, is a professor in human factors, and is the creator and director of the Centre for Human Factors and Sociotechnical Systems at the University of the Sunshine Coast, Queensland, Australia. He currently holds an Australian Research Council Future Fellowship in the area of transportation safety and leads major research programmes in the areas of road and rail safety, cybersecurity, and led outdoor recreation. His current research interests include accident prediction and analysis, distributed cognition, systems thinking in transportation safety and health care and human factors in elite sports and cybersecurity. Paul has coauthored 11 books, more than 150 journal articles and numerous conference articles and book chapters. He has received various accolades for his contributions to research and practice, including the UK Ergonomics Society's President's Medal, the Royal Aeronautical Society's Hodgson Prize for best research and paper and the University of the Sunshine Coast's Vice Chancellor and President's Medal for Research Excellence. In 2016, Paul was awarded the Australian Human Factors and Ergonomics Society Cumming Memorial Medal for his research contribution.

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