Murdoch University

Measurement of Rail Safety Culture - an Australian Sample

A dissertation submitted for the degree of
Doctor of Philosophy

by

Izumi Hart

BA, BSc (Hons) (Psych)

Perth, Western Australia

July 2013

Revised April 2014
DECLARATION

I declare that this thesis is my own account of my research and contains, as its main content, work which has not previously been submitted for a degree at any tertiary education institution.

IZUMI HART
School of Psychology
Murdoch University
Murdoch
Western Australia
July 2013
ACKNOWLEDGEMENTS

Seven years of cumulative learning and the completion of this thesis may not have been possible without continuous support and encouragement from a wide range of people.

This research project (since March 2006) was kindly funded by eight rail organisations in Australia, facilitated by the Planning and Transport Research Centre (PATREC). These organisations remain anonymous due to the confidential nature of the survey in which six of them participated. I also acknowledge a Murdoch University Scholarship for the first three years of my candidature.

Special words of gratitude go towards my principal supervisor Professor Laurence Hartley, School of Psychology, Murdoch University and Adjunct Professor Fred Affleck, former inaugural Executive Director of PATREC. Professor Hartley, for his enduring interest, expert advice, formidable intellect, continuous oversight and mentoring throughout the candidature. Adjunct Professor Fred Affleck, for his vision of the significance of measuring the safety culture of the Australian rail industry, which served as the impetus for this research project, his facilitation for fund raising, and for serving on the supervisory panel as a rail industry expert and a PhD scholar.

I was fortunate to be co-supervised by a multi-disciplinary panel of scholars from Murdoch University, and industry experts. They include Professor Iain Walker, former Dean of School of Psychology, and Lecturers Ms. Melanie Freeman and Ms. Libby Brook, who provided invaluable insight into human factors, organisational psychology and safety research. Valuable guidance on statistical matters was provided by Dr. Natalie Jackson and Dr. Guy Curtis. Further supervision from an industry perspective was provided by Professor Greg Martin, former Executive Director of PATREC.

I wish to express my gratitude to Shell International Exploration and Production B.V. and the Energy Institute for permission to use a selection of questionnaire items from their *Hearts and Minds Program* and their enduring interest in the study.

In the latter part of my PhD candidature, I fortuitously joined the Office of Rail Safety, Department of Transport, Western Australia. The insight and industry knowledge gained at work added substantial contextual dimension to my research. Special appreciation goes to Mr. Rob Burrows, Director, and Ms. Glenda Winney, Human Factors and Safety Information Manager, for their sustained encouragement, guidance, mentoring and facilitation, and to colleagues Mr. Matthew Bradanovich, Mr. Chris
Green, Ms. Roselynd Johnson, Mr. Peter Malaspina, Mr. Geoff Smith, Mr. Clive Weaire and Mr. Ross Williamson who provided me with invaluable rail industry knowledge.

I also express my appreciation to a large number of people from rail organisations, who provided invaluable assistance. First and foremost are the six rail organisations who participated in the current study. Their support and co-operation ensured that the project progressed. The executives of these organisations, who shall remain anonymous, played a pivotal role in facilitating the administration of the employee questionnaire through their active participation and assistance. Special thanks go to all who took part in the survey. The majority completed the lengthy questionnaire in their own time and many also added valuable personal comments, which provided contextual richness to their quantitative feedback.

I extend my gratitude to a group of rail experts who provided invaluable assistance. They include Mr. Stan Sexton, Corporate Manager Safety, Public Transport Authority, for his meticulous assistance in modifying the questionnaire items from Shell to suit the Australian context and his introduction to colleagues from the PTA and industry associates, who became involved in the pilot study. They include Ms. Christine Teague, then a PhD candidate herself, Mr. Peter Ferguson from the Australian Services Union, and former PTA employees including Mr. Adam Koval, Mr. Robert Sanders, and Mr. Phil Woodcock. Special words of appreciation go to Mr. Gerard Forlin QC, and various anonymous experts for proofreading relevant parts of my manuscript. I also acknowledge Ms. Renée Petrilli’s scholarly support.

Ongoing assistance from Murdoch Library staff for procuring literature, Murdoch University staff in the School of Psychology and in Research and Development Office for administrative, IT and training support was invaluable. I also acknowledge Murdoch Print for timely and professional printing service. Furthermore, Ms. Emiko Nishikawa and Ms. Ayumi Yamashita meticulously entered and reconciled data. Emiko’s assistance in many other areas and Mr. Maher Elsherbiní’s IT assistance was pivotal to the study’s progress.

Last but not least, I cherish the ongoing love and support from my beloved husband Bill, our children Tashi (21) and Aska (19) Hart, and furry Princess (8). They each deserve a medal of exceptional endurance for seeing me through thick and thin! I am also indebted to unflinching support from my mother-in-law Jean Hart, my parents Masaomi and Yukiko Suzuki, and my special friends Peter and Wai Chu Whyte. I know my father Masaomi and Peter, both of whom passed away in 2012, will be somewhere nodding with a big smile of satisfaction that I have reached the finishing line.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................... 2

Table of Contents .................................................................................................................. 4

List of Tables ........................................................................................................................ 6

List of Figures ......................................................................................................................... 9

ABSTRACT .............................................................................................................................. 11

Measurement of Safety Climate and Culture in the Australian Rail Industry ..... 11

CHAPTER 1 Introduction .......................................................................................................... 13

1.1 Overview .......................................................................................................................... 13

1.2 Rail Safety Statistics in Australia .................................................................................. 15

1.3 Safety Culture and Human Factors within Legal Framework and Rail Safety Regulation ........................................................................................................... 20

1.4 Historical Progression of Accident Models ...................................................................... 21

1.5 The Concept of Sociotechnical Systems and the Discipline of Human Factors ..... 24

1.6 Sociotechnical Accident Model and Indicators of Safety Health .................................. 27

1.7 Conceptual Confusion over Climate and Culture ............................................................ 36

1.8 Conceptual Origins – Climate vs. Culture and their Derivatives – Safety Climate vs. Safety Culture .................................................................................................................. 37

1.9 Other Models of Safety Culture ......................................................................................... 48

1.10 Sub-Climates and Sub-Cultures ................................................................................... 54

1.11 Prediction of Safety Performance based on Safety Climate/Culture ............................. 56

1.12 Previous Research on Rail Safety Climate/Culture in Australia .................................... 57

1.13 Rationale for the Current Study and Research Questions ............................................ 60

CHAPTER 2 Analysis of Rail Accident Investigation Reports .............................................. 64

2.1 Introduction ....................................................................................................................... 64

2.2 Background to the Current Study ................................................................................... 69

2.3 Method ............................................................................................................................. 72

2.4 Results ............................................................................................................................... 75

2.5 Discussion ......................................................................................................................... 80

CHAPTER 3 Method – Questionnaire Construction and Survey Administration 83

3.1 Structure of the Questionnaire ....................................................................................... 83

3.2 Item Generation ................................................................................................................ 87

3.3 Pilot Testing ....................................................................................................................... 105

3.4 Survey Administration ..................................................................................................... 105
LIST OF TABLES

Table 1.1 Biannual Count of Australian Rail Fatalities by Jurisdiction and Year, 1 July 2002 to 30 June 2012 ................................................................. 17
Table 1.2 Biannual Count of Australian Rail Serious Injuries by Jurisdiction and Year, 1 July 2002 to 30 June 2012 ................................................................. 19
Table 1.3 Sample Process Performance Indicators for the Whole Installation – Chemical Industry ..................................................................................................... 33
Table 1.4 Sample Process Performance Indicators for the Whole Installation – Rail Industry ..................................................................................................... 34
Table 1.5 Statements Describing Various Dimensions of Safety Culture at the Five Maturity Levels .......................................................................................... 52
Table 2.1 Summary by Type of the Most Proximal or Causal Factors for Each Accident .... 76
Table 2.2 Summary of Proximal Factors Categorised by Type of Unsafe Acts and Psychological Precursors .............................................................................. 77
Table 2.3 Location of Accidents due to Organisational Failures ..................................... 78
Table 3.1 Structure of the Rail Safety Perception & Culture Employee Questionnaire ........ 84
Table 3.2 Aspect 1 – Commitment to HSE and Care for Colleagues .................................. 96
Table 3.3 Aspect 2 – Balance between HSE and Profitability ........................................... 97
Table 3.4 Aspect 3 – Workforce Interest in Competency and Training ................................. 98
Table 3.5 Aspect 4 – Work-Site Job Safety Techniques (modified to Workplace Safety Controls) ........................................................................................................ 100
Table 3.6 Aspect 5 – Purpose of HSE Procedures .............................................................. 101
Table 3.7 Aspect 6 – Repercussion and Feedback after Accidents ....................................... 102
Table 3.8 Aspect 7 – Audits and Reviews ........................................................................... 104
Table 3.9 Record of Mail Outs and Responses (N = 422) .................................................. 108
Table 3.10 The Australian Census 2006 Railway Workers Categorised by State and Occupational Group ......................................................................................... 109
Table 4.1 Distribution of Age Group for the Initial Dataset ............................................... 113
Table 4.2 Section-Based Breakdown of Cases that answered All Items vs. Those Who Had One or More “Not Applicable” Responses ........................................... 114
Table 4.3 Criteria for Filtering out Cases Containing “Not Applicable” Responses ............. 116
Table 4.4 Factors Identified through Factor Analysis (PAF) – 87 Items Reduced to 81 Items ........................................................................................................... 118
Table 4.5 Distribution of Age Group for Factor Analysis on Section A – Combined Sample (N = 158) ......................................................................................... 119
Table 4.6 Section A1 – Statements Comprising the Factors and Loadings for the Combined Sample (N = 158) ................................................................. 122
Table 4.7 Distribution of Age Group for Factor Analysis on Section A – Safety-Critical Group

Table 4.8 Section A1 – Statements Comprising the Factors and Loadings for the Safety-Critical Group (N = 143)

Table 4.9 Section A2 – Statements Comprising the Factors and Loadings for the Combined Sample (N = 224)

Table 4.10 Section A2 – Statements Comprising the Factors and Loadings for the Safety-Critical Group (N = 197)

Table 4.11 Distribution of Age Group for Factor Analysis on Section B1 – Combined Sample (left) and Safety-Critical Group (right)

Table 4.12 Section B1 – Statements Comprising the Factor and Loading for the Combined Sample and the Safety-Critical Group

Table 4.13 Section B2 – Statements Comprising the Factor and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.14 Section B3 – Statements Comprising the Factor and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.15 Section B4 – Statements Comprising the Factor and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.16 Section B5 – Statements Comprising the Factors and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.17 Section B6 – Statements Comprising the Factor and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.18 Section B7 – Statements Comprising the Factor and Loadings for the Combined Sample and the Safety-Critical Group

Table 4.19 Global Factors Identified through Factor Analysis (PAF) – 67 Items reduced to 13 Items

Table 4.20 Global Factors for Section B – Statements Comprising the Factors and Loadings for the Combined Sample and the Safety-Critical Group

Table 5.1 Factors and questionnaire items for group comparisons

Table 5.2 Group Sample Size Breakdown per Section for Descriptive Statistics

Table 5.3 Section A1 – Statements Comprising the Factors and their Loadings

Table 5.4 Section A2 – Statements Comprising the Factors and their Loadings

Table 5.5 Statements in Section A3

Table 5.6 Section B1 – Statements Comprising the Factor and their Loadings

Table 5.7 Section B2 – Statements Comprising the Factor and their Loadings

Table 5.8 Section B3 – Statements Comprising the Factor and their Loadings

Table 5.9 Section B4 – Statements Comprising the Factor and their Loadings

Table 5.10 Section B5 – Statements Comprising Factor 1 and their Loadings

Table 5.11 Section B6 – Statements Comprising Factor 1 and their Loadings
Table 5.12 Section B7 – Statements Comprising the Factor and their Loadings .......... 191
Table 5.13 Group Sample Size Breakdown per Section for Descriptive Statistics ................. 205
Table 6.1 Distribution of Age Group for Prediction Analyses (N = 241) ...................... 243
Table 6.2 Means and Standard Deviations per Occupational Group and for the Total Sample with Results of Kruskal-Wallis Tests ........................................... 249
Table 6.3 Mann-Whitney Tests for Six Pairs of Occupational Groups ......................... 250
Table 6.4 Pooled Within-Groups Matrices (N = 240) ............................................. 255
Table 6.5 Correlations and Standardised Coefficients of Predictors with Discriminant Function ............................................................................................................ 255
Table 6.6 Descriptive Statistics for the Accident and Non-Accident Groups on Each Predictor Variable ................................................................. 257
Table 6.7 Pooled Within-Groups Matrices (N = 240) ............................................. 260
Table 6.8 Correlations and Standardised Coefficients of Predictors with Discriminant Function ............................................................................................................ 261
Table 6.9 Descriptive Statistics for the Near Miss and Non-Near Miss Groups ............. 263
Table 6.10 Descriptive Statistics and Correlations between Variables for Multiple Regression Analyses (N = 238) ............................................................... 286
Table 6.11 Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr²) for Each Predictor in a Standard Regression Model Predicting Frequency of Near Misses (17 Predictors) ...................................... 290
Table 6.12 Descriptive Statistics and Correlations between Variables (N = 240) .......... 292
Table 6.13 Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr²) for Each Predictor in a Standard Regression Model Predicting Frequency of Near Misses (11 Predictors) ...................................... 294
Table 6.14 Descriptive Statistics and Correlations between Variables (N = 238) .......... 297
Table 6.15 Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr²) for Each Predictor in a Standard Regression Model Predicting Frequency of Safety Defect Reporting (19 Predictors) .................. 298
Table 6.16 Descriptive Statistics and Correlations between Variables (N = 240) .......... 301
Table 6.17 Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr²) for Each Predictor in a Standard Regression Model Predicting Frequency of Safety Defect Reporting (13 Predictors) ............... 302
LIST OF FIGURES

Figure 1.1. Biannual Count of Australian Rail Fatalities by Jurisdiction and Year, 1 July 2002 to 30 June 2012 ................................................................. 16

Figure 1.2. Biannual Count of Australian Rail Serious Injuries by Jurisdiction and Year, 1 July 2002 to 30 June 2012 ................................................................. 18

Figure 1.3. The SHEL model illustrating the interrelationships between the three types of system resource and the environment (left panel) and three-dimensional model (right panel). Adapted from Edwards (1988). ................................................................. 26

Figure 1.4. A model of accident causation, failure types and failure tokens (adapted from Reason, 1990) ........................................................................ 29

Figure 1.5. Five channels of a safety information system as they relate to the failure type-token model of accident causation (adapted from Reason, 1991) .......... 31

Figure 1.6. Levels of culture (adapted from Schein, 1992). ........................................ 42

Figure 1.7. Cooper’s reciprocal safety culture model (2000). .................................... 45

Figure 1.8. Relationship between (safety) culture and (safety) climate. (After Glendon & Stanton (2000)). ................................................................. 48

Figure 1.9. Modified conceptualisation of safety culture (adapted from Grote & Künzler, 2000). ................................................................. 49

Figure 1.10. The safety culture maturity ladder (adapted from 2005) ......................... 51

Figure 2.1. Diagrammatic representation of Reason (1990) and Edkins and Pollock’s model (1996) (Adapted) ........................................................................ 70

Figure 2.2. Summary of Incidents by Railway Problem Factors (N = 267) .................. 79

Figure 4.1. Histogram showing the frequency of the number of “Not Applicable” (NA) responses in Section A1 Work Environment (28 items) for the overall data .......... 115

Figure 5.1. Section A1 Work Environment – Distribution of factor-based mean scores by group .................................................................................. 162

Figure 5.2. Section A2 Potential/Actual Safety Problems – Distribution of factor-based mean scores by group ................................................................. 169

Figure 5.3. Section A3 Adequate Safety Measures Overall? – Score distribution by group 172

Figure 5.4. Section B1 Commitment Level of Workforce to HSE & Care for Colleagues – Distribution of factor-based mean scores by group ............................................ 176

Figure 5.5. Section B2 Balance between HSE and Profitability – Distribution of factor-based mean scores by group ............................................. 178

Figure 5.6. Section B3 Workforce Interest in Competency & Training – Distribution of factor-based mean scores by group ............................................. 181

Figure 5.7. Section B4 Work-site Safety Controls – Distribution of factor-based mean scores by group .................................................................................. 184

Figure 5.8. Section B5 Purpose of HSE Procedures – Distribution of factor-based mean scores by group .................................................................................. 186

Figure 5.9. Section B6 Repercussion and Feedback after Accidents – Distribution of factor-based mean scores by group .................................................................................. 189
Figure 5.10. Section B7 Audits and Reviews – Distribution of factor-based mean scores by group ................................................................. 192
Figure 5.11. Section C – Score distribution by group.................................................. 194
Figure 5.12. Section A1 Work Environment – Distribution of factor-based mean scores by group ........................................................................ 208
Figure 5.13. Section A2 Potential/Actual Safety Problems – Distribution of factor-based mean scores by group ...................................................................... 212
Figure 5.14. Section A3 Adequate Safety Measures Overall? – Score distribution by group ............................................................... 214
Figure 5.15. Section B1 Commitment Level of Workforce to HSE & Care for Colleagues – Distribution of factor-based mean scores by group ........................................................................ 218
Figure 5.16. Section B2 Balance between HSE and Profitability – Distribution of factor-based mean scores by group ........................................................................ 220
Figure 5.17. Section B3 Workforce Interest in Competency and Training – Distribution of factor-based mean scores by group ...................................................................... 222
Figure 5.18. Section B4 Work-site Safety Controls – Distribution of factor-based mean scores by group ........................................................................ 224
Figure 5.19. Section B5 Purpose of HSE Procedures – Distribution of factor-based mean scores by group ........................................................................ 226
Figure 5.20. Section B6 Repercussion and Feedback after Accidents – Distribution of factor-based mean scores by group ........................................................................ 229
Figure 5.21. Section B7 Audits and Reviews – Distribution of factor-based mean scores by group ........................................................................ 232
Figure 5.22. Section C – Score distribution by group.................................................. 235
Figure 6.1. Means and Standard Deviations per Occupational Group and for the Total Sample with Results of Kruskal-Wallis Tests .................................................. 248
Figure 6.2. Histogram showing the frequency of LTIs (left) and near misses (right) \(N = 241\). ........................................................................................................ 252
Figure 6.3. Results of CHAID based on dichotomous dependent variable D3 Experience of Accidents (using 17 predictors) ................................................................. 268
Figure 6.4. Results of CHAID based on dichotomous dependent variable D3 Experience of Accidents (using 11 predictors) ................................................................. 270
Figure 6.5. Results of CHAID based on dichotomous dependent variable D7 Experience of Near Misses (using 17 predictors) ................................................................. 273
Figure 6.6. Results of CHAID based on dichotomous dependent variable D7 Experience of Near Misses (using 11 predictors) ................................................................. 276
Figure 6.7. Results of CHAID based on dichotomous dependent variable D8 Frequency of Near Misses (using 17 predictors) ................................................................. 279
Figure 6.8. Distribution of combined scores for Safety Defect Reporting ..................... 283
Figure 6.9. Mediation model (adapted from Preacher & Leonardelli, 2010-2012) .............. 288
ABSTRACT

Measurement of Safety Climate and Culture in the Australian Rail Industry

Safety culture and safety climate have been a focus of heated debate for over three decades. Despite the general recognition of their importance in safety performance, many disparate views exist in their definition and theoretical framework. While some researchers stress the importance of clear distinctions between safety culture and safety climate, others seem to take a more flexible view using the terms interchangeably. One of the dominant definitions describes safety culture as “the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation’s health and safety management” (Health and Safety Commission, 1993). Safety culture is based on shared underlying beliefs, values and assumptions towards work and the organisation in general. On the other hand, safety climate is defined as organisational members’ shared perceptions about their work environments, safety policies and practices. Safety culture is regarded as stable and long-enduring, while safety climate can fluctuate in response to external factors (e.g. political and socio-economic change). Safety climate is regarded as a “snapshot” of the underlying safety culture. Proponents of the culture-climate distinction maintain that safety culture cannot be quantified and that safety climate can be used as a ‘surrogate’ measure of safety culture, for example, through self-report questionnaires. Other researchers take a more pragmatic approach and claim safety culture can also be measured. For the purpose of the current study, the definitional distinction is respected with the understanding that safety climate is an integral part of safety culture.

An industry-specific questionnaire was created, utilising retrospective and prospective approaches for evaluating safety perception and culture in the rail industry in Australia. This was achieved through: a) analysis of 104 rail safety accident investigation reports based on Reason’s Generic Error Modelling System; and b) adapting items from an instrument extensively used by a large multinational organisation for assessing the level of safety culture maturity based on Westrum’s typology. This facilitated a holistic approach, which addressed both technical/structural aspects and psychological aspects of safety as perceived
by the employees. Six rail organisations in four jurisdictions across Australia participated, which yielded 241 responses. Factor analysis was conducted to identify safety perception and culture factors for further statistical analyses. Kruskal-Wallis ANOVA revealed significant differences among occupational groups in the evaluation of the organisations’ safety measures and culture. Predictive analyses were also conducted to investigate factors potentially associated with safety outcomes. Hierarchical regression analyses revealed that when the effect of occupational group was controlled for, a safety perception factor *External Factors* and a safety culture factor *Reactivity – Blame Culture* were significant predictors of the experience of near misses. Furthermore, when the effect of occupational group, tenure and near miss frequency were controlled for, *Workplace Stress* and *Reactivity – Blame Culture* were significant predictors of the frequency of safety defect reporting. The predictive values of both retrospective items (predominantly safety climate pertaining to employees’ perception about technical/structural aspects of safety measures) and prospective items (safety culture) were both validated. The implications of the results are discussed, particularly in terms of cultivating leadership attributes which embrace organisational learning.