

https://dspace.org/

Systemic factors in the investigation of South African railway occurrences

Hutchings, Jessica

2017

https://hdl.handle.net/10539/23846

Hutchings, Jessica (2017) Systemic factors in the investigation of South African railway occurrences, University of the Witwatersrand, Johannesburg, <https://hdl.handle.net/10539/23846>

Downloaded from a DSpace repository. https://dspace.org/

SYSTEMIC FACTORS IN THE INVESTIGATION OF SOUTH AFRICAN RAILWAY OCCURRENCES

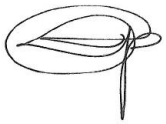
Jessica Hutchings

A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

Johannesburg, 2017

DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Jessica Hutchings

9 October 2017

NOTE TO THE READER

The results of this research were based on information developed from data collected at a particular time from certain organisations - with their full support - and in the interest of process improvement. The author recognises that some of the findings may since have been addressed or are in the process of being addressed by these organisations where the data were collected. They have been provided with a copy of this research and the findings. The organisations are aware of the findings and have reiterated their commitment to improving railway safety by considering the implementation of the corrective actions and initiatives at a strategic level to address the results.

ABSTRACT

The principle focus of this research is to provide a novel approach to accident investigation theory by focusing on the investigation process itself as a complex system. A number of systemic factors inherent in this system impact on the effectiveness (accuracy, quality, validity, reliability and objectivity) of railway investigations. There is a need to explore why railway occurrences remain high in South Africa, despite railway Operators investigating occurrences. If occurrences are investigated, why then do the number of events remain unchanged? Ineffective investigations impact on the accuracy of the findings identified and the suitability of the recommendations. Added to this is the failure of implementing recommendations from investigations contributing to the high number of occurrences and repeated occurrences. Complex influencing factors inherent within the railway system influence the actual investigation process and therefore its effectiveness. This is despite interventions put in place by various organisations, industries, and sectors to improve railway safety.

A critical review of the literature, in terms of accident investigation theory, indicates that the current research targets various approaches, methods and models to determine why accidents occur; from a human, technical, or system perspective. The literature focusses on accident causation by addressing the system and its role in contributing to such events. However, very little critical analysis exists on the actual investigation process of accidents as a complex system in its own right, and its contributory role in the ongoing high number of accidents. Rasmussen's (1997) Risk Management Framework is used in this research to illustrate the South African railway system hierarchy.

A qualitative mixed methods approach using triangulation was adopted. Methods included a print media analysis of reported railway accidents, document analyses of governance documents, analyses of railway investigation reports, semi-structured interviews with railway investigators and observations of investigation inquiries. Thematic content analysis was conducted to identify the themes emerging from the data.

The results indicate that systemic factors influence the manner in which occurrences are investigated. Examples include no National Rail Policy, limited resources to investigate, shortage of skilled investigators, absence of investigator training, non-compliance to

governance documents, an underinvestment in rail, financial constraints, and a blame culture. An Accimap summarises the systemic factors impacting on the effectiveness of the accident investigation process, its outcomes and the recurrence of accidents. Conclusions demonstrate that the accident investigation process is indeed an example of a complex system. Systemic factors collectively behave to influence the effectiveness of the investigation process, but also on the bigger rail socio-technical system which impacts on the safety, reliability and efficiency of the South African railway system.

The theoretical contribution of this research is identified in the useful and novel application of Rasmussen's (1997) Risk Management Framework to illustrate that the accident investigation process is an example of a complex system. Adjustments to Rasmussen's (1997) Risk Management Framework were made in order to contextualize it to the problem of this research, confirming the importance and application of Rasmussen's work in the system of accident investigations and not only in accident causation.

ACKNOWLEDGEMENTS

Completing a PhD has always been an aspiration and I knew that I would one day be able to achieve this. It has been a rollercoaster of a journey filled with many personal experiences that I did not know I would ever have to go through, but I made it. I owe an enormous depth of gratitude to a number of people:

My supervisors, Professor Ian Jandrell and Professor Andrew Thatcher, who provided guidance, insight and encouragement. In particular, thank you to Professor Thatcher for his continuous feedback, support and willingness to always be available.

To my husband, Glen, for being my rock when we went through so many life changing events that neither of us expected in such a short space of time. Without your positivity, encouragement and belief in me to succeed I am not sure I would have completed my PhD. I cannot thank you enough for your continuous support.

To the organisations that assisted in this research, in particular with the data collection, thank you for giving up your time to be available, for your commitment to this research and for your enthusiasm.

To my family and friends, for your continuous support, excitement and encouragement throughout these last 4 years. Without all of you I am not sure I would have found the courage to continue at certain times, but you were always there, and for that I am grateful.

To my colleagues, Gill van der Heever, Paul Bester, Letlotlo Phohole, Nic Cloete-Hopkins and Professor Beatrys Lacquet, for your motivation, encouragement, advice and lots of cake to get me through this incredible journey.

To my "PhD support group", Shelley Macaulay and Dr Estelle Watson thank you for the encouragement, distractions, fun and laughter. Your unwavering support has meant so much to me. Thank to Teresa Hattingh, Robyn Letts and Jessie Yen for your support.

To Nadine dos Santos and Cloe-Ryssa Murugan who helped with the data collection and Chantel Ferreira for helping me with the transcriptions.

CONTENTS

NOTE TO THE READER ..... **iii**

ABSTRACT ..... **iv**

ACKNOWLEDGEMENTS ..... **vi**

LIST OF FIGURES ..... **xii**

LIST OF TABLES ..... **xiii**

LIST OF ACRONYMS ..... **xiv**

CHAPTER 1: INTRODUCTION **1**

1.1 Background 2

1.2 Problem Statement 5

1.3 Research Hypothesis 9

1.4 Rationale for this research 9

1.5 Research Question 12

1.6 Structure of the thesis 13

1.7 Concluding remarks 14

CHAPTER 2: THE SOUTH AFRICAN RAILWAY INDUSTRY **15**

2.1 Background to the South African railway industry 15

2.2 South African railway system hierarchy 19

2.2.1 Department of Transport (DoT) 20

2.2.2 The Railway Safety Regulator (RSR) 22

2.2.3 Passenger Rail Agency of South Africa (PRASA) 25

2.2.4 Transnet Freight Rail (TFR) 28

2.3 State of railway safety in South Africa 30

2.4 Reporting of railway occurrences in South Africa 32

2.5 Concluding remarks 37

CHAPTER 3: HUMAN FACTORS AND SYSTEM PARADIGMS **39**

3.1 Human factors as a systems discipline 39

3.2 Understanding systems theory 43
3.3 HF/E and systems thinking 44
3.4 Modern view of HF/E and systems theory 47
3.5 HF/E, systems theory and the railway industry 48
3.6 Systems Engineering and System HF/E 51
3.7 Systems thinking and its approach to accident theory 53
3.8 HF/E and accident causation theory 54
3.9 Concluding remarks 55
CHAPTER 4: ACCIDENT CAUSATION THEORY 56
4.1 Understanding socio-technical systems 56
4.2 Systems theory summary 61
4.3 Accident causation theory 63
4.4 Explanation of traditional approaches to accident causation 65
4.4.1 Sequential accident models 65
4.4.2 Epidemiological accident models 67
4.5 Systemic approaches to accident causation 68
4.6 Accident analysis methods 70
4.6.1 Reason's (1990) Swiss Cheese Model 71
4.6.2 Leveson's (2004) Systems Theory Accident Model and Processes (STAMP) 73
4.7 Rasmussen's (1997) Risk Management Framework 75
4.7.1 Motivation for selecting Rasmussen's (1997) Risk Management Framework 75
4.7.2 Explanation of Rasmussen's (1997) Risk Management Framework 77
4.7.3 Explanation of an Accimap 84
4.7.4 Summary of Rasmussen's (1997) Risk Management Framework 86
4.8 Concluding remarks 87
CHAPTER 5: ACCIDENT INVESTIGATIONS 88
5.1 A systems approach in accident investigations 88

5.2 The purpose of accident investigations 91
5.3 Requirements for effective investigations 93
5.4 Investigation techniques 96
5.5 Learning from accidents 96
5.6 Independence in accident investigations 101
5.7 Theoretical contribution of this study 103
5.8 Concluding remarks 104
CHAPTER 6: METHODS **106**
6.1 Operationalising Rasmussen's (1997) Risk Management Framework 106
6.2 Research design 110
6.3 Data collection methodologies 113
6.4 Media Analysis of railway occurrence reporting in South Africa 113
6.4.1 Sample 115
6.4.2 Instruments 116
6.4.3 Procedure 118
6.4.4 Data analysis 119
6.5 Analyses of governance documents 121
6.5.1 Sample 122
6.5.2 Instruments 123
6.5.3 Procedure 124
6.5.4 Data analysis 124
6.6 Evaluation of occurrence investigation files 124
6.6.1 Sample 125
6.6.2 Instruments 126
6.6.3 Procedure 127
6.6.4 Data analysis 129
6.7 Interviews with occurrence investigators and managers 129

6.7.1 Sample 129
6.7.2 Instruments 132
6.7.3 Procedure 134
6.7.4 Data analysis 135
6.8 Observations of occurrence inquiries 140
6.8.1 Sample 141
6.8.2 Instruments 141
6.8.3 Procedure 141
6.8.4 Data analysis 143
6.9 Ethical considerations 144
6.10 Concluding remarks 144
CHAPTER 7: RESULTS **146**
7.1 Media Analysis results 146
7.1.1 Reporting of railway safety in the media 147
7.1.2 Comparison of the number of media reports to the number of occurrences 147
7.1.3 Themes and sub-themes identified from the media analysis 149
7.1.4 Factors that affect readership 150
7.2 Governance document analyses results 154
7.2.1 RSR governance documents 154
7.2.2 TFR governance documents 161
7.3 Occurrence investigation files results 164
7.3.1 RSR investigation files 164
7.3.1.1 RSR BOI investigation file 167
7.3.1.2 RSR Level 1 and 2 investigation files 171
7.3.2 TFR investigation files 179
7.4 Interviews at the DoT, RSR and TFR results 188
7.4.1 Government interview 189

7.4.2 RSR interviews 198
7.4.3 TFR interviews 207
7.4.3.1 CSO results 207
7.4.3.2 Line Management results 217
7.5 Observations of occurrence inquiries results 224
7.5.1 RSR's observations 224
7.5.1.1 RSR Level 2 investigation 224
7.5.1.2 RSR BOI investigations 231
7.5.2 TFR observation 242
7.6 Accimap of the accident investigation system 250
7.7 Summary of the results 252
7.8 Concluding remarks 254
CHAPTER 8: DISCUSSION, RECOMMENDATIONS AND CONCLUSION 255
8.1 Accimap of the system of accident investigations 255
8.2 Accimap discussion 258
8.3 Summary of the Accimap outcomes 270
8.4 Limitations of the research 275
8.5 Recommendations for the South African railway industry 278
8.6 Directions for future research 282
8.7 Conclusion 284
REFERENCES 290
APPENDIX A: RSR OPERATIONAL OCCURRENCE CATEGORIES 314
APPENDIX B: EXAMPLE OF THE INTERVIEW QUESTION PROTOCOL 315
APPENDIX C: ETHICS PROTOCOL 319
APPENDIX D: THEMES AND SUB-THEMES FROM THE MEDIA ANALYSIS 322
APPENDIX E: DISCUSSION OF THE THEMES FROM THE MEDIA ANALYSIS 323
APPENDIX F: CAPTIVE HEADINGS FROM THE MEDIA ANALYSIS 332

LIST OF FIGURES

Figure 1.1 Railway safety performance trends in South Africa 6
Figure 2.1 The South African railway system hierarchy 19
Figure 2.2 Sources of policy resistance 21
Figure 2.3 Annual number of operational occurrences 33
Figure 2.4 Annual number of fatalities and injuries 33
Figure 2.5 Rate of collisions for TFR and PRASA 35
Figure 2.6 Rate of derailments for TFR and PRASA 36
Figure 4.1 Reason's (1990) Swiss Cheese Model 71
Figure 4.2 Rasmussen's (1997) Risk Management Framework 79
Figure 4.3 The dynamic forces that change systems behaviour 83
Figure 4.4 An example of an Accimap 85
Figure 6.1 Methods and sources of data used in this research 113
Figure 6.2 Data analysis process 136
Figure 6.3 An example of a category or theme 137
Figure 6.4 DoT interview themes 138
Figure 6.5 RSR interview themes 139
Figure 6.6 TFR CSO interview themes 139
Figure 6.7 TFR Line Management interview themes 140
Figure 7.1 Themes identified and number of media articles 149
Figure 7.2 The main themes from the DoT interview 189
Figure 7.3 The theme challenges from the DoT interview 195
Figure 7.4 The main themes from the RSR interviews 198
Figure 7.5 Summary of the RSR interview findings 206
Figure 7.6 The main themes from the CSO interviews 207
Figure 7.7 RSR Penalty fee system as a theme from the CSO interviews 210
Figure 7.8 Competency / experience a theme from the CSO interviews 214
Figure 7.9 The main themes from the Line Management interviews 217
Figure 7.10 Accimap of the system of accident investigations 251
Figure D1 Themes and Sub-Themes from the Media Analysis 322

LIST OF TABLES

Table 4.1 Models of socio-technical systems 59
Table 4.2 Aspects of a systems approach 62
Table 6.1 The South African rail hierarchy structure 108
Table 6.2 Keywords used to search the media 118
Table 6.3 Formal analysis rubric from the media analysis 119
Table 6.4 Number of interviews in the rail hierarchy 130
Table 6.5 Categories of the interview questions 133
Table 7.1 Comparison of railway occurrences: RSR and the Media 148
Table 7.2 Themes and quotes from the media 151
Table 7.3 Number of investigations conducted by the RSR 165
Table 7.4 Findings from the RSR BOI investigation file 167
Table 7.5 CEO's comments about the RSR's recommendations 170
Table 7.6 Findings from the RSR Level 1 and 2 investigation reports 172
Table 7.7 Findings from the CSO investigation files 180
Table 7.8 The total number of investigations completed by the CSO 184
Table 7.9 RSR Level 2 occurrence investigation: observations on arrival 225
Table 7.10 RSR Level 2 occurrence investigation: observations onsite 226
Table 7.11 RSR Level 2 occurrence investigation: observations from the interviews 228
Table 7.12 Observations from the RSR BOI's 231
Table 7.13 Observations from theTFR BOI 242
Table 7.14 TFR BOI: observations pre-inquiry and arrival 245
Table 7.15 TFR BOI: observations onsite 245
Table 7.16 TFR BOI: observations from the interviews 246
Table A1 Railway occurrence categories 314
Table F1 Captive headings from the media analysis 332

LIST OF ACRONYMS

ATSB	Australian Transportation Safety Bureau
BBC	British Broadcasting Commission
BOI	Board of Inquiry
BRICS	Brazil, Russia, India, China and South Africa
CEO	Chief Executive Officer
CIA	Central Intelligence Agency
CNN	Cable News Network
CREAM	Cognitive Reliability and Error Analysis
CSE	Cognitive Systems Engineering
CSO	Corporate Safety Office
DG	Director General
DoT	Department of Transport
DPE	Department of Public Enterprises
eNCA	ENews Channel Africa
EU	European Union
FRAM	Functional Resonance Accident Model
GAIN	Global Aviation Information Networking
HAZOP	Hazard and Operability Study
HFACS	Human Factors Analysis and Classification System
HF/E	Human Factors / Ergonomics
HSI	Human Systems Integration
IEA	International Ergonomics Association
INCOSE	International Council on Systems Engineering
NATMAP	National Transport Master Plan
NFLS	National Freight Logistics Strategy
NHS	National Health Services
NTSB	National Transportation Safety Board
PRASA	Passenger Rail Agency of South Africa
RAIB	Rail Accident Investigations Branch
RCAT	Root Cause Analysis Technique
RIC	Rail Incident Commander
RSR	Railway Safety Regulator

RSSB	Rail Safety and Standards Board
S.A.	South Africa
SACAA	South African Civil Aviation Authority
SADC	Southern African Development Community
SANS	South African National Standard
SAPA	South African Press Association
SMS	Safety Management Systems
SPAD	Signals Passed At Danger
STAMP	Systems Theoretic Accident Model and Processes
SWIFT	Structured What-If Technique
TAP	Train Accident Prevention
TCO	Train Control Officer
TFR	Transnet Freight Rail
TSB	Transportation Safety Board
UK	United Kingdom
USA	United States of America
WYLFIWYF	What you look for is what you find

CHAPTER 1: INTRODUCTION

Rail has the potential to play an important role in the sustainability of transport within South Africa. The benefits of rail include: creating economic growth, reducing congestion on roads, providing mobility to citizens and contributing to re-industrialisation. For rail transport to play a vital role in society, the primary and overall requirement is that it is a safe mode of transport. A safe railway instils confidence in the public, passengers, customers and investors (European Union Agency for Railways, 2016). Regardless of whether accidents and incidents result in fatalities and/or injuries, there are significant costs to businesses. Therefore the financial, moral and legal impacts of accidents and incidents needs to be managed effectively. One such way of managing accidents and incidents is through effective and independent investigations. Investigations are important as the purpose is to identify what happened and to implement remedial actions to prevent a recurrence.

Before proceeding it is necessary to highlight a few definitions of South African railway terminology used in this research. Railway *occurrences* are defined in the National Railway Safety Regulator Act No. 16 of 2002 (2009) as railway accidents or incidents that are either due to operational or security events. The focus of this research is on *operational occurrences* which includes, amongst others, derailments, collisions and level crossing events. These may result in fatalities and/or injuries. Occurrences, accident, events and incidents are used interchangeably in this research. *Railway safety performance* in this research is defined by the number of operational occurrences, number of security incidents such as theft and vandalism, and accidents, fatalities and injuries.

Owing to the importance of rail's role in the sustainability of transport, the focus of this research is to understand how effectively railway occurrences are investigated in South Africa. This is as railway safety performance trends indicate that the number of occurrences have increased, despite the fact that occurrences are investigated. The actual investigation process of accidents will be evaluated to determine how the systemic factors impact on the effectiveness of the investigation process and therefore the findings and recommendations that emerge from the investigation. Systemic factors are defined as the challenges, pressures, frustrations and obstacles inherent within the investigation system creating its complexity. The effectiveness of the investigation process refers to the

accuracy, reliability, quality, validity and objectivity of the actual investigation process, its findings and recommendations.

This research illustrates how the complexity of the South African railway system, combined with systemic factors impact on the entire accident investigation process. It focusses on the system of accident investigations and not the accidents themselves. Adopting a systems approach allows for a holistic and comprehensive identification of the external and internal parts or components within and between organisations, their interactive nature, feedback and interdependence, in addition to the role of the environment influencing the investigation systems performance. Rasmussen's (1997) Risk Management Framework provides the theoretical framework for this research and is used to illustrate the South African railway system. The identification of the systemic factors influencing the investigation system will not only benefit the railway industry but will also contribute to accident investigation theory by providing an alternative approach. This first chapter provides the background to the definition of the problem that this research will answer, and then outlines the aims of the research, the research hypothesis, and the research questions.

1.1 Background

South Africa's railway network is the largest and most developed on the African continent. The Railway Safety Regulator (RSR) reports that in South Africa, an estimated 2.2 million commuters use rail as a mode of daily transport and that, per annum, rail carries 11 trillion tons of freight (Railway Safety Regulator [RSR], 2015). Safety, an emergent property of a system, is therefore a major priority for a complex socio-technical system such as rail.

The RSR states that, in South Africa, railway occurrence numbers illustrate a slight upward trend and that the safety performance of the railway industry is in constant fluctuation (RSR, 2011a; 2015). A similar trend was identified in the European Union (EU) where over the period of 2013-2016, the number of accidents increased in the EU (Eurostat, 2016). The EU statistics on railway safety performance further illustrate that no progress has been made in reducing the number of accidents with collision and derailment numbers stagnating. While it is acknowledged that the increase in accident numbers may be as a result of increased reporting, it is also suggested that the numbers are due to deterioration in safety performance (European Union Agency for Railways, 2016). With

traffic volumes remaining constant in the EU, this was found to not be of any significance influencing safety performance. In South Africa the constant fluctuation in safety performance may be attributed to the increase in tonnage traffic, with passenger volumes and kilometres travelled remaining fairly constant. However, the RSR remains concerned with the absolute values for occurrences and those resulting in fatalities and injuries indicating a general increase (RSR, 2015). This is discussed in more detail in chapter 2.

The upward trend of accidents in South Africa (and the EU) is of concern due to the implications for improving safety. Railway occurrences result in fatalities, injuries, damage to the environment and infrastructure, and financial costs. The RSR (2016) reported that derailments, collisions, level crossing accidents, theft, vandalism and train fires cost the South African economy R889 661 85 during the 2015/2016 reporting period. This amount only reflects the operational occurrences and security incidents mentioned and *does not represent the total cost for all operational and security events*. In 2011, the RSR reported that the total direct cost for operational occurrences and security incidents exceeded R1 billion for only *two of the major Operators* (RSR, 2011b). A significant amount of money is therefore lost due to railway occurrences. This has a direct implication on the South African economy and the safety of its citizens. In order to mitigate the financial, moral and legal costs associated with such events, comprehensive occurrence investigations are key to managing safety. The purpose of investigations is to understand what occurred in the rail socio-technical system and what remedial actions should be adopted to prevent recurrence. This research explores the effectiveness of railway occurrence investigations in South Africa in adequately addressing the reasons for such events. Furthermore, the suitability of the recommendations suggested post an occurrence, and more importantly whether these are implemented to prevent recurrences is also investigated in this study.

The South African Department of Transport (DoT), states that transport is at the heartbeat of South Africa's economic growth and social development (Department of Transport [DoT], 2012). An important domain of the transport sector is the railway industry. The cost of railway occurrences highlighted above, illustrate the impact that railway occurrences and security incidents have on the economy, and South Africa's ability to achieve economic growth. South Africa relies on rail to transport people and transport goods that are distributed locally and for export. There is an increased need to shift freight from road

to rail transport as part of South Africa's rail revitalisation (SAPA, 2014). Increased road freight traffic also impacts on the state of roads within South Africa and has implications for road users' safety. In 2013, Kgalema Motlanthe, the then deputy president of South Africa, (SAPA, 2013), acknowledged this and stated that South Africa needed to increase its use of rail freight to boost economic growth and to preserve the country's roads. Considering the importance of rail in South Africa; this research investigates how railway safety and unsafe railways impact on people and businesses that depend on rail. This research explores railway safety by providing a theoretical framework to address the challenges, pressures, obstacles and frustrations (systemic factors) that influence the effectiveness of the investigation process of railway occurrences. This will contribute to the South African railway industry's efforts to improve rail safety for all users.

A number of international researchers in the railway industry have tried to address railway occurrences (despite increasing regulatory control and innovative technology) by offering different perspectives for the problem of railway accidents. Railway research in accident causation has been conducted in a number of countries for example, Australia (Baysari, Caponecchia, McIntosh & Wilson, 2009; Baysari, McIntosh & Wilson, 2008; Klockner & Toft, 2014) in the United Kingdom (Clarke, 1998a, 1998b; Jeffcott, Pidgeon, Weyman & Walls, 2006; Kim & Yoon, 2013; Lawton & Ward, 2005; Wilson & Norris, 2005), in the Slovak Republic (Cicmancova, 2013), and in India (Ghosh, Banerjee & Ganguly, 2012). In terms of South Africa, research in the railway industry with particular focus on human factors, and accident causation is limited, however some research has been conducted on rail economics and logistics (Havenga, Simpson & De Bod, 2014; Havenga, 2015; Pienaar, 2003, 2010), one study on railway injuries (Lerer & Matzopoulos, 1996), and more recently papers presented by the RSR at conferences on preserving railway knowledge, critical railway skills, degraded mode of operation and safety culture respectively (Bouwer & Hubinger, 2014; Mathebula, Poya & Makwela, 2014; Mathebula & Sopazi, 2016; Tau, 2016).

Over the last number of decades, much research has been devoted to understanding why accidents occur. The literature available today contains an extensive number of models of, and theories on, accident causation (Katsakiori, Sakellaropoulos & Manatakis, 2009; Kim & Yoon, 2013). However, for the purposes of this research the question is not what causes railway accidents, although this will be discussed, but whether it may be the way in which

accidents are investigated that are contributing factors for the recurrence of railway accidents. The importance of conducting *thorough* investigations is paramount to ensure that safety is managed effectively. In a study looking at why shipping accidents continue to occur, Celik, Lavasani and Wang (2010) contend that previous research identified system complexity, automation, human errors and human-centred system design failures as possible reasons for shipping accidents. Celik et al. (2010) argued that shipping accident investigation processes are an extremely significant task for increasing safety. A comprehensive investigation procedure is important to provide insight into the active and latent factors contributing to the occurrence otherwise feedback from the accident investigation reports to the maritime community would be insufficient (Celik et al., 2010).

A critical review of the literature in terms of accident investigation theory clearly indicates that the current research targets various approaches, methods and models to determine why accidents occur either from a human, technical, or system point of view. However, very little was found on the actual investigation process of accidents as contributory reasons for why the number of accidents continues to remain high despite interventions put in place by various organisations, industries, and sectors. The identification of the systemic factors that impact on the effectiveness (accuracy, quality, reliability, validity and objectivity) of railway occurrence investigations will therefore be determined. The principle focus of this research is to provide a novel and alternative approach to accident causation theory and safety science by focusing on the *investigation process itself as a complex system.* Chapters 3, 4 and 5 detail the existing literature and to which theories this research will contribute.

1.2 Problem Statement

The problem that this research addresses is that *despite the Regulator and railway Operators in South Africa investigating occurrences, the safety performance trends have remained largely unchanged over recent years* (RSR, 2011a). The goal of this research is to determine why the number of occurrences remains high and what is being done by the railway industry to reduce the number of occurrences. Figure 1.1 illustrates the problem with a summary of the number of railway occurrences, injuries and fatalities for the RSR's financial reporting periods from 2008/2009 to 2014/2015 (RSR, 2015). This is discussed in detail in chapter 2.

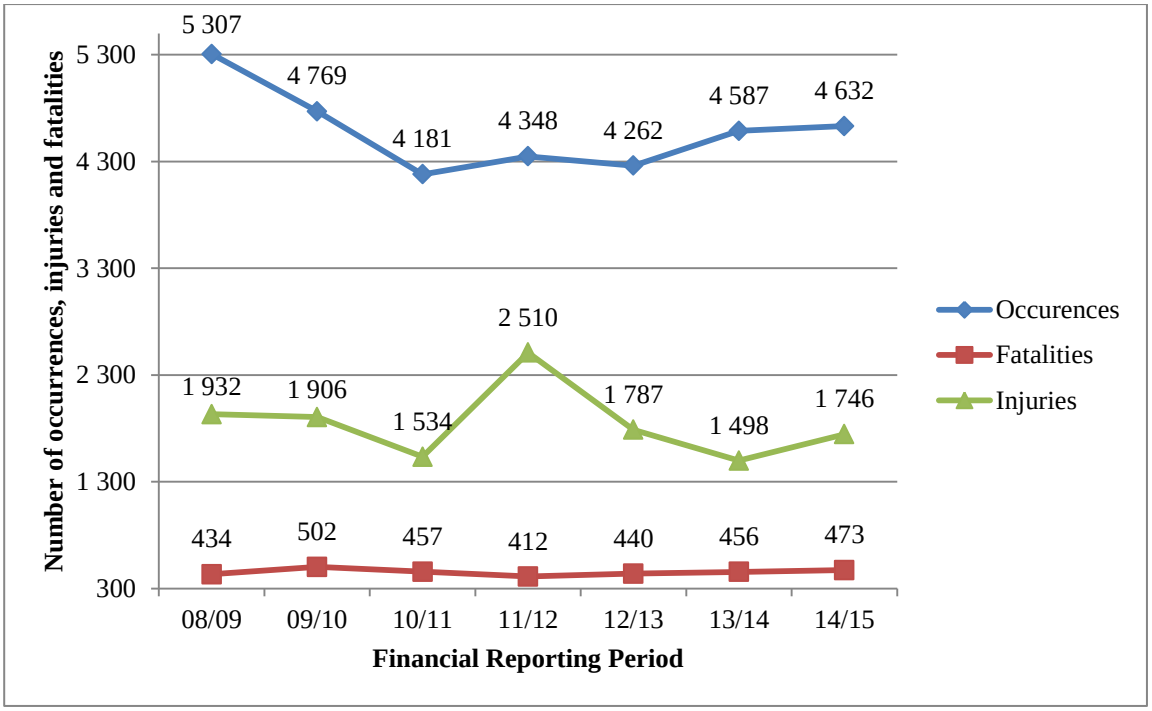


Figure 1.1 Railway safety performance trends in South Africa (Adapted from RSR, 2015)

Figure 1.1 demonstrates that safety performance trends show little improvement. Given the added impact of occurrences on the economic growth of South Africa and the status of safety performance in Figure 1.1, there is a need to understand how effective interventions are within the railway industry in addressing critical occurrences such as derailments, collisions and level crossing incidents. Figure 1.1 illustrates that since the 2013/2014 reporting period, the number of occurrences, fatalities and injuries have increased. However, the RSR affirms in the 2015 RSR State of Safety report that progress has been made with respect to rail safety, contrary to the increased numbers in Figure 1.1 since 2013/2014. This is despite a 1% increase in operational occurrences during the 2015 review period from 4587 operational occurrences in 2013/2014 to 4632 operational occurrences in 2015.

South Africa's unenviable railway safety record warrants further analysis, with the RSR acknowledging that one of its safety interventions is to investigate railway occurrences as part of its mandate to oversee railway safety. While railway Operators are obligated to report, and investigate, all occurrences to the RSR, the RSR investigates occurrences that have led to major loss for example fatalities, injuries, major damage to property, and those that attract public attention. The RSR maintains that the purpose of its investigations is to

identify the immediate and root causes and prevent recurrences (RSR, 2015). In striving to ensure railway safety, the RSR's vision for the period of 2015-2020 is to aspire to achieve zero occurrences (RSR, 2015). While this is a positive progression, it is argued that this may be a major feat given the high occurrence rate and inherent complexities of a rail socio-technical system, further emphasising the importance of addressing this research problem.

This research is important not only because of the existing problem in South Africa (with regards to railway safety performance trends), but also due to the existing literature on accident investigations. A number of important studies examining accident causation have been produced. Much of this work tends to focus on the accident itself, determining the events leading up to the accident and more recently what factors within the system contribute to accidents. While work exists on the investigation of accidents, little attention has been given to *the investigation process of accidents as a complex system* in its own right. This work examines the system of accident investigations as a complex system and not the accident itself. A systems approach applied to the investigation process of accidents is important as systemic factors influence the effectiveness (accuracy, quality, reliability, validity and objectivity) of the investigation process, and therefore its outcomes (findings and recommendations).

This research is unique as there has been no published work in South Africa that documents human factors, accident causation theory and systems theory together especially in the railway industry. Research in this field in South Africa is in its infancy given the scarcity of human factors experts in the country and provides further motivation for conducting this research. The need to address rail systems as a complex socio-technical system, and therefore the adoption of a systems approach to occurrence management is supported by many recent authors in the field, however viewing the investigation process as a complex system in its own right is novel. Applying a systems approach to determine the effectiveness of the investigation process is important as the performance of the whole system must be considered, rather than its parts, in how it affects the practicality and relevance of the findings and recommendations. This research acknowledges the dynamic interactions and constraints of the various components in the accident investigation system and will identify the deficiencies that hinder the accident investigation process from producing the desired outcomes. By improving the manner in which occurrences are

investigated this will enable organisations to better understand the importance of occurrence management and how this can create a safer system for employees, the public, customers and the greater railway community.

In the literature, journals such as *Accident Analysis and Prevention, Applied Ergonomics and Safety Science* detail a considerable amount of information on accident causation highlighting the importance of this field. Given the tragic consequences of accidents it is not surprising that the field of safety and accident prevention are important areas of interest. The intention of this research is to extend the theory on accident causation to suggest that accident causation models need to be more inclusive of the actual *investigation system*, focussing on the manner in which accidents are investigated. As will be evident in this research, an ineffective investigation process is a contributor to why accidents recur as superficial findings and inappropriate recommendations are identified. Current models may require an extended formation in order to explain the systemic factors that influence the *investigation process of railway occurrences* rather than just focussing on what resulted in an accident. This would be particularly useful in cases where there are repeated occurrences to determine the thoroughness of previous investigations in trying to mitigate such events.

While it may seem obvious to conduct an investigation properly to prevent the same thing happening over and over again, this may not be the case in industry given the multiple requirements of productivity and safety, competing goals, resource constraints, and external constraints on the system. Industries may have inherent challenges that are obstacles preventing organisations from achieving good safety records. The intention of this research is to identify what these systemic challenges may be, and to determine whether these differ from the obstacles that also contribute to accidents. Poor investigations with little emphasis on what actually went wrong, failing to adopt a systems approach to uncover the events leading to the accident, and apportioning blame makes for unreliable investigations. These factors may offer insight into the possible indirect causes for why safety trends remain largely unchanged despite a number of interventions by various organisations.

The number of occurrences, fatalities and injuries, in addition to the impact that bearing the cost of these occurrences has on the fragile economy of South Africa, provided the

motivation for this research. With considerable money being invested to upgrade the South African railway system, the Government, the Regulator, and Operators will have to ensure that incidents are investigated methodically in order to preserve this investment, minimise damage to existing and new infrastructure and to the environment, but also to guarantee the health and safety of the employees and public. This research provides the railway industry with opportunities to improve the manner in which occurrences are investigated. With improvements to the way incidents are investigated, and therefore managed, this will advance the safety and reliability of the railway system. There will be benefits for the economy of South Africa as interested parties will want to invest in rail transportation. The results of this research will highlight the challenges within the South African railway socio-technical system, with systemic factors inherent in society, the Government, the Regulator and the Operators that impact on the effectiveness of occurrence investigations.

1.3 Research Hypothesis

This research addresses the problem statement by stating that the effectiveness of the investigation process of occurrences contributes to the accuracy, validity, quality, objectivity and reliability of the findings, recommendations and the number of occurrences. *It is therefore hypothesised that there are systemic factors influencing the investigation process of occurrences in South Africa.* This indirectly contributes to the high numbers of occurrences as superficial findings and unsuitable recommendations are identified resulting in latent conditions remaining unnoticed. Deficiencies in the investigation system limit the effectiveness of the entire investigation process from achieving its objectives, offering an explanation for why railway safety trends remain unchanged in South Africa. This may be true for other countries that demonstrate similar safety performance trends. Furthermore, this is despite interventions that are put in place by various levels in the socio-technical system to reduce occurrences, fatalities and injuries.

1.4 Rationale for this research

In the 1980s a number of major international disasters occurred, for example Piper Alpha (1988), Chernobyl (1986) and Bhopal (1984) that resulted in an increased need for research in the field of safety. Today accidents in high risk industries have also resulted in major disasters for example the recent air crashes of TransAsia (2015), AirAsia (2014), Air Malaysia MH370 (2014), Fukushima nuclear plant (2011), and the Deepwater Horizon oil

rig (2010). Given the catastrophic consequences of such disasters, Le Coze (2013) questions whether we (i.e. regulators, society, industry) ever really learn from accidents in the past given that technological disasters continue to reoccur. Furthermore, Le Coze (2013) contends that learning from accidents in high risk industries is still a young field despite the literature growing in the last few decades in terms of feedback from accidents. Notwithstanding the growing interest, the literature is still fragmented in terms of feedback from accidents and more is needed to develop a unified and integrated approach. While it may be argued that learning from accidents is part of the wider field of safety science, Le Coze (2013) argues that the field of safety science is in itself still young and scattered given the different disciplines that approach it (for example Sociology, Management, Engineering, Ergonomics, and Psychology) and therefore questions whether it is an independent discipline. Le Coze (2013) therefore advocates for a field of learning from accidents to be a separate field of inquiry or discipline which is less fragmented and offers a wider integrated perspective. Investigations are one such way of learning from accidents, albeit a reactive intervention. This research investigates whether the South African railway industry really does learn from accidents given the numbers and the recurrence of repeated accidents. This provided the motivation for conducting this research as the number of lives lost and the financial impact that railway occurrences have on the economy of the country are detrimental to the sustainability of the railway industry.

Occurrence investigations are one example of many interventions conducted by railway Operators in addressing their safety performance. Occurrence information not only provides information on the industry's trends but also provides insight into the underlying hazards or risks that lead to or could lead to occurrences. Despite Operator's compliance with basic regulatory requirements, the RSR contends that the high incidence of operational (and security) occurrences provides evidence of inherent gaps in the total system (RSR, 2011b). It is for this reason that there is a need to understand what *systemic* factors within the South African railway system influence the investigation process of railway occurrences. It is believed that these factors may influence not only the accuracy, quality, validity, objectivity, and reliability of the occurrence investigation process itself, but also the outcomes and recommendations; consequently impacting on the safety performance of the industry. This is supported in the literature that if incidents are investigated thoroughly, then there should be a reduction in the number of incidents as the primary aim of an investigation is to uncover the events at all levels of the system, and to

identify remedial actions to prevent a recurrence (Cedergren & Petersen, 2011). Furthermore, the implementation, and follow up of recommendations is equally important in ensuring that repeated events do not occur.

The objectives of this research are to illustrate that the investigation process of railway occurrences is an example of a complex system influenced by a number of systemic factors. The aim is also to affirm that the systemic factors exist outside of the human and organisational systems. Furthermore, the competency and skills of investigators is important in order to conduct an in-depth analysis covering a broad range of system factors. Adequate staffing in terms of the number of investigators for the number of occurrences is important to make sure that not only are all occurrences investigated, but more importantly to confirm the effectiveness of corrective actions in preventing recurrences. Therefore this research provides the railway industry with opportunities to address the systemic issues impacting on the investigation system.

The concept of 'zero vision' and 'zero harm' emerged in the late 1990's in Sweden in the road safety community and has since become widespread in many other industries (Zwetsloot, Aaltonen, Wybo, Saari, Kines & Beeck, 2013). While commitments are made to achieving zero harm (for example, eliminating hazards, risk and injuries), the concept of zero accidents is more controversial. Dekker (2014) argues that safety is an emergent property of a system and therefore totally eliminating accidents and hazards is unachievable given the dynamic nature of systems. The additional pressure that this places on front line staff to ensure they meet the company's goal of zero accidents would require organisations to make sense of socio-technical system behaviour by considering the trade-offs between values, goals, strategies, and resources. With the RSR's vision for the next 5 years to achieve zero accidents, it would require an extensive understanding of systems theory, and maturity to achieve such a goal. Zwetsloot et al. (2013) contend that improving safety in complex systems and preventing deaths and injuries is one of the most difficult tasks for company managers. The zero accident vision may not be a literal numerical target but rather a way of encouraging employees to act towards achieving zero accidents, therefore creating a way of thinking (Zwetsloot et al., 2013). While the purpose of this research is not to delve into the merits of this concept, it is highlighted because in order to strive towards this, occurrence investigations are a fundamental part of any company's safety management system and therefore need to be effective to achieve success.

Another objective of this research is to provide a greater understanding within the System paradigms and allied fields in terms of accident causation theory and Human Factors. In the domain of Human Factors much is written about accident causation and accidents models, more recently using Systems Thinking and Systems Engineering principles. To the contrary, less focus has been given to the contribution of people within a system in the domain of Systems Engineering. The International Council of Systems Engineering (INCOSE) (2011) affirms that while many System Engineers intuitively understand that the human operator and maintainer are part of the system they often lack the expertise or information needed to fully incorporate human capabilities with the capabilities of the hardware and software (INCOSE, 2011). This research will extend the body of knowledge in Systems Engineering to be more inclusive of Human Factors as an allied science.

Furthermore, the intention of this research is to suggest that perhaps South Africa, like many other countries have already done, should explore the possibilities of establishing an independent transportation safety board whose purpose would be to advance transportation safety by being impartial to other government departments that regulate or operate elements of maritime, rail, road and air transportation systems. Van Vollenhoven (2002) affirms the importance of independence as a key factor that allows for transparency, autonomy, encourages openness and honesty, and eliminates the need to apportion blame. All too often safety takes a back seat, where investigations end up being used more for judicial or civil proceedings, and where individual parties stand to gain if the true causes of an accident are not revealed (Van Vollenhoven, 2002). Safety ought to be a priority in any company and with this fact in mind it should justify the need for independent investigations. This research will explore how independent railway investigations are in South Africa, as objectivity is a criterion used to determine the effectiveness of the investigation process.

1.5 Research Question

Railway occurrences are investigated by both the RSR and Operators in South Africa. As will be highlighted in chapter 2, the RSR is not required to investigate every occurrence; however Operators are required to “investigate” all occurrences. Given that investigations are (at least nominally) conducted, the question is: *why then do the numbers of occurrences remain high?* The research question that this work seeks to answer is stated as follows:

What are the systemic factors (challenges, pressures, frustrations and obstacles) influencing the investigation process of railway occurrences in South Africa?

In an attempt to answer the research question, a number of other questions will be explored:

- What are the levels that make up the railway system hierarchy in South Africa?
- What is the process followed when investigating an occurrence?
- How are the results of the incident investigation communicated from a bottom-up to top-down level and vice versa to effect interventions?
- How are railway occurrences currently investigated? What are the methods / models used to investigate incidents?
- Is the loop closed between the recommendations in the investigation reports and what is implemented in practice?
- What barriers outside of the organisational and human systems contribute to the manner in which occurrences are investigated?

1.6 Structure of the thesis

The following chapter (chapter 2) focusses on the South African railway industry that provides the background and context for this research. The railway system hierarchy in South Africa is explained and the state of safety in terms of railway occurrence trends is illustrated. The literature review is discussed in three parts. In Chapter 3:3, a review of the literature in terms of human factors and system paradigms, and how these disciplines are applied in accident investigations, provides the theoretical background for this research. Chapter 4 addresses accident causation theory, highlighting that while there is significant research available on accident causation, there is a limited amount of literature focussing on the investigation process as a complex system in its own right. The chapter includes Rasmussen's (1997) Risk Management Framework, the foundation of this study. Rasmussen's work is used in this research as the theoretical framework and to answer the research questions. Rasmussen's model is adapted to illustrate how the various levels within the South African railway system hierarchy influence the effectiveness of the occurrence investigation process. Chapter 5, the last part of the literature review, discusses accident investigations highlighting the purpose of, and requirements for, effective

investigations. The theoretical contribution of this study concludes the literature review chapters. In order to address the research question, a number of qualitative methods were adopted and are discussed in chapter 6. These include a media analysis of occurrences reported by the media, governance document analyses, a review of investigation files, interviews with investigators and observations of actual inquiries. This chapter includes the steps taken to conduct this research, the research design, ethical considerations, sampling, procedures, and data analysis. The results are presented in chapter 7 and include the themes that emerged from the thematic content analysis of the interview data. Findings are detailed for each level of the hierarchy in the investigation system. The results are summarised and demonstrated in an Accimap (pronounced axi-map) developed by Rasmussen (1997) and Rasmussen and Svedung (2000). The Accimap is adapted to illustrate the systemic factors influencing the effectiveness of the investigation process and therefore the recurrence of accidents. The final chapter, chapter 8 discusses the findings from the Accimap addressing the main theoretical contributions of this research. An overview of the practical contributions and limitations of this study, together with the directions for future research, and final conclusions, are included in this chapter.

1.7 Concluding remarks

This chapter highlighted the current state of railway safety in South Africa by illustrating the number of railway occurrences, fatalities and injuries. South Africa's safety performance has not improved despite the RSR and Operators conducting investigations. With this in mind, the main objective of this research is to illustrate that the investigation process of occurrences, if not effective, influences railway safety performance. This is because the investigation process is an example of a complex system that's effectiveness is impacted by systemic factors. These broad range of contributing factors are inherent in the investigation system but also the bigger rail socio-technical system, illustrating the system of system concepts. This research contributes to existing theory on accident causation with important relevance in the fields of human factors, system paradigms and safety science.

CHAPTER 2: THE SOUTH AFRICAN RAILWAY INDUSTRY

The previous chapter highlighted the state of safety of South Africa's railway system and the need to have effective investigations to improve safety performance. The problem this research highlights is that despite railway occurrences being investigated, safety performance trends remain largely unchanged. Furthermore, the literature on accident causation has been devoted to understanding why accidents occur, with this research contributing by affirming that the effectiveness (quality, reliability, accuracy, validity and objectivity) of the investigation process impacts on the outcomes, namely the findings and recommendations. This chapter discusses the background and context of the South African railway industry, the railway system hierarchy and the reporting of railway occurrences in South Africa.

2.1 Background to the South African railway industry

Wilson, Farrington-Darby, Cox, Bye & Hockey (2007) highlight that all countries with a rail network of any importance try to achieve the same outcome. That is to move more people and more goods on time and safely in order to satisfy their customers. In South Africa the rail network is extensive totalling 20247km and is ranked 14th in the world in terms of the length of the rail network. Rail networks connect the ports with the rest of South Africa (RSR, 2014). In comparison to other BRICS countries (Brazil, Russia, India, China, and South Africa), South Africa's rail network is the smallest with China (86000km) and India (63974km) obvious leaders. These figures are based on the Central Intelligence Agency (CIA) 2012 world ranking for railway networks (Central Intelligence Agency [CIA], 2012).

In a Green Paper for a National Rail Policy published by the South African transport department, the DoT affirms that rail must play a pivotal role in the future of South Africa's freight and passenger transport system (DoT, 2015). Rail is a well-established industry in South Africa; however has experienced mixed fortunes over time with several events impacting adversely on the industry's development (DoT, 2015). South Africa's history, including Apartheid, has resulted in an underdevelopment and acute decline of large portions of the rail industry. A lack of investment, poor safety records, under-utilisation of the existing network, a lack of security for passengers and freight, deteriorating rolling stock, an inadequate availability of specialised technical skills,

unreliability of the rail service and an ageing infrastructure are some of the challenges the South African railway industry is faced with (DoT, 2015; Pienaar, 2003). The DoT goes as far as to describe the state of the railway industry in South Africa as *"moribund"* (DoT, 2015, p. 13).

The foregoing challenges mentioned above have resulted in road transport being favoured over rail by both short and long distance passengers and logistic service providers for freight transportation. Operationally inefficient railways and an inability to compete effectively in the marketplace have prevented the socio-economic impact that rail should have on the macro economy of South Africa (DoT, 2015). Furthermore an absence of a National Rail Policy has meant that there has been no coherent national direction to guide the rail sector to revitalise, to guide national decision making and to develop investment strategies to reposition rail as the backbone of the transport system (DoT, 2015).

In terms of reinvesting in the railway sector, the democratic Government (post 1994) improved certain transport sectors, however the rail infrastructure system was neglected resulting in an ageing and inefficient railway (Havenga et al., 2014; Havenga, 2015). In terms of growing the railway industry as a dominant player in freight logistics, this has not been successful with the South African Government (through the Minister of Transport) in 2013 only allocating 10% of the nation's freight bill to be spent on rail (Havenga et al., 2014). Havenga et al. (2014) advocate the need for a rail reform agenda in South Africa, however they state that the challenges that face South Africa make this an arduous task. Furthermore, Havenga et al. (2014) and Havenga (2015) state that this is because of disjointed policies and fragmentation between the two Government departments that both have railway responsibilities. These are the DoT and the Department of Public Enterprises (DPE). The DoT is responsible overall for rail transport whereas the DPE focusses on investment and productivity. The DPE is also the shareholder of Transnet, a state owned enterprise that focusses on freight rail and logistics (Department of Public Enterprises [DPE], 2014). The disjointed responsibilities contribute to a lack of accountability in implementing a transport policy for the country's logistics system (Havenga et al., 2014; Havenga, 2015). To date there is still no National Rail Policy in South Africa, only the Green Paper published in 2015 by the DoT. The DoT state that they are in the process of drafting a White Paper, and only once this is approved can a National Rail Policy Act be

promulgated. The implications of the absence of a National Rail Policy are discussed in chapter 7.

Despite these challenges, the South African Government acknowledges the need to improve its rail infrastructure, to increase its use of rail freight to boost economic growth, and to preserve the country's roads (DoT, 2015). In order to reposition rail to play to a pivotal role in South Africa, there has been a shift to revitalise the railway industry. The DoT (2015) refers to this at the *'rail renaissance'*. The rail renaissance has resulted in an increased investment to improve the aging and declining infrastructure. The result is there has been a great demand to move freight from road to rail for a number of reasons including damage to the national roads by heavy vehicles (Havenga et al., 2014; Pienaar, 2003; van der Mescht, 2006). While these different modes of transport have their own strengths and limitations, rail transport has a cost advantage with respect to bulk goods that can be carried over long distances. Examples of investments to improve the standard of rail infrastructure and rolling stock include: Transnet Freight Rail (TFR), as part of their capital investment program and market demand strategy, invested R300 billion in 2013 and the Passenger Rail Agency of South Africa (PRASA), in 2014 invested R51 billion to supply new passenger trains. These investments are some of the biggest ever public procurements in South Africa's democratic history, illustrating the country's strive to transform its rail network after decades of underinvestment (Creamer, 2013; Myburgh & van Rensburg, 2014).

Efficient and safe transport is vital for economic growth in developing countries which includes South Africa. However, high levels of injury and violence on South Africa's extensive rail network have marred the railways' strive to achieve economic growth (Lerer & Matzopoulos, 1996; Thompson, 2009). Lerer and Matzopoulos (1996) contend that in developed countries rail transport is regarded as one of the safest modes of public transport; however in South Africa millions of users who rely on rail to commute to work often do so in overcrowded and unsafe conditions. Rail incidents resulting in fatalities and injuries include suicides, falls from trains (due to overcrowding, jammed in doors, or caught between the train and the platform), struck by trains, and violence (passengers thrown from trains and firearm assaults). Despite the research conducted by Lerer and Matzopoulos (1996) being slightly outdated, it is one of the few articles found detailing

railway accidents in South Africa and the seriousness of these both socially and economically.

In terms of South Africa's history, the role of colonialism and Apartheid has had an influence on the railway industry, with Mathebula et al. (2014) acknowledging that critical railway skills in the South African industry are dwindling. The railway network in South Africa started in 1860, and for about 38 years prior to 1981, South Africa did not invest in its railway system. The consequence of this non-investment resulted in poor infrastructure and the current skills gap resulting in South Africa missing a generation of infrastructure modernisation. In the past (pre 1910 and even before South Africa became a Republic in 1961), the South African railways were the centre of empowerment, provided technical education in South Africa, provided education for its staff and built railway schools. Today, however this is regrettably not the case as the industry faces a critical shortage, and a lack of depth of skills in critical areas (DoT, 2015; Mathebula et al., 2014). The South African Government's mandate for supporting socio-economic and transport objectives in both urban and rural contexts increases the pressure on the railway industry to ensure sustainable freight and passenger transport. This, together with the scarcity of skilled railway professionals and the lack of general investment in rail, has impacted adversely on South Africa's rail revitalisation.

According to Mathebula et al. (2014) the RSR is concerned with the lack of sufficient skills and experienced staff throughout South Africa's rail network. Investigations of railway occurrences conducted by the RSR have highlighted errors and violations by operational staff as primary causes, with factors such as safety related decisions of senior staff, high vacancy levels in safety critical positions, and a lack of assurance and monitoring as contributing factors (Mathebula et al., 2014). Furthermore, Mathebula et al. (2014) affirm that in order for railway safety performance, key skills are required for modern approaches to railway safety management (including accident investigations, risk management, and auditing). With recent major investments in South Africa's railway and upgrading of rolling stock it has become even more pertinent to ensure the development and effective utilisation of all available skills in order for South Africa's expectation of becoming a world class railway system to be realised.

This section highlighted the background and context of the South African railway industry. The next section discusses the hierarchy of the South African rail socio-technical system.

2.2 South African railway system hierarchy

Within socio-technical systems there are a number of hierarchies each with their own roles, responsibilities, goals and constraints. To determine the systemic factors influencing the investigation process of railway occurrences, and therefore its effectiveness, the hierarchical structures in the South African railway system are important to acknowledge. These structures consist of the *Government*, represented by the DoT, the *Regulator*, represented by the RSR, and the *Operators* of which there are over a hundred. For the purposes of this study the two major Operators are discussed in this section. They include the Passenger Rail Agency of South Africa (PRASA) and Transnet Freight Rail (TFR). All of these organisations have a role to play in terms of impacting on the effectiveness of the investigation process of railway occurrences. The background and relevance of these role players is discussed in the following sections. Figure 2.1 is a schematic diagram of the railway system hierarchy in South Africa, with the red blocks the focus areas of this research.

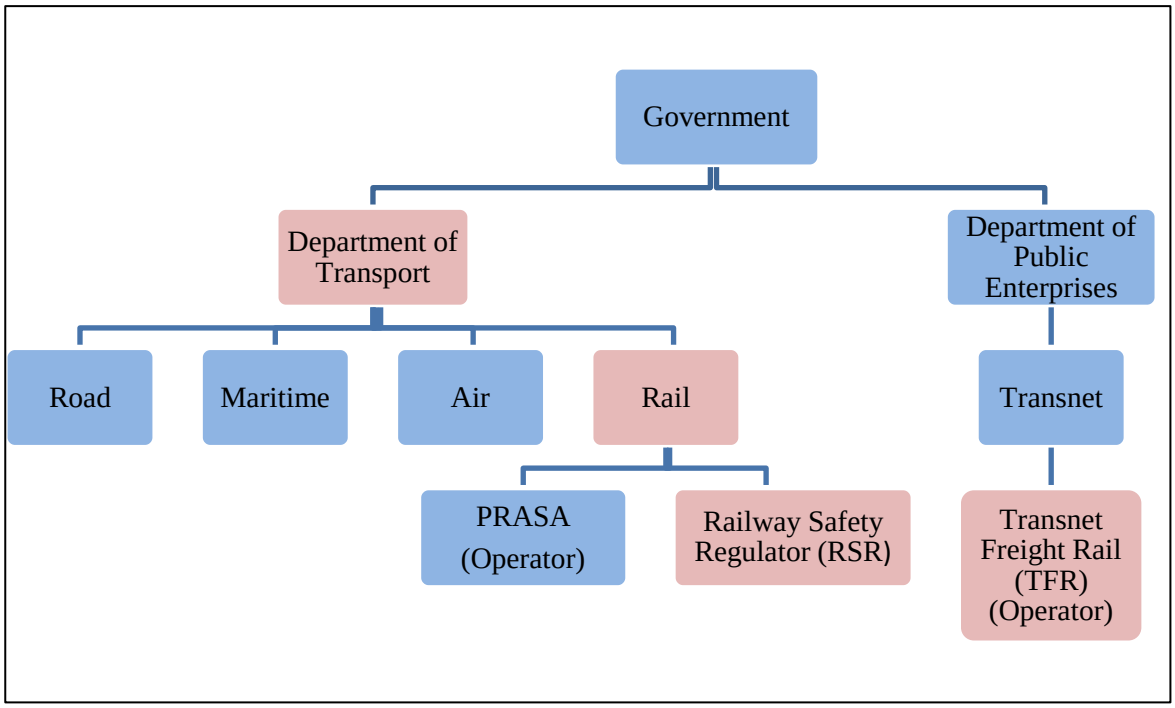


Figure 2.1 The South African railway system hierarchy

2.2.1 Department of Transport (DoT)

The Republic of South Africa, through the DoT, is responsible for the regulation of transportation namely road, rail, maritime and air (DoT, 2012). The responsibilities of the DoT pertaining to the rail sector include:

- Research, formulating legislation and policy for the development of sustainable rail transport;
- Assigning responsibilities to the 12 public entities that report to the Minister of Transport and other levels of government; and
- Rail economic and safety regulation through standards, infrastructure development strategies, and systems that reduce system costs and improve customer services (South African Government, n.d.).

The DoT monitors and oversees the Regulator (RSR) *and* an Operator (PRASA), who both report to the Minister of Transport. Whereas PRASA reports to the Minister of Transport as a passenger railway Operator, the major freight rail Operator, TFR, reports to the DPE. The reader will recall that Transnet is a state owned enterprise and reports to another ministry, the Minister of Public Enterprises. The reporting of both PRASA and the RSR to the Minister of Transport is an interesting observation. This creates the perception of a possible conflict of interest when it comes to railway safety management and the enforcement of safety regulations. TFR owns the entire rail network, over which PRASA operates, and has an effective monopoly in the railway industry. While the DoT is responsible for the overall transport policy, having TFR report to another ministry creates its own issues in terms of bureaucracy, regulation and enforcement. The main shareholder of Transnet is the Government which suggests another conflict of interest. Thompson (2009) states that Transnet has been largely unregulated, both in economic areas and in safety due to its dominance (size and existence). By default TFR has developed rail policy, and conducts economic and safety regulation. At each level of the railway system there are goals, constraints and priorities, where differing agendas and political conflicts create weaknesses in the system. The power of the agencies below the Government and the Regulator is indicative of their ability to resist reform if threatened. These factors are discussed further in the results chapter, chapter 7. Thompson (2009) states that where reporting lines and structures are consolidated, this results in a lack of transparency and

information, and makes oversight and regulation even more difficult if not impossible. Attempts to implement new regulations will conflict with policies and political objectives making the behaviours (of the system) unpredictable (Thompson, 2009). Factors such as the autonomy of the RSR and the conflict of interests mentioned above are discussed in chapter 7.

From a system perspective, the lack of a National Rail Policy to guide the various role players in the rail hierarchy may be a reason for why the autonomy and authority of certain role players is doubtful, impacting on the ability to reform the industry. Furthermore, Kumanyika, Parker and Sim (2010) state that resistance to policy arises due to an incomplete understanding of the feedbacks surrounding the decisions of all the role players in the system. Systems are made up of many feedback loops which influence agent's decisions and actions. These in turn alter the environment. Agents within the system aim to bring the state of the system in line with their goals; however in the example of policy resistance, this arises when agents fail to account for the side effects of their actions resulting in unintended consequences. Ignoring feedbacks leads to policy resistance. Figure 2.2 illustrates the sources of policy resistance that will be discussed in chapter 7 in more detail.

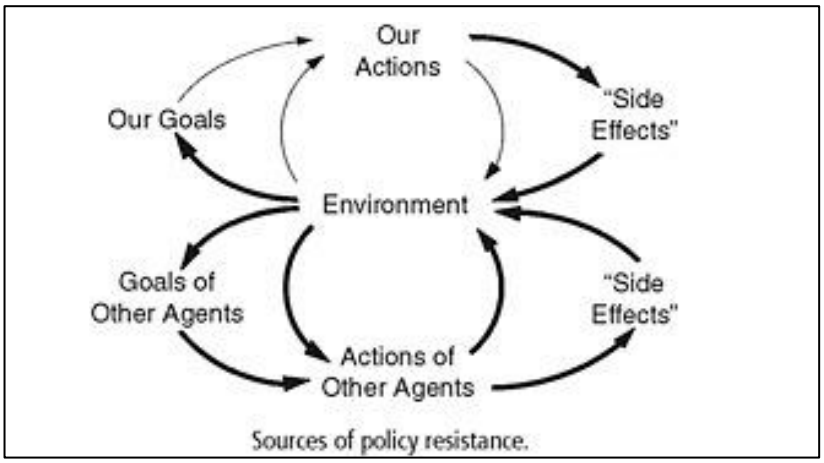


Figure 2.2 Sources of policy resistance (Kumanyika et al., 2010)

Figure 2.2 demonstrates how system thinking is important to illustrate how the actions of any agent in the system feedback to shape the environment (Kumanyika et al., 2010). System thinking is discussed in the following chapter with the results displaying similar findings of how different levels in the rail hierarchy influence the investigation system.

The long term vision of the DoT is detailed in the National Transport Master Plan, *Natmap 2050* (DoT, 2016) with the focus on an integrated transport plan to ensure that the different modes of transport complement each other to advance economic development and job creation. The aim is to achieve an integrated, smart, efficient, safe and accessible transport system (DoT, 2016). The DoT acknowledges that due to no National Rail Policy and the underinvestment in rail, there is a need to be robust and drastic if South Africa wishes to be globally competitive and achieve the Natmap 2050 objectives. It is for this reason that the DoT is revitalising the railway industry in South Africa to improve passenger and freight services to be safe and reliable. The South African Government, represented by the DoT is an important level in the rail socio-technical system. For the purposes of this research, an interview was held with a representative from the Rail Branch within the DoT.

2.2.2 The Railway Safety Regulator (RSR)

The National Railway Safety Regulator Act No 16. of 2002 (2009) provides for the establishment of a national regulatory framework for South Africa (hereafter referred to as Act 16) and therefore the RSR was established. The RSR is a public entity reporting directly to the Minister of Transport. Act 16 was developed to monitor and enforce safety compliance within the rail sector. The RSR's legislative mandate is to enforce safety performance of all railway Operators in South Africa, and to provide safety standards and regulatory practices for the protection of persons, property and the environment (National Railway Safety Regulator Act No.16 of 2002, 2009). It is governed by a Board of Directors and a Chief Executive Officer (CEO) that are appointed by the Minister of Transport (RSR, 2014).

Prior to the establishment of the RSR, the railway environment was self-regulated from the inception of railways in South Africa. One factor which led to the establishment of the RSR was the acknowledgment by the State that railways are key to sustained economic growth and that safety plays a pivotal role in advancing operational efficiency of South Africa's railways (RSR, 2011a). The RSR acts in an oversight role in terms of railway safety with its strategic plan focussing on sustainable, safe, secure and reliable passenger and freight railway operations. The mandate of the RSR, as per Act 16 (National Railway Safety Regulator Act No.16 of 2002, 2009) is summarised as follows:

- To oversee safety of railway transport, whereas Operators remain responsible for managing the safety of their operations;
- To promote improved safety performance in order to promote the use of rail;
- To monitor and ensure compliance through the conducting of audits, inspections and occurrence investigations;
- To develop regulations and standards in order to establish and enforce a regulatory regime;
- To conclude appropriate cooperative agreements or other arrangements with organs of state to ensure effective management and overseeing of safe railway operations;
- To collect and disseminate information relating to safe railway operations;
- To develop, adopt and accept standards for safe railway operations; and
- To promote the harmonisation of the railway safety regime of South Africa within the Southern African Development Community (SADC) railway operations.

Act 16 recognises that safe railway operations are fundamental to the safety of all persons and the environment (National Railway Safety Regulator Act No.16 of 2002, 2009). While safety performance of road transport in South Africa has a higher number of accidents and fatalities than rail (given the increased number of users and greater kilometres of road network), poor safety performance on rail inhibits South Africa's strive to revitalise the rail sector. Safe railway operations promote the use of railways as a mode of efficient transportation and that this must be effectively overseen, managed and co-ordinated. This is the responsibility of the RSR. Act 16 acknowledges that the RSR has a primary role to play in safe railway operations and recognises that Operators have the primary responsibility and accountability of ensuring the safety of railway operations (National Railway Safety Regulator Act No.16 of 2002, 2009).

The objective of this research is to illustrate the systemic factors influencing the effectiveness of the investigation process, thereby acknowledging that the investigation process is an example of a complex system. It is therefore necessary to explain how railway occurrences are required to be reported and investigated in South Africa. Act 16 defines railway occurrence reporting where an Operator must report to the RSR CEO the category and type of all railway occurrences as prescribed by the Minister (National

Railway Safety Regulator Act No.16 of 2002, 2009). In terms of railway occurrence investigations, the role of the *Operator* is to:

- Investigate every railway occurrence in order to identify the root cause or causes within a reasonable time after the occurrence; and
- Furnish the Regulator upon request any occurrence investigation report.

In terms of the role of the *Regulator*, the RSR *may*:

- Require the Operator to assess the impact of its recommendations in order to effect safety improvement;
- Investigate any railway occurrence for the purposes of preventing similar occurrences in the future as per a directive from the Minister;
- Request any person affected by the investigation to give evidence or make oral or written representations relevant to the investigation; call witnesses and lead evidence on any questions and question any person who testified as a witness in such an investigation; and
- Also appoint a suitably qualified person to carry out any investigation whereby this person must furnish a written report to the Regulator upon completion of an investigation.

What it exactly means to be suitably qualified is not defined in Act 16 and was one of the questions asked during the interviews with the RSR Inspectors. The results are discussed in chapter 7. In terms of the investigation of occurrences, the RSR is not required to investigate every occurrence. The RSR conducts three types of occurrence investigations classified by levels. The level of investigation is determined by the severity of the impact. These levels were identified from the review of the RSR's governance documents and are briefly discussed below with further discussions in the results chapter. The three levels include:

- Level 1 (Board of Inquiry [BOI]): *Major impact occurrence* for example, injury or fatality, damage to infrastructure, rolling stock and the environment, dangerous

goods spillage resulting in line closure or community evacuation and attract lot of media attention.

- Level 2 (RSR Occurrence investigation): *Minor and Major impact occurrence* for example, injury or fatality, damage to infrastructure, rolling stock and the environment, dangerous goods spillage resulting in line closure or community evacuation and attract lot of media attention.
- Level 3 (Review of the Operators investigation report): *Recurring occurrence / occurrence investigated by the RSR* for example, minor and major injury or damage to infrastructure, rolling stock and the environment.

Level 1 and 2 occurrences are for the more severe occurrences. BOI's are the highest level of investigation and people external to the RSR are appointed to be Board members for the investigation. A BOI is instituted by the RSR when an occurrence has a major impact on people, property, assets and the environment. A BOI is conducted over and above the Operator who is still required to investigate every occurrence. Level 2 investigations are similar to a Level 1, but are conducted by the RSR inspectors internally. Level 3 investigations are more of a review of the Operators' investigation reports, and if the RSR does not deem it satisfactory it is sent back to the Operator for improvements. The classification system, the differences between the Level 1 and 2 occurrences and the criteria for the level of severity are provided in chapter 7.

2.2.3 Passenger Rail Agency of South Africa (PRASA)

PRASA is a national government business enterprise that reports to the Minister of Transport and is wholly owned by the South African Government (Passenger Rail Agency South Africa [PRASA], 2013). The vision of PRASA is to be South Africa's number one public transport Operator responsible for rail (urban metro commuter and long distance intercity and cross border train services) and bus transport services (PRASA, 2013). Over 2.2 million passengers are transported daily by metro commuter rail services across South Africa. PRASA's strategy is to become a modern public entity that is able to deliver quality passenger services by 2018. As part of South Africa's rail revitalisation, PRASA has embarked on upgrading existing passenger railway systems and rolling stock. Many of PRASA's current rolling stock is older than 30 to 40 years and are beyond the maintenance lifecycle, posing significant danger to the public (PRASA, 2013; RSR, 2014).

As illustrated in the rail hierarchy in Figure 2.1, it is clear that both the RSR and PRASA, the biggest passenger Operator in South Africa, report to the Minister of Transport. In section 2.2.1 it was explained that the structure and reporting lines illustrate a conflict of interest. The South African Government is required to ensure that public transport is available and is reliable for many of South Africa's citizens that cannot afford their own mode of transport due to the socio-economic history of the country. The Government therefore subsidises train tickets at 70% of the operating costs in order to alleviate the socio-economic conditions of many South Africans (Government Communication and Information System, 2015). It is acknowledged by the South African Government in the Green Paper for a National Rail Policy (DoT, 2015) that passenger rail transport has also been neglected, there is a lack of security for passengers, it is unreliable and the rolling stock has deteriorated due to underinvestment. These factors also contribute significantly to unsafe railways. The RSR requires that Operators manage railway safety; however the Operators are also challenged given the conditions under which they operate. This makes the job of the RSR difficult in terms of overseeing railway safety given the current state of the industry. The conundrum for the DoT is that it is required to provide transport for the public but is also required to regulate railway safety; two conflicting demands that impact on the effective functioning of the system.

The conflicts of interest alluded to are relevant to this research as they impact on the successful functioning of the railway system, and as will be demonstrated in this research, the effectiveness of railway investigations. To further explain the conflict of interest between the RSR and PRASA, the following example is described. PRASA's passenger doors on the trains do not always close while the train is in motion resulting in a number of passengers being fatally injured (Nolan, 2016). Furthermore, overcrowding and security issues, together with open doors, are additional factors that contribute to railway injuries and fatalities. When the train driver presses the button for closing the doors, passengers are able to override this and break the doors to keep them open. Allowing trains to run with open doors is contrary to PRASA's own operating instructions and is a basic safety requirement that the RSR should be able to enforce (Nolan, 2016). This obvious safety risk indicates that PRASA does not comply with its own basic safety procedures. The seriousness of this issue was escalated to the highest court in South Africa, where a Constitutional Court judgement in 2004 ("Metrorail and those doors", 2016) and more recently a Constitutional Court judgement in 2016 was brought against PRASA (Nolan,

2016). It is concerning that twelve years since the 2004 court case that this issue is still not rectified and continues to contribute to poor railway safety, injuries and a loss of life. This example is highlighted to demonstrate that the authority of the various actors in the system is doubtful and questions the railway organisations commitment to railway safety. The 2016 judgement found PRASA liable for damages due to the failure of PRASA to close the doors of the train while it is in motion. The judgement stated that this was an essential safety procedure and PRASA was negligent to not observe this basic safety critical practice (Nolan, 2016). This example, together with the railway system hierarchy, reporting lines and structures in South Africa poses a few questions:

- If the Government is serious about public safety how are these trains allowed to depart in such an unsafe condition?
- What pressure is the Government exposed to given the number of people that rely on rail transport to commute to work? If the trains are removed from service (due to safety concerns), would this result in industrial action and increased vandalism by frustrated passengers? Is safety therefore comprised at the expense of providing an unsafe means to get to work?
- If the RSR's duty is to oversee safety, and the closing of doors is a basic safety requirement, how are PRASA trains allowed to operate and still be provided with an annual safety permit?
- Is society aware of such unsafe practices and the poor state of the railway industry in South Africa? The users of these trains surely are aware, however given the socio-economic climate in South Africa are left with very little alternative.

The above questions are examples of the types of questions asked during the interviews with the RSR and the DoT during the data collection of this research. They illustrate examples of systemic factors that not only impact on the rail socio-technical system, but also the effectiveness of the occurrence investigation process. Chapter 7 discusses these systemic factors in more detail. For the purposes of this research, data was not collected from PRASA to not add additional variables related to passenger safety. However, the issues relating to the reporting lines and structures formed part of the interview questions with the DoT and RSR. The next section details the role of TFR in the rail socio-technical system and this organisation formed part of the data collection of this research.

2.2.4 Transnet Freight Rail (TFR)

In 1990 the rail system, ports and pipelines were amalgamated into one state owned enterprise, Transnet Limited with the South African Government, under the DPE as the sole shareholder. The inception of Transnet Freight Rail (TFR), an operating division of Transnet, resulted in South Africa having its own national freight carrier and TFR was able to operate as a profit-orientated division of Transnet Limited (Thompson, 2009). In terms of reporting structures, TFR reports to Transnet Group who reports to the DPE and *not* the DoT.

The strategic intent of Transnet is to deliver efficient, safe, reliable and cost effective services to promote economic growth in South Africa (Transnet, 2015). TFR is the largest division of Transnet and is a heavy haul freight company representing 80% of Africa's total rail infrastructure (Transnet Freight Rail [TFR], 2010a). The vision and mission of TFR is to enable the competitiveness, growth and development of the South African economy by delivering reliable freight transport and handling services that satisfy customer demands. TFR owns and maintains most of the route network across South Africa and consists of 6 business units which were implemented in 2012. The coal business unit accounts for 60% of TFR's revenue. The amount of coal transported and exported is part of South Africa's long term strategy to reduce the amount of road traffic and move from road to rail transport (TFR, 2010b).

Thompson (2009) states that TFR's dominance is largely attributed to its size of operations and existence in South Africa resulting in a number of challenges for the organisation. Thompson (2009, p. 11) describes the freight railway system by quoting the National Freight Logistics Strategy (NFLS) presented by the DoT in 2005:*"The freight system is fraught with inefficiencies at system levels. There are infrastructure shortfalls and mismatches: the institutional structure of the freight sector is inappropriate…and the regulatory frameworks are incapable of resolving problems in the industry"*. This disconnect has dire consequences for railway safety, as political, historical, and organisational issues (systemic factors) hamper achieving a safe and reliable railway system.

Freight transport is needed in South Africa as it is an important driver of national competitiveness. However, this is only true if the transport is efficient and reliable.

According to Havenga et al. (2014) and Havenga (2015), South Africa has unfortunately failed in terms of capturing the South African market due to a number of reasons. These include a hiatus in rail investment in the late 1980s during the last few years of Apartheid and a lack of policy direction regarding road and rail transport in the freight transport industry (Havenga et al., 2014; Havenga, 2015). These factors and others have resulted in the exponential growth in road freight where almost 90% of long distance freight is transported by road (Havenga, 2015). As part of the rail renaissance in South Africa, it has been acknowledged by the Government to shift freight from road to rail to improve the South African economy (SAPA, 2014).

In terms of occurrence investigations, TFR has four levels of occurrence investigations. Level 1 and 2 occurrences, referred to as a BOI, are investigated by the Corporate Safety Office (CSO), while Line Management (responsible for operational management at a depot level) must investigate *every* occurrence irrespective of the level. The CSO will still investigate an occurrence if it meets the criteria for a Level 1 or 2 investigation irrespective of the Line Management investigation. The classification and criteria for the different levels of investigation was obtained from the governance documents at TFR as part of the data collection for this research. This is discussed further in the results chapter. Examples of the criteria for each level of investigation include:

- Level 1: Undesirable occurrences that meet one or more of the following criteria
    - Asset damage exceeding R10 million
    - Significant business interruption
    - The death of an employee, contractor or a member of the public on Transnet premises as a result of Transnet operations
    - Significant quantities of dangerous substances are spilled
    - Major political or media focus on the image of TFR
    - Environmental damage that has a significant impact on the physical or biological environment

- Level 2: Undesirable occurrences that meet one or more of the following criteria
    - Asset damage exceeding R5 million
    - Events resulting in serious business interruption

    - Work related physical harm/injuries to a person or persons that result in hospitalisation
    - Fatalities and injuries to 3rd parties from level crossing incidents
    - Environmental damage that has moderate impact on the physical or biological environment

- Level 3: Occurrences that meet one or more of the following criteria
    - Damage to assets greater than R1 million
    - Minor business interruption
    - Physical harm that does not result in hospitalisation
    - All Signal Passed at Danger events (SPAD)
    - Minimal quantities of a dangerous substance spilled

- Level 4: Minor occurrences that meet one or more of the following criteria
    - Damage to assets less than R1 million
    - First aid cases
    - Shunting derailments

For the purposes of this research, TFR was selected to represent the operational level of the system, together with the RSR and the DoT representing the Government. The reason for selecting this Operator as opposed to other Operators is due to the fact that TFR, as the railway network owner, is independent of the DoT, existed prior to the establishment of the Regulator, and is an established organisation. The ability to access information from TFR was also relatively easy given its proximity to the University. Given that TFR reports to a different Ministry, the researcher also wanted to determine whether this would have any significance in terms of the complexity of the investigation system.

2.3 State of railway safety in South Africa

The RSR is legally required by Act 16 to produce an annual report on the safety of workers, the public, and the environment associated with railway operations. The *State of Safety Report* details occurrences and reports on the safety statistics and safety performance of railway Operators for a specific reporting period. The reporting period is based on the financial reporting period of the RSR which is from 1 April to 31 March. The

purpose of this report is to identify areas of concern and thereby develop strategic interventions (RSR, 2011b; RSR, 2013).

In the RSR State of Safety report for the 2011/2012 reporting year (RSR, 2012), the RSR claimed to have embarked on a journey to curb occurrences that affect passengers, employees, and the environment due to safety performance results. The RSR, in its efforts to improve safety trends, established *"aggressive interventions"* during the 2012/2013 period (RSR, 2013). The RSR, along with being tasked to oversee railway safety, is also required to promote rail as the preferred mode of transport whilst making a significant contribution towards economic growth in South Africa (RSR, 2014). However, after the subsequent year of implementation of the interventions, the RSR reported in the 2013/2014 report that the positive trend noticed prior to the implementations had reversed with an increase of 7% in operational occurrences compared to the 2012/2013 performance record (RSR, 2014). It is interesting to note that this increase occurred on the back of the RSR finalising the penalty system that is aimed at enforcing compliance and a reduction in occurrences (RSR, 2014). Those familiar with safety culture literature can attest that creating a punitive culture does not necessarily lead to improved safety (Dekker, 2012), a possible explanation for the increase in operational occurrences.

The RSR in the State of Safety reports also detail the number of fatalities and injuries. The RSR (2014) states that a contributing factor to the number of fatalities and injuries are the socio-economic realities of South Africa that impact on the safety of the railway industry. The socio-economic conditions have resulted in people living along the railway tracks in informal settlements. The issue of settlement encroachment into the rail reserves and increased levels of theft and vandalism have resulted in a negative impact on the rail industry. Demand for rail transport has also increased as levels of urbanisation have increased due to issues resulting from poverty and unemployment in South Africa's past (RSR, 2014). Community behaviour, especially as people occupy parts of the railway reserve for human settlements, increases the number of people crossing the rail network increasing the risk of occurrences. The CEO of the RSR stated that a lot remains to be done in educating communities, the railway industry and municipalities on safe railway operations. The RSR (2014) acknowledges that in some areas improvements have been made while in others there is potential for disaster (RSR, 2014).

As stated in chapter 1, one of the RSR's objectives for the period 2015-2020 is to aspire towards achieving zero occurrences (RSR, 2014; RSR 2015). However, in the 2014/2015 State of Safety Report, the CEO of the RSR highlighted that despite noticeable improvements in Operators reducing the percentage of derailments and level crossing occurrences, the safety risk controls of the national railway system are ineffective (RSR, 2015). This research aims to bring to the railway industry's attention the need to improve the investigation process of railway occurrences in order for the RSR to fulfil its mandate of ensuring safe railway operations. This study will highlight the systemic factors that influence not only the investigation process, but also the bigger rail socio-technical system from achieving its objectives of a safe railway system.

2.4 Reporting of railway occurrences in South Africa

Section 37 of Act 16 stipulates that an Operator must report to the CEO of the RSR all railway occurrences including the type and category of occurrence (National Railway Safety Regulator Act No.16 of 2002, 2009). The *South African National Standard (SANS) 3000-1: 2009 Railway Safety Management,* developed by the RSR, stipulates the minimum requirements that Operators need to adhere to. Included in the standard are the minimum requirements for the reporting of operational and security occurrences to the RSR (SANS, 2009). Railway occurrences are classified by the RSR into two broad categories: operational occurrences and security-related incidents. Operational occurrences that typically occur on South African railways are derailments, collisions, SPAD and level crossing incidents (RSR, 2011b). A detailed list of the types of railway operational occurrences can be found in Appendix A. The reader will recall from chapter 1, that this study only focusses on the operational occurrences as security events are largely managed by the South African police. The RSR only plays a supportive and advocacy role in terms of security incidents (RSR, 2014). The following figures highlight the state of railway safety in South Africa as reported by the RSR in the annual State of Safety reports. Figure 2.3 depicts the total number of operational occurrences from 2008/2009 to 2014/2015 financial reporting period. Figure 2.4 illustrates the total number of fatalities and injuries for the same financial reporting periods. These numbers reflect the total number of occurrences, fatalities and injuries for the entire South African railway industry.

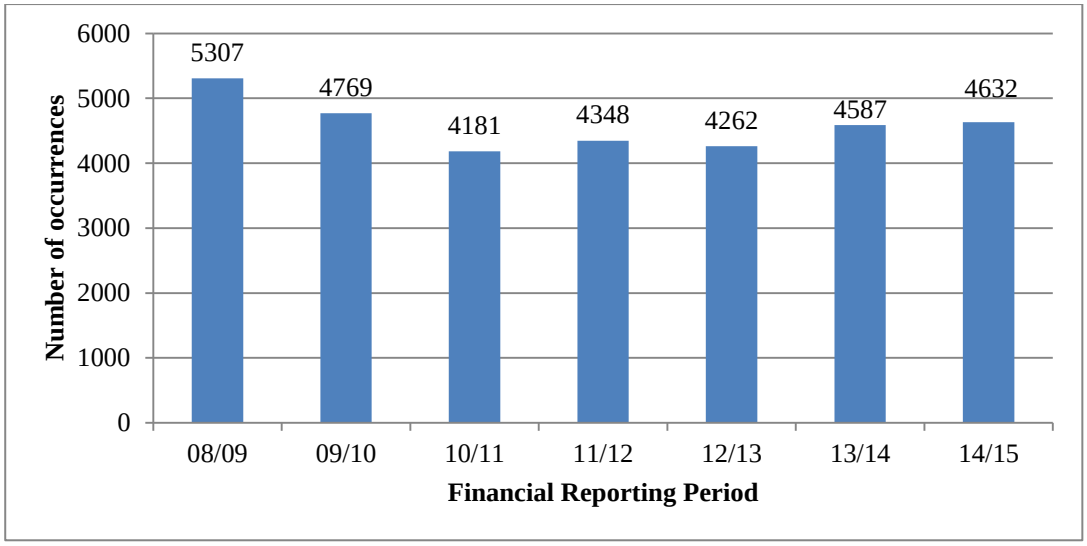


Figure 2.3 Annual number of operational occurrences (Adapted from the RSR, 2015)

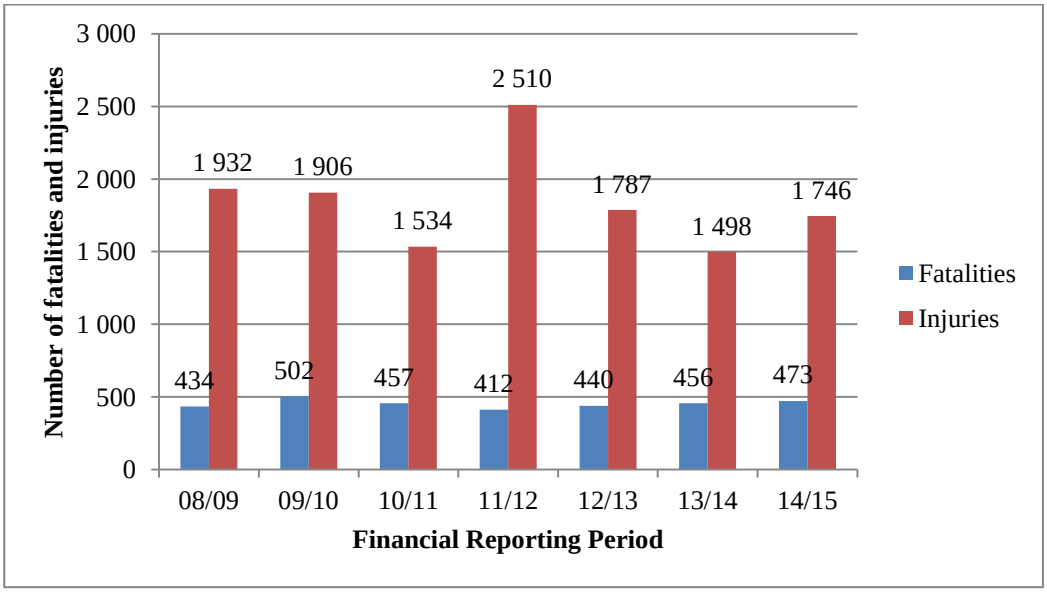


Figure 2.4 Annual number of fatalities and injuries (Adapted from the RSR, 2015)

The information demonstrates the fluctuation in safety performance trends with the numbers having remained relatively high illustrating an increased trend. Operational occurrences illustrate a steady increase since 2010/2011 and the number of fatalities increasing since 2011/2012. However, the number of injuries illustrate a steady decline since 2011/2012 with an upward trend observed from 2013/2014, a noted concern for the RSR (RSR, 2015). In order for safe railway operations the RSR contends that these numbers should decline instead of increase (RSR, 2014). For some Operators, zero

occurrences were reported, however TFR and PRASA have always accounted for the highest number of operational occurrences. These Operators accounted for 91% of the total operational occurrences during the 2014/2015 reporting period (RSR, 2015). Given that TFR and PRASA are the two largest Operators it is expected that their contributions would be the highest. According to the RSR (2015) the reasons for the number of fatalities, are as a result of people:

- Who live within close proximity to the railway line and therefore expose themselves to the dangers of train operations;
- Being struck by trains other than at level crossings;
- Removing electrical components on the railway track illegally; and
- Train surfing often suffering from electrocution.

The findings illustrate that most of the fatalities include members of the public, illustrating the significant role of the public in the rail socio-technical system. The question that this research addresses is what is being done by the South African Government, Regulator and Operators to prevent the loss of life and the effect that this has on society and the economy of South Africa?

In addition to the moral and social costs of occurrences, the financial costs of occurrences are also an important consideration. The direct cost of operational occurrences and security incidents is another measure used for operational safety and security (RSR, 2015). In terms of costs, during the 2014/2015 reporting period TFR presented a 17% increase for direct railway costs of occurrences totalling R480.5 million. Of the total costs, one train-on-train collision cost R56 million and a derailment on a running line cost R33 million. The occurrences that contributed the most to TFR's costs were derailments, collisions, and level crossing occurrences. However, PRASA recorded a 14% decrease for both operational and security incidents over the same period with a total cost of R111.5 million. The contributors for these costs were train fires, theft, and level crossing occurrences (RSR, 2015).

In terms of analysing the statistics provided by the RSR, it is important to look at rail traffic volumes in order to normalise the data with the number of occurrences. This gives

an accurate and more reliable account. An accident per million train kilometres is the universally accepted index of safety (Rao & Prasad, 2013). The RSR (2015) states that collisions and derailments are critical areas that contribute to injuries, fatalities and high costs. The RSR State of Safety report (RSR, 2015) highlights the collision and derailment data normalised per million train kilometres to illustrate the rate at which these occurrences happen. Figure 2.5 demonstrates the collision rates for TFR and PRASA.

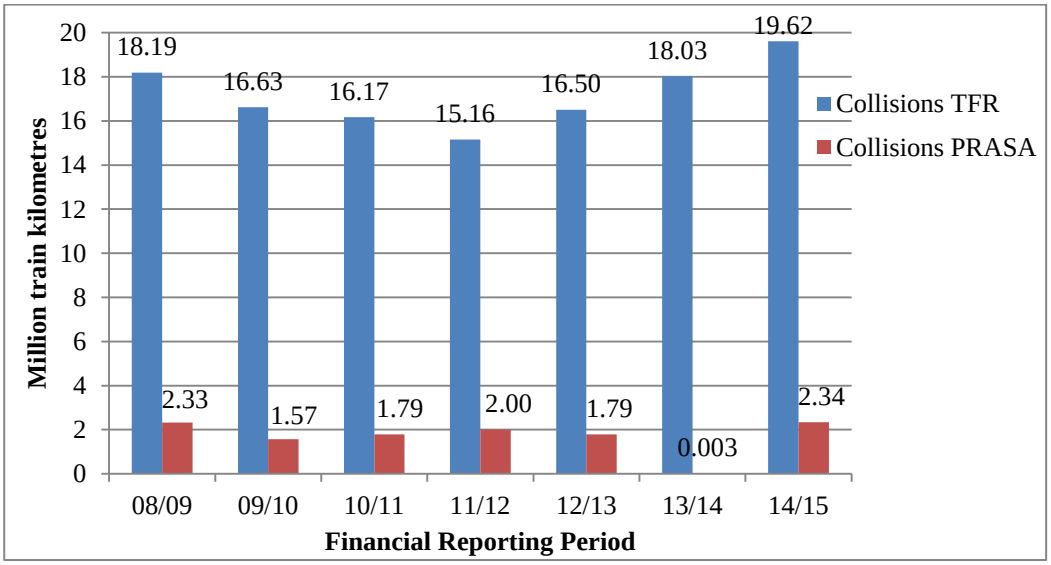


Figure 2.5 Rate of collisions for TFR and PRASA (Adapted from the RSR, 2015)

The rate of collisions normalised per million train kilometres illustrates a steady increase for both Operators between the 2013/2014 and 2014/2015 reporting period with TFR's collision rate increasing by 8% and PRASA's increasing by 779% (RSR, 2015). Figure 2.6 highlights the rate of derailments normalised per million train kilometres for TFR and PRASA.

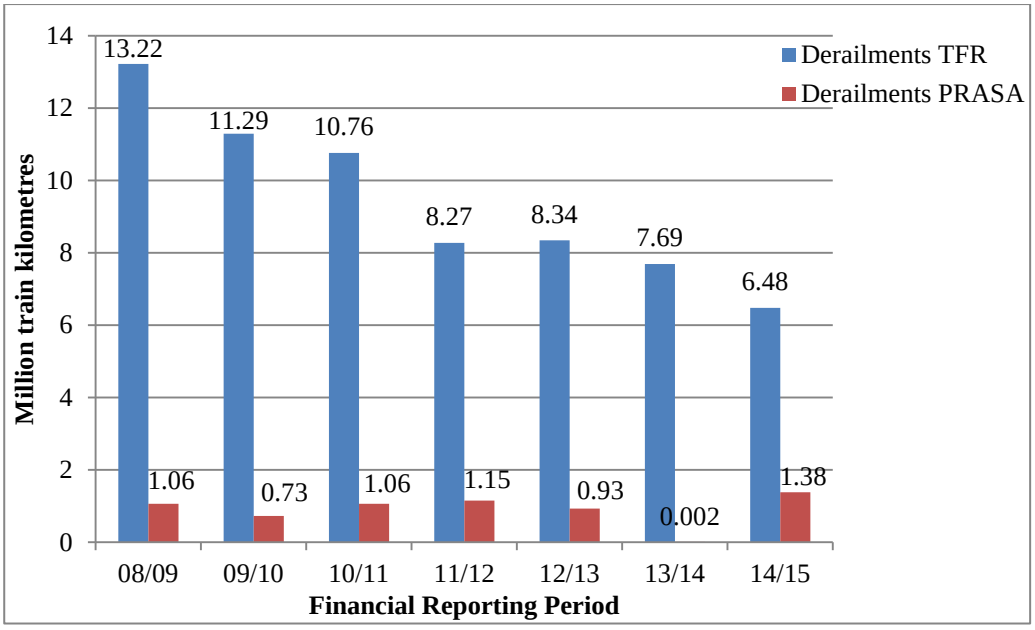


Figure 2.6 Rate of derailments for TFR and PRASA (Adapted from the RSR, 2015)

The rate of derailments normalised per million train kilometres for TFR indicates a steady decrease since 2008/2009, while PRASA derailment rates have fluctuated during the 2008/2009 to 2014/2015 financial reporting period. While the rate of derailments indicate a steady decrease, the consequences in terms of damage to infrastructure and rolling stock, in addition to the direct and indirect financial costs associated with these types of occurrences, remains a concern for the railway industry, in particular TFR.

In terms of comparing South Africa's trends to international railway safety trends, Lawton and Ward (2005) provide information for the United States of America (USA) and Britain for the period between 1993-2003 in terms of train crashes. The information collected by Lawton and Ward (2005) illustrated minor fluctuations of between 3.5 and 4.3 fatal crashes per 1.6 million train kilometres for the USA. In Britain the number of train accident fatalities fluctuated between 1 and 33 during the same period with an average of 10 fatalities in train accidents per year (Lawton & Ward, 2005). In another report, Rao and Prasad (2013), state that the numbers of railway accidents in India have caused doubt amongst the public about the safety of rail transport and the health of the rail network. Rao and Prasad (2013) affirm that this is despite Indian Railways priority on safety. In the year 2000/2001 train accidents (collisions, derailments, fires, level crossings and other causes) totalled 464 compared to 165 in the 2009/2010 year (Rao & Prasad, 2013). Indian

Railways experienced a reduction in rail accidents per million train kilometres from 0.65% in the 2000/2001 reporting period to 0.17% in the 2009/2010 year (Rao & Prasad, 2013) due to a multi-pronged approach to safety. Comparing South Africa's railway safety statistics to other countries was a challenge given that certain countries use different criteria for their classification systems. For example, some countries include suicides on the railway track as part of the number of railway fatalities while for instance South Africa does not. Furthermore, derailments can include shunting derailments and derailments on the running line which further complicated the comparisons to other countries railway statistics. Despite the difficulties in comparing railway statistics, the numbers recorded for Britain, the USA and India (Lawton & Ward, 2005; Rao and Prasad, 2013) are considerably lower than South Africa's statistics as highlighted in the previous figures. This further emphasises the importance of investigating occurrences effectively in order to prevent recurrences.

2.5 Concluding remarks

This chapter highlighted the South African railway industry, the railway system hierarchy, and the state of railway safety in South Africa. The reader will recall that the South African Government, represented by the DoT and the Minister of Transport is responsible for both the RSR and PRASA. TFR, the major freight Operator reports to a different ministry, the DPE. The reporting lines and structures in the rail socio-technical system hierarchy were discussed illustrating that a conflict of interest is evident. The impact of this on the management of railway safety and other systemic factors are detailed in the results chapter of this research.

In South Africa railway safety performance trends, including the number of occurrences, fatalities and injuries have fluctuated between 2008 and 2015. This is a concern acknowledged by the RSR and serves as the motivation for this research. The number of occurrences remains a challenge for the industry; emphasising the important need to thoroughly investigate occurrences to minimise the loss of lives, damage to infrastructure, the environment, and the associated moral, social and financial costs. Railway operations, both passenger and freight, are vital for the South African economy. However, the failure of South Africa to invest in rail has negatively contributed to the slow growth of the South African economy. This is acknowledged by the DoT in the Green Paper for a National Rail

Policy (DoT, 2015). In order for the economy to grow, rail needs to be reliable, efficient and safe, which the underinvestment has unsuccessfully achieved.

This research will contribute to improving railway safety by illustrating the systemic factors inherent within the rail socio-technical system that impact on the effectiveness of the investigation process. Furthermore, this research illustrates that the accident investigation system is an example of a complex system in its own right given the complexities already alluded to in this chapter. This is explained in more detail in the results chapter, chapter 7. Good occurrence management will help to improve railway safety performance and must be an important goal of the revitalisation of the South African railway industry.

The following chapters, chapter 3, 4 and 5 details the literature reviewed that provides the theoretical framework for this research. The reader will recall from chapter 1, that the literature review consists of three parts. The first part, chapter 3, discusses the literature relating to human factors and system paradigms with the importance of recognising human factors as a systems discipline. Systems theory is explained as this research adopted a systems approach to identify the systemic factors influencing effectiveness of the investigation process. Furthermore, this research advocates that the investigation process is an example of a complex system in its own right highlighting important systems theory concepts. Chapter 4, the second part of the literature review discusses accident causation theory and the final part of the literature review, chapter 5 details the literature relating to accident investigations.

CHAPTER 3: HUMAN FACTORS AND SYSTEM PARADIGMS

Chapter 2 described the state of safety of South Africa's railway industry, highlighting the various levels in the railway system hierarchy. This chapter is the first part of the literature review and includes the following topics: understanding human factors as a system discipline, the importance of systems theory and systems thinking, the application of human factors and systems theory in the railway industry, and systems engineering and human factors. This research demonstrates that the investigation process of railway occurrences is an example of a complex system in itself. It is therefore important to understand systems theory. Examples of system principles that impact on the accident investigation system include goals, constraints, demands and feedback of information. Furthermore, the environment in which the investigations take place is important to understand. These principles and others are discussed in the following sections.

3.1 Human factors as a systems discipline

The fundamental objective of Human Factors, also referred to as Ergonomics and, hereafter referred to as HF/E (Human Factors/Ergonomics), is to contribute to human performance. HF/E knowledge and methods have been used extensively in systems where the risk for accidents is high, posing major threats for humans and the environment (Grote, 2014). Given the number of disasters over recent decades, there has been an increase in awareness for the importance of managing risks in a proactive and systematic fashion (Grote, 2014). Cacciabue (2004) recognised the increasing contribution of HF/E in the design and the safety assessment process of technological systems including the end users, stakeholders, and regulators of technological systems (Cacciabue, 2004). Historically the focus in HF/E was on the human-machine interface and the mismatches of these resulting in accidents and injury. Technology and humans interact within an organisational context and organisations operate within larger environmental systems. With the growth in technology and the complexity of organisations increasing, this has resulted in renewed challenges. Therefore there is a need to go beyond the human-machine interface level and attend to the larger system (Kleiner, 2006). Shorrock (2016) affirms that HF/E should not only be recognised for contributing to human performance, but also for its role in system integration. The following sections will explore this further.

Hollnagel (2014) states that in recent years HF/E has received much attention in terms of its position as a science, the profession and as a discipline. Dul, Bruder, Buckle, Carayon, Falzon, Marras, Wilson & van der Doelen (2012) suggested that HF/E be seen as a systems science because HF/E is about systems in which humans interact with their environment. Hollnagel (2014) further discussed this matter in a paper entitled *Human Factors/Ergonomics as a systems discipline?*. However, Hollnagel (2014) questions what is meant by the term *system* as there are a number of differences in the word's interpretation and application. In the definition of HF/E used by the International Ergonomics Association (IEA) reference is made to *elements of a system*, however the word system is not defined (IEA, 2016). In defining what is meant by the term system, Hollnagel (2014) states that the system describes the independent parts or elements that are interrelated, acknowledging that the whole is bigger than the sum of the parts. Furthermore Hollnagel (2014) affirms that in order for HF/E to take a systems approach, there is a need for a deeper understanding of what is meant by a system.

Wilson and Carayon (2014) in an editorial for a special issue on *Systems HF/E* highlighted the work done by Dul et al. (2012) and also acknowledge that HF/E is a systems discipline. In defining what is meant by systems, Wilson (2014) states that a system can be an organisation, environment, community or society. Wilson and Carayon (2014) contend that there is a general agreement that systems involve processes that transform input to output for the benefit of society. However, as systems have become more complex and given changes in major socio-technical systems, mention is nowadays made of *'system of systems'*. Wilson (2014, p. 8) further explains that HF/E is about optimising the *"interactions involved with the integration of human, technical, information, social, political, economic and organisational components"*. This view supports the functions of systems theory where the interactions between the system elements should be the focus rather than the actual system elements (Carayon, Wetterneck, Rivera-Rodriguez, Hundt, Hoonakker, Holden & Gurses, 2014; Wilson, 2000; 2014). Wilson (2014) provides a useful operational definition of a *system* in which humans are included and what HF/E is concerned with:

> *Understanding the interactions between people and all other elements within a system, and design in light of this understanding, a system being a set of inter-related or coupled activities or entities (hardware, software, buildings, spaces,*

> *communities and people) with a joint purpose; HF/E seeks to understand the links between the entities may be of state, form, function and causation; HF/E conceptualises any system of interest as existing within a boundary and thus a defined context, having inputs and outputs which may connect in many to many mappings; HF/E treats the system as holistic with the whole usually greater (more useful, powerful, functional etc.) than the sum of its parts; and HF/E explicitly recognizes that the system changes and modifies its state and the interactions within it in the light of circumstances and events, thus showing emergent properties.* (Wilson, 2014, p. 12).

HF/E plays a great role in the design of all kinds of systems where people interact with their environment; however the potential of HF/E is under exploited. In a paper on the future of HF/E Dul et al. (2012) indicated that HF/E has great potential to ensure that any designed artefact, which includes an organisational environment, is shaped around the capacities and aspirations of humans in order to optimise performance and well-being. When HF/E is not considered, this results in sub-optimal systems, deficits, reduced efficiency, illness and dissatisfaction. Dul et al. (2012) and Grote (2014) affirm that the uniqueness of HF/E lies in its three fundamental characteristics:

- HF/E takes a systems approach;
- HF/E is design driven; and
- The outcomes HF/E focusses on achieving are: performance and wellbeing.

The inclusion of HF/E in occurrence management is important to ensure that a systems approach, focusing on the whole system and how various roles outside of the human and organisational system, may contribute to the comprehensiveness of occurrence investigations. Therefore the extent to which HF/E and a systems approach is considered in the South African railway investigation process will be identified.

HF/E, and its focus on adopting a systems approach, became recognised in the 1990's especially in the medical and health fraternities as critical for patient safety (Carayon et al., 2014). Healthcare professionals recognised the importance of HF/E as a scientific discipline given the role it can play in improving patient safety by redesigning healthcare

systems. Carayon et al. (2014) state that in order to make a significant impact, healthcare systems need to consider issues across the whole system, including organisational factors such as the organisational context in which technologies may be used. Interestingly, in an article published in *The Guardian*, Campbell (2016) reported that hospitals in the UK were failing to investigate many deaths and that the health service's failure was described as a systems-wide problem. Furthermore, Campbell (2016) questions whether hospitals do learn from their mistakes, and thus stopping other tragedies if they do not investigate. Refusal to accept accountability for the failings of the National Health Services (NHS) in terms of patient care in the United Kingdom (UK) emphasises the importance of a systems approach in accident investigations. Although this research's system of interest is the railway industry in South Africa, Campbell's (2016) contention of a systems-wide problem is also true for the state of safety of South Africa's railway system. This research will illustrate that the systemic factors influencing the effectiveness of the investigation process are a systems-wide problem contributing to the complexity of the accident investigation system.

HF/E has been defined as a systems discipline for many years with early leaders in the field, for example Chapanis and Rasmussen calling HF/E a systems discipline (Wilson, 2014). Chapanis and Rasmussen both came from a systems engineering and control background into the HF/E field (Wilson, 2014). In Wilson's extensive time in the field of HF/E, Wilson (2014) identified on many occasions that reports and journal submissions reviewed by him did not acknowledge the importance of context which influences the interactions within a system. The result is that a micro view or a narrow non-systems approach is adopted. Furthermore, in his paper entitled *Fundamentals of systems ergonomics/human factors*, Wilson (2014) argues that for HF/E to have a future, there is a need to accept that it is a systems discipline.

HF/E considers the broader context of the human within the environment irrespective of the people, the environments or at what level the focus is, and this is referred to as adopting a systems approach or a holistic approach (Dul et al., 2012; Rasmussen, 2000). Synonymous terms, for example *participatory ergonomics*, *systems ergonomics* and *macroergonomics*, are used in the literature illustrating how terminology has over time changed with the progression towards understanding the role of HF/E in systems (Wilson, 2014). Kleiner (2006) defines macroergonomics as the design of work systems with the

focus on organisation-system interaction. Furthermore, Kleiner (2006) believes that macroergonomics therefore offers a systems approach whereas system ergonomics provides much of the philosophy behind macroergonomics with the underlying theoretical framework of socio-technical systems. Waterson (2015) states that macroergonomics is concerned with organisational ergonomics and focusses on the larger socio-technical system, whereas physical and cognitive ergonomics is more likely to have microergonomics as the focus, with the emphasis on the human-machine interactions. Karsh, Waterson and Holden (2014) support Kleiner (2006) that the background theory for macroergonomics is derived from systems theory. Karsh et al. (2014) address the need to bring together the micro and macroergonomics approaches and therefore highlight the concept of *mesoergonomics*. The term *meso* is generally used to refer to an echelon of a system, for example a group or team level, whereas *macro* refers to the organisational system influencers, and *micro* individual influencers. When references are made to the human component in systems it can refer to both the individual and collective groups, and social aspects from a micro to macro level. For the purposes of this research the bigger rail socio-technical system in South Africa is the focus in which the system of accident investigations is nested in. This illustrates the 'system of systems' concept. The objective of this research is to determine the systemic factors outside of the organisational and human systems by looking at the context in which occurrence investigations take place. Therefore the stakeholders such as society, the South African Government, the RSR and railway Operators roles in terms of influencing the effectiveness of occurrence investigations are explored in this research and the results provided in chapter 7.

3.2 Understanding systems theory

Systems theory includes the principles, models and laws necessary to understand complex interrelationships and interdependencies between the components of the system such as the human, technical, organisational, and management components that make up a system (Qureshi, 2007). *The whole is greater than the sum of its parts* is a concept well recognised in systems theory. Reference is made to the components that make up a system that cannot be looked at individually (i.e. in isolation), but rather their interactions and interconnections. In other words it is the system as a whole entity that should be investigated in complex systems (French, Bedford, Pollard & Soane, 2011; Underwood & Waterson, 2013). In accident investigations, a systems approach is important to address the whole system and not just focus on the micro level. Qureshi (2007) states that the system

maintains equilibrium by means of feedback loops of information facilitating the dynamic nature of complex socio-technical systems. A systems approach encompasses the whole picture where the broader context is an important consideration. The real-world contexts, together with consideration for the interactions at multiple levels, and recognising the dynamic shifts over time are important systems theory principles (Kumanyika et al., 2010). Furthermore, each system exists within and interacts with a hierarchy of nested systems, increasing the complexity of the system of interest. French et al. (2011) do not advocate focussing on only a sub-set of components of the system (also referred to as parts), and expecting that these will represent the entire system. This is because of influencing factors that impact on the systems performance, such as the following examples:

- Human behaviours at any level within the system (i.e. at the individual, group or organisational level)
- The wider organisational context which includes strategic and economic imperatives
- The cultural context
- Team and local management structures
- External influences such as societal pressures and larger external pressures
- The historical context

This research acknowledges the statement proposed by French et al. (2011) and therefore addresses the above influencing factors as part of the systemic factors influencing the effectiveness of the investigation process of railway occurrences in South Africa.

3.3 HF/E and systems thinking

Much of today's HF/E literature includes the application of systems thinking in various domains (Carayon et al., 2014; Salmon, Cornelissen & Trotter, 2012; Shorrock, Leonhardt, Licu & Peters, 2014; Underwood & Waterson, 2013, 2014; Wilson, 2014; Zink, 2014). Underwood and Waterson (2014) state that the systems approach is a dominant paradigm in today's accident analysis research of socio-technical system accidents and human factors research. Shorrock et al. (2014) believe that understanding safety requires a systems focus where the system and the interactions between the elements or the parts are

considered holistically. Underwood and Waterson (2014) describe three broad interrelated themes that are core components of systems thinking. These include:

a) **System structure:** systems are formed from a number of sub-systems resulting in a hierarchy each with their specific functions. In order to understand how a system operates, it is necessary to understand each level and its relationships with adjacent levels. The higher up the system the more information one gets on the systems goals and the lower down the system the more one understands how the system functions to meet these objectives. The boundary of the system is also important to determine i.e. the interface between the system and the environment (Underwood & Waterson, 2014). In this research, the focus is on the hierarchies of the railway system and how the goals in terms of achieving safety by conducting accident investigations set at the higher levels, are actually achieved at the lower levels of the system, i.e. by those who are required to conduct actual investigations.

b) **System component relationships:** components within a system interact, with these interactions resulting in emergent behaviour. Safety is an example of an emergent property. This is what gives socio-technical systems their complexity as the behaviour may not be expected or planned for (Underwood & Waterson, 2014). Read, Salmon and Lenné (2013) affirm that accidents in socio-technical systems are an example of emergent properties. Various authors have described the relationships between components and have used different terminology. For example, Goh, Brown and Spickett (2010) refer to the concept of *holism*, Waterson (2009) refers to *the connectivity between elements,* and Leveson (2011) as *interactions*. For example, in the investigation of occurrences, investigators cannot just look at one component in isolation to explain the safety of the system or the reasons for the accident, but should consider the interrelationships between the contributing factors. In this research the relationships between, and within, the various levels of the railway system, for example the Government, the Regulator and the Operators are important considerations. This is detailed in chapter 7 and 8.

c) **System behaviour:** systems exhibit dynamic behaviour as the systems can adapt over time to various conditions and can migrate to a state of greater risk. This is what gives systems their complexity. Dekker (2011) describes this as a *drift into*

failure. It is important to understand that the components of a system do not operate in a vacuum and the performance of various components influences each other as well as the context. Feedback mechanisms provide information on the systems performance in order to ensure that the systems goals are achieved. Again, various authors use different terminology for the dynamic nature of systems. For example, Goh et al. (2010) refers to *causal loops*, Waterson (2009) *the transformation of inputs into outputs,* and Leveson (2011) makes reference to *feedback loops*. The performance of a system can therefore change at any given point in time as well as adapt over time to changing conditions (Read et al., 2013). In terms of learning from accidents, Underwood and Waterson (2014) state that these factors are important to consider as investigators need to appreciate and understand systems theory in order to note that systems evolve after an accident, as the accident itself may have changed the system, or technology may have advanced In this research the feedback loops between, and within, the various levels of the railway system will be analysed. In particular it will be determined whether the recommendations made in investigation reports are implemented accordingly and are effective in preventing recurrences. The appropriateness and effectiveness of recommendations are important as this provides feedback about the actual state of affairs of the system to the higher level decision makers in the system.

System theory and systems thinking therefore look at a system as a series of feedback loops between various hierarchies. For example, in the South African railway context, the RSR requires that all railway occurrences be investigated by the Operators (the next level below). In return the Operators provide feedback in the form of an occurrence investigation report, risk assessments etc. about the status of the occurrence investigation and the outcomes (findings and recommendations). The effectiveness of the investigation process in preventing recurrences is an indicator of the systems performance. The relationships between the various levels in the railway system hierarchy and the different feedback loops impacting on the effectiveness of the occurrence investigation process are discussed in chapter 7.

Systems theory therefore looks at requirements and constraints where the former represents the reason for existence of the system and the latter the ways in which the system can achieve its goals (Leveson, 2011). Leveson (2011) states that safety can be a

requirement and a constraint of a system. Furthermore, Leveson (2011) affirms that in terms of systems theory, the functioning or non-functioning of the whole can be explained by the functioning or non-functioning of the components. In accident investigation trends, it is common practice that attempts are made to understand the failure of components, for example the machine or human, often contributing to a blame culture rather than adopting a systems approach (Leveson, 2011). In accident investigations, the single greatest impediment is punishing people for making mistakes without having considered the systems behaviour at the time. As Shorrock et al. (2014, p. 7) state *"everything in a system is connected to something and nothing is completely independent"*. This research will explore whether a systems approach is adopted in the South African railway occurrence investigation process, alleviating the need to create a punitive culture.

3.4 Modern view of HF/E and systems theory

Dekker and Nyce (2012) highlight that the modern view in HF/E and system safety is that the successes and breakdowns of safety critical systems should not be attributed to component failures or human failures but rather the focus should be shifted to the complexity and dynamics of the activities within a system. These activities include those of the organisations managing the activities, regulators, people that use the system and also financial investors. The thinking behind adopting a systems approach in accident investigations is understanding the system as layers (an analogy of an onion is often used) whereby each peel reveals another activity. All of these activities are embedded in layers of systems designed to manage a number of goals at any one time. Some of these may contradict each other, for example, safety, punctuality, regulation and production. Dekker and Nyce (2012) state that the everyday, normal work processes result in accidents rather than spectacular causes i.e. failure can result from normal people doing business as usual in normal organisations. In this research the goals, constraints and demands of the DoT, RSR and TFR are investigated to determine the impact on the system of accident investigations.

Cognitive Systems Engineering (CSE) and its application to accident investigations promotes that the individual is but one actor in a system of many agents whose interactions and interconnections together determine the performance of the system. In essence, CSE is about focussing on the system and not the individual as the unit of interest (Dekker & Nyce, 2012). This modern view supports the need to move away from human error

reporting and apportioning blame at the sharp end especially during accident investigations (the sharp end is reference to the human performance immediately preceding the accident, and this is often why it is easier to blame the accident on human error or the operator without looking at the systems performance). Failure to adequately address the system in accident investigations will result in superficial findings with many latent conditions often going unnoticed. This is no wonder that recurrences, especially of similar accidents, continue to occur.

3.5 HF/E, systems theory and the railway industry

Wilson et al. (2007) define the railway system as a large complex socio-technical system and offer three reasons for this. Firstly the system is purposeful in that it is open to influences from, and in turn influences the environment that includes the technical, social, political, economic, and legal environments. Secondly, the people within the system need to collaborate in order for the system to work properly. Thirdly, in order for the implementation of change to be successful, there is a need for joint optimisation of the technical, social, and economic factors. Rail activities centre on people, the most complex part of a system. This is not often well understood by practitioners in industry. As Wilson et al. (2007) state, people play a role in building, servicing, managing, planning and operating the railways resulting in a number of interconnections between people and the functions necessary for a successful railway. With increased pressures from the technical, political, organisational, safety, and financial climates, Wilson et al. (2007) contend that there is a clear need for quality HF/E research to support these developments. This research contributes to HF/E research by illustrating a systems approach to occurrence investigation analysis, that the investigation process is an example of a complex system in itself and that an increase in occurrence numbers is indirectly influenced by the effectiveness of the investigation process.

Using the railway industry as an example, Wilson et al. (2007) states that engineering and operations management are key for a successful railway. However, HF/E is at the core because rail is a complex socio-technical system. For railways wanting to make improvements within engineering and operations these can only be achieved through integration and understanding of HF/E at a systems level (Wilson et al., 2007). It has been discussed in this chapter that traditionally many people may be more familiar with HF/E and the design of equipment and workspaces, for example a train cab. Wilson (2014) states

that the railway industry, particularly in the UK, has progressed to adopting systems theory into HF/E work. Examples of the application of systems HF/E in the railway industry include system focus, context, interactions, holism, emergence and embedding. These are discussed briefly.

- **System focus:** the system is the focus of interest and in particular the *interactions* of components rather than the individual components themselves. The interactions may not be stable, especially for complex systems. Many systems have resulted in *system of systems* due to their complexity, interconnections and shared goals. The railway industry is an example of a very large and complex system of systems with the interacting systems, for example, the railway network owner, the railway operating company, passengers, regulatory bodies etc. These are all systems in their own right but form a system of systems because of the interconnections and shared goals. In the railway environment, Wilson (2014) states that it is very difficult to define the systems boundaries and system of systems because of the complexity and size of the railway industry. For example a locomotive with a train driver can be considered a system but the whole transportation network i.e. the train, track, signals, the roads, stations etc. are also a system of systems.

- **Context:** the behaviour and performance of a system takes place in a particular setting or context. Waterson (2009) and Wilson (2014) support Rasmussen's (1997) well known Risk Management Framework that explains the layers of complex systems. Rasmussen's work is discussed in great detail in chapter 4, as it is the theoretical foundation of this research. Everything takes place in a context and is part of a system of goals, activities and artefacts. In the railway industry the context is critical given the complexity and many layers or levels of hierarchy. Based on Rasmussen's (1997) Risk Management Framework, Wilson (2014) discusses how context is influenced by: government at the top level that informs policy and strategies; the public's perception of how safe railways are and what their expectations are in terms of the level of safety required, the regulators' concerns with health and safety, and the organisation, its management and employees that are required to carry out the work. This research supports the use of Rasmussen's work,

discussed in chapter 4, and highlights how these layers contribute to the effectiveness of the investigation process of South African railway occurrences.

- **Interactions:** systems consist of interacting parts and the goal is to optimise the interactions involved with the integration of human, technical, information, social, political, economic, and organisational components throughout the system lifecycle (Wilson, 2014). The railway consists of a number of complex distributed components resulting in a distributed system spanning across regional and national boundaries. As an example, track maintenance requires a number of interacting functions such as the person in charge of the occupation, signallers, engineering supervisors and train drivers. These groups all have different roles and functions, and sometimes competing activities. These processes involve planning and communication with various stakeholders who may be geographically distributed. A system therefore contains a number of interconnected parts and multiple links.

- **Holism:** a systems view entails viewing all the interacting components holistically i.e. as a whole (Shorrock et al., 2014; Wilson, 2014) and not as a collection of parts (Shorrock et al., 2014). According to Wilson (2014) the rail system is an excellent example of a complex socio-technical system with stakeholders including signallers, controllers, drivers, engineers, and passengers. The rail system includes most types of work (planning, monitoring, physical work) with system processes occurring in settings such as locomotives, control rooms, and outdoors in all types of weather. Artefacts include signals, paper, vehicles, and visual display units resulting in human factors having a large role to play in such socio-technical systems.

- **Emergence:** Wilson (2014) affirms that systems have emergent properties. For example, systems with real users in real use and under the constraints of time, space and management pressures will display characteristics, and operate in ways that are not expected or planned for by designers. This is because people find ways to accommodate, overcome, avoid and work around system deficiencies in order for the system to work despite its shortcomings. This may be because of poorly designed systems where a lack of consideration may have been given to the context, users, tasks, and constraints (Wilson, 2014). In the railway industry the emergence

of new roles, communication channels, relationships, power structures, and decision making will change with changes in technology and different ways of working. These factors are considered in this research and how they influence the effectiveness of the investigation process of accidents.

- **Embedding:** HF/E and its fit within the organisational system, becomes embedded through participatory involvement with all stakeholders and subject matter experts (Wilson, 2014). In the railway industry the function of HF/E, no matter where it is embedded or situated, must collaborate with all other functions, especially within engineering.

The above examples of system theory concepts are discussed in the analysis of the results. Although Wilson (2014) highlights six concepts, Shorrock et al. (2014) identify ten principles to encourage a systems thinking approach to improve system performance. These include: involvement of field experts, local rationality, just culture, demand and pressure, resources and constraints, interactions and flows, trade-offs, performance variability, emergence and equivalence. These principles are discussed in the results chapter, chapter 7 and the final chapter, chapter 8. The results of this research illustrate the relationships between the various levels of the bigger rail socio-technical system and the behaviour that emerges from the interactions between the various components. The impact of these on the accident investigation process is highlighted contributing to the complexity of the system of accident investigations.

3.6 Systems Engineering and System HF/E

An outcome of this research is to bring together the disciplines of HF/E and Systems Engineering which is relatively, if at all, unexplored in South Africa. The discipline of Systems Engineering itself is relatively new in South Africa. The International Council on Systems Engineering (INCOSE) Handbook defines Systems Engineering as a perspective, a process, and a profession (International Council on Systems Engineering [INCOSE], 2011). According to Blanchard and Fabrycky (2011) there is no universally accepted definition of Systems Engineering, however consensus is reached that Systems Engineering includes a top-down approach, defining system requirements and is an interdisciplinary or team based approach. INCOSE (2011) add that Systems Engineering focusses on the whole system, dealing with a problem in its entirety and including all

variables of the socio-technical system. Systems Engineering is based on systems thinking and is therefore embedded in discovering and learning to better understand the real world (INCOSE, 2011). Systems consist of parts, but System Engineering (and systems thinking) centres on the whole and how the parts within the whole interrelate (INCOSE, 2011). Furthermore, in the handbook INCOSE (2011) attempts to address the link between HF/E and Systems Engineering as *Human Systems Integration* (HSI). HSI focusses on the human as an integral element of every system and in order to promote the total system; humans, technology, the operational context and the interfaces between these elements are all necessary in order for the system to function in harmony. Failure to consider HSI and within a Systems Engineering framework can result in major disasters, for example the Three Mile Island incident (INCOSE, 2011). HSI brings human-centred disciplines into Systems Engineering to improve the overall system design and performance by ensuring that the capabilities and limitations of the human are treated as critical system elements regardless of what level the humans operate at, for example, individual, team, or organisation (INCOSE, 2011). The section in the handbook addressing HSI is no different to HF/E and what has already been discussed in the previous sections of this chapter. If there are similarities between the two disciplines in theory, why in practise are the professions so fragmented?

Blockley (2011) contends that many engineers involved in forensic engineering need to learn lessons from failures. Often they are faced with technical reports embedded in human and social systems. When it comes to errors, mistakes and accidents, forensic engineers need to be sensitive to these subtle semantics as they are involved in identifying latent hazards that are technical and/or social (Blockley, 2011). Blockley (2011) affirms that this requires cross disciplinary interactions between 'hard' systems and 'soft' systems which require that engineers think in an integrated way. Engineering is often viewed as being only concerned with technical matters (Blockley, 2011) however, in practice engineers have to deal with a wide range of human and organisational issues. In complex socio-technical systems breakdowns occur due to technical, human, social, organisational and cultural hazards. Blockley (2011) asserts that in engineering safety, there are different approaches with the technical 'hard' approach adopting a scientific, testable and objective approach to accident prevention and the managerial 'soft' approach a social science approach that is subjective and not easily testable (Blockley, 2011). It is the author's view that the association of 'soft' systems to be a HF/E issue or a 'social science problem', and

that HF/E has no role to play in 'hard' systems, illustrates a naive understanding of the complexity of people as well as the discipline of HF/E. This is a frustration experienced by the author of this research in many work areas, where HF/E is seen as a 'soft' discipline rather than an important systems discipline. There is an important need to educate engineers in particular, that HF/E is a systems discipline concerning the interactions of system elements. It is not about human error as will be discussed in the next section. Blockley (2011) states that systems thinking helps to facilitate, and provides a way of looking for commonalities and alignment between fragmented professional silos. Perhaps then there is a need to apply systems thinking to connect the discipline of HF/E and Systems Engineering.

The INCOSE South African Chapter was founded in 2002 and currently has a membership of over 200 illustrating the novelty of the discipline in South Africa (INCOSE SA, n.d.). In South Africa, HF/E and the work conducted historically lends itself to the field of physical ergonomics. Integrating HF/E with other domains, for example, engineering, allows for a greater and enhanced understanding of how a system functions. Rasmussen (2000) believes that a cross-disciplinary approach is important so that the pieces of the system are brought together. It is the intention of this research to explore whether a cross-disciplinary approach is adopted in the accident investigation process to ensure that a systems viewpoint is considered. Furthermore, an outcome of this research is to support the case for HF/E as a systems discipline.

3.7 Systems thinking and its approach to accident theory

Due to changes in technology, the way work is performed in organisations, and HF/E and organisational design, these have made preventing accidents more difficult to achieve (Klockner & Toft, 2014). This has resulted in the need to investigate accidents by using a systems approach whereby investigators need to understand not only how the components work separately but also how the components work within the larger system in which they operate. Klockner and Toft (2014) state that systems thinking recognises that events are not clearly distinguished nor are they independent, time is not necessarily linear and the influence from one event to the other can be ambiguous resulting in constant states of change. Therefore complex socio-technical systems are dynamic and require non-linear cause and effect analysis (Klockner & Toft, 2014; Underwood & Waterson, 2013). Bar-Yam (2003) maintains that the fundamental difficulties with modern industries is their

inherent complexity. Complexity implies that different parts of the system are interdependent so that changes in one part may have effects on other parts of the system (Bar-Yam, 2003). The effects of the parts on each other may be unanticipated as systems become increasingly complex. Chapter 4 discusses in detail how accident theory has evolved to be more systems focused. In this research it is advocated that the investigation of railway occurrences is an example of a complex system in its own right and not just the accident itself. This is because of a number of interacting parts, conflicting goals, demands and pressures of the bigger rail socio-technical system that impacts on the system of accident investigations.

3.8 HF/E and accident causation theory

The HF/E literature abounds with research dedicated to accident causation (Salmon et al., 2012; Underwood & Waterson, 2013; Underwood, Waterson & Braithwaite, 2016) and is a profession with an important role to play in the field of Safety Science. Safety Science is the discipline concerned with identifying the HF/E behind accidents by looking at the interactions between people, technology and work with the adoption of a systems approach (Underwood et al., 2016). However, HF/E is not always well understood with the terms human factors and human error often being used (incorrectly) synonymously. For example, in numerous media reports and accident reports reference is made to *the human factor* as the one single cause for incidents and accidents (Korolija & Lundberg, 2010) resulting in finger pointing, often at an individual level. In a recent train collision in South Africa (October 2016), no later than four hours after the incident, the Operator reported to the media that *"human error may have caused the train crash"* ("Human error may have caused Tembisa train crash: Metrorail", 2016) with a subsequent article stating that the train driver would be charged with culpable homicide (Kubheka, 2016). All of this was reported in less than 24 hours after the incident, when the investigation had yet to commence. Setting operational staff up for failure, in particular train drivers, can have dire consequences as management point fingers without any accountability and responsibility for systemic failures. Dekker (2002) states that it is not about finding the bad apples but understanding what made sense at the time for people when they performed certain actions. In trying to understand why accidents happen, it is therefore prudent to conduct a thorough accident investigation, focussing on the system. This is to identify the systemic causes, the deep rooted underlying reasons, rather than adopting the view of looking to

apportion blame. Typically this is not often what happens in practice, questioning the validity of investigations.

HF/E professionals can play an important role in the study of system behaviour given their multidisciplinary knowledge and relationships with allied fields; such as Sociology, Engineering, Psychology and Economics, etc. HF/E professionals play an important role in accident investigations highlighting that HF/E is a scientific systems discipline and is not the same as human error. A systems approach in addressing what happened is vital for improving the systems performance. In the investigation of accidents a multidisciplinary approach is important to uncover what went wrong from different perspectives rather than a narrow, blame, or 'name and shame' approach. This naïve way of managing accidents does little for organisations in addressing what happened and results in superficial findings and recommendations. It is no wonder that similar accidents are repeated if the real reasons do not get identified or are overlooked. Furthermore, the implementation of recommendations, and following up that these are effective, is important for preventing recurrences.

3.9 Concluding remarks

This chapter provided the first part of the literature review. HF/E and system paradigms were discussed to provide the foundation for this research. The application of systems theory is important in the investigation of railway occurrences, and to what extent this is applied in the South African environment, will be determined in this research. The modern view in HF/E literature is to focus on a systems approach with systems thinking a dominant paradigm in accident analysis research. The role of HF/E and systems theory applied in the railway environment was discussed. Wilson (2014) highlighted the important concepts of systems HF/E to illustrate that HF/E is a systems discipline. The link between HF/E and Systems Engineering was briefly explained with an outcome of this research to bring together the two disciplines in South Africa

The following chapter, chapter 4, discusses accident causation theory emphasising the systemic approaches. The next chapter is a logical extension of this chapter to understand what work has been done in the field of accident causation and how this research contributes to current theory and practice. Methods and models used to determine why accidents occur are discussed.

CHAPTER 4: ACCIDENT CAUSATION THEORY

Chapter 3 highlighted that HF/E is a systems discipline and detailed system paradigm concepts that are important to acknowledge in this research. Many of the modern accident causation models have developed from the traditional linear cause-effect approach to a systemic approach founded on systems theory principles. This chapter, the second part of the literature review, details the theory related to accident causation, various accident causation models and Rasmussen's (1997) Risk Management Framework. Rasmussen's work provides the theoretical framework for this research. The objective of this study is not to understand why accidents occur as this is addressed to a large degree in the literature. Rather, this research advocates expanding existing accident causation theory to include the investigation process of accidents as a complex system of its own. Furthermore, the effectiveness of the investigation process also influences the accuracy and relevance of the findings and recommendations, an indirect reason for why the number of accidents remains high in the South African rail socio-technical system. This is based on the premise that if accidents are investigated, then why do they continue to occur? When accidents are not investigated thoroughly then this has an impact on the quality, accuracy, objectivity, reliability, and validity of the entire process and the outcomes. This chapter begins with an understanding of socio-technical systems and then discusses accident causation theory and accident methods.

4.1 Understanding socio-technical systems

In modern complex systems, humans develop and interact with technology in order to deliver certain outcomes. Qureshi (2007) contends that these goals or outcomes cannot be achieved in isolation and therefore the parts of the system need to collaborate to achieve the system's objectives. These systems are often referred to as complex socio-technical systems where human agents and technical objects are embedded within complex social structures (Qureshi, 2007). Examples of these structures include organisational goals, organisational policies, culture, and economic, legal, political, and environmental elements (Qureshi, 2007; Wilson et al., 2007). Socio-technical systems therefore can be defined as the interaction of, and interrelationships between humans and their social and organisational institutions together with the technical aspects of the system.

Rail is an example of a complex socio-technical system (Wilson et al., 2007). Railways are a complex transportation system compromising of technical aspects (trains, locomotives, wagons, signals, railway lines, etc.) that are interrelated and play an integral role in the transport system. These technical systems operate in a socio-organisational environment comprising of various rules, policies and procedures, legal, and financial aspects of the system (Wilson et al., 2007). For this system to function it depends not only on the technical objects, but also the social elements and the variable behaviour of humans (Qureshi, 2007; Wilson et al., 2007). Complex socio-technical systems arise from events, operations, people and technical systems distributed by time and space. Wilson et al. (2007) state that this creates complexity as the system needs to function holistically for successful performance. Furthermore the system may also be distributed across regional, national and cultural boundaries leading to additional challenges.

Socio-technical systems have experienced major catastrophes where the classical view has been to identify human error or one single person responsible for the event (Besnard & Baxter, 2003; Underwood et al., 2016). However with time and research, the more modern approach is to move away from the individual to the failures within the complex socio-technical system. Accidents occur as a result of a combination of factors that have become intertwined in a complex network over several levels of hierarchy. Flawed decisions at the higher level of the hierarchy can result in dramatic knock-on effects at lower levels that may result in major catastrophes such as Three Mile Island, Piper Alpha, and the Challenger space shuttle (Besnard & Baxter, 2003; Lundberg, Rollenhagen & Hollnagel, 2009).

Socio-technical systems according to Leveson (2004) must be treated as a whole where the facets of the system are not seen just as parts but rather how they interact and fit together. Using systems theory in accident modelling, allows complex systems to be viewed as a hierarchy of levels of organisation with each level more intricate than the other. Leveson (2004) states that the aim of seeing a system as a hierarchy of levels allows for the understanding of the relationships between the different levels, what generates these levels, what separates them and what links them together. When applied to accident causation it allows investigators, engineers, management, etc. to look for what went wrong with the system's organisation to allow the accident to take place (Leveson, 2004).

Hovden, Albrechtsen and Herrera (2010) and Rasmussen (1997) state that levels and layers within an organisation are subjected to stress from a number of external forces. These forces are what add to the complexity of systems and include the following examples:

- Political climate
- Public awareness
- Market conditions
- Financial pressures
- Competence and education
- The fast pace of technology development
- Globalisation

Socio-technical systems therefore need to adapt to these stressors in order to prevent accidents. With the increase in globalisation, trends have developed in terms of deregulation where government power in businesses has reduced, businesses look to cost cut, build profit, and save time (Hovden et al., 2010). Therefore organisations have become more complex due to the effects of globalisation (and a combination of other forces) resulting in the following concepts emerging:

- Downsizing
- Contracting
- Capital cost reduction
- Outsourcing
- Lean production
- Change management

As society is ever-changing, people, values, organisations, technology and knowledge are all subject to change. The changes in technology, market conditions and globalisation are all examples of dynamic forces in the environment. In this research these factors are considered as part of the systemic factors that influence the effectiveness of the investigation process of railway occurrences. The changes happening around, and within systems, place organisations under stress affecting the higher levels of systems (management, regulatory bodies and the public) rather than the micro levels. Hovden et al.

(2010) state that this is what gives rise to complex high risk socio-technical systems. The focus of this study is at the macro level of the railway system in South Africa, as it is at this level that the systemic factors originate influencing the investigation process. The micro level would include train drivers and controllers who are traditionally at the sharp end of the system and therefore more likely to be blamed. Although drivers and signallers act as informants in the investigation process, they are not responsible for the management of the investigation process. It is the actual investigation, the effectiveness of the investigation process and the management of the investigation system that is the focus of this research. Individuals at a micro level experience the consequences of macro level decisions to handle the external dynamic forces. However as Rasmussen (1997) states, it is important that the information about the actual state of affairs experienced at the micro level must flow back to the decision makers in order to determine the effectiveness and appropriateness of their decisions and actions.

The literature states that in socio-technical systems all aspects of a system are interconnected, that the parts should be designed jointly and none should take precedence over the other as this will result in sub-optimal system performance (Carayon et al., 2014). A number of authors have cited the need for increased focus on the interactions and integrations of parts within a system. Wilson (2000) highlights that HF/E is fundamentally about understanding people and their interactions in addition to the relationships between these interactions. Interactions occur between elements of the socio-technical system and people but also the wider environment of the system (Carayon, 2006; Wilson, 2000). In Table 4.1, Carayon (2006) highlights a number of socio-technical system models defining the various elements of a socio-technical system.

Table 4.1 Models of socio-technical systems
(Adapted from Carayon, 2006, p. 529)

Models of socio-technical systems		
Authors	**Model**	**Components of the socio-technical system**
Wilson (2000)	Model of interactions	People interact with the following elements: -Other people -Structure, policy and roles -Environment

		-Tasks -Hardware & software -Society, finance and politics -Remote agents (temporal and spatial interactions)
Carayon et al. (2014)	Model of work systems	-The individual -Tasks -Tools and technologies -Physical environment and organisational conditions
Rasmussen (2000)	Model of socio-technical systems	-Productive processes of the work performed by operators and workers -Staff involved in planning the work -Management who plans operations and supplies resources -Company that interacts with various regulations -Regulators and associations -Government
Moray (2000)	Model of socio-technical systems as a set of concentric circles	-Individual behaviour, physical devices and physical ergonomics at the centre of the system -Other layers include: team and group behaviours, organisational and management behaviour, legal and regulatory rules and societal and cultural pressures

Rasmussen's (2000) model of socio-technical systems is based on his Risk Management Framework (Rasmussen, 1997), with the latter the theoretical framework of this research. Rasmussen's (1997) Risk Management Framework best represents the South African rail socio-technical system hierarchy. In this research, this framework describes the elements in the system that influence, impact, and interfere in the effectiveness of the investigation process of railway accidents in South Africa. The reason for this selection is discussed in section 4.7.1.

Changes in socio-technical systems and increased complexity have resulted in the need to shift the focus from traditional viewpoints of accident causation to a more inclusive systems approach. The following section provides a summary of systems theory as was discussed in chapter 3. Thereafter the various accident causation models, in particular the systemic models, are discussed. Although this work does not focus on accident causation per se, it is the belief of the author that there are similarities between what causes accidents from a systemic viewpoint and what influences the effectiveness of railway occurrence investigations.

4.2 Systems theory summary

While chapter 3 detailed system paradigms in general, this section highlights the role that systems theory can play in accident causation. This research will draw on the principles of systems theory to illustrate the systemic factors (challenges, pressures, frustrations and obstacles) that influence the investigation process of railway occurrences. Within the railway system there is a hierarchy of organisations that need to operate together as a whole, a number of feedback loops of information, and various controls that are required for the safe operation of the system. In trying to understand what processes within the system influence the investigation of railway occurrences, this can be compared to accident causation methods or models. These in essence determine what went wrong within the system leading to such undesirable events. Many systemic accident models, theories, and analyses exist that try and predict why accidents occur. These are discussed in section 4.6.

Today's approach to analysing accidents is to adopt a systems approach given the complexity of today's safety critical systems; a shift from the individual reductionist approaches (Read et al., 2013). The traditional viewpoint concentrates on accident phenomena from the individual constituents of complex systems. Individuals are viewed as just another component of a system, like a piece of technology; where if something goes wrong with this part, the recommendations are then to replace the part or make the part more reliable (Dekker, 2002; Read et al., 2013). Furthermore, Read et al. (2013) state that the traditional approaches do not consider the context and the influence that this has on behaviour. Read et al. (2013) advocate how more researchers are now focussed on the systems approach when analysing safety critical domains. This is because this approach

considers the interactions between humans, and between humans and technology within a system. Factors other than the individual are considered; for example, organisational, social, and political factors which offer a broader explanation for accident causation (Read et al., 2013). In the systemic approach the sum of the parts are greater than the whole emphasising the importance of holism as discussed in chapter 3. In this research factors such as the organisational, social, cultural, and political dynamics of the bigger rail socio-technical system are investigated to determine the impact on the effectiveness of the investigation process.

The need for the application of a systems approach has been identified in many safety critical domains including the railway industry (Read et al., 2013; Reinach & Viale, 2006; Underwood & Waterson, 2014; Wilson, 2014; Wilson & Norris, 2005). Read et al. (2013) affirm that a systems approach in the safety domain of the railway industry is relatively new and has only recently begun to be explored. Systems theory, the basis of system approaches, has key principles and concepts. Although there is debate as to what these concepts are, authors have agreed on certain themes as the essence of systems theory. These are summarised by Read et al. (2013) in Table 4.2.

Table 4.2 Aspects of a systems approach
(Adapted from Read et al., 2013, p. 766)

Features of a systems theory approach	**Attributes of systems theory approach**	**Attributes of analyses that do not support a system theory approach**
Safety as an emergent property	-System is the unit of analysis -Focus is on the relationships of system components rather than their individual properties -Considers all components of the system and the relationships between them -Considers complex non-linear relationships -Focus is on emergent behaviour -Aim is “holism”	-Components are the unit of analysis -Does not consider the relationships between components -Focus is on establishing linear cause and effect relationships -Aim is optimising the performance of one component or sub-system i.e. the user

System and component performance is variable	-Acknowledges the variability of components in terms of interpreting behaviour -Offers a possible range of behaviours	-Normative approach is used i.e. only intended behaviours are captured -High level categorisations of behaviour
Systems are dynamic	-Acknowledges that systems are not static and change over time -Describes the possible range of behaviours	-Considers system only at a point in time -Normative approach is used
Systems as hierarchical structures	-Considers components at all levels of the system	-Considers components only at the physical system level

The four themes identified by Read et al. (2013) are similar to those highlighted in chapter 3 by Shorrock et al. (2014) who identified an additional six principles. In the analysis of the systemic factors influencing the effectiveness of the investigation process these themes and principles will be used to illustrate that the accident investigation process is indeed a complex system. The following section highlights the progression of accident causation theory from the traditional viewpoint to today's view of adopting a systems approach. Traditional and systemic accident models are discussed.

4.3 Accident causation theory

In terms of the evolution of accident theory, the causes of accidents have changed over time with changes in technological advancements and system complexities. During the eighties, the concept of *human error* emerged after the Three Mile Island disaster and the increasing interaction of humans and machines. In the nineties, Chernobyl occurred resulting in the concept of *safety culture*, with reference to the organisations role regarding safety, including the beliefs, norms, and work practises of managers and not just the workers. For the first time, managers could now be held accountable for occurrences. The concept of *organisational events*, by Reason (1997), resulted in increased attention being given to the interaction of the technical, human, and organisation as elements contributing to events.

Today, in the 21st century, focus has widened towards understanding systems and the interaction of various elements of systems, including the technical, human, and organisation as causes of occurrences (Carayon et al., 2014; Cassano-Piché, Vicente & Jamieson, 2006; Dekker, Cilliers & Hofmeyer, 2011; Dien, Dechy & Guillaume, 2012; Underwood & Waterson, 2013, 2014). Salmon et al. (2012) state that the literature on accident causation has generally accepted that accidents are as a result of complex system interactions where causal factors reside at all levels in the socio-technical system. This is supported by many renowned authors in this field; for example Leveson (2004), Rasmussen (1997) and Reason (1990). The complexity with how accidents develop has resulted in much research debating the causation of accidents. Salmon et al. (2012) state that our understanding of accidents may be incomplete and that accidents will continue to occur given the complexity of socio-technical systems. Despite the dominance of systemic accident analysis models and methods in the literature, Underwood and Waterson (2013) and Underwood et al. (2016) have found that a gap exists between research and what happens in practice. These authors state that in practice these techniques are not used in accident causation due to a general research-practice gap in accident analysis, the lack of a track record in industry using systemic accident analyses and that practitioners may be incentivised to use non-systemic analyses to facilitate attributing liability (Underwood & Waterson, 2013; Underwood et al., 2016).

Accident causation is a complex process that involves the entire socio-technical system that includes regulators, industry associations, insurance companies, engineers, management and operators. To understand why an accident occurs, one cannot look at the events leading up to the accident but rather understand the entire process (Underwood & Waterson, 2013; Underwood et al., 2016). To do this effectively requires that investigators are trained and knowledgeable in systems theory and systemic accident analyses. This is so that symptoms are not just identified with a recurrence of accidents (Leveson, 2011). For the purposes of this research, the socio-technical system of the South African railway system is discussed with particular reference to each level's role in terms of influencing the effectiveness of the investigation process. This is presented in chapter 7.

The researcher postulates that given the extensive research on accident causation, how best can this work be used to explain the systemic factors influencing the investigation process of accidents? It may be that in theory there is only a subtle difference between what causes

an accident and what influences accident investigations. However, it is necessary to examine the literature to argue for an extension of accident causation theory to encompass not only why accidents are caused, but also what influences the investigation of these. In trying to establish which accident model this research could contribute to, the researcher needed to explore the various accident causation models. In doing so, it was evident that a number of models exist given the changes over time and complexity of systems.

Debate exists in the literature as to what is the best model for accident causation given the number of accident causation models (Underwood & Waterson, 2014). Consensus is that there are two main approaches to accident causation models that have developed over time to predict accident causation. These are the traditional and systemic approaches. *Traditional approaches* are comprised of sequential and epidemiological models, whereas *systemic approaches* focus more on adopting a systems approach to accident causation. The evolution from traditional approaches is as a result of developments in the fields of Engineering, Behaviour Sciences, Psychology, and Social Sciences (Hollnagel & Goteman, 2004; Ouyang, Hong, Yu & Fei., 2010; Rivera, Baziuk & Nunezmcleod, 2011). These shall be discussed where it will be argued in this research that the systemic approaches can be used to validate factors that influence not only the causation of accidents, but also the entire investigation process.

4.4 Explanation of traditional approaches to accident causation

Traditional approaches in many investigations adopt a causal analysis approach whereby accidents are explained in a linear fashion. Goh et al. (2010) argue that using causal analysis tools which model events and causes linearly are not designed to analyse dynamic and complex accidents and safety culture. Therefore traditional causal analysis tools used in investigations should be enhanced by means of including principles of systems thinking (Goh et al., 2010). Traditional approaches to accident causation and the modelling of accidents can be described as sequential and epidemiological. These are discussed briefly.

4.4.1 Sequential accident models

These models explain accident causation as a simple chain of events that occur in a particular order. The Domino theory was one of the earliest theories proposed by Heinrich in the 1930's (Hollnagel & Goteman, 2004; Hollnagel, Leonhardt, Licu & Shorrock, 2013; Katsakiori et al., 2009; Kim & Yoon, 2013; Qureshi, 2007). Simply put this approach

discusses how five factors occur in a sequence of events where the fall of the first domino results in the fall of the entire row. The five factors are:

1) Social environment
2) Fault of the person
3) Unsafe acts or conditions
4) Accident
5) Injury

As each factor leads to the next, the final result is an injury (Qureshi, 2007). Hollnagel et al. (2013) state that at the time of these approaches, technological failures were almost exclusively the reason for accidents.

Traditional models are based on the premise that an undesirable event initiates a sequence of subsequent events leading to an accident. This principle implies that an accident is a result of a single cause. If a single cause can be identified and removed then the accident will not be repeated. The major critique of this approach is that accidents always have more than one contributing factor (Qureshi, 2007). Katsakiori et al. (2009) critique the Domino theory because of the linear one-by-one progression of events that lead to an accident. This theory may work in simple systems where it is assumed that the cause-effect relationship between the consecutive events is linear i.e. cause A leads to effect B. However, compared to complex socio-technical systems, accident causation occurs due to multiple factors combined in a complex way leading to system failures (Leveson, 2004; Qureshi, 2007). This is why systems need to be viewed holistically rather than linearly.

Sequential models, according to Hollnagel and Goteman (2004) were prominent in the first half of the 20th century, where system functions and components were loosely coupled; interactions were considered linear and easily understandable. However, as the world becomes more complex and interconnected due to technological developments, systems have become more complex. Sequential accident models are not sufficiently able to explain accidents in complex systems. Underwood and Waterson (2014) state that traditional cause-effect accident models view accidents as a result of something catastrophic i.e. equipment failure or human action. Accidents do not occur because of such trigger events but emerge as complex phenomena within the normal operations of a

system. Over time accident causation models have evolved from identifying a single cause to multiple causes to represent the whole system (Katsakiori et al.; 2009; Qureshi, 2007; Underwood & Waterson, 2014).

4.4.2 Epidemiological accident models

Leveson (2004) affirms that since World War II, the types of systems and the context in which they originated had to change to keep up with the pace of technological developments. This resulted in the accident models at the time being stretched to the limits. Changes in how systems operate have challenged accident models. Examples of changes include:

- Change in the nature of accidents
- New types of hazards
- More complex relationships between humans and automation
- Changing regulatory and public views of safety

During the second half of the 20th century, as the technical environment changed the focus of attention shifted from technological problems to human factors problems, problems with organisations and safety culture. However accident models did not develop in a similar way (Hollnagel et al., 2013). Towards the end of the 1970's the Domino model was seriously challenged by a number of major disasters which could not be explained using simple cause-effect links (Hollnagel & Goteman, 2004; Ouyang et al., 2010). These disasters resulted in accident models evolving as there was a greater need to understand how accidents occurred. Without question the most popular contributor to accident causation approaches during the 1980's was James Reason who proposed the Swiss Cheese Model (Katsakiori et al., 2009; Kim & Yoon, 2013; Reason, 1990). This model is discussed further in section 4.6.1. Epidemiological models regard accidents as a combination of factors or events where the outcome of these events may remain as latent factors or some become apparent resulting in an accident. These factors happen to exist together in space and time and are often analogous to the spreading of a disease where factors either manifest or remain latent (Hollnagel & Goteman, 2004; Lundberg et al., 2009; Ouyang et al., 2010; Qureshi, 2007).

Ouyang et al. (2010) and Qureshi (2007) positively recognise Reason's contribution to accident causation and that the idea of latent conditions is advantageous in the analysis of complex systems that advocate multiple failure situations. However, despite the positive acclamation for Reason's work, Ouyang et al. (2010) and Qureshi (2007) argue that epidemiological models still follow the principles of sequential models. This is because they define the direction of causes as being linear and static. They also regard organisational mistakes as management errors and do not consider the effects of the organisational culture. Socio-technical systems are more dynamic than Reason's model suggests. Despite the views that the Swiss Cheese Model offers a static view of the organisation, Reason (1997) does allude to system failures involved in accidents. Furthermore, Reason (1997) asserts that little is known about the system failures involved in safety critical domains despite it being widely acknowledged that these are present. Hollnagel and Goteman (2004) further argue that epidemiological models overcome the limitations of sequential models. They are able to describe the complex nature of accidents where simple causes cannot just be looked for. An understanding of the complex interactions among the different factors that contribute to an accident is required. Furthermore, Ouyang et al. (2010) argue that epidemiological models do not take into consideration the types of systems that exist today and their complex interacting components.

Sklet (2004) evaluated a number of causal analysis tools used in accident causation and found that these tools did not consider that actors within the system interact, and actions and consequences occur at different temporal and spatial levels. Furthermore, Qureshi (2007) and Underwood and Waterson (2014) affirm that traditional accident models are no longer adequate to explain accidents that occur in complex socio-technical systems, given that accidents do not occur from a single individual component or human error. The progression of accident causation theory to include more of a systems approach resulted in the move from epidemiological models to systemic accident models.

4.5 Systemic approaches to accident causation

Over the last 70 years, accident models have slowly developed from linear cause-effect sequential models to systemic models or systemic accident analysis. Accidents are viewed as emergent phenomena which are seen as normal or natural and should be expected (Hollnagel & Goteman, 2004; Klockner & Toft, 2014; Lundberg et al., 2009; Underwood

& Waterson, 2013). In terms of complex socio-technical systems such as high risk industries and in transportation, it was Perrow (1999) who introduced the idea of normal accident theory. Perrow (1999) stated that in some systems, accidents are inevitable and normal because of the multiple interactions. These result in unanticipated interactions leading to multiple failures. While this view may appear to be cynical, it has paved the way for shifting the blame from the human operators to management as a key contributor to accidents.

Accident causation theory has evolved after major disasters such as Chernobyl, Bhopal and the Challenger disaster. The paradigm shift over time towards a systems view has resulted in newer approaches to accident modelling. These consider the performance of the system as a whole and accidents occur due to several causal factors (Ouyang et al., 2010; Qureshi, 2007). Highly technological systems are complex with the potential for disastrous accidents as operations are carried out under time pressure or where there may be resource constraints (Qureshi, 2007). Therefore accidents in complex systems do not occur because of linear interactions but rather dynamic non-linear interactions between the system's components. Qureshi (2007) affirms that the systems performance as a whole is viewed as a network of interconnected events rather than a simple cause and effect chain of events. This case is also made for transportation accident causation theory that has evolved from simply considering the failures of technology and the ubiquitous human error to understanding the organisational and social context.

Systemic models are based on systems theory and include the interactions, interrelationships and interdependencies of the components of a system. Leveson (2004) states that these models include people; social and organisational structures; engineering activities; and physical and software components. Systemic accident models have also developed as technology and automation have introduced new problems for human operators. The impact of this on human performance has resulted in new failure modes. Unlike sequential accident models that focus on cause and effects, systemic accident models are able to study the failures and accidents in highly adaptable socio-technical systems. With sequential models focusing on the sharp end it can lead to equipment or humans being incorrectly blamed for an accident. This results in organisations having 'missed opportunities' for learning from previous events (Underwood & Waterson, 2013; Underwood et al., 2016). Leveson (2004) describes how systems theory is a useful way to

analyse accidents in complex systems as accidents do not occur due to individual component failures but rather when external disturbances or interactions amongst components are not adequately handled by the control system. By applying systems theory, accident models must view the entire socio-technical system as a whole and not just the parts separately. In this research systems theory is applied to view the system of accident investigations as a whole.

Hollnagel and Goteman (2004) argue for systemic models as they provide an understanding of the functional characteristics of a system rather than a series of hypotheses of causes and effects. Examples of systemic accident models, many of which have been developed based on CSE, are Cognitive Reliability and Error Analysis (CREAM), the Functional Resonance Accident Model (FRAM), and Rasmussen's (1997) Risk Management Framework (Hollnagel & Goteman, 2004; Qureshi, 2007). The latter presents a multi-level model of a socio-technical system and is discussed in more detail in section 4.7.

The sequential and epidemiological approaches no doubt have contributed significantly to the area of accident causation. Goh et al. (2010) believe that traditional cause and effect models are still useful and necessary in some accident analyses. However, modern advancements have resulted in the need to also capture the complexities and dynamics of modern socio-technical systems. Sklet (2004) asserts that systemic accident models are advocated more today as socio-technical systems become increasingly more complex. In this research, the systemic view of accident causation is applied to understand the *systemic factors influencing the effectiveness of the investigation process of railway accidents, and its outcomes* using Rasmussen's (1997) Risk Management Framework. This is applied in the context of the South Africa railway socio-technical system. This work examines the *system of accident investigations* which is seen as a complex system and not the accident itself. The following section provides examples of systemic accident analysis methods.

4.6 Accident analysis methods

Salmon et al. (2012) and Underwood and Waterson (2013, 2014) highlight three accident analysis models that are the most frequently cited and dominate the Human Factors literature. These include Reason's popular Swiss Cheese Model (Reason, 1990), Rasmussen's (1997) Risk Management Framework where an Accimap is the generic

approach used to identify contributory failures, and more recently Leveson's (2004) Systems Theoretic Accident Modelling and Processes model (STAMP). Although these are unique in their approach to analysing accidents, all three of these apply an underlying systems approach. Salmon et al. (2012) state that despite the differences in these approaches (the theory, methodology adopted and the outputs produced) there are very few guidelines to support one method over the other for accident analysis. As part of the literature review, all three of these models were explored in order to determine which would be the most applicable in this research to answer the research question: *What are the systemic factors influencing the investigation process of railway occurrences in South Africa?*

System based accident analysis methods identify causal factors in complex socio-technical systems, of which rail is an example. The Swiss Cheese Model and STAMP will be briefly discussed with a full section on Rasmussen's (1997) Risk Management Framework and Accimap as the selected methods for this research.

4.6.1 Reason's (1990) Swiss Cheese Model

Despite Reason's (1990) Swiss Cheese Model acknowledged as an epidemiological model, it is one of the most commonly used, and arguably the most popular accident causation model (Ayeko, 2002; Baysari et al., 2008; Salmon et al., 2012; Underwood & Waterson, 2014). Figure 4.1 illustrates Reason's (1990) Swiss Cheese Model.

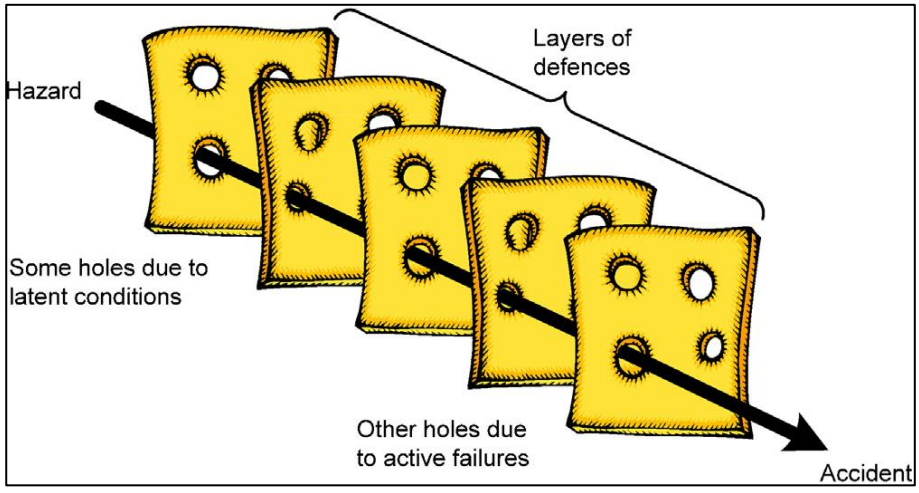


Figure 4.1 Reason's (1990) Swiss Cheese Model (Adapted by Underwood & Waterson, 2014, p. 76)

This model encourages investigators to look beyond the immediate circumstances and focus more on all of the preconditions at the time of the occurrence. This includes latent conditions created by management, regulators, designers, etc. French et al. (2011) contend that this model provides an understanding of system failure where barriers or layers of defences are referred to metaphorically as slices of Swiss cheese. The slices imply that systems do not fail from a single failure but because of several elements which fail almost simultaneously as if the holes in the cheese have lined up. The holes in the defences arise from active failures and latent conditions. Besnard and Baxter (2003) identified four key features of the Swiss Cheese Model. Firstly, systems can be decomposed into layers, with each layer representing a sub-system that impacts on the functioning of the entire system. Secondly, failures within a system may not initially result in catastrophes but rather brew as unstable conditions. Thirdly, events propagate and are not caused by sudden undesirable circumstances. Lastly, events escalate where failures within the sub-systems can result in the breakdown of the full system.

Although the Swiss Cheese Model provides useful arguments for understanding how latent failures surface, it was deemed to not be a theoretical model for this research. This is because this model is primarily used to understand why an event or accident occurred, which is not the focus of this research. The researcher felt that this model would not be able to explain the *systemic factors that influence the effectiveness of the investigation process*, because it does not illustrate the multiple layers of a socio-technical system. Furthermore, its focus is more on the sharp end of an incident (whether that is the human or the organisational system) with this work wanting to explore what happens outside of these two systems, specifically at a hierarchical level. This is in order to address the two sub-research questions:

- *What barriers outside of the organisational system and human system contribute to the manner in which occurrences are investigated?*
- *What are the levels that make up the railway system hierarchy in South Africa?*

This work therefore focusses on the hierarchy of the railway socio-technical system. Operational staff, for example a train driver is not part of the decision makers who manage the investigation process. Rather they provide information as informants in the form of a

written statement or witness testimony in the inquiry. As part of this work they formed part of the secondary data collected. Another reason for not using the Swiss Cheese Model is that too often the focus in investigations is to blame the human operator resulting in poor and incomplete investigations. The model does not include the higher levels of the system that are largely responsible for the investigation process, management and the organisation of investigations (areas where it is believed that systemic factors exist). The researcher supports French et al. (2011) who state that although the Swiss Cheese Model provides an understanding of system failures, it also results in systematic misunderstandings. This is because the focus remains on the errors made by the human element as reasons for system failures. The operational behaviour may have been completely rational and appropriate. Furthermore, French et al. (2011) contend that more emphasis is required on the broader context which should include the cultural, organisational, and social contexts other than just focusing on human error. Jeffcott et al. (2006) also acknowledge that organisational structures, culture, policies and management procedures can all play a role in the development of industrial failures. This research identified organisational structures, culture, policies and management procedures to be systemic factors that influence the effectiveness of the investigation process. This is detailed in the results chapter.

4.6.2 Leveson's (2004) Systems Theory Accident Model and Processes (STAMP)

Leveson (2004) proposed the Systems Theory Accident Model and Processes (STAMP) as a systemic accident model. This model considers technical (hardware and software) and human and organisational factors in complex systems. Systems have control mechanisms which, if the components of the system become disturbed or dysfunctional, accidents occur. Leveson (2004) states that this is because the control systems cannot handle the disturbing interactions between components. In essence the purpose of this method is to prevent the 'spread' of accidents by allowing those who use it to stop recurring systemic factors that result in repeated accidents of the same kind (Leveson, 2004; Ouyang et al., 2010). Underwood and Waterson (2014) state that the STAMP model uses three basic constructs to determine why control was ineffective and resulted in accidents:

- Safety constraints: these are barriers or actions that are responsible for maintaining safety and accidents occur when these constraints are not enforced;

- Hierarchical safety control structures: impose constraints and control the behaviour of the level beneath; and
- Control processes: two-way communication processes that operate between the various levels in a system to enforce the safety constraints.

Salmon et al. (2012) state that this method is useful and similar to Rasmussen's (1997) Risk Management Framework. However, in their study on accident analysis methods, they identified that the STAMP technique has not yet gained acceptance outside of academic circles, in particular with safety practitioners. This is attributed to the language used in STAMP (based on control theory) and the taxonomy that underpins STAMP making it more suitable for technical control errors than human decision making and organisational failures (Salmon et al., 2012). The STAMP model, although more comprehensive than the Swiss Cheese Model, was not selected for this research. Although the STAMP model is founded on Rasmussen's (1997) Risk Management Framework the latter was the preferred choice. This is because of the following and is supported by Salmon et al. (2012) and Underwood and Waterson (2014):

- The STAMP model is not as succinct as Rasmussen's Accimap
- The STAMP model is resource intensive to learn and use
- The STAMP model requires more detail on the system structure and components than was required for this research
- The STAMP model is confusing, especially if one does not have a background in control theory and was not as user-friendly as other systemic accident analysis methods
- The STAMP model excludes the impact of environmental conditions on the systems performance
- The representation of the findings in the STAMP model are illustrated in a number of documents (using text) rather than in a single graphical diagram like the Accimap
- The STAMP model offers little visual communication of an accident

The researcher therefore selected Rasmussen's (1997) Risk Management Framework and Accimap over the STAMP model. The Risk Management Framework and Accimap are easier to understand, offer a more practical representation of the South African railway

system, and the Accimap provides a comprehensive graphical illustration of a complex socio-technical system that considers the entire system as the unit of analysis. This is discussed in detail in the following section.

4.7 Rasmussen's (1997) Risk Management Framework

Underwood and Waterson (2014) state that Rasmussen's (1997) Risk Management Framework is one of the most popular systemic accident analysis methods and has also been used to analyse rail accidents. The framework demonstrates how every organisational level in a system affects the control of hazards which are potentially harmful. Poor and ineffective accident investigations can be hazardous for industries, as failure to investigate thoroughly will result in only the symptoms being addressed and not the underlying causes. This contributes to an increased number of accidents and recurrences of similar accidents. This has implications for the overall safety management of organisations. The following sections include the motivation for selecting this method, an explanation of the framework and also an explanation of the Accimap.

4.7.1 Motivation for selecting Rasmussen's (1997) Risk Management Framework

The researcher selected Rasmussen's (1997) Risk Management Framework as the theory to expand on and contribute to as part of the objectives of this work. There is much support in the literature for the Risk Management Framework as a systemic accident model despite its origin as a risk management model (Branford, 2011; Cassano-Piché et al., 2006; Leveson, 2004; Salmon et al., 2012; Sklet, 2004; Waterson, Le Coze & Anderson, 2017a; Waterson, Jenkins, Salmon & Underwood, 2017b). Furthermore, a special edition dedicated to the legacy of Jens Rasmussen was published in Applied Ergonomics in 2017. Waterson et al. (2017a) states that his work represents the most influential contribution to the fields of Human Factors, Safety Science and Cognitive Science and has inspired researchers and practitioners in the field of Engineering, Psychology, Sociology and Human Factors. Rasmussen's work has over a 1000 citations since its original publication (Waterson et al., 2017a). Waterson et al. (2017a) state that the Risk Management Framework is a popular model of complex socio-technical systems that is still highly regarded today. This is because the framework encompasses day-to-day challenges; for example the fast changing pace of new technology, the scale and growth of modern industries, and the aggressive competitive environments in which organisations operate.

Compared to the STAMP model, the entire system is considered, whereas the STAMP model does not consider the impacts of the environment on the systems performance.

The Risk Management Framework exposes how conflicts and priorities between the various levels of the socio-technical system (government, regulators, company managers, staff and work) can impact on accident causation. This research extends this theory to include how these conflicts and priorities impact on the *effectiveness of the investigation process of accidents and its outcomes*. The results of this work illustrate that the investigation process of occurrence investigations is an example of a complex system in itself and not just the accident. One of the outcomes of this work is to provide industry (practitioners) with an alternative way of managing railway investigations given the state of railway safety in South Africa. Waterson et al. (2017a) affirm how Rasmussen's work has had the ability to bridge the gap between research and practise, particularly in terms of the Accimap. The Accimap, developed by Rasmussen (1997) and Rasmussen and Svedung (2000) is a graphical representation of accidents, and complex work domains, and is a useful method to adopt to determine the dynamic behaviour of a system. This is explained in more detail in section 4.7.4. In chapter 7 an Accimap is produced from the results of this research and this is discussed in chapter 8.

Rasmussen's 1997 paper was a catalyst in shifting the focus of accident causation away from the orthodox view of human error, towards underlying organisational and system factors (Waterson et al., 2017a). The reader will recall that the systems approach factors into consideration the macro level (political and regulatory issues) and the micro level (organisational culture, team and individual behaviour). The premise is that behaviours at a higher level of function influence the levels below which turn these behaviours into normal and acceptable aspects of the everyday work context (Waterson et al., 2017b). This research demonstrates in the results chapter (chapter 7) how the investigation process of occurrences is influenced by higher level functions, decisions, constraints and challenges (systemic factors). These in turn impact on the levels below ultimately impacting on the level where investigations are conducted.

The researcher supports Rasmussen's (1997) shift away from human error towards the socio-technical system viewpoint. This researcher's work experience in the field of accident investigations has proven the significant emphasis placed on human error as the

cause of many railway occurrences. Too often this happens as a quick fix, fault finding exercise with little focus on the role of other elements and conditions inherent in the system. A motivation for conducting this work is to encourage practitioners to shift their focus in investigations away from *who caused the accident to what happened in the system.* The traditional viewpoint results in poor, incomplete, and unreliable investigations. Rasmussen's (1997) Risk Management Framework is extended in this work to demonstrate how everyday events, at any level in the system, impacts not only on accident causation, but also on the *effectiveness of the investigation process and the outcomes*.

Another reason for using Rasmussen's (1997) Risk Management Framework and Accimap is due to the extensive number of researchers and practitioners who support Rasmussen's 1997 paper for the explanation of accident causation. Examples include the Zeebrugge ferry accident (Rasmussen & Svedung, 2000), the South Korea Sewol Ferry accident (Kee, Jun, Waterson & Haslam, 2017; Lee, Moh, Tabibzadeh & Meshkati, 2017), public health problems (Karsh et al., 2014), outdoor activities (Salmon, Goode, Taylor, Lenné, Dallat & Finch, 2017), and in railway accidents (Underwood & Waterson, 2014). The various different contexts that this model has been applied to illustrates that the model is domain-generic and can be readily applied to most industries.

Given the motivations above, it is justifiable that Rasmussen's work is the most suitable for this research. The model in this work is used to explain the systemic factors that influence the investigation process. This work therefore extends the model's use beyond accident causation to also include the investigation of these events and the system of accident investigations. The model is explained and discussed in the next section.

4.7.2 Explanation of Rasmussen's (1997) Risk Management Framework

Although Rasmussen's model is primarily used for accident causation and risk management, this research uses this model to understand what systemic factors influence the effectiveness of railway occurrence investigations in South Africa. The model views the entire socio-technical system, which includes legislatures, government, industry, companies, company management, operations and the environment. Structure, hierarchies, constraints, priorities and other influencing factors are modelled to provide a picture of the socio-technical system. In this research the focus is the rail socio-technical system.

In 1997, Rasmussen proposed a Risk Management Framework for complex socio-technical systems. With the rapid advancement and pace of change of technology this led to the development of high risk socio-technical systems. These complex organisations operate in dynamic environmental conditions (Qureshi, 2007; Rasmussen, 1997; Rasmussen & Svedung, 2000; Svedung & Rasmussen, 2002) and include the following examples:

- Fast pace of change of technology
- Competitive environments
- Economic, social, and political pressures
- Legislation and regulation in response to changes
- Increased awareness about safety among social structures

Rasmussen (1997) proposed that these dynamic environments influence people's work performance within complex systems suggesting a move away from focussing on the 'sharp-end'. The framework is based on the premise that safety depends on the control of work processes within the context of the pressures and constraints in the operational environment. When there is a loss of control of the physical processes this is when injuries and disasters occur (Rasmussen, 1997). Therefore safety, and accidents, are emergent properties that arise as a result of the interactions between components within a particular system (Rasmussen, 1997; Salmon et al., 2012; Salmon et al., 2017). The Risk Management Framework comprises of two components:

- A structural hierarchy of the actors and organisation in a system; and
- The dynamic forces that can cause the system to change its behaviour

Both of these components are explained further to illustrate Rasmussen's work in socio-technical systems.

The structural hierarchy of the actors and organisation in a system

The structural hierarchy of the socio-technical framework consists of six levels and is illustrated in Figure 4.2 This illustration formed the basis for determining the structural hierarchy of actors and organisations of the South African railway system with the focus on the investigation process of railway occurrences.

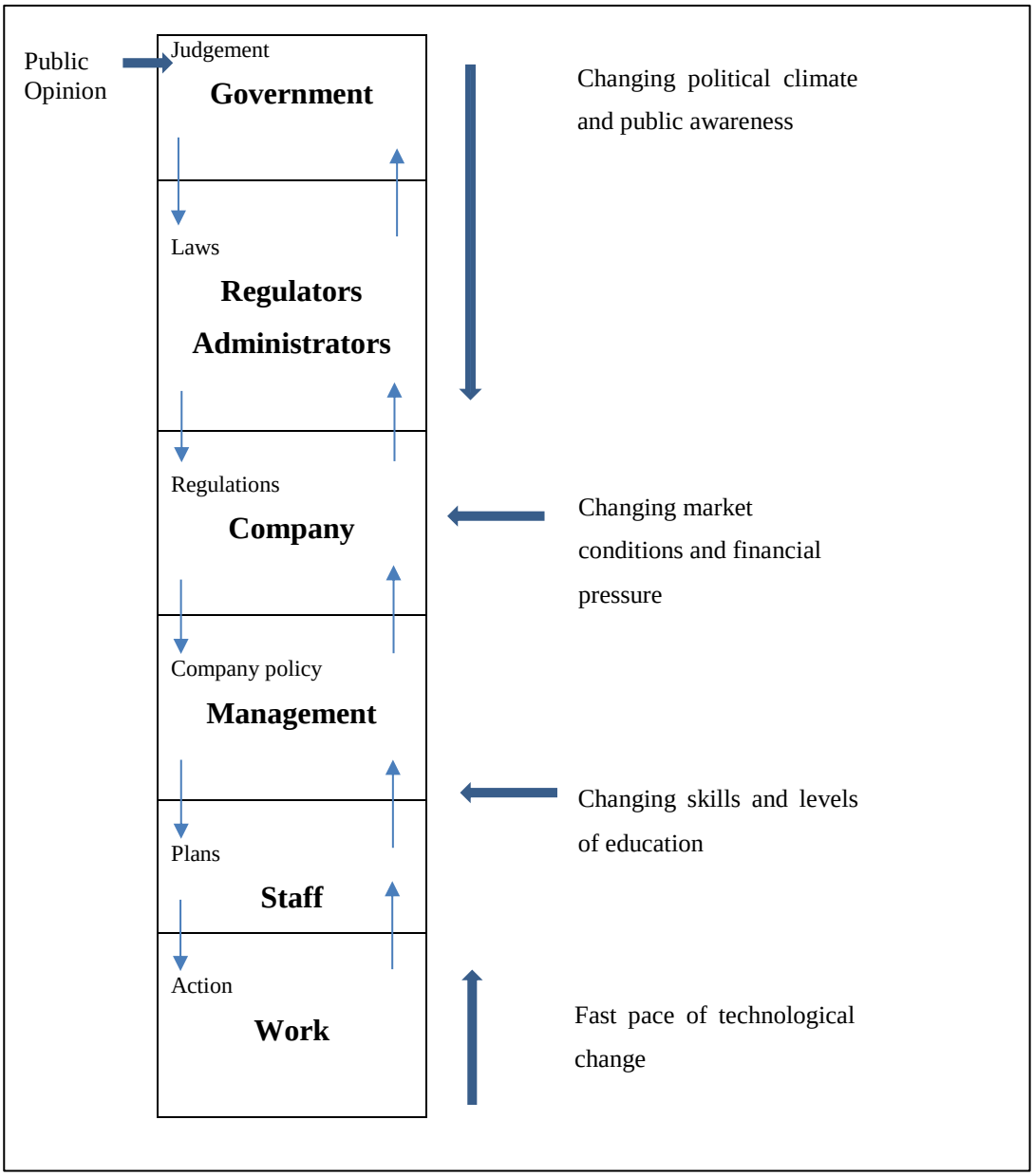


Figure 4.2 Rasmussen's (1997) Risk Management Framework (Adapted from Cassano-Piché et al., 2006, p. 386; Rasmussen, 1997, p. 185; Svedung & Rasmussen, 2002, p. 400)

The basic premise of this model is that systems comprise of various levels. Actions and decisions across these levels interact with one another to shape safety, accidents and the systems performance. In describing this model from the top, society seeks to control safety through the legal system and the *Public* domain places pressure on government to ensure safety is a priority. The *Government* level, through policy, budget, legislation, and laws control the practices of safety in society. The activities of the *Regulators and Associations* are responsible for converting this legislation into rules, standards and regulations for their

respective fields. The *Company* level refers to the activities of the entire organisation. It is at this level where regulations and standards are integrated into company management, budgeting, planning, rules, policies and procedures. The *Management* level describes the people that manage or supervise staff with reference to these rules and policies. This level is responsible for implementing company policy, and technical and operational management. Lastly the *Staff* and *Work* levels of the hierarchy describe the front line staff and their activities. This level also includes the hazardous processes being controlled; i.e. the work performed by those who directly interact with the equipment/technology or process, for example a train driver, nurse, or pilot (Branford, 2011; Cassano-Piché et al., 2006; Rasmussen, 1997).

Rasmussen (1997) states that in complex socio-technical systems vertical feedback loops across all the levels of a system are required for the system to function safely. This is supported by Branford (2011) and Vicente and Christoffersen (2006). The levels of a system are connected by the flow of decisions and information. The lower levels of the hierarchy need to circulate information about the actual status of the system up to the higher levels to inform the decisions and actions occurring at these levels. Likewise, the decisions and actions made at a higher level in the form of laws, regulations and policies needs to be propagated downward to the lower levels. These need to be reflected in the decisions and actions occurring at the lower levels (Rasmussen, 1997). This flow or vertical integration of information creates feedback loops. The overall safety of the socio-technical system is dependent on these closed loop feedback systems and exchange of information to control hazards (Rasmussen, 1997). Accidents therefore do not occur through the decisions and actions made by the workers but by *decision makers / individuals at every level* in the system. The *interactions between these levels* are also reasons for why accidents occur (Branford, 2011; Cassano-Piché et al., 2006; Qureshi, 2007; Rasmussen, 1997; Salmon et al., 2012; Vicente & Christoffersen, 2006). This dynamic two way integration is vital for the system to be safe and in control. Any variation in routine work practices and normal behaviour of various actors in the system can result in accidents (Salmon et al., 2012). Therefore accidents are caused by multiple, interacting factors beyond the immediate context of the accident (Salmon et al., 2012).

What differentiates the Risk Management Framework from STAMP is that environmental conditions are considered. On the right of the framework in Figure 4.2, external forces in

the environment can influence the various layers of complex systems and therefore the stability of the system. Given that today's society is dynamic where change is more frequent, external disruptive forces may be unpredictable, rapidly changing and can be powerful enough to influence the behaviour of the system (Qureshi, 2007). Qureshi (2007) states that actions and decisions of individuals and organisations at the various levels within the system can impact on the system's safety as they are subjected to different pressures that occur at different times. Therefore in trying to maintain the system's state of safety (i.e. control), requires a coordinated effort from all levels. Examples of external influences include political, financial, and technological circumstances, often resulting in conflicting priorities (Branford, 2011; Rasmussen, 1997; Svedung & Rasmussen, 2002).

Rasmussen (1997) asserts that the exact number of levels in the hierarchy and the references of each level can vary depending on the system being studied. This model was adapted to illustrate that the investigation process of railway occurrences in South Africa is an example of a complex system in itself. In terms of the hierarchical structures, two difficulties were experienced by the researcher in applying this framework to the South African rail socio-technical system. Firstly at a *Company* level, the Operator selected (TFR) is its own operating company but forms part of a bigger operating division (Transnet). This division or group consists of 5 operating companies and develops policies for its companies to adhere to. In terms of occurrence investigations, an overarching policy is developed by Transnet. TFR is required to adhere to this policy but is also required to develop its own policies and procedures for occurrence investigations. Therefore the *Company* level in this research represents the operating division (Transnet) and the operating company (TFR).

The second difficulty occurred at the *Management* and *Staff* levels. TFR consists of two *Management* levels, Corporate and Line (regional) Management. Policies developed at the Corporate Management level at TFR need to be adhered to, and implemented by the depots (distributed all over South Africa). Line Management are in charge of all the depots. The Corporate Management level represents the office responsible for occurrence management in general for the whole company. This includes overseeing that occurrences are investigated at a Line Management level. However, for occurrences that are more severe, the Corporate Management level gets involved in occurrence management by coordinating the occurrence investigation. In most instances, they also participate as a member of the

investigation team. This then places them at a *Staff* level as they are required to carry out the investigation process while also having to develop occurrence management policies and procedures as part of the *Company* level. Line Management are required to investigate all occurrences in their area of jurisdiction but are also responsible for managing the depots and the running of trains (operations). This places them at a Management level but also at the *Staff* level as they must initiate, conduct and conclude the investigation. The challenge of who to place at a *Staff* level i.e. the people responsible for doing the actual investigation is as a result of TFR (the company) not having officially appointed investigators in the company. By means of being a Line Manager, the employee is able to investigate occurrences. This is a finding in itself and is discussed in chapter 7. The difficulties experienced in classifying the role players for each level of the rail socio-technical system illustrated the *system of systems concept*. Within the entire rail socio-technical system and within each hierarchical level there is a system of systems. Therefore the decisions and actions at a macro level as a whole and within each level are discussed in the results chapter.

Rasmussen's (1997) Risk Management Framework is operationalised for the South African rail socio-technical system and this is explained in the methods chapter (chapter 6). The adjustments to the model illustrate the theoretical contribution of this work and are used to illustrate that the accident investigation system is a complex system on its own. The following section discusses the second part of Rasmussen's framework.

The dynamic forces that can cause the system to change its behaviour

In order to understand how accidents occur in context it is necessary to understand the dynamics of the system, the second part of Rasmussen's framework. Branford (2011) and Rasmussen (1997) argue that in order to analyse the safety of a domain it is important to identify the boundaries of safe operations and the dynamic forces that may cause the socio-technical system to migrate towards or across these boundaries. These dynamic forces can influence the system's behaviour over time where for example, workload pressures and economic considerations can push the systems away from safe performance closer to the margin of error (Rasmussen, 1997; Waterson et al., 2017b). Figure 4.3 illustrates how dynamic forces can affect and change the behaviour of a complex socio-technical system, impacting on the systems stability.

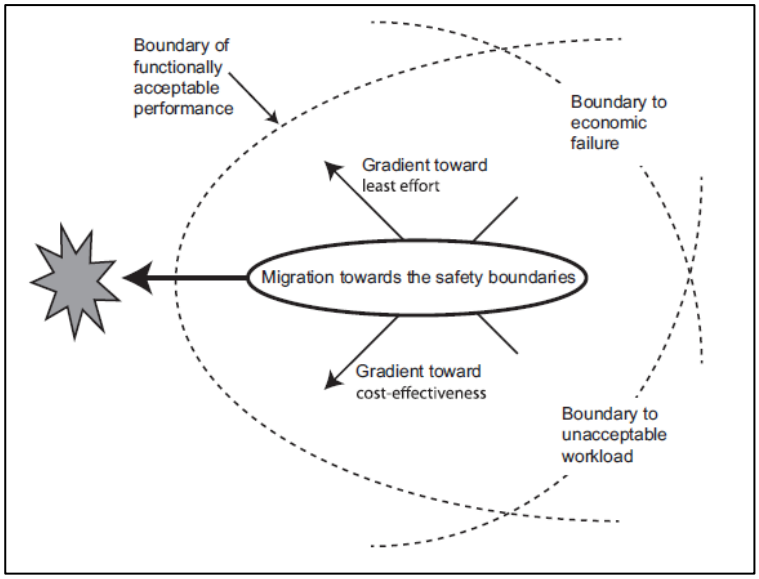


Figure 4.3 The dynamic forces that change systems behaviour (Branford, 2011, p. 32)

Branford (2011) and Rasmussen (1997) state that humans are required to make decisions and act within the system, however this freedom is constrained by financial, administrative, and safety constraints. For example in today's competitive environment people throughout the system are under pressure to be cost-effective (refer to Figure 4.3). This cost gradient pushes workers and the entire system towards efficiency and away from the boundary to economic failure (Branford, 2011). While this occurs an effort gradient directs them away from unacceptable workloads towards easier ways of working. These pressures result in workers seeking to find a balance between effort and cost-effectiveness in their work. Shorrock et al. (2014) refer to this as trade-offs. Accidents occur when the boundary of acceptable performance is crossed (Branford, 2011; Rasmussen 1997). The difficulty in systems is that individuals cannot judge where the safety boundaries lie because the boundaries are relevant to decisions and activities of *other people, at different times, in different parts of the system.* These only become visible after they have been crossed and an accident occurs (Branford, 2011; Rasmussen, 1997). This happens over time and people are often unaware of what has happened because their actions deviated slowly from the recent past (Cassano-Piché et al., 2006; Rasmussen, 1997). Safety is therefore an emergent feature of a system which is impacted by the actions and decisions of individuals and organisations at various levels. The impact of these on the effectiveness of the investigation system is explained in the results.

4.7.3 Explanation of an Accimap

Rasmussen and Svedung (2000) identified the need to graphically represent the causal flow of accidents based on the principles of Rasmussen's (1997) Risk Management Framework. The Accimap (pronounced axi-map) is a tool that is used in accident causation analysis to structure the socio-technical systems behind an accident, the preconditions, the functions of the different system levels involved, and how they contributed to an accident. The Accimap is used to illustrate decision making during normal work for all the levels of the system and the influence of the stressors found in modern dynamic society (Rasmussen & Svedung, 2000). The Accimap is a popular accident analysis tool and has been used in a wide variety of domains, for example:

- Esso Australia gas plant explosion (Hopkins, 2000)
- Contamination of drinking water (Vicente & Christoffersen, 2006)
- Uberlingen mid-air collision (Branford, 2011)
- Grayrigg train derailment (Underwood & Waterson, 2014)
- Led outdoor activities (Salmon et al., 2017)
- Sewol ferry accident (Lee et al., 2017)

An Accimap is constructed as a causal diagram, mapping multiple contributing factors to an accident and their relationships onto the levels of the socio-technical system (Branford, 2011). Branford (2011) states that by doing this, the context within which the accident occurred and the interactions that resulted in the event are visually displayed. In this research instead of the traditional use of the Accimap in determining why an accident occurred, it is used to demonstrate what systemic factors influence the effectiveness of the investigation process, and therefore a recurrence of accidents. Multiple contributing or systemic factors are mapped onto the levels of the South African rail socio-technical system illustrating the context in which accident investigations are conducted resulting in the effectiveness of occurrence investigations being compromised. This work illustrates a novel and useful approach to Rasmussen's work.

Waterson et al. (2017b) state that an Accimap focusses on six levels of analysis: government policy and budgeting; regulatory bodies and associations; local area government planning and budgeting; physical processes and actor activities; and

equipment and surroundings. Rasmussen (1997) states that each level is involved in safety management and has a role to play in controlling hazardous processes. An example of an Accimap is illustrated in Figure 4.4.

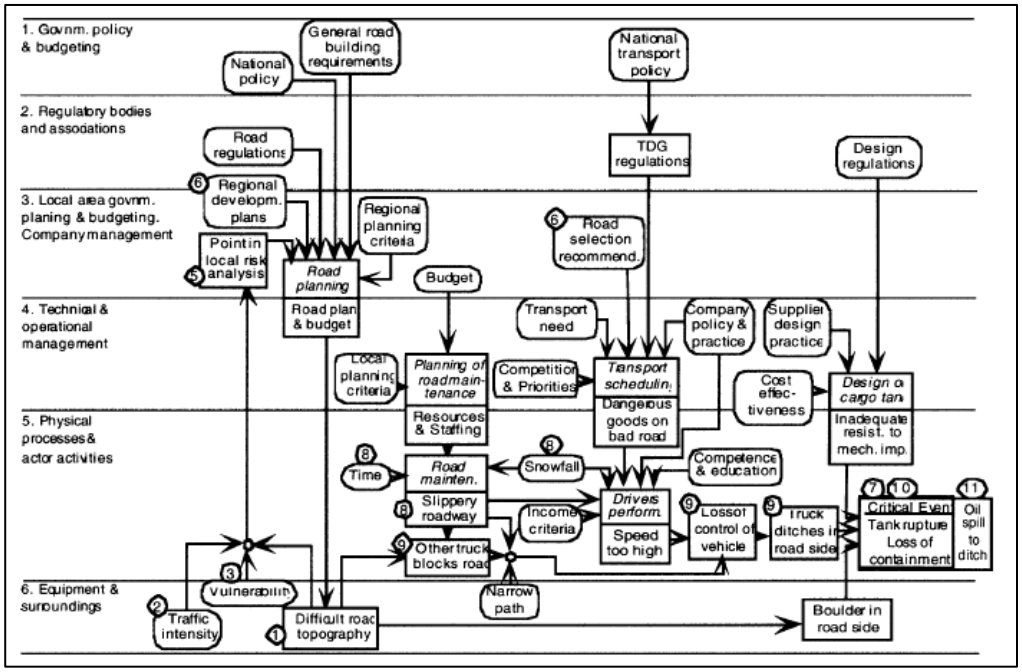


Figure 4.4 An example of an Accimap
(Svedung & Rasmussen, 2002, p. 409)

Accimaps are easy to use and provides a succinct graphical summary of the accident or outcome (Underwood & Waterson, 2014). The six levels of analysis in the Accimap can also be adjusted to suit the socio-technical system of interest. Accimaps also provide a big picture of the system of interest and also illustrate system of systems (Waterson et al., 2017b). Waterson et al. (2017b, p. 492) refer to the variations of how the Accimap has been interpreted, evolved and applied across various studies as *"remixing"* Rasmussen's work, demonstrating the popularity and versatility of this method. The advantages of the Accimap have added to its popularity as an accident analysis method. However, in terms of its reliability, Underwood and Waterson (2014) state that compared to other models the reliability of the Accimap is doubtful given the qualitative nature of the model. Other critiques of this tool are that it is resource intensive to use and learn, and is time consuming. Branford, Naiker and Hopkins (2009) claim that the Accimap has not been readily accepted by new users due to the absence of documentation regarding how to use the approach. It is for this reason that the authors identified the need to develop useful

guidelines for applying the Accimap technique to analyse the causes of single accidents. These guidelines were a useful resource for this research.

Although used as an accident analysis tool, this research uses the Accimap in a different context to illustrate the systemic factors influencing the investigation process of railway occurrences. The Accimap in this research instead illustrates a systemic view of the *accident investigation system* instead of its traditional application in accident causation. This is because this research examines the *system of accident investigations* and not the accident itself. The Accimap illustrates the systemic factors impacting on the *effectiveness of the investigation process* and the *outcomes of the investigation,* namely the findings and recommendations. The Accimap is illustrated in chapter 7 and discussed in chapter 8.

4.7.4 Summary of Rasmussen's (1997) Risk Management Framework

To summarise, Rasmussen's (1997) Risk Management Framework provides seven predications:

- Safety is an emergent property of a complex socio-technical system. It is impacted by the decisions of all the actors.
- Threats to safety (or the investigation process) are usually caused by multiple contributing factors not just a single catastrophic decision or action.
- Threats to safety or accidents (or the investigation process) usually result from a lack of vertical integration across all levels of a complex socio-technical system, not just from deficiencies at any one level alone.
- The lack of vertical integration is caused in part by a lack of feedback across levels of a complex socio-technical system. Actors at each level cannot see how their decisions interact with those made by actors at other levels so the threats to safety are far from obvious before an accident.
- Work practices in a complex socio-technical system are not static. They will migrate over time under the influence of a cost gradient driven by financial pressures in an aggressive competitive environment, and under the influence of an effort gradient driven by the psychological pressure to follow the path of least resistance.

- The migration of work practices can occur at multiple levels of a complex socio-technical system, not just one level alone.
- Migration of work practices causes the system's defences to degrade and erode gradually over time, not all at once. Accidents (or the outcome of the investigation process) are realised by a combination of systematically induced migration in work practices and a triggering event. Accidents are not as a result of an unusual action or an entirely new, one time threat to safety.

The popularity of the Risk Management Framework and Accimap is evident by the wide ranging industries that have used this approach and continue to do so nearly 20 years since its introduction. This framework helped to identify the sources of data selected as part of the research methodology. The framework is operationalised for the South African rail socio-technical system and this is explained in chapter 6.

4.8 Concluding remarks

This chapter explained the modern approach to accident causation which is based on system paradigms. Socio-technical systems and the complexity of these systems was discussed. Traditional accident causation approaches, which include sequential and epidemiological models, do not address the complexity of socio-technical systems, the dynamic nature of systems and the influence of environmental factors on the systems performance. Due to these reasons, systemic accident models are favoured over traditional models. An example of a systemic accident model is that of Rasmussen's (1997) Risk Management Framework and Accimap which were selected for this research. Despite Accimaps being used to illustrate why an accident happened the novelty of this research is to illustrate that an Accimap can be used to determine what impacts the effectiveness of accident investigations system, its findings and recommendations (outcomes). Ineffective investigations can lead to recurrences of accidents as only symptoms are addressed.

The next chapter, chapter 5, describes accident investigations, the system of interest in this research. Chapter 5 is the last of the literature review chapters. Investigations need to be effective to assist organisations with determining what went wrong and what can be done to prevent a recurrence. The purpose of conducting investigations and whether we really learn from accidents is discussed next.

CHAPTER 5: ACCIDENT INVESTIGATIONS

The previous chapter highlighted that the modern approach to determine why an accident happened is to understand the actions and decisions of the entire system. This chapter focusses on the importance of investigating accidents to identify remedial actions to prevent a recurrence. The system of interest in this research is the *system of accident investigations*. Railway accident numbers remain high in South Africa despite the RSR and the Operators conducting investigations. In chapter 1 the hypothesis of this research stated that there are systemic factors influencing the effectiveness of the investigation process of railway occurrences in South Africa. These systemic factors are inherent within the bigger rail socio-technical system and influence the entire investigation system including the quality, objectivity, validity, reliability and accuracy (effectiveness) of the process. Furthermore, the findings and recommendations (outcomes) are also affected resulting in only symptoms being addressed contributing to the recurrence of events. This chapter addresses the purpose of occurrence investigations, the requirements for effective investigations, whether we really learn from accidents and the need for independent investigations. This chapter concludes with the theoretical contribution of this study.

5.1 A systems approach in accident investigations

Accident investigations that do not adopt a systems approach generally focus on identifying the individual who was accountable and responsible for the occurrence. A systems approach in accident investigations allows investigators to move away from blaming the individual. Instead a number of agents and actors at all levels in the system hierarchy, and their interactions, are analysed to identify what happened. Dekker and Nyce (2012) state that investigators need to acknowledge that accidents can arise from normal people doing business as usual in a normal environment where failure is possible. This often results in frustrations as investigators want to be able to pin point a cause, a single individual or source and do not understand that the issues are inherent in the system (Dekker & Nyce, 2012). As a result, Dekker and Nyce (2012) believe that investigators would rather find a scapegoat than give the illusion that they don't understand what could have gone wrong. The researcher supports Dekker and Nyce (2012) that it is easier for investigators to find fault with someone than to appear uncertain about how the system failed when everything was normal. Investigators therefore need to be trained and have knowledge of systems theory to understand how systems operate. Furthermore, this

knowledge is important to be able to use systemic accident causation models correctly. This understanding will assist investigators to identify a whole host of systemic causes thereby improving the effectiveness of the investigation process and the outcomes.

Lawton and Ward (2005) conducted a system analysis of the well-known railway disaster in the UK, Ladbroke Grove. They identified that the incident was not due to a single case of human error but rather a systemic combination of factors that resulted in the events leading up to the accident. They concluded that train crashes cannot simply be attributed to single factors but result from system failure. Lawton and Ward (2005) affirm that accidents occur because of unpredicted interactions between various components of the system happening simultaneously at an inopportune time. In an analysis of train crashes in the USA between 1999 and 2002 Lawton and Ward (2005) identified that human error and track problems represented the biggest causes. In another study of train incidents in the UK between 2002 and 2003, Lawton and Ward (2005) recognised that the primary cause of these incidents was attributed to staff error. These findings support the researcher's view that it is easier to apportion blame at a micro level. This simplistic view of accident causation limits the identification of other possible factors. Furthermore, the traditional linear cause and effect approach restricts investigators' and organisations' ability to prevent future railway occurrences. Factors that may be latent, or contexts that may occur as a result of interactions with other components, may be reasons for the actions of humans that made sense at a particular time. To improve railway safety, a systems perspective is necessary in the investigation of railway occurrences to move away from the ubiquitous human error.

The importance of adopting a systems approach in accident investigations is supported by Ayeko (2002) who states that investigators need to recognise that accidents occur because of the complexity of systems. Ayeko (2002) also state that there are five important elements in a system that play an interactive role in the cause of an accident and include:

- Human
- Machine (ships, locomotives, aircraft, etc.)
- Medium (internal and external environments)
- Mission (schedules, goals, needs, financial objectives, policies, procedures, etc.)

- Management (organisation, regulatory bodies, organisational management, etc.)

Ayeko (2002) assert that humans and machines interact in a medium confined by missions and management all together creating and maintaining the system. Therefore investigators need to be cognisant of these factors in trying to uncover what happened and acknowledge the role of the system in contributing to accidents. By way of example, Ayeko (2002) explains how the Canadian Transportation Accident Investigation and Safety Board (TSB) in the analysis of a number of accidents, identified in most of their investigations multiple causes rooted in underlying factors. Human and organisational factors were the most common (Ayeko, 2002). The TSB acknowledged that their investigation practices needed to adopt a broader systems approach as the identified causes were often attributed to human error (Ayeko, 2002). This emphasises the importance of practitioners who are responsible for occurrence management to be qualified and trained in systems theory so that individuals are not always identified as the root of a problem. They are only one component involved in complex interactions with other system components such as procedures, equipment and other humans. Furthermore, the influence of the operating environment and the demands to accomplish a certain objective are additional system principles that must be considered. Baysari et al. (2008), studied railway accidents in Australia and identified failures within all levels of the system providing strong support for a systems approach to accident causation. System problems on a whole were identified as the biggest contributors to accidents and incidents (Baysari et al., 2008).

Dekker et al. (2011) support the argument for a systems approach as many accident investigations look for singular factors. These include *chain of events*, *human error*, *what was the cause* and *who was to blame* resulting in the system level factors being diffused in accident investigations (Dekker et al., 2011). Despite the popularity and advantages of systemic approaches, Underwood et al. (2016) contend that the systemic perspective is not adopted in practice as much as it is in research, resulting in a research-practice gap. In practice, investigation reports present accidents as sequential cause-effect events with the focus on the sharp end factors. The extent to which a systems approach is adopted by investigators in the South African railway industry is discussed in chapter 7 and 8.

5.2 The purpose of accident investigations

Underwood and Waterson (2014) and Underwood et al. (2016) state that accident investigations involve determining why a number of events and conditions contributed to an accident. Investigations provide an opportunity to learn important lessons about system safety to prevent accident recurrences. Hollnagel et al. (2013) assert that although investigations are a reactive way of managing safety, the objective of conducting an investigation is two-fold. Firstly the objective is to determine the facts surrounding the event and to propose solutions in order to prevent future, similar occurrences. Secondly accident investigations have a litigation aspect to them with the objective of identifying a culprit and instituting penalties. This is generally the case as humans are seen as the cause of failure (Hollnagel et al., 2013; Saleh, Marais, Bakolas & Cowlagi, 2010). However, Saleh et al. (2010) claim that accident causation can also serve as a forward looking objective. Organisations can view the analysis as a mechanism for identifying and eliminating failure causes, thereby contributing to the future safety of the system.

Saleh et al. (2010) state that the interest in accident analysis is not only because of the consequences of the tragic loss of life but also the financial, environmental, ethical, and moral considerations. These are strong incentives for organisations to focus on system safety to prevent such accidents (Saleh et al., 2010). Saleh et al. (2010) believe that the analysis of accidents often results in a shared sameness in the way they occur. Findings frequently highlight technical flaws, system design issues, operational failings, workforce challenges, and management shortcomings. Repeat accidents and accidents where similar findings are identified can often result in complacency, with the outcome leading to regulatory oversight and deficient analyses (Saleh et al., 2010). This supports this researcher's view that accident investigations in the South African railway industry may have reached a plateau (i.e. a level of complacency in terms of how accidents are investigated), and are not as effective at identifying what really happened. This is particularly evident in recurrences of level crossing accidents and derailments in South Africa. This is further discussed in the results chapter.

Hollnagel et al. (2013) state that it is common practice that safety is viewed by people as the absence of accidents and incidents, or where an acceptable level of risk is deemed appropriate. Hollnagel et al. (2013) term this perspective as Safety-I where safety is defined as a state where as few things as possible go wrong. Safety in this state is managed

by responding when something happens or the level of risk is viewed as unacceptable. Typically an investigation is conducted with the purpose to identify the causes and contributory factors, while a risk assessment aims to determine the likelihood of the hazard to eliminate the cause. Hollnagel et al. (2013) critique this traditional view of accident investigations under a Safety-I approach as being reactive. Organisations respond when something has happened.

With this is mind, Hollnagel et al. (2013) support a change in how safety is managed and advocates a Safety-II approach that offers a different view to looking at safety. The Safety-II approach is aligned with system principles and acknowledges the demands on systems and system complexity. These authors believe that the definition of safety should be changed from *avoiding something that goes wrong* to *ensuring that everything goes right*. Hollnagel et al. (2013) believe that this view explains why human performance always goes right and the system's ability to succeed under varying conditions. Hollnagel et al. (2013) and Shorrock et al. (2014) assert that moving from Safety-I to Safety-II offers a more proactive safety management approach where events are continuously anticipated. In this instance the purpose of investigations is to understand how things usually go right as a basis for explaining how things occasionally go wrong (Hollnagel et al., 2013). Furthermore, these authors state that the Safety-II approach should not replace the Safety-I approach but a combination of the two ways of thinking should be applied. As discussed in the previous chapter, accidents do not only happen in a linear cause-effect way but include phenomena that emerge from the complexity of the overall system. Hollnagel et al. (2013) and Shorrock et al. (2014) believe that a paradigm shift is required for safety experts to move from only asking *why and because* type questions. This does not explain the system and therefore does not lead to an improvement in safety (Hollnagel et al., 2013). The results of this research illustrate that the South African railway industry is very much still in Safety-I. An outcome of this study is to encourage practitioners and industry to move toward a Safety-II approach.

Reinach and Viale (2006) affirm that despite the reactive nature of accident investigations they are still an important qualitative approach in managing transportation safety. The impact of occurrences costs railway companies financially, legally, and morally and in order for economic growth it is vital that transport systems are efficient and safe (Lerer & Matzopoulos, 1996; Pienaar, 2003). It is therefore important that occurrences are managed

and investigated in order to prevent incidents from recurring; thereby ensuring railway transportation is safe and reliable. The next section describes the requirements for effective investigations.

5.3 Requirements for effective investigations

In this research the effectiveness of the accident investigation process is defined as the accuracy, quality, reliability, validity and objectivity of the investigation process that has an impact on the appropriateness of the findings and recommendations. The investigation process consists of a number of different stages that varies from industry to industry. As an example, Lundberg et al. (2009) describe a number of stages that many investigators encounter as part of the investigation process and include:

- Initiation of an investigation
- Planning of time and resources in order to conduct interviews and read through documents
- Data collection of relevant information through interviews, observations and experiments
- Representation of the data into various forms that can be used by the investigators; e.g. event trees, diagrams, etc.
- Analysis of the accident / incident to reconstruct the events
- Recommendations of remedial actions
- Decisions about action and the implementation of recommendations
- Follow up activities

This research highlights that at any stage in the investigation process systemic factors, pressures and challenges (from any level in the rail socio-technical system hierarchy), impact not only on the process but also the outcomes. The results chapter highlight the systemic factors impacting on the effectiveness of the investigation process of South African railway occurrences.

During an investigation, Underwood and Waterson (2014) state that evidence is collected in a variety of formats. Examples may include photographs, documents and witness testimonies. Evidence is then preliminarily analysed in order to convert the evidence into

suitable information that can be used in the accident causation analysis. Furthermore, Underwood and Waterson (2014) state this stage may require certain techniques, for example photogrammetry to measure the distribution of wreckage from accident photographs. Lundberg, Rollenhagen, Hollnagel and Rankin (2012) assert that because systems today have become more complex, for example railways and nuclear plants, there is a need to implement sophisticated accident investigation techniques to manage incidents. Examples of accident causation methods that address complex systems were discussed in the previous chapter with section 5.4 addressing some of these techniques. For accident investigations to be effective, this research supports the need for a systems approach. Likewise, a systems approach is adopted in this research to illustrate that the investigation system is an example of a complex system on its own.

Reinach and Viale (2006) affirm that in order for investigations to be effective the aim should be non-punitive, to identify the root causes and recommend remedial actions to rectify system failures. If investigations are not thoroughly conducted then factors within the system are either superficially addressed or go unnoticed. These remain as latent conditions waiting to happen, with the end result often being catastrophic (Cedergren & Petersen, 2011; Kletz, 1994). The quality of the investigation is paramount to ensuring that not only are incidents managed correctly but also to safeguard the railway system. Studies in accident analysis have shown that there are severe problems with the reporting of accidents, where a large percentage of underreporting occurs, and the actual written reports that are generated are often inaccurate and incomplete (Cedergren & Petersen, 2011). In this research accident investigation reports formed part of the data collected. Furthermore, the Rail Safety and Standards Board (RSSB) in the UK believe that the process of data collection for investigations is a specialised discipline and requires extensive training, preparation, timely access to personnel, equipment, procedures and the scene of the accident (RSSB, 2014).

Lundberg et al. (2009) highlight that investigations are about following a method or procedure which directs investigators in terms of what to look for rather than going into an investigation with just an open mind. The phrase used by Lundberg et al. (2009) is *What-You-Look-For-Is-What-You-Find (WYLFIWYF)*. Given the broad categories that investigators need to explore (for example, human, social, organisational, technology, etc.), specific expertise is therefore required. Investigators' competence is therefore critical

for the quality of results. Resources such as people, equipment, and time are important as this determines which accident models can be used (Lundberg et al., 2009). The investigation processes can be influenced by levels of experience of investigators, and political, economic, and external influencers such as the police and authorities. These factors are referred to as systemic factors in this research.

Accident investigations are important constituents of organisations' Safety Management Systems (SMS) and the main purpose of these is to find ways in which to avoid future occurrences (Dekker, 2006; Lundberg et al., 2012). Reason (1997) and Reinach and Viale (2006) claim that too often incidents are blamed on human error, however it is only by understanding the context that provoked the error that organisations can begin to limit its recurrence. Reinach and Viale (2006) assert that effective incident investigations should be able to identify a broad range of factors that contributed to the accident beginning the search for causes with the error (moments before the accident) to senior level executive decisions made a number of years before. Using the railway industry as an example, it is often faced with many uncertainties for instance, changes in technological developments, organisational changes, competition between clients and growing demands (Reinach & Viale, 2006). This is especially true for the South African railway industry with years of underinvestment and underdevelopment to more recently the need to revitalise the industry. This was discussed in chapter 2. Grote (2014) believe that in terms of safety, safety departments need to evaluate the effects of these developments and the capabilities and needs of different groups of employees in order for employees to perform their jobs effectively and safely. The changes in socio-technical systems affect the variability of the systems performance (in this study the system of accident investigations) and the complexity of systems. Investigators should consider these factors in terms of contributory evidence.

Roed-Larsen and Stoop (2012) state that accident investigation methods and practices have raised scientific interest and have come under public and political scrutiny. This is due to the challenges that accident investigations are influenced by. Examples include:

- The external conditions under which investigations have to be conducted
- The competencies and required skills of staff

- Independence
- Scope of the investigations
- Development of a methodology
- The training of staff

These all impact on accident investigations in practice and are identified in this research as systemic factors. Furthermore, Roed-Larsen and Stoop (2012) highlight the challenges accident investigations are faced with in Europe. Examples include:

- A lack of integration at various institutional levels and various sectors (including global, national, regional and local levels); and
- Dealing with different interests held by various stakeholders and organisations.

These two examples are similar to what this research has identified for the South African railway industry and the results of this work are detailed in chapter 7.

5.4 Investigation techniques

In the review of the literature for this research, many articles were found pertaining to accident investigations. However, the focus was on the methods, tools, techniques, and models to assist organisations with improving the current way of identifying the causes of accidents. This was found for a number of industries; for example construction, aviation, rail and healthcare (Baysari et al., 2008; Saurin, Formoso & Cambraia, 2008; Sklet, 2004; Underwood et al., 2016). Examples of the most commonly reported techniques were fault tree analysis, root cause analysis, event tree analysis, Human Factors Analysis and Classification System (HFACS), Accimap, and STAMP. With a large number of tools, techniques, and methods available to various industries, it is therefore evident that accident investigations are an important safety tool for organisations to adopt to reduce and prevent occurrences. This research will aim to determine what methods are used by the railway industry in South Africa and are discussed in the results chapter.

5.5 Learning from accidents

In an analysis of major accident reports prepared by independent inquiry teams and experts on major accidents, Dien et al. (2012) found that the focus still remains predominantly on

the technical failures and 'first line' human operators' actions as event causes. Dien et al. (2012) quote the investigators of the Columbia space shuttle disaster:

> *Many accident investigations do not go far enough. They identify the technical cause of the accidents, and then connect it to a variant of "operator error" […]. When the determination of the causal chain is limited to the technical flaw and individual failure, typically the actions taken […]are also limited […]* (Dien et al., 2012, p. 1401).

The result of conducting investigations in this manner is that the problem is not solved as the remedial actions put in place lead to another mistake. Dien et al. (2012) believe that many investigations do not consider aspects such as history and time, both in terms of going back and as a cause. Investigations need to go as far back into the history as possible rather than the common practice of beginning at the time of the active failure, going back only a few steps before the failure occurred.

The question that arises is despite what we know about accident causation and investigations, do we ever really learn from accidents? Lindberg, Hansson and Rollenhagen (2010) state that to prevent injury-causing incidents it is critical to learn from past events and near misses. Furthermore, the intention of reporting accidents is to facilitate organisational learning and to help prevent recurrences by implementing changes (Salmon et al., 2017). Hovden, Størseth and Tinmannsvik (2011) explain why organisations don't learn from accidents and provide a number of reasons for this. Factors such as:

- Blame may hamper learning
- Balances between liability versus learning are often antagonistic
- Regulatory pressure
- Feedback is often ambiguous
- Reports can be untruthful
- Contexts can be highly politicised
- There may be secrecy where people avoid blame

Failure to learn from accidents renders the investigation process ineffective. Investigating accidents for the sake of compliance does little for improving organisations' safety performance. Hovden et al. (2011) state that the results of accident investigations should provide useful information from which individuals, stakeholders, organisations and government bodies can learn from. Furthermore, Hovden et al. (2011) believe that learning from accidents does not only apply to individuals who are responsible for investigations, but should have a wide reach in terms of all agents in the system; for example companies, sectors and authorities. Therefore learning from accidents should be viewed as a set of systems learning rather than just one system learning (Hovden et al., 2011). For example, a number of railway companies in the same sector of rail transportation should share lessons learned.

As discussed in chapter 4, accidents occur as consequences of interactions of actors between layers and levels in organisations (Hovden et al., 2011; Leveson, 2004; Rasmussen, 1997). Often when accidents happen, many of the reasons behind why the event occurred were already evident within the system as warning signs. Hovden et al. (201, p. 99) refer to this as *"learning disability"* and attribute this to issues regarding safety management, cost cutting, reward structures, leadership, decentralisation, etc. Learning from accidents is the match between the recommendations of accidents and the follow up of these to ensure what is recommended is put into practice. When learning from accidents (and therefore from experience), one would expect that the number of accidents would reduce given the opportunity to learn from such events (Leveson, 2011; Ouyang et al., 2010). Leveson (2011) and Ouyang et al. (2010) state that accident analysis has almost become useless as not much progress has been made in reducing incidents with similar systemic causes. Leveson (2011) offers three possible explanations for this. Firstly it may be that the accident analysis methods do not discover the underlying causes of events. Secondly learning from experience does not work as it's supposed to, and thirdly learning is happening in the wrong places. Hovden et al. (2011), Jørgensen (2011) and Lundberg et al. (2009) support Leveson (2011) that learning from previous events is seldom done and if it is, question whether it is done properly. Jørgensen (2011) condemns what many investigations simply describe in a few lines of text as to what occurred and then go on to inform the person who was at fault to be more careful in the future. Furthermore, Jørgensen (2011) believes that accidents are either very rarely investigated or provide very little information about the cause of the event. This does little to prevent incidents from

recurring. For this reason many authors advocate the use of accident analysis tools, methods, and processes to support a deeper analysis of an event in order to achieve safety as an outcome (Baysari et al., 2008; Branford, 2011; Leveson, 2011; Reason, 2000; Underwood & Waterson, 2014).

Conducting accident investigations, especially in complex systems, requires practice as it is often the invisible or obscure components that are the real reasons for the accident, resulting in investigators overlooking important information. Jørgensen (2011, p. 38) states that *"The way the investigation is conducted reflects the groups skills and insight just as much as it will reflect the causes of the accident"* emphasising the importance of thorough accident analyses and also expert investigators. Clarke (1998b) contends that thorough investigations require cooperation between the parties involved, good communication, information sharing, openness and honesty, and avoiding placing liability and commercial sensitivity above the need for a thorough investigation. In South Africa, the high incidence of repeated occurrences and evidence of repeat findings and recommendations identified in this study, question whether any learning does take place.

Failure to learn from accidents can also be attributed to whether organisations value a just culture. Just culture refers to a supportive organisational environment that fosters trust, encourages open communication as a means to improve safety and clearly distinguishes between acceptable and unacceptable behaviour (Global Aviation Information Networking [GAIN], 2004; Khatri, Brown & Hicks, 2009). Members are allowed to express their concerns, ask questions and report errors, near misses and risky actions without fear of ridicule or punishment. This is because of an open, ethical and trusting environment (Khatri et al., 2009; Pepe & Cataldo, 2011). Dekker (2009) states that in accident investigations an account of the event is required to satisfy the demands of accountability, to contribute to the learning and development of the organisation and its safety system. However in inquiries, it is acknowledged that witnesses resist participating due to fear and a lack of trust entrenched in a blame culture (Dekker 2009; Dekker & Laursen, 2007; Khatri et al., 2009). Just culture seeks to combat these issues by encouraging a culture in which trust is established, thus improving the reporting of safety issues and errors (GAIN, 2004; Shorrock et al., 2014). Once a reporting culture is established, the organisation is provided with an accessible memory that then facilitates a learning culture in which information is used to provide feedback to the members, educate members and develop

and maintain safety (GAIN, 2004). Jeffcott et al. (2006) state that a just culture seeks to distinguish culpable acts from non-culpable acts and ensure effective communication regarding safety related information. Catino (2008) claim that organisations that foster a blame culture, attribute incidents to the fault and inattention of individuals where their actions are seen as criminal acts and the actors themselves as guilty. In these organisations the response to incidents usually involves punishing individuals using disciplinary action, removal and in some instances prosecution. Dekker (2009) and Khatri et al. (2009) assert that this cultivates and reinforces fear and distrust. The consequence of this is that members of such organisations rather respond with silence and withhold information regarding safety and accidents in order to protect themselves and avoid being reprimanded and punished (Dekker, 2009; Khatri et al., 2009). This does little for organisational learning and impacts on the reporting of occurrences, where underreporting occurs for fear of the consequences.

This research explores whether just culture is understood and operationalised in the South Africa railway system. A lack of a just culture, or conversely a blame culture, contributes to the effectiveness of the investigation system. Dekker (2009) believes that creating a just culture seeks to produce forward looking accountability. However, this requires that organisations recognise mistakes and respond with opportunities to improve safety and reduce the risk of occurrences (Dekker, 2009). In doing this, it encourages organisational learning due to the increase in shared information, the organisation's ability to learn from accidents and make appropriate improvements to reduce the risk of occurrences (Khatri et al., 2009). In this research the South African Railway Safety Management standard (SANS, 2009) produced by the RSR contains the word just culture, however offers no definition or explanation of the term. One of the interview questions for the investigators at the RSR and TFR was to determine whether investigators know what the term means, understand the concept and whether a just culture exists in the investigation system.

Another factor that impacts on the credibility of the findings and recommendations of an investigation is independence. Acting independently of a particular organisation or sector is important to remove any bias. Independence improves the quality, reliability and objectivity of the investigation process. An outcome of this research is to advocate for an independent transportation investigation body in South Africa as currently none exist.

5.6 Independence in accident investigations

Smart (2004) questions what is meant by independence, as this is dealt with differently in different countries. Smart (2004) affirms that in essence independence is about objectively examining all the evidence and circumstances, including looking into company management, regulatory frameworks, and the government department responsible for transport policies. Van Vollenhoven (2002) defines independence as free from influence, guidance or control of others.

Smart (2004) affirms that the biggest prerequisite for building trust in the public and in industry is independence, as this creates a level of comfort with the public that a thorough and objective independent investigation will be conducted. This is supported by Van Vollenhoven (2002) who believes that independent investigations are the only way to establish exactly what happened, as the actions of the team can be made transparent. The extent to which railway investigations are independent in South Africa is detailed in chapter 7. Van Vollenhoven (2002) affirms that independent accident investigations should be separated from an inquiry into the parties to blame. Furthermore, Van Vollenhoven (2002) states that in order for an independent investigation to be successful it needs to be anchored in law with regulations and provisions governing the investigators powers separate from any judicial investigations.

Smart (2004) highlights a further issue and that is the quality of the investigating body and the professionals involved. Investigators represent bereaved families, the public, and the survivors who will be interviewed. If the investigators are not able to establish credibility, expertise, and knowledge of the subject area, then this can limit the amount of information shared by interviewees. This influences the evidence that is gathered (Smart, 2004). Establishing a reputation for excellence requires that the accident investigation body recruit highly skilled, motivated, and professionally qualified staff for the important role of being an investigator. However, Van Vollenhoven (2002) states that not every country has independent investigating bodies and usually investigations are carried out by government inspectors. The role of government is to draft regulations and monitor compliance therefore government inspectors can never truly be independent. This is because they are too closely involved in conflicting interests making them both player and referee (Van Vollenhoven, 2002). The ‘impartiality’ of the RSR was briefly discussed in chapter 2

where the Operator (PRASA) and the RSR both report to the same ministry illustrating that the RSR is both a player and referee in the investigation system.

Safety is a complex subject in any business, with the dichotomy of productivity and safety known to many practitioners in the field. The conflicting interests often result in safety taking a back seat amongst discussions centred on profits, with parties involved standing to gain if the true causes of an accident are never revealed (Van Vollenhoven, 2002). There is consensus amongst various actors in the system that when a serious accident occurs there is a call for an investigation. The media, public, members of parliament, the government, etc. may all request an investigation, but the question that remains is how independent is the investigation in practice? The role of the media in the investigation system is discussed in the next chapter.

In a review of investigation inquiries, Smart (2004) identified that an important principle of an accident investigation body is its independence and that this should be recognised by the public and everyone in the industry. By means of an independent investigation body this ensures that there is no conflict of interest, reducing any 'cover ups' and creating a blaming game. Smart (2004) affirms that an independent body should be functionally independent of any national authorities and any party whose interest could conflict with the task entrusted to the body investigating. This body should also be provided with the means required to carry out its responsibility independently, should be able to obtain sufficient resources, and investigators should be given the status to guarantee their independence. Van Vollenhoven (2002) also emphasises that independent safety boards should be publically funded, anchored in law, autonomous, and be able to address recommendations directly to the concerned parties. This is the only way to ensure independence and is invaluable to society. Another advantage of a permanent independent safety board is that it can ensure recommendations are followed up, an important stage of the investigation process that is often overlooked. Examples of independent safety bodies internationally in the railway system include the Rail Accident Investigation Branch (RAIB) in the UK, the European Railway Agency (ERA), the National Transportation Safety Board (NTSB) in the USA, and the Australian Transport Safety Bureau (ATSB). In South Africa there is no independent accident investigating body for any mode of transport only Regulators who are Government agencies and are therefore not impartial.

5.7 Theoretical contribution of this study

The literature review consisted of three parts. Chapter 3 highlighted the importance and the application of HF/E and system paradigms in understanding why accidents occur. This set the scene to illustrate that this research focusses on system paradigms with the system of interest the entire accident investigation system. Chapter 4 explained the different approaches to accident causation with the modern view of moving away from traditional cause and effect approaches to systemic approaches. The latter address the role of the entire system. Accidents can occur because of actors and activities at any level of the socio-technical system, due to external conditions and due to the interactions of the parts of the system. This approach shifts away from using human error as the cause for an event. This chapter, the last of the literature review, discussed the application of system theory in accident investigations, the factors that influence the effectiveness of occurrence investigations and why learning from previous occurrences does not always happen. These three chapters provide the theoretical foundation for this research.

The literature predominates with accident causation models and the need for a systemic approach to determine why accidents occur. However; little critical analysis of the literature has focussed on the actual investigation process as a complex system and therefore a reason for why accidents continue to recur. This research argues that systemic factors inherent in the bigger rail socio-technical system (in which the system of accident investigations is in) impacts on the effectiveness of the investigation process and its outcomes (findings and recommendations). The effectiveness of accident investigations refers to the quality, objectivity, accuracy, reliability and validity of the process. Ineffective investigations impact on the accuracy of the findings and the appropriateness of the recommendations therefore contributing to recurrences as the real reasons for why the event happened remain unnoticed.

This research examines the entire system of accident investigations as a complex system on its own and *not the accident itself.* Accident causation and the different methods used to highlight how the system contributes to accidents are adequately addressed in the literature. The novelty of this research is seeing accident investigations as its own complex system, where systemic factors in the system impact on the effectiveness of the investigation process and its ability to prevent recurrences. Rasmussen's (1997) Risk Management Framework was used in this research to illustrate the South African rail

socio-technical system hierarchy. To contextualise the framework to the South African context necessary adjustments were made to the framework and this is discussed in the next chapter. An Accimap is developed in chapter 7 to map the systemic factors for each level of the railway hierarchy and how these contribute to the effectiveness of the investigation process and a recurrence of accidents. This is discussed in chapter 8.

This research contributes to accident causation theory and its theoretical contribution lies in the useful and novel application of Rasmussen's work and Accimap. This research demonstrates how the Accimap, traditionally an accident analysis tool, can be used to analyse the systemic factors influencing the system of accident investigations. Therefore this study extends Rasmussen's work and demonstrates that the use of the Accimap can extend beyond its traditional practice as an accident analysis tool. The Accimap is a useful tool that illustrates the complexity of the *system of accident investigations* that before this research was not known to be a complex system on its own. This research contributes to existing theory by illustrating that the system of accident investigations is a sub-system within the bigger rail socio-technical system. Furthermore, the extension of Rasmussen's work and Accimap explains how the system of accident investigations can influence the findings and recommendations (outcomes) of the investigation process and also contribute to a recurrence of events. The systemic approach adopted in this study is unique to accident investigations because it is the system of accident investigations that is being examined not the accident itself. In this sense, the actual railway Operators are only part of the system to the extent that they determine the operational explanations (or failure to give an explanation) for why the accident occurred. The investigation system is therefore largely affected by the higher echelons of the system i.e. by those who inform and develop policy, the public, history and the environment. The deficiencies in the investigation system and the disparities of the different parts of the system add to the complexity of the system of accident investigations. The final chapter of this research discusses the theoretical contribution of this research further.

5.8 Concluding remarks

Tragic incidents, as unfortunate as they are, do provide valuable opportunities to understand and improve the safety of complex socio-technical systems. This chapter highlighted the importance of accident investigations and the need for these to be effective and independent to prevent recurrences. The importance of adopting a systems approach in

accident investigations allows investigators to perform more powerful investigations and therefore improve the learning from events. Investigators need to realise that basic linear cause and effect analyses are no longer sufficient for complex socio-technical systems. An overview of accident investigations, the requirements for effective investigations and the need for independent investigations were discussed. Leveson (2011) questions why accidents with the same or similar causes keep happening and Le Coze (2013) asks whether we ever really learn from accidents. These questions formed the basis for conducting this research as the researcher identified the same problem with the South African railway industry. The manner in which accident investigations are conducted impacts on the credibility of the entire accident investigation system.

The following chapter, chapter 6 details the methods used in this study to illustrate the theoretical contribution of this work. A qualitative mixed methods approach was adopted. The sources of data were determined based on the hierarchical structure of Rasmussen's (1997) Risk Management Framework, the theoretical framework of this research.

CHAPTER 6: METHODS

Chapter 3, 4 and 5 discussed the literature relevant to this research. The importance of including HF/E and system paradigms in accident causation was highlighted. Rasmussen's (1997) Risk Management Framework was selected as the most relevant theory for this research to illustrate the structure of the system of accident investigations in South Africa. In this chapter the framework is operationalised for the South African investigation system illustrating the various levels in the hierarchy that influence the investigation of occurrences. The purpose of this chapter is to provide the steps taken in order to address the research question i.e. *what are the systemic factors influencing the effectiveness of the investigation process in South Africa?* This chapter highlights the methods adopted to determine the systemic factors, and to illustrate that the system of accident investigations is a complex system. Qualitative research methods were used in this study. This is because qualitative research is primarily exploratory and gives the researcher data which is deep and rich. It is used to gain an understanding of underlying meanings, language, opinions, motivations and insight to address a particular problem (Grosvenor, 2000). In this study, the problem is that railway occurrences in South Africa remain high, despite the RSR and Operators conducting occurrence investigations. The research design, steps taken to conduct this research, data collection methods and the ethical issues involved are explained. The following section explains the hierarchy structure based on Rasmussen's (1997) Risk Management Framework.

6.1 Operationalising Rasmussen's (1997) Risk Management Framework

Rasmussen's (1997) Risk Management Framework was discussed in chapter 4 and describes the structural hierarchy of actors and organisations in a system. These include:

- Government
- Regulators and Administrators
- Company
- Management
- Staff
- Work

The above levels served as sources from which the data was collected for this research. For the purposes of this study, the system of interest is the system of accident investigations and not the accident itself. In order to contextualise Rasmussen's (1997) Risk Management Framework to suit the South African railway context adjustments to the levels were necessary. Rasmussen (1997) states that the exact number of levels and references of each level can vary depending on the system being studied. As was explained in chapter 4, there were a few difficulties in doing this, particularly at the Management and Staff levels. The *Staff* level generally refers to operational front line staff, for example a train driver or signaller. In this study looking at the investigation system, the Staff level refers to the individuals who conduct investigations. However, investigators were also *Management*, as was identified in TFR (Operator/Company) who did not have appointed investigators, but by virtue of being a Manager could investigate. This is a finding in itself, given the skills and competencies required to be an investigator and whether the Managers are equipped with such. This is further discussed in the results chapter. Operational front line staff are not responsible for the investigation process as their role in occurrence investigations is to act as witnesses. They do not play any role in the administration and organisation of investigations. Operational staff in the investigation system act as informants. Other witnesses observed in the observations also acted as informants in this study and in the review of the accident investigation reports. This is because of their involvement in the incident and the part they played in conveying (or not) information. Informants formed part of the secondary data gathering. In terms of the *Work* level in the system of accident investigations, this refers to the actual work of conducting an investigation or inquiry

An additional adjustment to Rasmussen's hierarchy is the inclusion of the *Public* as a level in the system of accident investigations. Rasmussen's (1997) Risk Management Framework does not include the public as an actual level but makes reference to public opinions and pressures influencing the system (dynamic force) at a Government level. Public opinion regarding railway safety was deemed an important level to include in this research and is represented by way of the media. The role of society, represented by the public is acknowledged as an external pressure that can force the Government to introduce legislation and control the practices of safety. However, in this research the inclusion of the public as part of the system of accident investigations gives more impetus to the public to increase pressure on the Government. With reference to the system of accident investigations, the demands of the public on the Government are that accident

investigations should be thorough, effective and independent. This is important to not only curb the number of accidents, but to ensure that the many citizens relying on rail transport to commute to work, or customers transporting freight, can do so safely. Furthermore, the purpose of including the public as a level rather than an outside pressure is because the author believes that the role of the public is far greater than just an external pressure especially in South Africa. The socio-economic conditions and the historical context have resulted in many people relying on the South African Government to provide safe and reliable transport after years of underinvestment, segregation and the deterioration in rail infrastructure. Furthermore, the increase in urbanisation has resulted in greater demands for rail transport as a mode of travel to get to work (DoT, 2015). The inclusion of society as part of the system of interest can therefore play a more significant role in determining the systems performance. An additional reason for including the public (represented by the media) as a level on its own is because the media influences the severity and level of an occurrence investigation. The governance documents at the RSR and TFR revealed that if an occurrence receives media attention and public outcry that this increases the level of investigation. In other words, the occurrence is deemed more serious than may have originally been classified. This is discussed further in the results chapter. The public (represented by the media) therefore is an important decision maker in the system of accident investigations.

Operationalising Rasmussen's (1997) Risk Management Framework to the accident investigation system in South Africa is summarised in Table 6.1. Table 6.1 includes the hierarchical structure, based on Rasmussen's (1997) work, in the left column. The role of each level in the accident investigation system in South Africa and the methods used to collect the data are explained in the middle and right column respectively.

Table 6.1 The South African rail hierarchy structure

Hierarchy structure	Role in the investigation system	Data collection methods used in this research
Public Public opinion and pressure ↓	-Society and the media can influence the Government to control the practices of accident investigations	-Media analysis of occurrence reporting to determine if the public is aware of the state of railway safety to effect pressure

Government (DoT)	-Develop laws and legislation to formalise processes -Not involved in conducting investigations	-Interview at the Rail Branch -Analysis of legislation: National Railway Safety Regulator Act No.16 of 2002 (2009)
Regulator (RSR)	-RSR converts legislation into industry rules, standards and regulations for safe railway operations -RSR develops internal policies and procedures for occurrence management -RSR conducts investigations	-Analysis of SANS 3000-1: 2009 -Analysis of RSR internal occurrence management policies and procedures -Interviews with investigators at the RSR -Analysis of RSR investigation reports -Observations of RSR inquiries
Company (Transnet Group)	-Safety regulations are integrated into company rules and policies -Transnet Group develops a group policy for BOI's for all its Operating Divisions	-Was not included - focus is on the railway operating company, TFR -Analysis of Transnet Group BOI Policy implemented by TFR
Company/ Operator (TFR)	-Railway safety regulations from the RSR are integrated into TFR rules and policies -Develops internal company policies and procedures for occurrence management	-Analysis of Transnet Group BOI policy implemented by TFR -Analysis of internal occurrence management policies and procedures
Management -Corporate Safety Office (CSO) -Operational Management at the depots	-Manage and supervise staff activities with reference to the safety rules and policies initiated at the company level -CSO conducts investigations -CSO reviews investigation reports from the depots -CSO analyses incidents	-Analysis of investigation reports -Interviews with CSO Management and Line Management responsible for conducting investigations -Observation of an investigation inquiry

(Line Management)	-Line Management must investigate every occurrence in their jurisdiction	
Staff* (CSO Managers and Line Management) **No appointed investigators in the entire company. Investigate by virtue of being a Manager*	-Responsible for the entire investigation process, administration, organisation and conducting of occurrence investigations -Develop investigation reports with findings and recommendations -CSO monitors that Line Management implements corrective actions	-Analysis of investigation reports -Interviews with CSO and Line Management who conduct investigations -Observation of an investigation
Work	-Actual accident investigation	-Results and Accimap illustrate the investigation system

The above table highlights the hierarchical structure in the system of accident investigations. The following sections details the research design adopted in this research.

6.2 Research design

This research used a multi-method design approach (McNaughton Nicholls, Mills & Kotecha, 2014) and included: a media analysis of railway accidents reported, a governance document analysis, a review of investigation files, interviews with investigators, and observations of inquiries. The interviews served as the central method. The core data from the interviews was compared to the data from the other methods. The advantage of using a multi-method design is that it provides scope for repeated re-examination and reinterpretation of different types of data. The interwoven interpretations create rich data, making more sense of the research topic (McNaughton Nicholls et al., 2014).

In contrast to quantitative research, which uses statistical analysis, qualitative research focusses on observing and describing events as they occur in order to establish a greater understanding of specific trends (Strangor, 2007). This research adopted a qualitative

approach to explore the factors, reasons, and challenges that originate within the investigation system that contribute to the manner in which occurrences are investigated. A qualitative approach provides a rich picture of the context in which accidents occur and how these are managed through accident investigations. Qualitative research is useful to go deeper into issues of interest and explore nuances related to the problem at hand. That is, if accidents are being investigated, why then are there still a high number of railway occurrences in South Africa?

The aim of qualitative data analysis is to identify meanings and interpretations to form a conceptual framework or model which is used as a reference for further analysis (Farrington-Darby, Pickup & Wilson, 2005). Despite the benefits of qualitative research, cognisance is given to the role of the researcher, as analysing records is largely subjective. This is due to the human element involved in choosing what data to analyse and how this information can be decomposed to uncover participant's feelings, interpretations and meanings (Hignett, 2005). It is important in any qualitative study to recognise the researcher's impact on the research, which in turn impacts the interpretations and the findings. This is because the researcher is a fundamental part of the interpretation of the findings, and the background of the researcher can also play a role in interpreting the information.

An example of a qualitative technique to analyse data in this study is that of thematic content analysis and thematic analysis. This method is used to systematically identify and organise patterns of meaning, or themes within the data set in order to be able to identify, analyse and report on themes that emerge from the data (Braun & Clarke, 2006). Content analysis shares many of the same principles and procedures of thematic analysis. However, thematic analysis allows the researcher to focus on meanings across a data set, for example across a number of interviews so as to make sense of collective shared meanings and experiences (Braun & Clarke, 2006; Marks & Yardley, 2004). Typically, both qualitative approaches analyse artefacts of social communication, such as written documents or transcripts of recorded verbal communication with the aim of making inferences by identifying themes present in the documents both systematically and objectively (Berg, 2004). The definition of a theme is a specific pattern of interest found in a set of data which is worth further investigation (Marks & Yardley, 2004). A number of themes or patterns may become evident across the data set, with the purpose of the analysis to

identify those relevant to answering the research question. Braun and Clarke (2006) state that thematic analysis is widely recognised as a valuable and increasingly popular qualitative method. As flexibility is one of the benefits of this type of qualitative approach, the researcher is able to fully, and unrestrictedly, interpret the various aspects of the data and report on semantic meanings and/or deeper latent meanings that lie behind what is obvious. Therefore the researcher plays an active role in identifying the themes that are of interest; however there is a need to acknowledge that this can lead to researcher bias. Despite this, the potential themes that will emerge from the data are acknowledged and recognised as judgements and decisions taken by the researcher to include and discuss (Braun & Clarke, 2006).

Document analysis is another example of a qualitative method. It has both advantages as well as limitations, and according to Bowen (2009), is an efficient, cost effective and stable research method. Document analysis is efficient in that it requires the researcher to select data rather than collect it requiring less time, however the actual analysis is an iterative process and thus still requires a significant amount of time. The document analysis method also has some limitations, such as producing insufficient detail needed to answer a research question as documents are produced according to an established purpose (Bowen, 2009). Biased selectivity can occur as the selection of some documents over others may yield biased reflections (Bowen, 2009). It is for these reasons, that the researcher adopted a multi-method design to improve the validity and reliability of the data collected by verifying the data across the methods for similarities and differences.

Triangulation is an approach used in qualitative research design in which evidence is deliberately sought from a number of independent sources and by different means to improve the validity of the outcomes. Different sources of information help to confirm and improve the clarity of the findings (Lewis, Ritchie, Ormston & Morrell, 2014). If conclusions from each method are the same or similar, then validity is established. In this study *triangulation of sources* was used. This is where data is compared from different qualitative methods (Lewis et al., 2014). For example information collected from the investigators' accounts in the interviews was therefore compared to the information in the document analysis and the same for the findings collected from the observations and investigation files. One of the risks of data triangulation is that multiple sources can be exposed to researcher biases (Barbour, 2001); i.e. focussing on a singular construct to

support or refute a hypothesis, or in other words, forcing a finding. Convergent results will support the research question whereas divergent results will require further exploration and explanation. Despite this, triangulation is beneficial as the verification of the data helps to improve the validity of the information, which is particularly important in qualitative research.

6.3 Data collection methodologies

A multi-method design was used in this research consisting of different sources of data and methods. Figure 6.1 briefly describes each method with the following sections detailing each method separately.

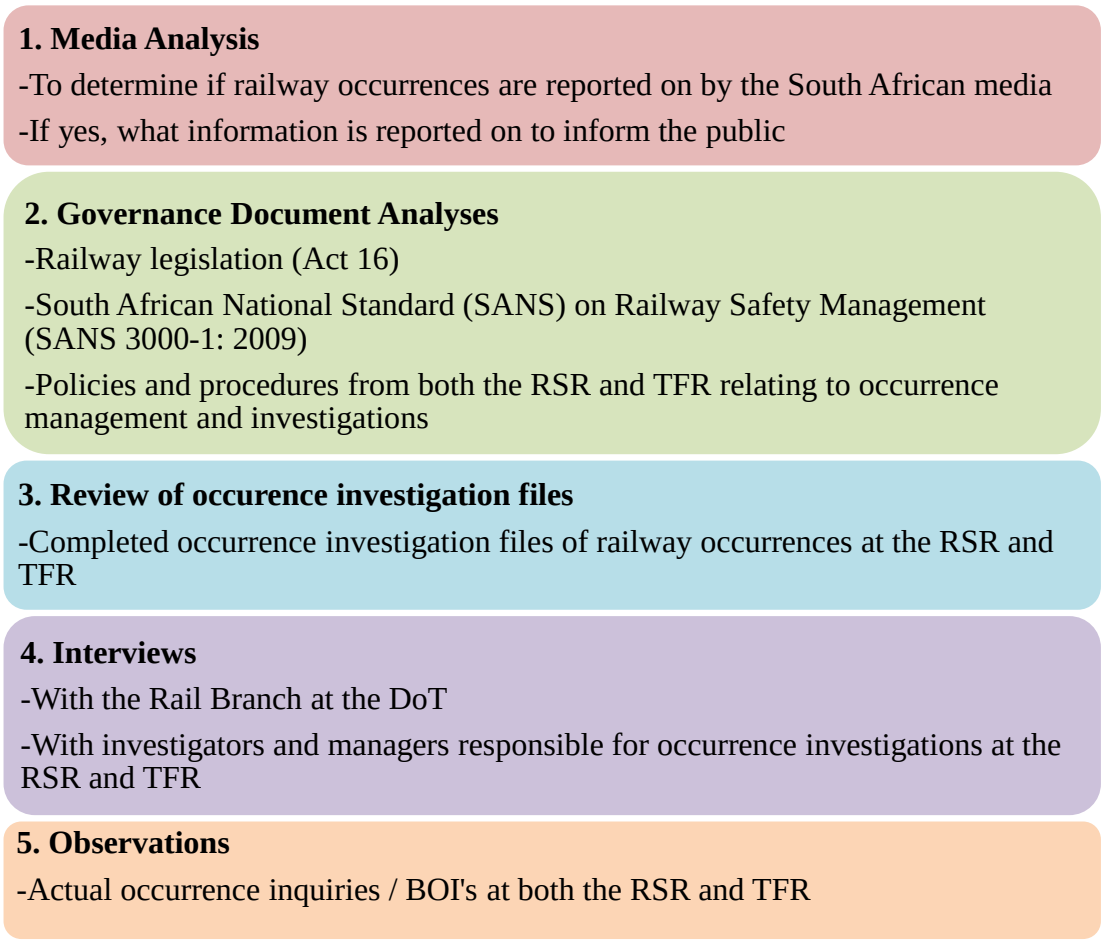


Figure 6.1 Methods and sources of data used in this research

6.4 Media Analysis of railway occurrence reporting in South Africa

The purpose of the media analysis was to determine whether the public are aware of the state of railway safety in South Africa given the number of railway occurrences. The

public as users of both passenger and freight rail require safe, efficient and reliable transport. One way that the public can be informed about railway occurrences and railway safety is through the reporting of these in the media. It is proposed that if the public are not adequately informed about railway occurrences and railway safety, then public opinion and pressure will not be strong enough to influence the South African Government to control the practices of safety. In this research the practices to control safety refer to thorough, independent and effective occurrence investigations. Van Vollenhoven (2002) believes that independent investigations are of great significance to society as they are required to establish what happened and to put any concerns of the public at ease. In addition to the reporting of occurrences by the media, the type of information reported on is also important. If railway accidents and incidents are reported on in the public domain, what information is provided to society? Is society acceptably informed by the media about the state of rail safety as a mode of transport? Furthermore, is the media even aware themselves of the state of railway safety in South Africa in order to sufficiently inform the public? These questions are addressed in the results chapter. The results and information from the media analysis were also used in the development of the interview questions.

The role of the media is to select certain issues that they believe to be worthy of reporting and present the public with some kind of information relating to the event. The media can be utilised to determine the public perceptions of what is regarded as an important matter of concern, in addition to the risks attributed to that significant topic (Anden-Papadopoulos & Pantti, 2013; Falasca, 2014; Singer & Endreny, 1993). Therefore, it is fair to say that South African citizens are informed about railway occurrences largely by way of what is portrayed in the media. Literature suggests that the more newsworthy an occurrence is perceived to be by journalism standards (for example how relevant, objective and accurate an event is portrayed), the more attention it will receive in the public arena (Anden-Papadopoulos & Pantti, 2013; Boudana, 2011; Hutter & Lloyd-Bostock, 1990; Le Coze, 2013; Singer & Endreny, 1993). Furthermore, occurrences that are regarded as being more newsworthy are those that have resulted in greater detrimental outcomes (such as the loss of life, environmental damage, or enormous expense). These outcomes increase the likelihood of reporting these types of occurrences as they receive greater attention and recall from the public (Singer & Endreny, 1993). What the public learns from the accident is therefore influenced by what is covered by the media. Cotter (2010) states that there are

certain factors to consider while investigating the notion of newsworthiness and these include:

- The type of information reported
- The headline
- How much space or time is devoted to the topic
- Inclusion of visuals or not

Hutter and Lloyd-Bostock (1990) provide further reasons as to why it is important to report serious accidents in the media:

- Media reporting communicates the risks associated with using rail as a means of transportation.
- Attention is brought to the officials responsible for regulating health and safety to public attention.
- Allows for public and sometimes political scrutiny. This may appear to be a negative way of justifying why railway accidents should be reported however, citizens have a right to know how safe (or unsafe) railway transportation is in their country. If public lives are at risk, or the economy of a country is affected, this warrants a greater need for reporting.

Added to the above is that the media also influences the level of severity of an investigation conducted by the RSR and TFR. The greater the public outcry and media attention, the more likely the RSR will select the incident to investigate. Whereas in TFR, the level of investigation will be escalated to the CSO to conduct an investigation. The assumption is that if there wasn't media and public attention would the occurrence get investigated? Furthermore if it does get investigated how thoroughly is the event investigated? These questions are addressed in the results of this research.

6.4.1 Sample

A sample of media reports were selected based on a survey of the South African media to identify all articles pertaining to rail, railway safety and railway occurrences. Media reports that were considered were those published during 2008 to 2013. In 2008 the RSR

started publishing its annual State of Safety reports and this method was conducted in 2014. One of the steps in this method was to compare the number of media reports with the number of occurrences in South Africa. The RSR State of Safety reports were used as a reference. The media survey was only performed on articles reported in the South Africa media; however a web search on two international news broadcasters, namely Cable News Network (CNN) and the British Broadcasting Corporation (BBC) World News was also performed. This was conducted to identify if any South African railway occurrences featured in international news, increasing the significance or *newsworthiness* of the occurrence (Hutter & Lloyd-Bostock, 1990). Railway accidents in South Africa did not appear in the CNN headlines and two media reports for train collisions were reported in the BBC news during the period of 2008 to 2013.

There were no requirements as to the length of the media reports and there was a maximum requirement of 60-90 media reports for railway occurrences and incidents. The collected articles revealed the frequency, and level of detail, of railway occurrence reporting. Articles in the media had to be railway safety related; however the reporting may have also included separate issues; for example investment, security, regulation and the economy. Articles were not restricted to any one railway Operator responsible for the occurrences and included articles pertaining to passenger and freight rail occurrences. Reports mentioning the RSR and the South African Government in relation to rail safety were also included. This was in order to capture the hierarchy according to Rasmussen's (1997) Risk Management Framework.

6.4.2 Instruments

The media survey focussed on online print media only, for example newspaper and magazine articles. All other forms of media, for example audio, video or social media were excluded. Cherian and Jacob (2013) in a study of university students' attitude towards online and print publications found that in this modern age, next to television, people obtain information about daily events from the internet, and newspapers are ranked as the third news platform. Many people read newspapers via mobile phones accessing social websites to read newspapers with information supplied online quicker than waiting to get a newspaper.

Two South African online news media sources were used: *News24* and *S.A. Media*. News24 is a premier online news resource available to the public and allows readers to search across a number of digital publishing brands for any article using keywords (News24, n.d.). S.A. Media is a comprehensive database that consists of more than 3 million newspaper reports and periodical articles (S.A. Media, n.d.). Articles stored on the database include 22 categories relating to transport, politics, economic affairs, industry, health and social issues, and local and national government (S.A. Media, n.d.). Furthermore, S.A. Media was appropriate for the research as the database covers more than 120 South African newspapers and periodicals. The reasons for only conducting the survey on online news media, as opposed to physically browsing through print newspapers were due to the following:

- The articles could be accessed immediately.
- It was convenient as the researcher only required a computer and internet access.
- It minimised the time consuming nature of manually searching through newspapers and periodicals as the researcher could insert keywords to search through the volume of information.

The researcher does acknowledge that there is an element of bias in what media reports were provided based on the keyword search and the type of media (online print media) used. Other media sources and keywords may have provided fewer or more articles. However, a number of articles were identified from the online print media only, confirming that railway occurrences are reported on in the media. By using the S.A. Media database, the researcher was able to cover a large number of newspapers across a range of board categories, reducing the bias in the types of reports identified. The online format was able to provide an answer fairly quickly through the use of keywords in the search function. The purpose of the media analysis was primarily to determine if railway occurrences are reported on in the media, and if so, what content is provided to inform the public.

6.4.3 Procedure

The process began with a search on railway related articles on News24 followed by a survey of the database available on S.A. Media, accessed through the University's online library resources. Table 6.2 details the keywords used to search News24 and S.A. Media.

Table 6.2 Keywords used to search the media

Rail	Railway accidents
Railway	Railway level crossings
Railway occurrences	Railway collisions
Railway incidents	Railway cable theft
Railway security incidents	Railway vandalism

A second step was to compare the number of media articles on railway occurrences with the statistics published by the RSR in the annual State of Safety reports. This comparison determined whether all railway occurrences are reported in the media, and if not, what is reported to the public so that they are acceptably informed of the state of railway safety in South Africa. The operational occurrences reported by the RSR in the State of Safety reports for 2008 to 2013 were compared to the media findings for the same period.

The next step was to then identify themes present in the news articles to determine what type of information is provided to the public through the media. Three categories emerged from the preliminary analysis, namely *operational*, *security*, and *regulation*. The categories were also in line with the RSR reporting of operational occurrences, for example derailments and collisions and security incidents, for example vandalism and cable theft. Articles relating to regulation pertained to the role of the RSR in enhancing railway safety; for instance, the issuing of improvement directives to prospective train Operators.

A formal analysis rubric was developed for each category of reporting. This was used by the researcher to identify and extract critical information about railway occurrences and incidents portrayed in the media. Berg (2004) asserts that the benefits of using a rubric allow for no arbitrary or superficial interpretations of the data, enables the establishment of the rules for data selection, and it assists future researchers to examine the data set and obtain similar or comparable results. Table 6.3 depicts only the headings of the rubric

developed for the media analysis. The full tables with all the information from the different media articles can be provided upon request.

Table 6.3 Formal analysis rubric from the media analysis

Article number	Nature of the incident	Themes present
Article title	Location of the incident	People quoted in the article
Date of publication	Severity of the incident	Examples of quotes
Source of publication	Word count	

In total 133 articles were collected from the review of the media reports. Articles that discussed the same occurrence, or mentioned the same piece of news, incident or regulation were labelled A, B, C, etc. and were counted as one media report. As a result, there were 55 operational occurrence reports, 23 security incident reports and 12 regulatory reports. Themes and specific quotes were identified and included in the formal analysis rubric.

A comparison of the number of occurrences and incidents found in the media to the actual number of occurrences that were stated in the RSR State of Safety reports was performed for each of the RSR financial reporting years. The quality of the reports, the level of detail reported on, the major themes identified and the important quotes present in the report were important to note. In order to determine the level of detail, a word count was performed on each article with the average word length for each reporting category calculated. The purpose for doing this was to allow the researcher to explore which category received the most media attention. The final procedure was then to analyse the content and meaning of themes that emerged from the data.

6.4.4 Data analysis

The purpose of the media analysis was to determine whether or not South African media reports on railway occurrences, and if they do, what is the content that is reported? For the data analysis, the researcher combined thematic content analysis, namely that of an inductive data driven approach, with traditional forms of content analysis, including frequency analysis. According to Berg (2004), thematic content analysis as a qualitative approach, requires analysing artefacts of social communication, such as written documents or transcripts of recorded verbal communication. The aim is to make inferences by

identifying themes present in the documents both systematically and objectively. The data analysis focussed on the combination of four categories from each of the media reports. These included words, themes, characters and semantics, and are briefly described:

- *Words*: The average word length of each of the categories was considered in order to compare which categories received more attention. The words attributed to each media report were calculated and used as a way to demonstrate the level of significance given to the media article.
- *Themes*: Themes were generated from the media reports in order to determine what information the public is informed about through what is reported on in the media. Main themes and sub themes were established.
- *Characters*: Paying attention to characters or people that were either quoted or referred to in the media reports provides significant information to the analysis. For instance, the mentioning of a political figure, for example a Minister, and whether this would increase the media attention given to such a report.
- *Semantics*: In addition to the number and type of words present in each media report, the semantics of headings was noted and discussed. It is acknowledged that article headings that contain captive language are more likely to *grab* the attention of the public. Cotter (2010) states that the article's heading is the first source of information given to the reader. If the reader perceives the heading to be interesting, then the reader will more likely read the rest of the article. The more the media article is able to shock, anger or revoke a response in the reader by using strong emotive words, the more the reader is drawn into the message of the article.

The results in chapter 7 highlight the findings from the data analysis. A brief synopsis of the results illustrate that on average, operational occurrences had the lowest number of words per article (331), despite the highest number of articles identified in this category. The average number of words for security related articles was 367 words. Regulation articles were the longest with an average of 417 words per article. In total 15 themes were identified from the thematic content analysis and examples of captive headings are further discussed in chapter 7. The next method, the analysis of governance documents is discussed in the next section.

6.5 Analyses of governance documents

Governance documents include all railway occurrence investigation related legislation, standards, policies and procedures produced by the various hierarchies in the investigation system. The purpose of this method was multiple. Firstly the documents served as background information to familiarise the researcher with the processes and requirements in terms of occurrence investigations for the DoT, the RSR and TFR. Secondly the researcher was able to gain an understanding of the various roles and responsibilities of the different levels in the system as depicted in Rasmussen's (1997) Risk Management Framework. Thirdly comparisons were drawn between the various documents. For example legislation developed at a Government level (Act 16) was compared to what was then mandated to the Regulator in terms of their role as overseer of railway safety and enacted in the RSR's internal governance documents. The Regulator then develops standards for railway Operators to adhere to, for example SANS 3000-1: 2009 Railway Safety Management (SANS, 2009). The Operator (TFR), responsible for railway safety then develops its own governance documents based on the minimum requirements set out in the RSR standards. The RSR and TFR in the hierarchy structure are also required to have their own internal policies and procedures for the investigation of occurrences as they both conduct investigations. These are developed based on the requirements of Act 16, other related legislation and standards. Policies and procedures of the RSR and TFR were compared to the respective governance documents. Procedures for occurrence management developed by each organisation (RSR and TFR) were also compared to the information stipulated in the specific organisations policies. This was to determine compliance to occurrence management processes. Fourthly, the information captured in the documents was also used to develop the interview questions. Lastly, the documents were used as a means of verification against the data collected in the interviews, the observations, and in the analysis of the investigation files in order to determine if what is stated in the policies, procedures and standards a) happens in practice, and b) is well understood by the investigators.

Furthermore, the comparison of the documents to other data sources allowed for any discrepancies and deviations to be noted. The governance documents were also identified as examples of systemic factors that influence the investigation process of railway occurrences if the following were evident:

- Legislating and documenting requirements that are ambiguous or not necessarily familiar to those who are required to implement them. For example the concept of just culture is mentioned in SANS 3000-1: 2009 Railway Safety Management (SANS, 2009) but is not defined or explained. The RSR expects that Operators will implement these concepts with the assumption that the folk have the required understanding to effectively implement the concepts. If gaps exist in legislation and standards this filters to the next level in the hierarchy system (Rasmussen, 1997).
- If the documents were in draft format but were being implemented.
- If the documents were implemented and not signed off by any higher authority.

6.5.1 Sample

Legislation (Act 16), standards, policies and procedures pertaining to railway occurrence investigations were requested from both the RSR and TFR where these were not publically accessible. The DoT does not investigate railway occurrences therefore no policies and procedures relating to occurrence investigations were collected. Act 16 and SANS 3000-1: 2009 Railway Safety Management (SANS, 2009) are both accessible in the public domain and were downloaded from the RSR's website. Act 16 was reviewed in order to represent the Government level of the system and to determine what the expectations are for the various levels in the investigation system.

The RSR is required to develop standards which provide the *minimum* requirements for railway Operators to adhere to. In terms of the investigation system, the South African railways are legislated by SANS 3000-1: 2009 Railway Safety Management (SANS, 2009). Subject areas include Occurrence Management, Occurrence Investigations and Human Factors Management. SANS (2009) was developed to establish a uniform national standard for railway safety management. It prescribes the minimum requirements of an appropriate risk management system for railway Operators. Operators are required to identify and manage technical and operational hazards and risks to people, property, and the environment (SANS, 2009).

Each level in the hierarchy structure is an organisation in itself. Therefore as a company they are required to have policies and procedures. Both the RSR and TFR investigate occurrences. The RSR's mandate is to oversee railway safety and it does not have to

investigate every occurrence. Operators, for example TFR, are required to investigate *every* occurrence. Policies, procedures and standards for occurrence investigations were requested from the RSR and TFR. The researcher was not prescriptive in what documents should be made available or in terms of the number of documents. Instead the RSR and TFR were asked to provide any documentation pertaining to occurrence investigations and occurrence management. This was done in terms of minimising any bias that would be created if the researcher requested certain documentation.

6.5.2 Instruments

Instruments included electronic and/or hard copies of Act 16, standards, policies and procedures, manuals or guidelines and any other relevant documents relating to occurrences, occurrence investigations and occurrence management. These were provided to the researcher by the RSR and TFR. The list includes the sample of documents collected however; the actual names of all the documents are not always included due to confidentiality reasons:

- National Railway Safety Regulator Act No.16 of 2002 (2009), DoT
- SANS 3000-1: 2009 Railway Safety Management (SANS, 2009), RSR
- SANS 3000-4: 2011 Human Factors Management (SANS, 2011), RSR
- RSR State of Safety Reports 2008-2015
- RSR Annual Reports 2008-2015
- Occurrence Reporting Manual, RSR
- Human Factors Protocol, RSR
- Occurrence Investigation Procedure, RSR
- List of occurrences investigated for 2014-2015, RSR
- Board of Inquiry (BOI) Policy, TFR
- Occurrence Investigation Procedure, TFR
- Railway operational occurrence statistics, TFR
- List of occurrences investigated for 2014-2015, TFR

Not all of the documents were signed off by the designated authority and some documents were in draft format. These are findings in themselves and are discussed in chapter 7.

6.5.3 Procedure

In terms of obtaining the information, the researcher held a number of introductory meetings with the RSR and TFR to request the information listed above. The information was either sent to the researcher electronically or in hard copy for the researcher to analyse. Publically accessible documents were retrieved from the internet. Where a certain document made reference to an applicable document which was not supplied to the researcher, this document was then requested.

6.5.4 Data analysis

In terms of analysing the information from the documents, no formal analysis such as thematic content analysis was conducted. The purpose of the document analysis was firstly to do a checking process between what was stipulated in Act 16 to what was written in internal documentation of the RSR and the standards developed by the RSR. This allowed the researcher to determine if there was alignment or any gaps. The checking process was repeated for each level of the system (i.e. whatever was required to be in the Regulator's documentation as required from the DoT, to what was required to be in TFR's documentation as stipulated by the RSR). A comparison was performed on each level of the system's documentation and compared to the level above for alignment. The purpose of the document analysis allowed the researcher to determine compliance and to identify any gaps between the levels of the system. Furthermore, the documents were also used to develop the interview questions. Comparisons were also made with the other data collection methods. For example, the information from the investigation files, the interviews and direct observations. Triangulation improves the validity of the findings if similar findings are established from various sources. It was evident from the analyses that what was written in the policies and procedures does not always happen in practice. The results are further explained in the next chapter.

6.6 Evaluation of occurrence investigation files

Occurrence investigation files contain all the evidence pertaining to a particular occurrence. Examples may include:

- An indication of the chairman of the inquiry
- List of panel of members who conducted the interviews with the witnesses

- List of evidence collected
- Photographs of the occurrence
- Initial reports
- Witness statements
- List of findings
- List of recommendations
- Final investigation report

The purpose of collecting this data was to understand the investigation process, what evidence and information is collected by the RSR and TFR when conducting an investigation, the procedures and methods used for collecting evidence and to determine how the conclusions of the investigation (in terms of the findings and recommendations) are derived. The data collected also provided the researcher with cues to use during the observations and the interviews.

6.6.1 Sample

The sample included occurrence investigation files for investigations completed by the RSR and TFR. The researcher requested access to completed investigations for the period of 1 April 2014 to 31 March 2015 from both organisations. This time frame was selected as it was both organisations' financial reporting year prior to when this data collection method commenced.

The analysis of the governance documentation highlighted in the previous section enabled the researcher to identify that occurrences are categorised into varying levels of severity at both the RSR and TFR. In chapter 2 it was highlighted that the RSR categorises occurrences into 3 levels (Level 1 to 3) and is not required to investigate every operational occurrence. This was detailed in the governance documentation reviewed. At TFR both the CSO and Line Management investigate occurrences. The CSO investigates the most severe occurrences (Level 1 and 2) and also reviews Line Management investigations. Line Management must investigate every occurrence, irrespective of the level. For the purpose of this research only investigation files at the CSO were reviewed. This is because Line Management investigation reports are submitted as part of the evidence for the CSO

investigations. The researcher was also able to evaluate the Line Management investigation reports while reviewing the CSO investigation files.

In total 11 investigation files were reviewed at the RSR and 15 for TFR. For the purposes of this part of the methods, the numbers of files provided were sufficient as the same information reoccurred, the researcher was able to understand the investigation processes followed and was able to note the types of evidence collected. Saturation of information was reached in terms of the types of documents in the files and the content thereof.

6.6.2 Instruments

Instruments included the completed investigation files for the RSR and TFR and were reviewed at the premises of the respective organisations. A list of the occurrences for the reporting period of 1 April 2014 to 31 March 2015 were provided to the researcher as part of the railway statistics collected during the document request step. This allowed the researcher to complete a checking process of occurrence investigations completed with the total number of occurrences for the reporting period. Completed investigation files were provided to the researcher upon requesting the investigation files in advance.

In chapter 2 the state of railway safety was explained where the annual numbers of railway occurrences were in the thousands in comparison to the number of investigation files reviewed by the researcher. The RSR does not have to investigate every occurrence. For the reporting period that the data was requested, the RSR investigated 33 occurrences (Level 1 and 2 occurrences) and 20 Level 3 occurrences which entail reviewing the Operators' investigation reports. For TFR, Line Management is required to investigate every occurrence and the CSO Level 1 and 2 occurrences. The researcher was informed that the CSO can investigate any other occurrence but that it depends on capacity, the quality of Line Managements reports received and the CSO's review of Line Managements findings and recommendations. The CSO's review of Line Management investigations is a Level 3 investigation. For the reporting period under review, the CSO conducted 35 Level 1 and 2 occurrence investigations and 120 Level 3 occurrence investigations. The checking process revealed that not all of the occurrence files for the number of occurrences reported during the reporting period were present. This is because some of the occurrences were still under investigation (and therefore not completed), while others were not made available without an explanation. Discrepancies between the number

of investigations compared with the number of occurrences are discussed in the results chapter.

6.6.3 Procedure

The completed investigation files for the specified reporting period were requested in advance by the researcher for the RSR and TFR. Upon arrival at both sites, the researcher was provided with a private office and the completed investigation files were made available. No documentation was reviewed in electronic format but in hardcopy only. The first step was the checking process. Each file that was made available to the researcher was compared with the list of occurrences for the requested reporting period and ticked off against the list if the file was available. Not all the files were made available and the researcher was then granted permission to locate the files that were stored in a filing room. This was a difficult process as there was no organised system in the filing rooms at both the RSR and at TFR. Locating the investigation files amongst all the records for previous years was a time consuming process and an important finding in itself. In some instances the researcher had to ask the personnel where the missing files were as these could not be located in the storeroom. Despite this process, not all the completed files for the reporting period could be located. Had the investigation files been organised per year or per category of occurrence this may have assisted in locating the files.

Each file was thoroughly reviewed which entailed searching the documents for information that the researcher deemed necessary from having already conducted a literature review and the review of the governance documents. The researcher also had prior experience and knowledge with the occurrence investigation files that made it easier to identify important aspects relevant to this research. The researcher used field notes that contained a list of criteria, questions and observations. Notes that were collected from the previous methods highlighted above, the literature review, and researcher's experience also formed part of the field notes. These notes were used in the analysis of the investigation files to determine the following:

- The quality of information collected (i.e. completed fields in certain documents, length of the investigation reports, comparison of findings compared to the background of the occurrence, whether documents were signed off, and to identify any discrepancies).

- The timing of the investigation from the date of the occurrence (i.e. the date of the occurrence compared to the date of the investigation) compared with the timelines required by the policies and procedures.
- Who was interviewed (i.e. who was selected to be witnesses/informants)?
- Who formed part of the panel of the investigators that conducted the interviews?
- If a checklist of questions was used for the interviews, and if so, what questions were asked of the witnesses/informants?
- Who the chairperson of the inquiry was and to note compliance with the policies and procedures. These state who the chairperson should be depending on the level of the investigation?
- What evidence was collected, and how this evidence was used to determine the outcomes of the investigation?
- Whether there was consistency across similar occurrences in terms of what evidence was collected, the outcomes of the investigations, and compliance to policies and procedures.
- The roles and responsibilities of various stakeholders within the investigation system.
- How the outcomes and recommendations of the occurrence investigation were concluded.
- Verification of information and evidence contained in the files against the requirements written in the policies and procedures.
- What methods and approaches were used in the investigation of occurrences to determine the findings, contributing factors and conclusions?

The information collected from the analysis of the investigation files was recorded in a notebook. The review of the investigation files was a time consuming process, despite the researcher being familiar with the environment. This was because the files contained a large amount of documentation and evidence to review (over a hundred pages per investigation file). The investigation files were also not ordered into any specific sections which would have made it easier to locate and review certain evidence.

6.6.4 Data analysis

No formal thematic content analysis was conducted on the data collected. The review of the investigation files provided the researcher with the number of investigations conducted compared with the number of occurrences that take place. This is important because if every incident is not investigated, or is only partially investigated for compliance reasons, then these are examples of systemic factors in the investigation system. The reasons for the discrepancies were discussed in the interviews with the RSR and TFR to determine any challenges that the organisations experienced. The data from this method were also used to develop the interview questions, corroborate or refute the information in the policies and procedures, and compared to the data collected from the observations of the actual inquiries. The data from the review of the investigation files served as a means of verifying if what happens in practise supports the policies and procedures. The field notes collected allowed the researcher to address any concerns, or seek clarity during the interviews.

6.7 Interviews with occurrence investigators and managers

Interviews served as the central method used in this multi-method design approach. Interviewing is a useful qualitative technique as information is provided from individuals on their thoughts, opinions, beliefs and experiences. Interviews provide information not only about what people say but also how they say it. For example a silence after a question is asked can be interpreted (and misinterpreted) by the interviewer who is required to make sense of not only what is said, what was implied and also what was not said (Yeo, Legard, Keegan, Ward, McNaughton Nicholls & Lewis, 2014). This is why body language, laughter, and facial expressions are important factors to consider when interpreting the qualitative data. Interview data can provide a story of participant experiences which in this research was compared to the information collected from the document analysis of the governance documents, the investigation files, and the observations.

6.7.1 Sample

Several meetings were held with Senior Management at the RSR and TFR before the interviews took place. These meetings provided the researcher with an idea of who would be required to be interviewed based on the input from the RSR and TFR and also from the data already collected in the above mentioned methods. In terms of the DoT, numerous emails and telephone calls were made in order to identify who would be best to interview

given the nature of this research. The researcher was provided with contact details for an individual to interview in the Rail Branch of the DoT.

In-depth, face-to-face interviews were conducted at the DoT, RSR, and TFR. Face-to-face interviews enable an environment where the interviewee can respond freely, allows for the establishment of a good rapport between the researcher and the participant, and the researcher is able to take non-verbal communication into account (Yeo et al., 2014). Table 6.4 outlines the number of people interviewed.

Table 6.4 Number of interviews in the rail hierarchy

DoT	RSR	TFR
1	11	11

At the DoT there was only one person responsible for railway safety regulation in the Rail Branch and therefore this person was interviewed. This is a finding in itself and questions the South Africa Government's priorities regarding railway safety with only a single resource for an important aspect of rail transport. At the RSR, the interviewees included:

- Executive Manager: Occurrence Investigations
- Principal Inspector of Occurrence Investigations
- 4 Occurrence Investigators
- 3 Trainee Investigators
- 1 Human Factors Manager
- 1 Human Factors Trainee

These employees were the full complement of staff employed in the Occurrence Investigation department. Given the number of railway occurrences in South Africa, it raises the question as to whether the number of investigators and human factors personnel are adequate for the department to carry out their duties effectively. The small number of investigators compared with the number of occurrences (average of 4500 annually) impacts on the number of investigations that the RSR is able to conduct. Despite the RSR not being required to investigate every occurrence; the data indicates that less than a

percentage of the total number of occurrences is investigated by the RSR. This is an example of a systemic factor and is discussed in detail in the next chapter.

At TFR, there were no individuals appointed to be solely investigators in the entire company. This is an important finding and questions the knowledge, competence and skill of those required to investigate occurrences. The reader will recall that by virtue of being a Manager that this enabled one to investigate an occurrence. Rasmussen (1997) acknowledges that the level of competence and practical skill of decision makers is important in being able to make the appropriate decisions in complex systems.

The researcher relied on the meetings with Senior Management to determine who would then be appropriate to interview. The researcher deemed it necessary to conduct interviews at both the CSO and in the depots where the Line Management are situated. The researcher was provided with a list of employee positions (for example Safety Manager) for the Line Management at the depot that would be the most suitable to interview based on their role in investigations. In order to determine which depots to conduct the interviews at, the researcher requested occurrence data of all operational occurrences for the period of 2010 to 2015. These statistics were analysed and the researcher selected 3 depots based on the depots being *hot spots*, or areas with the most number of railway occurrences. The researcher presented the choices to the CSO for consideration and input and it was agreed that interviews could be conducted with the Line Management. For confidentiality and anonymity reasons, the depots selected and the employee titles are not disclosed. The researcher travelled to these areas to conduct the interviews.

At TFR, interviews were conducted with personnel at two levels within the company; the CSO and Line Management. The CSO is responsible for the following activities, amongst others, relating to the investigation of occurrences:

- Overall responsible for occurrence management within the company
- Coordinates BOI's for Level 1 and 2 occurrence investigations (the more severe incidents)
- Follows up that corrective actions emanating from all investigations are implemented

- Managing railway occurrence trends
- Managing the relationship/interface between the RSR and TFR

Three people were interviewed at the CSO and included the Executive Manager of Occurrence Management, the RSR Interface Manager and the Manager of Accident Investigations for the company.

The next level of interviews was conducted at a Line Management level. Line Management are responsible for the following activities, amongst others, relating to the investigation of occurrences:

- Operational Management of the depot
- Managing and supervising operational staff (for example train crew, supervisors, safety personnel etc.)
- Operational activities such as the running of trains, infrastructure maintenance and train control

The reasons for conducting interviews at a Line Management level was because they are required to investigate all occurrences that take place in their jurisdiction, irrespective of the level of severity. Another reason is because there were no individuals appointed to solely investigate occurrences within TFR as this is the responsibility of Senior Managers. Eight Managers were interviewed at a Line Management level. In total eleven people were interviewed at TFR.

6.7.2 Instruments

The review of the literature, the researcher's experience within the field and all of the methods already discussed, provided the researcher with information that was used to develop the interview questions. The questions were semi-structured and consisted of open questions. This allowed the researcher to probe further or discuss a particular topic in more detail. This supports Yeo et al. (2014) who state that the aim of in-depth interviews is to achieve both breadth of coverage and depth of content across key issues. The same questions were asked to all the interviewees with only a few questions differing depending

on which organisation was being interviewed. Table 6.5 illustrates the categories of the interview questions and Appendix B details the full interview protocol.

Table 6.5 Categories of the interview questions

Demographics	Challenges	Political influences
General	Suggestions for improvement	Financial influences
Investigations	Human Factors	Communication
Training	Safety	Knowledge and comprehension of railway standards

The interviewer used a digital voice recorder to record the interviews and the interview sheet also provided the researcher with an opportunity to write brief notes. The voice recorder was helpful as it allowed the researcher to listen attentively and give full attention to the discussion. The recording provided a full account verbatim of what was said in far more detail than would ever be possible with note-taking. The notes included observations, changes in body language, pauses in answering any questions, hesitations, comments that required further exploration, and input into additional questions to probe further. Field notes after each interview allowed the researcher to summarise the contents of the interview, the researcher's thoughts, ideas for further exploration, the key points of the interview, themes that emerged from the interviews and information pertaining to the context of the interview.

Spoken text needs to be transcribed into a written form for analysis. In terms of transcribing the interviews, the researcher used an independent transcriber to type the voice recorded information verbatim. The accuracy of the transcription plays a role in determining the accuracy of the data that are analysed, the degree of creditability and validity. The researcher reviewed the transcripts in conjunction with playing back the voice recording to determine the accuracy of the information. Where there were errors or inaccuracies, issues that required clarification or railway terminology and acronyms that were used, these were corrected by the researcher. This process ensured the transcripts were accurate.

As part of the data analysis colourful sticky notes were used to group data into themes and to visually display the themes. A software tool called SimpleMind™ was used to

electronically display the mind maps of the thematic content analysis from the written charts.

6.7.3 Procedure

Each interviewee was informed of the interview by email and followed up telephonically. The researcher interviewed the participants at their place of work in a private room to ensure confidentiality and to enable the participant to feel comfortable and talk freely. Only the participant and the researcher were present during the interview. The researcher travelled to the various depots to interview personnel at TFR so as to not inconvenience the participants during working hours. The interviewer followed the interview schedule with a certain degree of flexibility depending on how the questions were answered by the interviewee, whether probing was necessary, and following up with additional questions as the discussion continued. The interviewees were given an opportunity to clarify any question at any stage, were informed that they did not have to answer if they did not feel comfortable, and were given an opportunity at the end of the interview to ask the researcher any questions. On average the duration for all the interviews was 1 hour 30 minutes with the longest interview lasting 2 hours and 5 minutes and the shortest interview 58 minutes.

Field notes included drawings of the interviewee's organisational structure or organogram of the company or division as was described to the interviewer to build a picture of the investigation system and to identify the links between the various levels in the system. In addition a list of referenced material that was discussed relevant to the occurrence investigation process was noted. Additional questions that emerged as the interviewees provided information were noted, and any additional documentation that required the researcher to review as part of the document analysis was captured. Reflective information of the researcher's thoughts, ideas, questions and concerns that developed during the conversations was recorded. Observations included noting any facial expressions and non-verbal behaviours (e.g. rolling of the eyes, hand gestures, hesitation, delays in responding and body language) of the interviewees that would not be apparent in the verbal recording but were important cues to note for the analysis. Both the field notes and the observations detailed any emergent and reoccurring themes that were evident for the data analysis and results chapter.

Once all the interviews were completed, the interview recordings were given to a transcriber to transcribe verbatim in order to convert the verbal format into a written format which could be analysed. This information was used together with the researcher's observations and field notes from the interviews.

6.7.4 Data analysis

Hignett (2005) and Miles and Huberman (1994) state that qualitative studies involve two important stages: (1) data reduction and (2) data analysis. Data reduction involves breaking the information down (decomposing) and coding the information into different categories and themes. In this way the true essence of people's objectives, situations, and words can be understood. It is a process of selecting, focusing, simplifying, abstracting, and transforming data where information is summarised, coded, and discarded based on the researcher's aims (Miles & Huberman, 1994). Data analysis is a more complex and iterative process, where once the information is coded into themes, the data is then displayed in various ways so that the information can be compared and understood (Hignett, 2005; Miles & Huberman, 1994). Discovering meanings, patterns, explanations and causal flows therefore allows conclusions to be drawn.

A qualitative approach, using thematic content analysis, was used in the analysis of all the interview transcriptions. Relevant phrases, sentences and words were identified from the transcripts which formed the basis of identifying what themes were common across the interviews. Information relating to each other or to a particular theme were grouped together to form the conceptual framework. All the decomposed information was categorised into themes.

Thematic analysis involves discovering, interpreting, and reporting patterns and clusters from the data. Spencer, Ritchie, Ormston, O'Connor and Barnard (2014) summarise the steps taken to conduct the formal analysis process in Figure 6.2. In essence concepts and categories are developed from the data to explain patterns and linkages within the data. This was used to generate theories and hypotheses relating to the systemic factors influencing the investigation system.

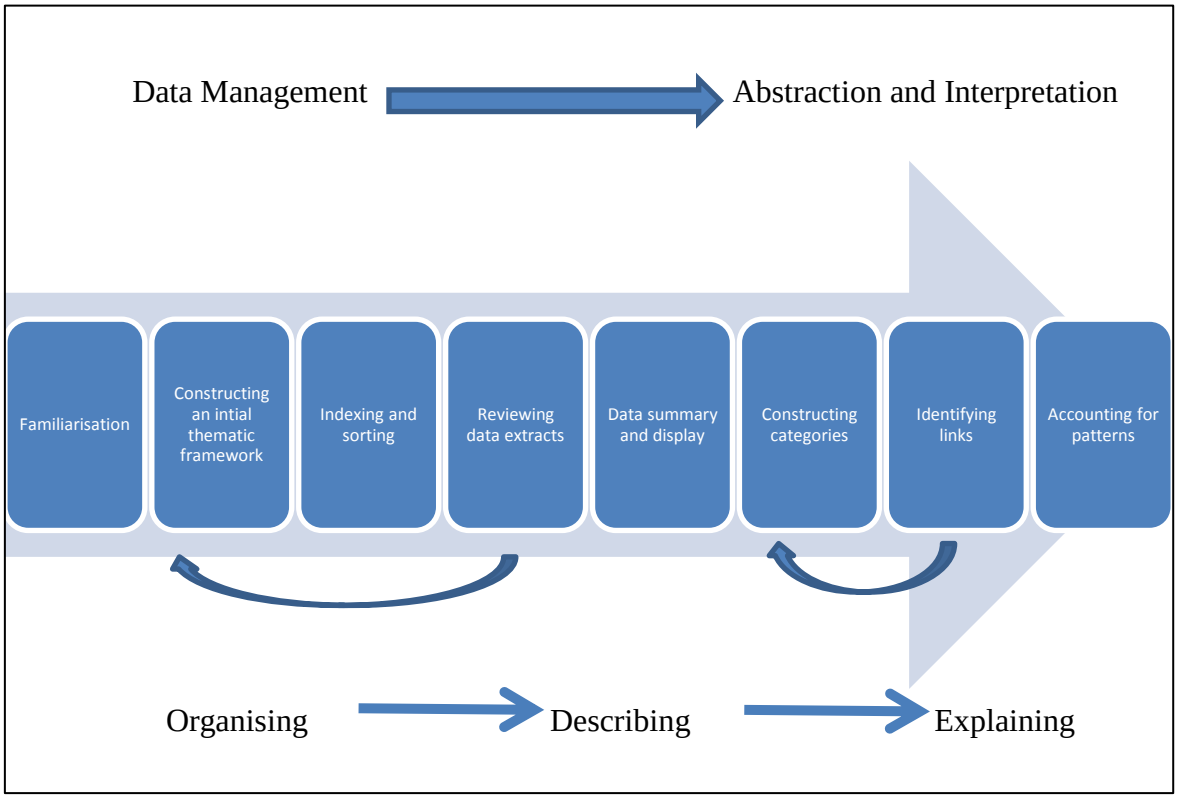


Figure 6.2 Data analysis process
(Adapted from Spencer et al., 2014 p. 281)

Data management is the process of making qualitative data manageable. This requires labelling and sorting the data according to themes or concepts in preparation for a more interpretative analysis (Spencer et al., 2014). The data analysis of the interview transcripts required working systematically through the written texts where the researcher immersed themselves in the data. This is referred to as familiarisation with the data and allowed the researcher to establish an initial framework. Gaining an overview of what people say relevant to the research question is an important first step. Identified topics emanating from the text were recorded on the transcriptions. In order to construct an initial framework, the researcher developed a list of possible topics to determine under what headings people's views, experiences, and opinions could be organised. Having already developed a list of possible topics from the preliminary overview of the data, the topics were noted and the process repeated, until themes emerged from the data that addressed the overall research question. Thematic content analysis is an iterative process and is very time consuming as the researcher constantly refers back to the data in order to refine and sort the information. Indexing and sorting the data allows for an initial thematic framework consisting of a set of themes and sub-themes, thereby making the data more organised. The

iterative process starts with a general read through of the data to gain a more in-depth analysis of paragraphs and then sentences. Chunks of data were labelled into categories, and because semi-structured interviews were conducted, this was fairly easy as the data was already well-ordered into topics. The initial analysis resulted in a crude thematic framework. In order to refine the data further into more coherent groupings, the researcher reviewed the data again, this time looking at the chunks of data and the group extracts, words, and opinions. Labels given to the chunks of data were amended where necessary. Although thematic analysis is time consuming and is an iterative process, this approach allowed the researcher to be immersed in the data, going beyond the surface of the data.

At this stage the researcher found it useful to use colourful sticky notes in order to be able to visually separate, index, and sort the data. Once the initial steps of the data management stage (indexing and sorting, reviewing the data extracts and displaying the data in topics) were completed, the next stage was developing categories. Spencer et al. (2014) state that once the data has been managed, the researcher commences with the abstraction and interpretation process. The categories developed were based on a number of abstract questions, interpretations, and thoughts that the researcher developed during this iterative process in order to address the range of things people were saying about a particular theme. For example, all the sticky notes pertaining to a theme were grouped together. Figure 6.3 provides an example of the theme *challenges* (in relation to the challenges with respect to occurrence management) and all the codes or sub-themes pertaining to this theme. Examples include a lack of education and training, an inefficient system and a lack of strategy.



Figure 6.3 An example of a category or theme

This process was performed for each interview. Each interview transcription was ‘deconstructed’ to identify the themes or categories, each with sub-themes or codes. For the DoT only 1 interview was conducted. Figure 6.4 illustrates all the overall categories identified with the respective codes for the DoT.

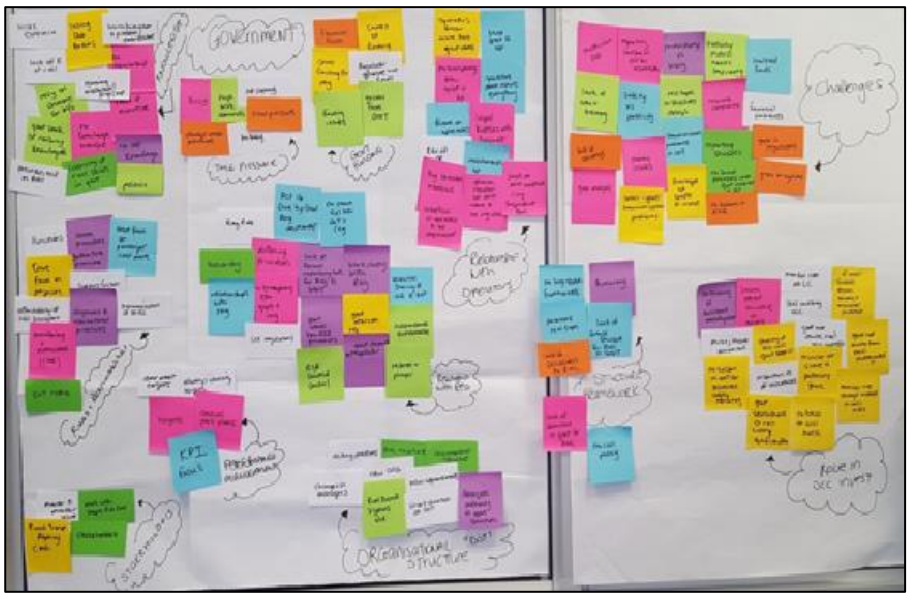


Figure 6.4 DoT interview themes

The information in the mind maps were then transferred into an electronic format, using the SimpleMind™ software. The results are illustrated in the results chapter.

For the RSR, the same process as described above was completed for each interview. The overall categories are depicted in Figure 6.5 for all of the interview data from the RSR. The results are reported for the RSR as a whole and illustrate that systemic factors at a Regulator level are present. These impact on the effectiveness of the investigation system. In the results chapter only individual quotes are captured where examples are necessary to illustrate a point. Therefore all 11 interviews were indexed and sorted, codes identified and then categorised into themes for the entire organisation.



Figure 6.5 RSR interview themes

The information in the mind maps, as depicted in Figure 6.5 were then transferred into an electronic format, using the SimpleMind™ software. Chapter 7 includes the results.

In terms of TFR, the data were separated for the CSO and Line Management. As explained earlier in the hierarchy structure for TFR the various levels of Company, Management and Staff overlap given the different roles and responsibilities in the investigation system. The exact same processes as for the DoT and RSR were performed for TFR. Figure 6.6 illustrates the CSO mind map with the themes and sub-themes and Figure 6.7 depicts themes and sub-themes from the Line Management interview data.



Figure 6.6 TFR CSO interview themes



Figure 6.7 TFR Line Management interview themes

SimpleMind™ was then used to electronically display this information. This enabled the researcher to further analyse and interpret the data. Where there were links between certain themes these were noted. In other words logical sense of the patterns within the data were developed. The results chapter provides an analysis and discussion of the findings.

6.8 Observations of occurrence inquiries

To determine how accidents are investigated, the researcher sat in on actual inquiries as an observer to witness the process of conducting an inquiry so as to identify any systemic factors influencing the investigation process. Inquiries consist of a panel of experts who are required to conduct a site visit, interview witnesses/informants, and collate the evidence as part of the occurrence investigation process. A consolidated investigation report is then written, detailing the background of the occurrence; the list of witnesses interviewed; the findings, immediate cause/s, root cause/s; contributing factors; and the recommendations as per the report writing requirements stipulated for each organisation.

The purpose of this method was to understand the process of how inquiries are conducted to determine the outcomes of the investigation. Information collected in the document analysis of the governance documents, the review of the completed investigation files and the interviews were compared to the data from the observations. In contrast to most ethnographic methods, the purpose was not to observe individual behaviours, beliefs or cultural norms but rather to gather rich data on the practice of investigating. In other words observing the processes, techniques and procedures so as to question *why* what is observed

may relate to the expectations and assumptions of the problem statement of this research. McNaughton Nicholls et al. (2014) state that the presence of the researcher during an observation is a vital part of the method; however the degree to which they participate varies. The researcher acted as *observing as participant* that involved observing unobtrusively as possible but was engaged in the setting to some extent. The researcher was open about their purpose, visibly recorded in the natural setting, and did not engage deeply with the participants. The reason for this type of participation is because the researcher was familiar with the environment, had previous experience in the rail industry, and knew some of the people. Therefore the researcher's presence could not be unknown to those who were part of the investigation. The observation was just one approach of a multi-method design and was not the central method used.

6.8.1 Sample

In terms of selecting which occurrences to sit in as an observer, the researcher relied on the RSR and TFR to inform the researcher when an inquiry would be commencing. In total two BOI's and one Level 2 investigation were observed for the RSR and one BOI for TFR. This variance was due to the time availability of the researcher and the Operator not giving enough prior notification to the researcher to be available. The number of days for each inquiry varied, due to travelling to the site, witnesses' availability and the actual questioning of the witnesses. The two RSR inquiries occurred over three days and the other inquiry over two days. The investigation at TFR involved four sittings, totalling six days spread over two months. This was due to the availability of the Board members and witnesses. The delays in commencing and completing the inquiry are examples of systemic factors and are discussed in the results chapter.

6.8.2 Instruments

The role of the researcher was purely to observe the processes and field notes captured the necessary information. No information was digitally recorded as the researcher's aim was to gain perspective on the processes which were essential to the research question.

6.8.3 Procedure

Decisions on what to observe were informed by the researcher's prior experience and knowledge of the field, data collected from previous methods, and from the reviewed

literature. A variety of factors can be observed during the process with McNaughton Nicholls et al. (2014) stating that the following settings are important to consider:

- The physical setting (the place and location of the inquiry)
- The human setting (individual and group behaviours)
- The interactional setting (formal and informal interactions that take place)
- The programme setting (the activities that take place and the organisation of resources)

The above formed part of the researchers field notes during the observations of the inquiries. In addition the following were also observed during the site visits and inquiry:

- Date of the site visit and inquiry in respect to the date of the occurrence
- Resources used to capture and record evidence
- Number of people investigating the occurrence / Board member composition
- Who chairs the inquiry
- Roles and responsibilities of the various panel members
- Processes for interviewing witnesses
- Types of questions used in interviewing the witnesses
- Processes and procedures during the site visit
- What HF/E methodologies are used to analyse the occurrence
- Who compiles the investigation report
- Deriving the findings, conclusions and recommendations
- Interactions and behaviours of witnesses
- Interactions and behaviours of panel members

Once the researcher was notified of the inquiry, the researcher attended the site meetings and the inquiry that included the interviews with the witnesses. The researcher informed the chairperson of the inquiry that the researcher would only be sitting in as an observer. The role of the researcher was purely to observe the process and not to participate as a Board member (i.e. ask questions to the witnesses or contribute to the report).

The observations were carried out sequentially after the other data collection methods. The advantage of using the observations as the final data collection process allowed the researcher to verify the data from the governance document analysis, investigation files and the interview data by observing if the same processes played out in practice.

Data was captured and recorded using field notes during the observation. After each day of observing, a summary of the events was captured. The detailed field notes included:

- Observations relating to the aims and central research question
- Accounts of what participant's said that were as close to verbatim as possible
- Summaries of selected comments of participant's
- Reactions and behaviours of witnesses and panel members
- Documentation referenced in the inquiry
- Mental notes of the researcher's thinking
- Jotted notes recorded during the site visits
- Pictures taken on site, and of any documents for recall at a later date
- Descriptions of who was present, the processes and procedures. For example where were witnesses seated in relation to the Board members
- Subjective reflections of the researcher including views, feelings and thoughts of how the researcher felt in the setting

6.8.4 Data analysis

The information collected was compared to the data collected from the interviews, the governance documents, and also the investigation files. This means of verification allowed the researcher to determine if what happens in practice is the same as what is written in the policies and procedures. The data from the observations was also compared to the literature reviewed. A positivist paradigm asserts that in order to evaluate the validity of a scientific theory, our knowledge claims or predictions should be consistent with the information we obtain empirically (Kaboub, 2008). The observations therefore aided in confirming or refuting the information that had already been collected and to identify if any gaps existed.

Thematic content analysis was not conducted on the observation data. The primary method used in this research was the interviews with the observation data providing implicit explanations (based on the researcher's interpretations of the data) for making the case and argument in this research. The interviews provided explicit explanations of participants' own accounts of what influences the investigation system that was compared to the implicit explanations collected by the researcher during the observations. Linkage of the data from the multi-method design allowed the researcher to develop a set of explanations to account for the patterns associated with discovering the systemic factors influencing the effectiveness of occurrence investigations. This is analogous to putting together the pieces of a puzzle to construct a convincing argument and making logical sense of the patterns in the data (Spencer et al., 2014).

6.9 Ethical considerations

Conducting this research required obtaining permission from the DoT, RSR and TFR to access company governance documentation and the investigation files, permission to be an observer during the inquiries and primarily permission to interview investigators. The media analysis did not require ethical consideration as no human subjects were used to provide information and the material was freely accessible in the public domain.

Given that confidential information was provided in the documentation analysed and that human subjects were involved in the interviews and observations, the researcher was required to apply for University Ethics Approval. Approval was granted with the ethics protocol number H14/09/14. Ethics principles such as informed consent, anonymity, confidentiality, the right to withdraw and the provision of feedback were all included as part of the ethics submission. Appendix C details the ethics approval documentation.

6.10 Concluding remarks

A multi-method approach was adopted in this research and included a media analysis, document analysis of governance documents, a review of investigation files, interviews with those responsible for investigating, and observations of inquiries. Qualitative techniques allowed the researcher to be engaged with the data collected. Qualitative research is an iterative process of reading, analysing and interpreting the data, developing appropriate frameworks, identifying meaningful texts, and exploring relationships and interactions between the information collected. Although qualitative research is a

subjective process; the researcher adopted a multi-method design to improve the validity and reliability of the data collected. The various data collection sources were selected on the basis that the different methods were the best fit to address the research question. The advantages of adopting qualitative research using a multi-method design provided the researcher with an in-depth understanding of the railway system, the investigation system and the intricacies within a *system of systems*.

The next chapter, chapter 7, details the findings from the various data sources highlighted in this this chapter. Although systemic factors emerged during the data collection and analysis conducted in this chapter, the next chapter provides a detailed account of the findings. The findings are discussed in line with the research objectives. That is to illustrate that there are systemic factors influencing the effectiveness of the investigation system, and that the investigation of accidents is an example of a complex system within the bigger rail socio-technical system.

CHAPTER 7: RESULTS

The previous chapter highlighted the qualitative approach of this research with a mixed methods design. The methods adopted included: a media analysis, analysis of governance documents, a review of investigation files, interviews with personnel responsible for investigations and observations of inquiries. This chapter presents the results of the data collected. The findings from the media analysis are discussed first followed by a brief discussion of the findings from the governance documents. The findings from the document analysis are discussed in more detail in each of the other set of results. The purpose of this method was to establish the context of occurrence investigations and to determine if what is required by policy is applied in practice. The findings from the review of the investigation files, the interviews and lastly the observations are discussed in-depth. As stated in the previous chapter, triangulation helps to improve the validity of the results especially in qualitative research. The relationships between the findings from the different methods are discussed amongst the results. For example, a statement in a policy was verified against the findings from the investigation files, interview responses and/or the results from the observations. Similar findings were identified across the different methods, demonstrating the validity of the results. The results prove that there are a number of systemic factors that impact on the effectiveness of the investigation process, contributing to the complexity of the investigation system. The reader is reminded of the list of acronyms.

7.1 Media Analysis results

In chapter 4 Rasmussen's (1997) Risk Management Framework depicted how public opinion can play a role in influencing the *Government* level. This level, through policy, budget, legislation and laws control the practices of safety in society. This is an example of an information feedback loop between the different actors of a socio-technical system. Moray (2000, p. 861) also describes this as "*societal and cultural pressures"* where members of society, who are outside of the system place demands on the system for performance improvement. In chapter 6 Rasmussen's (1997) Risk Management Framework was operationalised for the South African context with the focus on the system of accident investigations. Rasmussen's hierarchy structure was extended to include the public as another level in the system of interest and not as an outside pressure. By bringing the public into the system of interest, they can then play a bigger role in influencing the

Government to ensure investigations are thorough, independent and effective. The incentive for the public would be a safer, reliable and efficient railway system benefiting both commuters and freight users of rail in South Africa. Therefore in this study the hierarchy structure has the public (representing society) as the highest level in the system of accident investigations.

The purpose of analysing the print media was three-fold. Firstly, it was necessary to determine whether the public are aware of the poor state of railway safety in South Africa through the reporting of such events by the media. The results confirm that the media does report on railway safety with the articles fitting into three broad categories: operational, security and regulation articles. Secondly, it was worth noting the number of occurrences published by the RSR each year in comparison to the number of media articles reporting on railway occurrences. The results illustrate only a small number of articles are reported on in the media. Lastly, determining what exactly the public knows about railway safety by way of the factors that affect readership and what content the media reports on to inform the public was a necessary step. The results illustrate several themes discussed in the following sections. Correctly informing the public is important in order for the public to influence Government to control the practises of thorough, independent and effective investigations of railway occurrences. The following sections detail the results from the media analysis.

7.1.1 Reporting of railway safety in the media

Railway occurrences and safety are reported in the media and 133 media articles were identified. In chapter 6 it was highlighted that articles reporting the same event were grouped together. Operational occurrences were reported on the most (55 articles), followed by security incidents (23 articles) and then reports relating to regulation (12 articles). This was expected as operational occurrences are more newsworthy and would be perceived by the media to hold more risk to the public due to resultant fatalities and injuries.

7.1.2 Comparison of the number of media reports to the number of occurrences

To determine whether the public is acceptably informed about the state of railway safety in South Africa, the number of media articles were compared with the number of occurrences reported by the RSR in the State of Safety reports. In order to provide an accurate

comparison, the articles were organised according to the RSR's financial reporting period of 1 April to 31 March for 2008 to 2013. Table 7.1 illustrates the comparisons.

Table 7.1 Comparison of railway occurrences: RSR and the Media

	Financial reporting year				
	08/09	**09/10**	**10/11**	**11/12**	**12/13**
Operational occurrences reported by the RSR	5307	4769	4181	4348	4262
Operational occurrences reported in the media	10	7	13	12	7
Security related incidents reported by the RSR	3986	5661	6379	5702	4124
Security related incidents reported in the media	2	5	5	7	3

It is evident from Table 7.1 that there is a discrepancy in the number of railway occurrences found in the media compared to those reported by the RSR. This may be attributed to either one or all of the following:

- The media not being aware and informed themselves of the seriousness and frequency of railway occurrences.
- Not all occurrences result in unfavourable consequences and are therefore not considered newsworthy.
- Operators, the RSR and the South African Government may not provide the media with information post-event for confidentiality reasons.
- Operators, the RSR and the South African Government may not disclose information of this nature as it could negatively impact on the respective organisations, and hence the system's reputation.

Moray (2000) in a study identified that those organisations that adopt openness and have continuous discussions with stakeholders yielded positive results. The public was identified as an example of a stakeholder. Transparency reassured the communities rather than allowing suspicion amongst the public. For this to work, Moray (2000) affirms that

this requires public relations that are able to effectively work with the media and no political pressures against the adoption of an open policy. In the South African context, it would appear that there is little transparency between the state and its agencies (including major railway Operators), and the public about the state of railway safety. This is indicated by the small number of media articles reported by way of the media to inform the public. The next section discusses the content of information reported on by the media illustrated by the themes that emerged from the articles.

7.1.3 Themes and sub-themes identified from the media analysis

In total, 15 main themes were identified with 14 of the themes containing sub-themes (refer to Appendix D for the themes and sub-themes). Figure 7.1 highlights the themes found in the articles and the most prominent theme. *Investigations* were the most reported theme (13%) as most articles stated that the occurrence would be followed by an investigation or reported that an investigation would be conducted. The *type of occurrence* was the second most reported theme (12%) and supports the finding of operational occurrences being reported on the most. Level crossing events and collisions were the most reported occurrences. The third most reported theme was e*conomic* (10%) and this related to the reporting of the costs of occurrences both direct and indirect costs.

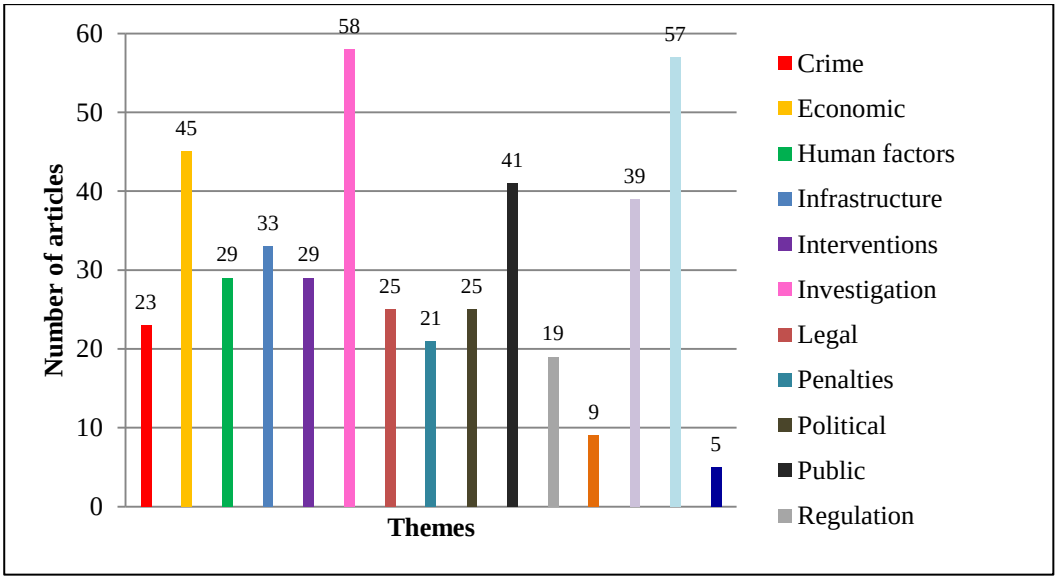


Figure 7.1 Themes identified and number of media articles

Each theme in Figure 7.1 is discussed in detail and is presented in Appendix E. It is worth briefly discussing the theme of *investigations* given the focus of this research. It was

common practice for media articles to include that the event was under investigation; however no further information emanating from the inquiry was communicated with the public. For example *"An in-depth investigation into the incident will be conducted but is expected to take two to three weeks"* (SAPA, 2010b). The inclusion of feedback to the public through follow up reports regarding the outcomes and recommendations of the investigations would present readers with an opportunity to be reassured that efforts by the various levels in the system do exist to ensure public safety. As stated by Moray (2000), transparency is important rather than allowing suspicion. A lack of integration, flow of information and feedback between the levels of the investigation system (in both directions) impacts on the effective performance of the system. Furthermore, this research suggests that by presenting the public with more information on an event's investigation process (and more importantly the remedial actions to ensure public safety), a deeper understanding and appreciation for railway safety would be achieved. The inclusion of the public into the investigation system, rather than an outside force, would enable a more holistic system.

The theme of *public* emerged from the media reports. This is worth discussing given that this research includes the public in the hierarchy structure of the investigation system. Insight into the public's perception regarding the frequency of railway occurrences is extracted from a 2009 media article reporting on a collision: *"I mean, what are the odds that people can be involved in a train accident?* (Masemola, 2009, p. 3). This statement indicates that the public are not adequately informed about the number of railway occurrences that take place on South Africa's railways, either by way of the media, the Government, its agencies and the Operators. The number of occurrences for the 2009/2010 reporting period equates to approximately 13 operational occurrences per day in South Africa. While the odds for people to be involved in a train accident are not necessarily more likely, the numbers indicate that railway accidents are far more frequent than the public (and the media) are aware. The next section discusses the factors that affect readership and therefore public opinion.

7.1.4 Factors that affect readership

In chapter 6 it was discussed how the amount of space devoted to covering the occurrence or incident, the type of words used to describe the event in the article and the heading of the article were important considerations in determining public opinion regarding railway

occurrences. In terms of **word length**, operational occurrences had the lowest word average of 331 words, followed by security incidents with 367 words. Regulation articles had the highest average number of words with 417 words per article. Although the operational category of reports had the most number of articles, they were attributed the least number of words on average than any other category. This is likely due to the social and moral effects of these types of events where more words are not necessary to make a stronger impact. Regulation articles included quotes from political figures, unions and government personnel, increasing the word length but necessary to encourage readership. Articles with **captive headings** included words such as *unsafe*, *dicing with death*, *horror crash*, *hunt you down* and *imprison you*. Captive headings contain words that revoke a response in the reader because they are usually strong emotive words that draw the reader into the message of the article (Cotter, 2010). Articles containing **quotes** from witnesses, injured passengers or political figures were significantly longer in word length compared to those with no quotes. Pape and Featherstone (2005) state that the use of quotes helps bring the story to life and encourages readership. Table 7.2 provides examples of quotes and the themes identified (refer to Appendix F for a detailed list of captive headings from the media analysis).

Table 7.2 Themes and quotes from the media

Theme	Examples of Quotes
Crime	"Acts of violence, intimidation, vandalism and malicious damage to assets have become a daily occurrence and undermine the Operator's ability to provide a safe service" (D. Williams, 2010, p. 3)
Economic	"The social and economic implications of these incidents (cable theft) are massive as they result in line closure, expensive repair costs, delays for freight trains and passenger trains, train cancellations as well as huge consequential costs to the economy" (SAPA, 2012a)
Infrastructure	"It is totally unacceptable that human life is disregarded by failing to upgrade and maintain necessary infrastructure in our country" (SAPA, 2009b, p. 4)
Investigations	"In this investigation, our principle objective is to look at the root cause and evaluate this against similar incidents in recent months" (SAPA, 2009a, p. 1)

Human Factors	"The South African Bureau of Standards (SABS) on Friday published a national standard on human factors management, which it said was developed primarily to provide railway operators with the minimum requirements to manage human factors" ("Moves to improve rail safety", 2011)
Interventions	"An amounted R5.85 million had been dedicated to fence repairs across rail reserve" (Kinnear, 2011, p. 5)
Legal	"I will keep a close eye on the investigation to ensure that justice is served. I will also work together with Metrorail and law enforcement agencies to do everything humanly possible to ensure that a tragedy like this does not happen again" (SAPA, 2010c)
Type of occurrence	"Four people have died at the dangerous Rocky Bay level crossing in Park Rynie this year" (Mthethwa, 2009, p. 5)
Regulation	"Strict monitoring and adherence to train working rules by train operations and staff and drivers nationally" (Tau, 2009, p. 2)
Train Operator	"PRASA was instructed to make sure that the doors of commuter trains were closed before departure from a station" (SAPA, 2009c)
Penalties	"Watchdog intends to introduce hefty fines in an attempt to crack down on errant rail Operators who endanger the lives of commuters" (Dlamini, 2009b, p. 2)
Political	"Fedusa perceives the lack of regard for safety to be totally unacceptable" (Bathembu & Vos, 2009, p. 3)
Public	"We are worried about people who build shacks next to the railway because it is not safe as children love playing on the tracks" (Mthethwa, 2009, p. 5)
Reputation	"It could take decades for this country to recover from the negative images that would result from such a tragedy" (The Times, 2009, p.10)
2010 FIFA world cup	"We want to assure South Africans, as well as our international visitors, that this accident is an isolated incident that does not have any impact on the integrated transport plan that the Department of Transport is in the process of operationalising ahead of the 2010 FIFA World Cup, or the country's ability and readiness to host the tournament" (SAPA, 2010a)

The themes and the quotes highlight the social, moral and financial consequences of railway occurrences in South Africa. The statements in Table 7.2 were made by union representatives, Government ministers, the RSR, Operators and concerned citizens, indicating that railway safety is a concern of a number of actors within the bigger railway socio-technical system. Some of the quotes are similar to the views shared by the participants involved in the interview method in this study, further highlighting the need to improve railway safety in South Africa. The question then is what is being done by the decision makers, actors and stakeholders especially at the higher echelons of the system to reassure society that rail is a safe mode of transport? This is addressed in the next sections.

The results from the media analysis illustrate that the public are informed about railway occurrences, however are not acceptably informed to understand the poor state of railway safety in South Africa. It is suggested that the media can be an effective tool for various actors in the investigation system to assist in improving railway safety. One way is to utilise the media as a means to inform and educate the public. The Government (the DoT), the RSR and railway Operators can also use the media to communicate how the public can contribute to enhancing railway safety, especially at level crossings. Furthermore, the public can raise their issues of concern regarding railway transport in the media, where these can then be addressed openly by the various stakeholders. This encourages mutual trust and confidence between all the actors in the investigation system.

In the RSR and TFR governance documents, reference is made to occurrences attracting media and public attention. This escalates the level of investigation irrespective of the type occurrence. The media analysis revealed that the media isn't informed about every occurrence. If this was to change, and the media reported more on railway occurrences, then this would be a challenge for the RSR and TFR. As will be explained in the next sections, both organisations do not have capacity to investigate every occurrence. Furthermore, the higher levels of investigation cost more financially for both the RSR and TFR due to using external people. Constraints within each organisation already limit the number of occurrences each organisation is able to investigate, exacerbating the complexity of the accident investigation system. These constraints may also be reasons for why the media (and the public) are not acceptably informed about railway occurrences, as the organisations would not be able cope with the demands of increased media and public pressure.

The next findings detail the results from the review of the governance documents. The results are discussed for each level of the hierarchy in the investigation system.

7.2 Governance document analyses results

The findings from the review of the governance documents are briefly explained according to the themes that were identified from the analyses. The results are discussed separately for the RSR and TFR. The DoT does not investigate occurrences and therefore were excluded from this analysis. However, Act 16 the legislation for railway safety developed by the Government is referenced in the RSR findings as the Act provides for the establishment of the RSR (National Railway Safety Regulator Act No.16 of 2002, 2009). The governance documents are detailed in the results from the investigation files, the interviews and in the observations as a means of verification.

7.2.1 RSR governance documents

The themes identified from the review of the RSR's governance documents include: regulation, authority of the RSR, competence, non-compliance to policy and procedure, human factors, classification system, accident causation methods, stand-by procedures, budget, role of Government and just culture.

Regulation: The RSR Occurrence Investigation Policy was issued in June 2014 (the same year this policy was reviewed by the researcher). Prior to this policy, the researcher was informed by the RSR that a draft policy had been in place since 2006. This questions the organisations commitment to safety and impacts on the investigators successfully executing their activities with little direction.

Authority of the RSR: The RSR Occurrence Investigation Policy states that the occurrence investigation report will be utilised by the RSR to, amongst others *"terminate the unsafe activities when Operators fail to take the agreed remedial actions"*. The review of the investigation files, the interviews and the observations revealed a number of repeated unsafe activities by the Operators. The media analysis also highlighted this in some of the articles. This was also raised as a concern by one of the attorneys in the BOI observations as to why Operators have been allowed to continually perform unsafe activities without any consequences from the RSR. In one investigation file, an Operator referred to the RSR as being *"soft"* illustrating the perception that the RSR is not authoritative. The inability or

reluctance of the RSR to terminate the unsafe activities of Operators raises the following questions:

- Does the RSR in reality have enough power and autonomy to enforce safety compliance despite Act 16 and the RSR Occurrence Investigation Policy suggesting it does?
- Is railway safety really prioritised by the Government to which the RSR reports, and in the RSR and Operators especially given the number of occurrences?
- Are investigations conducted more for compliance than to prevent repeated occurrences?
- How much does bureaucracy and political interference between the Operators, RSR and the Minister impact on the effectiveness of the investigation process and complexity of the investigation system in South Africa?

In addition to the questions surrounding the authority of the RSR, its independence in the investigation system is also doubtful. This is despite statements in the RSR's Occurrence Investigation Policy suggesting the RSR is independent. For example:

"demonstrate to the public and Operators the contribution of the independent safety Regulator in promoting safe railway operations"
"it (BOI) *will be deemed to be an independent investigation as it is independent of any investigation undertaken by the Operators…"*

In practice it was established that the independence of the RSR is a concern of both Operators and the RSR itself. The RSR relies on the Operators for evidence and their investigation reports due to resource constraints. Furthermore, the autonomy of the RSR is compromised due to a conflict of interest. This is because of reporting structures between the RSR and an Operator that both report to the same Minister. This was discussed in chapter 2. Other findings relating to the RSR not being a true independent organisation in the investigation system are discussed further on in this chapter.

Competence: In both the Occurrence Investigation Policy and in Act 16 it is stated that the RSR can appoint *"a suitably qualified person to carry out the investigation"* (National

Railway Safety Regulator Act No.16 of 2002, 2009). Further on in the policy reference is made to investigators being *"competent"* in addition to suitably qualified. The policy defines competent investigators to be from three fields: railway industry operations, human factors, and/or engineering. However, what it means to be *"suitably qualified"* is not defined in Act 16 or in the policy. During the interviews at the RSR the researcher was informed that the attorneys, some of the external people appointed to BOI's and the interns were not *"suitably qualified"* to be investigators as they lacked railway knowledge, experience and investigation skills.

A similar finding was also evident in SANS (2009) where reference was made to who is legible to investigate occurrences. This document is developed by the RSR for railway Operators to abide by. The standard stipulates that *"persons appointed to investigate occurrences shall have the necessary competence and seniority, both in relation to the nature and the seriousness of the occurrences, and the scope and level of the investigation"* (SANS, 2009, p. 26). The RSR is more 'specific' in the standard that Operators must adhere to but not in its own policy. Furthermore, neither competence nor seniority is explained further. The ambiguity in the standard may offer an explanation for why TFR did not have appointed investigators, as the standard is non-prescriptive in defining the competency, skill and knowledge necessary to conduct occurrence investigations. In terms of *"seniority"* this is also ambiguous. If an individual is a Line Manager at TFR, does this translate to being senior or is it experience within the organisation, or both factors that qualify? The interview findings also demonstrated that not all of the Line Management who conducts investigations has experience, training and knowledge in occurrence investigations. The generic nature of the standard allows for decision making to be delegated to the next level of the system illustrating that decisions (or by implication no decisions) higher up the system shape the actions of the levels below and therefore the systems behaviour.

The examples above illustrate how vague and ambiguous legislation in Act 16, developed by the Government impacts on the next level in the system, the RSR. The RSR who develops standards for the Operators to comply with are also unclear leaving much up to the Operators to decide what is acceptable. The lack of integration between the various levels in the bigger rail socio-technical system influences the investigation system from achieving its objectives. The repercussions of not specifying that investigators should be

trained qualified experts, impacts on the accuracy, quality, validity, reliability and objectivity of the entire investigation process and its outcomes. This is discussed in more detail in other examples further on in this chapter.

Non-compliance to the policy and procedure: The RSR Occurrence Investigation Policy mentions a reporting management system to capture occurrence investigation reports. However, at the time of the interviews (almost a year later) this was still not operational. The delay in implementing the information management system is discussed in the interview findings, but was a reason for the Principle Inspector not always being aware immediately of when an occurrence has happened. The policy also states that the Minister can initiate a BOI, however during the interviews it was explained that the Minister rarely instructs the RSR to investigate occurrences, unless there is significant media attention, and usually this is when children's lives are at stake during a level crossing accident.

The policy states that a RSR BOI is required to be initiated within one working day after the incident occurs. The actual investigation is required to take place within one working day after the finalisation of the BOI preparatory work, which according to the procedure can be up to a week after the occurrence. The review of the investigation files and the interviews demonstrated that this rarely happened with many investigations commencing several weeks to months after the occurrence.

The RSR Occurrence Investigation Procedure states that *"to assist with evidence collection, it is very important for the RSR to arrive at occurrence sites at the earliest possible time prior to the site being disturbed"*. In practice, the RSR inspectors often arrived on the scene several days to weeks after the event. This statement, in particular *"at the earliest possible time"* is also vague and open for interpretation. The investigation files and observations confirmed that the arrival of the RSR at occurrence sites was delayed and in many instances the site had already been cleared of all evidence.

Human Factors: Act 16 defines human factors but only makes reference to the fact that human factors regulations may be established. No mention of the role of human factors in occurrence investigations is mentioned. The Occurrence Investigation Policy stated that a Human Factors Specialist either from within the RSR or external would form part of the BOI as a Board member. In the interviews it was explained that this rarely happens for

BOI's, although in one of the observations a Human Factors Specialist was a board member but was from the RSR. This suggests that the RSR BOI's are not completely independent and is discussed further on. Furthermore, the policy states that for Level 2 occurrences a minimum of two RSR investigators *"including a Human Factors Specialist must carry out the RSR investigation for occurrences"*. Only in one of the observations was a Human Factors Specialist part of the Board. From the interviews it was explained that it was not always possible to include a Human Factors Specialist as the RSR had only just appointed their first Human Factors Specialist and an intern (at the time of the data collection in this research). Since the RSR's existence the organisation had never employed Human Factors Specialists. The findings from the interviews demonstrated that the workload of the human factors team was very demanding, and because they were only two people, they were unable to sit in every investigation. The Occurrence Investigation Procedure references the Human Factors Occurrence Investigation Protocol. In the interviews some of the investigators were not even aware of this protocol and others stated that this was rarely used as they had received no training on it and were not subject matter experts in human factors to use it. Human factors was not always included in the investigation reports or represented in the inquiries, illustrating that what happens in practise differs to policy and procedures.

Rasmussen (1997) explains how generic legislation is not easily enforceable or effective as it leaves much up to the companies to determine the implementation. In this research, this was evident where in the legislation (Act 16) and in the RSR's own governance documents human factors is barely mentioned. SANS (2009) describes the minimum requirements for Operators to adhere to, and contrary to the RSR's own governance documents, it describes human factors in far more detail. This again illustrates how the RSR's own internal governance documents are not as detailed as the expectations they have of the Operators, especially as the RSR is also required to conduct investigations. In chapter 12 of the standard (SANS, 2009), the entire chapter is dedicated to human factors with detailed requirements for Operators to manage human factors. The RSR identified in 2011 the need to develop a full standard on human factors, *SANS 3000-4: 2011 Human Factors Management* (SANS, 2011). This was due to the RSR identifying that a number of occurrences were as a result of *"human error"* and *"human factors"*. The purpose of the standard *"is to reduce occurrences attributable to human error".* However, the investigation files, the interviews and the information from the observations demonstrated

that human error remains a common finding in many investigations. The minimal inclusion of human factors in the RSR's own documents, questions whether the RSR views human factors management as an operational requirement instead of a systems requirement. In addition, the attribution of occurrences to human error suggests that a system focus is not adopted by the railway industry.

SANS (2011) did not include any requirements for human factors in accident causation and occurrence management, including investigations. No accident causation methods, techniques, tools or theory were documented despite the prominence of human factors in accident causation literature. In SANS (2009) reference is made to *"human factor root (basic) cause"* where Operators must identify these in operational occurrences. Eight categories of *"human factor root (basic) cause"* are provided by the RSR. The interviews, observations and investigation files illustrated that there is a misconception that human factors and human error were synonymous terms. This may be attributed to none of the participants interviewed having received any human factors training.

Classification system: The classification of the different investigation levels was also ambiguous. The difference between a Level 1 and 2 occurrence investigation in terms of severity was difficult to determine as both mentioned the same events and criteria. The only difference in the classification was that for Level 1 incidents the procedure read *"occurrences needing immediate reaction"*. For Level 2 incidents the scale of the events included *"major and minor impact occurrences"*. There was no difference between the two Levels in the number of fatalities or injuries. Additional examples of ambiguous statements relating to the classification system included:

*"**Severe impact** on human beings, technology and the environment"*,
*"**A lot** of media attention"*
*"**As soon as** the occurrence occurs"*
*"Executive shall at the **earliest opportunity** meet with the chairperson of the BOI"*
*"**Major** financial loss"*

The ambiguity in the policy was verified by the RSR participants. Most of the participants gave varying answers as to what differentiates a Level 1 from a Level 2 investigation, with

most conceding that there was no real difference. In practice the terms Level 2 and a BOI were used instead. The policy also makes reference to a *"serious occurrence"* but does not define what this is. Every participant provided a different definition for this.

Accident causation methods: The policy mentions root cause(s) and contributing factors, however there is no explanation on how to establish these. The procedure stated that investigators *"shall assess the situation by asking the relevant questions pertaining to the occurrence"* but these were not explained. However, in the investigation report template root cause analysis techniques; for example *"5M analysis"* and the *"fishbone diagram"* were described. How to use these methods and examples were not provided. In the review of the investigation files and from the observation findings, these technqiues were rarely used as investigators did not know how to use them.

Stand-by procedures: The procedure stated that the Principal Investigator *"shall compile a yearly stand-by roster for a team of investigators that will swiftly react with these occurrences"* (with reference to occurrences that require immediate reporting to the RSR by the Operators). In the interview results it emerged that the stand-by system was removed yet the policy had not been updated to reflect this. This contributed to the delay in the RSR responding immediately to the site especially after-hours and on weekends.

Budget: The policy makes reference to *"the fee structure for BOI members external to the RSR"* and the procedure stated that investigators would either be granted time off or be remunerated *"if budget allows"* for working stand-by. Budget constraints impacted on a few factors including the removal of the stand-by system and the number of RSR BOI's per year because of the financial costs of lawyers and consultants. This theme is discussed in more detail further on in the chapter.

Role of the Government: The role of the Government is mentioned in the policy and procedure but only in reference to the Minister of Transport. No mention is made of the role of the Minister of Public Enterprises, to whom TFR reports, and keeping this ministry abreast about railway safety. The role of Government in occurrence investigations is only advisory. South Africa not having a National Rail Policy to give direction and inform policy for the various stakeholders in the railway system contributes to the contents of Act 16. This has ramifications for the rest of the railway hierarchy levels in the system.

Just Culture: SANS (2009) stipulates that Operators are "*encouraged"* to adopt a just culture in occurrence investigations with most of the other requirements using the word *"shall"* instead. This indicates that it is not mandatory. The ramification of this 'choice' for the Operators is that a just culture is not adopted. The full requirement reads:

> *"Operators are encouraged to adopt a just culture to occurrence investigations in which the sole focus will be to determine the facts and the root causes of the occurrence and to make recommendations to prevent or reduce the risk of recurrence than to allocate blame or liability (or both)*" (SANS, 2009, p. 26)

Furthermore, in the list of definitions in SANS (2009) just culture is not defined. In the interviews the participants' were asked to define just culture. Two participants at the RSR and three participants at TFR were able to define the term. All of the participants interviewed at both the RSR and TFR did not know that the standard mentioned just culture. This illustrates that within the RSR that there is a lack of understanding of the organisations own standards. Furthermore, the RSR expects that Operators comply and implement a just culture shifting the responsibilities onto the Operators. Given that the RSR is the custodian of railway safety in South Africa, it would be expected of the RSR to also *"adopt a just culture to* (their) *occurrence investigations"*. Overall a blame culture in the rail socio-technical system was a common theme identified in this research and may be attributed to a lack of knowledge of what a just culture is.

7.2.2 TFR governance documents

The following themes were identified from the review of TFR's governance documents: non-compliance, investigators, accident causation, timelines, independent investigations and human factors.

Non-compliance: Transnet Group develops a BOI Policy for all its operating companies and therefore is a generic policy. TFR needs to comply with this policy. Rasmussen (1997) states that generic policies result in delegated decisions and distributed organisations. In these situations there is a need to formally consider the impact of generic decisions on the objectives of all the stakeholders. It was explained during the interviews that TFR does not always adhere to the BOI Policy due to its own challenges and constraints. During the observations the following extracts from the policy were also not adhered to:

"The BOI shall be constituted within 10 days from the date of the occurrence"
"The first sitting will take place within 5 working days of its constitution"
"The Presiding officer shall convene an alignment meeting where the BOI members shall acquaint themselves with the terms of reference and BOI protocol"
"The last sitting of the BOI shall take place no later than 20 business days after the first sitting"
"BOI's for Level 1 occurrences shall consist of a minimum of 60% external members (non-Transnet employees)"
"Representative of Group Risk as a BOI member is compulsory"
"A risk based investigation method (root cause analysis technique [RCAT] or similar) shall be implemented by the members of the BOI when investigating the occurrence…"

The non-compliance to the above requirements indicate that the decisions made higher up in the company level of the system do not consider the impact of decisions on the objectives of the next levels in the system. Non-compliance to the BOI policy is further discussed in the interviews. This finding supports Kumanyika et al. (2010) that ignoring feedback leads to policy resistance.

Investigators: The BOI Policy and TFR Occurrence Investigation Procedure do not make reference to appointed investigators. By virtue of being a Manager this enables one to investigate an occurrence. At the CSO there were also no appointed investigators. In the Occurrence Investigation Procedure reference is only made to establishing a team consisting of *"designated members from multidisciplinary functions depending on the nature of the occurrences"*. The policy states that TFR members who sit on the Board *"shall be released from their normal work related duties so that they can commit to the terms of reference of the BOI"*. This influenced the quality of the Line Management investigations as Managers rushed the investigations to resume their normal operational functions.

Accident causation: The BOI Policy detailed a section relating to adopting a risk-based approach to investigations. This method focusses on the human and organisational systems but does not consider the systems conditions, illustrating similarities to an epidemiological

approach to accident causation. Examples of extracts pertaining to adopting a risk-based approach include:

"Aims to identify local factors and failures within the broader organisation and productive system that contributed to the occurrence"
"Occurrences rarely occur due to a single failure or breach in risk controls. Rather they are as a result of multiple events"
"A risk based approach requires that we give cognisance to both the management controls and risk and behavioural influences leading up to the occurrence"
"Both management control and risk and behavioural influence are influenced through 5 levels of action: decision makers, line management, preconditions, productive activities, and defences"

The TFR Occurrence Investigation Procedure highlighted investigation techniques to establish and analyse the evidence. Examples included the "*Structured What If Technique (SWIFT)"*, *"5 WHY's"*, *"Failure Mode Effect Control Analysis"*, *"HAZOP"*, and "*People evidence, Position evidence, Parts evidence and Paper evidence"*. In terms of root cause identification the RCAT methodology was prescribed to determine the immediate and root causes. Two occurrence investigation files reviewed stated that they applied the RCAT methodology, but in the files there was no trace of the techniques. In the interviews, participants stated that they did not use any accident causation methods, including the above.

Timelines: The TFR Occurrence Investigation Procedure was developed primarily for Line Management who must investigate every occurrence. Line Management are required to establish an investigation team immediately after the occurrence and must complete the investigation *"within 7 working days"*. This was identified to place significant pressure on the Line Management investigation team and impacted on the quality of the reports as they were rushed. Again the consequences of higher level decisions on the next level of the system impacts on the objectives of conducting effective investigations.

Independent investigations: In terms of Line Management investigations, the procedure stated *"where possible and necessary it is advisable that the appointed investigation team*

should be from another area to remove bias and allow for independent investigations". Many of the interviewees were unaware of this clause, and those who were, stated that in practice this does not happen.

Human Factors: This was not mentioned in the BOI policy and the Occurrence Investigation Procedure. However, in one of the annexures of the procedure, reference was made to *"root causes: human factors (weaknesses associated with people)* and *root causes: job factors (weaknesses with procedures, workplace or operation)"*. The term *"weaknesses"* has a negative connotation, leads to apportioning blame and encourages the use of the word human error. This also illustrates a lack of understanding about human factors. It was acknowledged in the interviews that human factors doesn't feature in TFR's investigations, impacting on the effectiveness of the investigation process, the accuracy of the findings and appropriateness of the recommendations.

In summary, the governance document analyses highlight that what is stipulated in the governance documents does not always happen in practice. Furthermore, the impacts of decisions made at higher levels in the system are not always considered by decision makers influencing the systems behaviour i.e. the effectiveness of the investigations. The next section details the results from the review of the occurrence investigation files.

7.3 Occurrence investigation files results

The reader will recall that the DoT does not conduct investigations. The results from the review of the investigation files are separated for the RSR and TFR.

7.3.1 RSR investigation files

South Africa on average has approximately 4500 railway occurrences annually. Investigating this many occurrences would require a number of resources. Chapter 6 highlighted the number of investigators in the RSR's Occurrence Department which included 4 investigators and 3 trainee investigators (not all of the participants interviewed regularly investigate occurrences). The RSR is not required by legislation to investigate every occurrence. However, to ensure that a significant percentage of occurrences are investigated, this would require an increased number of investigators at the RSR. This is an example of a systemic factor as resource constraints put the investigation system under severe pressure to prevent occurrences and create a safe system. Achieving the goal of

effective investigations that are accurate, reliable, valid, objective and thorough is severely impacted by a shortage of investigators. Furthermore, using trainees to investigate who do not have the competence, skill and experience yet required, adds further pressure to the investigation system achieving its objective. This not only impacts on the investigation system but also the bigger rail socio-technical system achieving safe railway operations.

Given the number of occurrences in South Africa and the number of investigators it is necessary to determine how many investigations the RSR conducts. Investigation files were requested for the financial reporting period of 1 April 2014 to 31 March 2015. During this reporting year there were 4632 operational occurrences. Table 7.3 provides the number of investigations conducted by the RSR:

Table 7.3 Number of investigations conducted by the RSR

Level of Investigation	Number of Investigations
Level 1 (BOI)	2
Level 2 (RSR Occurrence Investigation)	31
Level 3 (Review Operators reports)	20
Total	**53**

The number of investigations conducted by the RSR was considerably fewer than the annual number of occurrences. The researcher included the totals for Level 1 and 2 investigations as these involved the RSR conducting an investigation and not a review of Operators reports. In total 33 occurrences were investigated by the RSR for the 2014/2015 reporting period. Of the total number of occurrences for the same period, the RSR investigated less than 1%. This is an example of a systemic factor because investigations, although reactive, help organisations learn about the event and what can be done to prevent repeat occurrences. The RSR acknowledges that its purpose when conducting investigations is to identify what went wrong to prevent a future recurrence. However, if only a small percentage of investigations are conducted, it is questionable whether these numbers add any significance to improving the state of railway safety in South Africa. Furthermore, establishing a learning culture to identify the vulnerabilities of the investigation system, but also the bigger railway system, need to be understood and verified to avoid repeated occurrences. Dekker (2007) believes that learning from occurrences contributes to organisational development and system safety, with this

researcher's view that it would also improve the effectiveness of the investigation system. The selection criteria for choosing which occurrences to investigate and the reasons for the low number of investigations are provided in the results from the interviews.

Level 3 investigations are in essence more of an audit or review of Operators reports than an actual investigation as an inquiry does not take place. In these investigations the RSR is reliant on the Operators having conducted their own investigations. Although an objective and necessary measure, the effectiveness of the Operator's investigation process, and therefore the validity and reliability of the findings and recommendations are unverified. This is because the RSR does not conduct its own independent inquiry or visit the scene of the occurrence and is reliant on the information provided by the Operator. These factors impact on the effectiveness of the investigation system and also the accuracy, thoroughness, objectivity, reliability and validity of the findings and recommendations. While the participants admitted at TFR that their investigations are not always thorough, the RSR participants stated in the interviews that it not often that the Operators reports are sent back by the RSR. The question then is how much value do the RSR's Level 3 investigations really add in terms of improving railway safety?

The difficulty in locating the investigation files and lack of any organised filing system at both the RSR and TFR was an important finding. Rasmussen (1997) discusses commitment to safety and whether management are prepared to allocate adequate resources to maintain the systems defences. Rasmussen (1997) also questions whether decision makers are aware of the safety implications of their business and every day work planning. The decision makers in the investigation system are the personnel employed in the investigation department. The safety implications of not having an organised filing room impacts on organisational learning where repeat occurrences and trends can be analysed from using previous occurrence investigation data. However, the difficulty in finding a specific investigation file may hamper this opportunity.

The files reviewed at the RSR included a BOI investigation, Level 1 and Level 2 investigations. The results are separated as the BOI is chaired by an external attorney and the report is in a different format to the RSR investigations conducted internally.

7.3.1.1 RSR BOI investigation file

A BOI is an independent investigation conducted by an external chairperson, normally an attorney and a panel of Board members who are external subject matter experts. The role of the RSR in BOI's is to coordinate and arrange the logistics, rather than to participate as a Board member. This is to ensure 'independence'. However, in the BOI file that was analysed two RSR inspectors were part of the BOI panel. This was also identified during the observations. The BOI's are therefore not completely independent and also confirms that policy requirements do not always play out in practice. These are examples of systemic factors influencing the investigation system achieving its goal of thorough, independent and effective investigations. The BOI findings are highlighted in Table 7.4.

Table 7.4 Findings from the RSR BOI investigation file

BOI	
Type of occurrence	Derailment passenger train
Level of investigation	BOI
Date of occurrence	26 June
Initiation by the RSR for a BOI	27 June
RSR notification to the Operator for the establishment of a BOI	10 July
Date of request for information from the Operator for a RSR preliminary investigation	11 July
Date of the RSR preliminary investigation on site	17 July
Date of pre BOI meeting on site	21 August
Date for request for information from the Operator & interviews with the Operator for the BOI	25 August
Date of site visit for the BOI	1 September
Date of interviews for the BOI	2 & 3 September
Board Members	Chair: Attorney Track & Permanent Way (perway): external Rolling Stock Engineer: external

	Principal Inspector Human Factors: RSR Senior Inspector: RSR
Number of days for the BOI	2 Days
Evidence of tools/methods used	Root cause analysis technique: -Position evidence -People evidence -Parts evidence -Paper evidence -Process evidence
Human Factors report	Yes
Immediate cause (as stated)	-Wheels of locomotive out of specification & track components defective -No pre train departure inspections to have identified the faults
Root cause (as stated)	-System deficiency or substandard actions or risk behaviours or unsafe conditions which includes amongst others...maintenance equipment, unqualified staff, staff shortages, lack of proper maintenance record keeping -These conditions preceded the derailment and had they not existed the root cause would have been identified
Number of recommendations	Short, medium & long term for rolling stock, perway and human factors
Date of the BOI report submitted to the Operator	17 March (following year)
Date for submission of the Operator's Corrective Action Plan to the RSR	18 April (following year)

The RSR conducts a preliminary investigation, separate to the BOI, and prior to commencing with the independent BOI. The RSR's role is to collect and understand the factual data relating to the incident to be able to assist the BOI. A report from the

preliminary investigation conducted by the RSR's inspectors is then submitted to the Board for review. The preliminary investigation impacts on the objectivity and independence of the BOI as the Board enters the BOI with preconceived ideas. The Board relies on this investigation by the RSR as the Board only arrived at the scene of the occurrence two months after the incident. Subsequently, the evidence from the scene had already been cleared giving the Board little opportunity to do an onsite investigation. In fact it would appear to be a visit to familiarise the Board with where the incident occurred rather than to conduct an onsite investigation. The onsite investigation is an important stage of the investigation process that is not performed by the BOI team, but by the RSR themselves. This is a systemic factor as the investigation process for BOI's is only partially completed. The BOI relies on the RSR's findings and recommendations impacting on the independence of the process. This was also observed during the observation where the Board visited the scene sometime after the event as a means of orientation rather than to conduct an onsite investigation.

Another systemic factor is that the BOI interviews took place nearly three months after the occurrence; impacting on the credibility and memory of the witnesses' testimonies. Loftus (1979) and Ryan, Hutchings and Lowe (2010) assert that the ability of witnesses to recall information post an event is impacted by the delay between the event and the time witnesses are required to recall information. A delay in recalling information not only influences the accuracy, reliability and validity of the evidence given, but also the effectiveness of the investigation process. The accuracy of the findings and therefore the applicability of the recommendations can contribute to repeat occurrences as the real reasons remain unidentified.

The BOI report did contain evidence of a root cause analysis technique, the only investigation file reviewed that had evidence of this. Despite using this technique the Board was *"unable to make proper conclusions as the Operator did not supply the Board with all the requested information".* This outcome indicates a shift of accountability to the Operator. Furthermore, the Operator's priorities and commitment to safety are doubtful. It also questions the RSR's authority to ensure Operators supply the RSR with the requested information. These systemic factors impact on the effectiveness of the investigation process and the ability to learn from such events if conclusions cannot be identified. The lack of integration between the two levels in the investigation system hierarchy impacts on

the effective functioning of the system. The constraints of the investigation system, if not controlled by the various hierarchy levels, lead to violations and subsequently investigations that are ineffective. The ability of the investigation system to also prevent recurrences is hampered. Factors such as the delay in arriving at the scene of the event, commencing with the onsite investigation and interviews are examples of systemic factors that constrain the investigation system from achieving its goals. Furthermore, the BOI report was finalised nine months after the incident. This violates some of the principles of learning (and hence a learning organisation). This leads to the question of how many incident recurrences could potentially have happened over this period?

The recommendations made by the Board were questioned by the CEO of the Operator in a letter to the RSR. The letter stated that the corrective action plan from the RSR was not specific as the recommendations were written as short, medium, and long term. The CEO requested the Regulator to be more *"specific"* as to these timeframes. Other comments made by the CEO of the Operator are included in Table 7.5 below.

Table 7.5 CEO's comments about the RSR's recommendations

"I don't know about this recommendation it is vague"
"What do we mean here? Don't understand"
"I don't understand, please be more clear on the instruction"
"Why are we soft on this? I think a penalty should be issued to the Operator X"

The CEO of the Operator issued with the recommendations was the previous CEO of the RSR and therefore was familiar with the RSR's BOI processes. Various actors and the relationships between the actors in the investigation system influence the dynamics of the system. Vague recommendations suggested by the RSR impacts on the decision makers in the next level of the investigation system, the Operator. The Operator is required to carry out the functions, with this distributed decision making also contributing to the effectiveness of the investigation process. As mentioned, Rasmussen (1997) states that vague or generic recommendations leave so much up to the companies and are not easily enforceable or effective (Rasmussen, 1997). Feedback in terms of the Operator's performance post implementation of the recommendations is difficult to measure where the recommendations were not specific. This further impacts on the investigation system

successfully achieving its objectives. Four questions emanate from the findings relating to these recommendations:

1. How powerful is the Regulator in terms of its position in the hierarchy of the system?
2. How comprehensive are the reports conducted by the RSR's attorneys in determining what went wrong?
3. How are recurrences prevented if there is a lack of cohesion between the levels of the system?
4. How are ambiguous recommendations monitored and measured for effective implementation?

There was evidence of a revised corrective action plan with specific dates suggesting that the Operator was able to successfully convince the RSR to amend the recommendations. The mandate of the BOI (as stated in Act 16, Section 38) is to make robust recommendations that are *"clear, specific and unambiguous as to what is expected; they are measurable, practical and attainable and are results orientated coupled to specific time frames"* (National Railway Safety Regulator Act No.16 of 2002, 2009). Therefore the above findings contradict the RSR's own mandate, questioning whether Act 16 is adhered to by the RSR, the very organisation established by the Act. Furthermore, the lack of railway knowledge and experience of the external attorneys and specialists who are not familiar with the railway environment constrains the investigation system in achieving its goals. Not adhering to legislation at the level of the system that is tasked to enforce the rules, propagates downward throughout the rail socio-technical system. This increases the degree of freedom by actors further down the system for diversion from the activities necessary for effective investigations.

7.3.1.2 RSR Level 1 and 2 investigation files

Level 1 and 2 investigations are conducted by the RSR internally. In practice there is little difference between a Level 1 and 2 investigation. The RSR refers to these investigations as Level 2's.The investigation files did not always contain the same types of documents and the evidence collected depended on the type of occurrence being investigated. In total 10 files were reviewed. Table 7.6 summarises the main findings from the review of the RSR investigation reports completed after an occurrence.

Table 7.6 Findings from the RSR Level 1 and 2 investigation reports

	1	2	3	4	5	6	7	8	9	10
Type of occurrence	Level Crossing	Collision	Level Crossing	Fatality	Runaway Collision	Collision	Yard Collision	Derailment	Derailment	Level Crossing
Level of investigation	Level 2	Level 1	Level 2	Level 2	Level 2	Level 2	Not stated	Level 2	Not stated	Level 1
Date of occurrence	17 Oct	18 Jun	6 Jun	3 Nov	17 Nov	30 Jun	12 Oct	24 Sept	10 May	8 Jun
Date for request for information & interviews from the Operator	3 Nov	23 Jun	4 Jul	3 Nov	21 Nov	16 Jul	29 Oct	3 Oct	21 May	13 Jun
Date of site visit by the RSR	17 Oct	7 Jul	10 Jul	13 Nov	19 Nov	31 Jul	18 Nov	16 Oct	28 May	25 Jun
Date of RSR interviews	11 Nov	8 Jul	10 Jul	13 Nov	26 Nov	31 Jul	12 Nov	17 Oct	28 May	25 Jun
Evidence of accident causation tools used	None	None	None	None	None	None	None	None	None	None
Number of RSR inspectors	2 & 1 intern	2	2	2	2	2	3	2	2	2
Human Factors report	Yes	No	No	No	No	No	No	No	No	No

	1	2	3	4	5	6	7	8	9	10
Immediate cause	Bus didn't stop at the sign	Tamping machine collided with the train	Failure of the driver of the vehicle to adhere to level crossing signage	Train driver standing too close to railway line and was run over by locomotive	Locomotive put in incorrect combination due to inexperience and ran away	Train authorised into a section blocked by a load & collided	Train standing foul in the yard (blocking the track)	Combination of slack on turnout & hollow wear on the wheels	Train went over the points which were run through by the previous train; Authorising of trains	Failure of the driver to move his vehicle from the level crossing
Root cause	Couldn't identify	Non-adherence to train working rules & lack of communication	Combination of factors that combined to cause the accident. Could not establish the root cause	Unsafe working as train driver was standing too close to the track. Driver was alone	Lack of supervision due to failure of management to ensure adequate staffing	Sub-standard processes; Sub-standard handover; Failure to give the train driver the vehicle list	Lack of enforcement from management to ensure adherence by personnel to train working rules	Failure of Operator to: identify & prevent abnormal wear; identify off-peak inspections & restore track to road worthy	Failure by management to ensure: TCO authorised accordingly during abnormal working; train drivers follow the rules during authorising	Driver failed to observe danger at the level crossing
Number of findings	4	4	4	11	6	4	9	4	12	2

	1	2	3	4	5	6	7	8	9	10
Number of recommendation	4	1	2	2	6	3	2	4	19	1
Date report submitted to Operators	5 Mar	12 Nov	21 Aug	20 Jun	31 Mar	29 Oct	23 Feb	5 Dec	30 Jun	10 Aug
Date for the Operator to submit their Corrective Action Plan to the RSR	20 Mar	25 Nov	26 Sept	31 Jul	30 Apr	10 Dec	30 Mar	26 Jan	29 Aug	12 Aug
Number of pages of the RSR investigation report	22	21	18	18	20	24	25	17	32	17

In terms of timelines, the RSR would issue a letter stating that they would be conducting an investigation and requested evidence from the Operator with very short timelines. In the interviews the researcher was informed that some of these timelines are unrealistic given the bigger Operators size of operations, the logistics of getting the information from the depots located all over South Africa and that many operational employees spend their time *"running trains"* rather than sitting in the office. Time pressure impacts on the accuracy, quality and type of information submitted to the RSR, thereby influencing the reliability and effectiveness of the investigation process.

It was evident in most of the level crossing investigation files that stakeholders in the bigger socio-technical system, namely the Operator, the Road Traffic Management Corporation and the municipalities demonstrated conflicting objectives in terms of maintaining safe level crossing infrastructure. Findings included debate over which organisation was responsible for the costs and maintenance of the infrastructure, road and signage. In one major level crossing accident, a recommendation to build a bridge over the level crossing was recommended by the RSR but the issue of funding this recommendation was argued extensively. None of the stakeholders mentioned above had the financial capital to fund this recommendation. Hutchings and Barker (2016) identified that the said level crossing was a repeated accident site with a number of fatalities and injuries. Despite repeated accidents, and little change to improving safety at this level crossing, the recommendation of the bridge shifted to a long term recommendation.

The various stakeholders in the bigger socio-technical system have competing goals and objectives, which influence the sub-system or 'system of systems' in particular the investigation system. The competing goals of being cost effective and ensuring safety was predominantly evident in the level crossing occurrences, supporting the 'Brownian movements' suggested by Rasmussen (1997). The inability to maintain control in dynamic systems that are constantly required to adapt to external influences, for example financial pressures, impacts not only the investigation system but the entire socio-technical system's effective functioning. In the investigation system, a way to maintain control is by implementing recommendations from investigations, provided they are realistic, appropriate and achievable. This is important for improvements in railway safety. Le Coze (2013) claims that the type of regulatory regime, and its ability to adapt and transform policies, influences the quality of the process of implementing recommendations. In the

findings, it was evident that there were repeated accidents at certain level crossing sites, the causes of level crossing accidents were always the same in addition to the recommendations. Furthermore, it was apparent that there is a lack of integration between the various institutional levels in the investigation system but also the bigger rail socio-technical system for example, local government, municipalities, road traffic departments and the RSR. This further constrains the investigation system from being effective in preventing recurrences.

The same findings and causes in many of the level crossings accidents questions how thoroughly these events are investigated. The motorist not stopping at the level crossing is the main finding with the RSR stating that the root cause could not be identified. The RSR (2016) acknowledges in the 2016 State of Safety report that the causes of level crossings are not determined. This is because the RSR does not conduct interviews with the motorist to ascertain why the person acted the way they did (RSR, 2016). In South Africa, given the number of level crossings (over 10000), the average number of level crossing accidents annually (137 between 2010 and 2015) and the resultant fatalities and injuries, emphasises the need to properly investigate such events. In addition achievable, relevant and effective recommendations are important but more so are the implementation of these. It is arguable as to why repeated level crossing sites do not receive any different recommendations and whether contributing factors for example, the maintenance of the crossing, the lack of responsibility and accountability of the various role players, poor signage, etc., are not considered. Adopting a systems view of how the various actors in the rail socio-technical system could have contributed to level crossings accidents appears to not be considered. Instead blame is centred on the motorist and this suffices as enough of a finding (for the railway stakeholders) rather than investigating what can be done differently to prevent such types of accidents from a *transport system* perspective. The role of the Minister of Transport would be expected to be more active and participatory in these situations.

Additional findings from the investigation files included the RSR requesting Operators to devise their own corrective action plan after an event while in other instances the RSR specified corrective actions for the Operators. Leaving Operators to determine their own corrective action plans impacts on the effectiveness and objectivity of the investigation process. Delegating crucial decisions downward to decision makers at the next level of the investigation system requires effective feedback loops so that information about the actual

status of the system is propagated upwards. Furthermore, the ability of the RSR to enforce, and monitor the implementation and effectiveness of the recommendations is hampered when the decisions are left to the Operators. This is because Operators have multiple degrees of freedom for action (Rasmussen, 1997) and can implement any recommendation that they deem to be appropriate, irrespective if these are considered to be inappropriate by the RSR. Feedback about the status of the investigation systems performance and control of the system becomes difficult to monitor due to too general or vague requirements by the higher levels of the system.

A further finding from the review of the investigation files was that only one of the files contained a report on human factors. This was due to the RSR having only just employed its first Human Factors Specialist who was able to contribute to the investigation. A notable statement made by the RSR in the 2015 RSR State of Safety report was that human factors elements were the largest contributor to railway accidents with 60% of all findings relating to human factors (RSR, 2015). With very little evidence of human factors methods, findings, reports or recommendations included in the investigation files (and verified in the interviews and observations) the accuracy of this statement is questionable. Furthermore, the lack of human factors investigators at the RSR suggests that the accuracy of such a statement may be misleading. In the interviews it was stated that human factors is seldom considered in the investigations as the investigators were not trained or specialists in this field.

The timing between the date of the occurrence, the date given by the RSR for the request of evidence and interviews from the Operators, and the date of the RSR site visit were examined further. The RSR visiting the scene of the occurrence on the same day as the event was evident in one investigation only. In all other instances the site visit took place a few days to weeks afterwards. The delay in visiting the site impacts on the effectiveness of the investigation process due to the influence it has on the credibility of the findings. By the time the RSR investigators arrive at the scene the site is cleared, offering no opportunity for the RSR to conduct an onsite investigation. The RSR is reliant on the Operator for photos and evidence from the scene therefore the RSR's investigations are not independent and objective.

None of the investigation files contained evidence of the RSR sending equipment for any metallurgical or technical tests. This is because the RSR does not have such facilities and relies solely on the Operators to do this. The issue of a lack of objectivity is an example of a systemic factor. The RSR's statement in its letters to the Operators: *"The RSR will be conducting an independent investigation in terms of Act 16 of 2002…"* is therefore contradictory to the findings identified in this research. The RSR has limited and unavailable resources that constrain the investigation system and its ability to achieve its objectives of thorough and effective investigations. The safety of the bigger rail socio-technical system is compromised as a result. Shorrock et al. (2014) believe that the success of a system is dependent on appropriate resources (people, equipment, competency etc.). At the RSR unavailable technology to conduct independent measurements to create accurate and valid findings hinders the investigation systems ability to achieve successful performance. Shorrock et al. (2014) further emphasise that the success and failure, for example of the accident investigation system, emerge from system behaviour, which is shaped by the systems conditions. This results in the system having to make trade-offs to adjust and adapt. To balance the investigation system and maintain stability, the RSR requests evidence and technical information from the Operators, an example of a constraint to control the performance of the investigation system. However the trade-off or compromise is the accuracy, reliability, validity and thoroughness of the investigation process.

The investigation files provided insight into the relationship between the RSR and Operators. In letters written by the RSR to the Operators requesting information for a particular occurrence, it was also stated what would happen if the Operators did not comply. For example *"Failure to comply will result in Section 45 being invoked or a penalty being imposed in terms of the Penalty Fee Regulations"*. This is an example of the RSR asserting its authority. However, the threatening tone did not appear to concern the Operators as in many instances the occurrence reports alluded to the Operators failing to submit evidence to the RSR. This resulted in the RSR not being able to conclude what the root causes were because:

"Absence of information made it difficult for the Board to make properly informed conclusions"

"Lots of information was not supplied to the Board"
"*No evidence provided to the Board on metallurgical impurities"*

As already discussed, the authority of the RSR is doubtful with the Operators repeatedly not submitting information to the RSR. It would appear instead that the major Operators are more dominant. This is an example of a systemic factor as the effectiveness of the investigation process is impacted upon. The credibility of the RSR's investigations is questionable given that the RSR investigators do not have all the evidence to make accurate conclusions and recommendations. This may contribute to repeated occurrences.

One investigation file contained information for two separate occurrences. The two occurrences did not take place at the same time, but the investigations were conducted simultaneously. It would appear that this was done fortuitously to accomplish two objectives with one action, as the investigators had to travel from Johannesburg to Cape Town. This may be attributed to saving costs. Interviews were conducted for a collision between 9:00-12:00 and then for a derailment between 13:00-16:00. This short duration only allows a few witnesses to be interviewed. It is therefore questionable whether all the necessary evidence required to determine what occurred can be gathered during this time. Furthermore, not using any accident causation methods or tools, and not having the facilities to conduct technical tests, exacerbates the effectiveness of the investigation process. Overall, most of the interviews conducted by the RSR's investigators were fairly short in duration, especially for occurrences where travel was required. One investigation file was prescriptive and stated: *"interviews should not take longer than 30 minutes"*. The issue of time is further discussed in the interview data and was a common theme identified across the interview data. The comprehensiveness of the investigation process is impacted on by rushing through the interviews in the interest of time, and costs.

7.3.2 TFR investigation files

A similar finding to the RSR was the challenge of locating the investigation files in the CSO. As discussed this impacts on organisational learning where previous events can be analysed to prevent future occurrences. The main findings from the investigation files are detailed in Table 7.7. The reader will recall from chapter 6 that 15 investigation files were reviewed for TFR.

Table 7.7 Findings from the CSO investigation files

	1	2	3	4	5	6	7	8	9
Type of occurrence	Level Crossing	Level Crossing	Injury on duty	Level Crossing	Derailment	Level Crossing	Derailment	Level Crossing	Fatality
Level of investigation	BOI (no mention of level)	Level 2	Formal BOI / Level 2	Formal BOI / Level 1	Level 1	Level 2	Level 2	Joint BOI / Level 2	BOI / Level 1
Date of occurrence	25 Jan	28 Feb	3 Sept	20 Jul	17 Jun	17 Jan	3 Apr	16 Aug	13 Nov
Date of the inquiry	18 – 19 Feb & 28 Feb	18 Mar – 20 Mar	15 Oct – 16 Oct	19 Aug – 21 Aug	8 – 10 Jul & 23 – 25 Jul	5 Feb – 6 Feb	20 May – 21 May & 30 May	3 Sept – 4 Sept & 12 Sept	2 – 4 Dec & 11 Dec
Chairperson of the inquiry	Legal Advisor, Transnet OD	National Quality Inspector, Transnet OD	Assets Manager, Transnet OD	Attorney	Attorney	Senior Manager, Compliance & Legal Services, Transnet OD	Manager Over - Border Wagons, Transnet OD	Compliance Manager Legal Services, Transnet OD	Attorney
Evidence of accident causation tools	None	None	None	None	None	None	RCAT	None	None
Human Factors panel members	None	None	None	None	None	None	None	None	None

	1	2	3	4	5	6	7	8	9
Immediate cause (as stated)	Driver of the car did not stop at the level crossing	Driver of the car did not stop	Unsafe act climbing between the buffers	Truck driver failed to stop	Mid set points & train to two routes	Driver did not stop	Rail break	Driver failed to stop at level crossing	Hit by train while under the bridge trying to avoid the rain
Root cause (as stated)	Couldn't be established	Undetermined	Person was negligent by taking a short cut to get to work to sign on	Truck driver ignored train whistle and failed to observe & obey sign	Non-adherence to train working rules accepted as the norm	The driver was not interviewed therefore could not be determined	Attributed to rail break	Not determined. Driver fatally injured	Deceased leaving his post & took an unsafe position in the path of a train
Date the report was completed	1 Apr	5 May	2 Dec	15 Oct	9 Sept	13 Mar	23 Sept	16 Oct	12 Mar

Table 7.7 Findings from the CSO investigation files (continued)

	10	11	12	13	14	15
Type of occurrence	Motor vehicle accident & serious injury	Derailment	Derailment	Level Crossing / contractor fatality	Level Crossing	Level Crossing
Level of investigation	BOI / Level 2	BOI / Level 1	BOI / Level 1	Level 2, Line investigation Joint investigation	BOI	Formal BOI / Level 2
Date of occurrence	17 Jun	21 May	10 May	13 Jun	20 Mar	9 Apr
Date of inquiry	13 Aug	24 – 26 Jun & 4 Jul	28 – 30 May	18 Jun	15 – 16 Apr 22 – 23 Apr	14 – 15 May
Chairperson of the inquiry	Senior Manager, Risk Management	Attorney	Attorney	No BOI report in the file	Attorneys	Compliance Manager, Transnet OD
Evidence of accident causation tools	None	None	None	RCAT	None	None
Human Factors panel members	None	None	None	None	None	None
Immediate cause (as stated)	Possible fatigue	Rail break	Cracked wheel	Deviations by the individual, deviations by supervisors, inattention, PPE not used	Driver did not stop at level crossing	Driver of car failed to stop at the stop sign

	10	11	12	13	14	15
Root cause (as stated)	Overworked due to shortages of staff & unfilled vacancies	Fatigue crack in flash butt of weld of rail 2	Unsure of the root cause of the cracked wheel	Human factors: inadequate mental state, behaviour, workplace factors, inadequate communication	Could not be determined as driver not interviewed	Could not be determined
Date the report was completed	Information not available	27 Aug	28 Aug	25 Jun	23 Jun	4 Jul

The CSO investigates mainly Level 1 and 2 occurrences, with Level 3 investigations a review of Line Managements investigations. Level 4 investigations are only performed by Line Management. The Level 1 and 2 files (BOI's) were more detailed in terms of the amount of evidence collected and the number of interviews held with witnesses. The CSO's terms of reference (remit) document for conducting investigations states that:

- The first sitting of the BOI must take place within five working days from the date of its establishment;
- The draft report is to be delivered within 14 days from the last sitting; and
- The final BOI report is to be delivered 30 days from the last sitting of the Board.

In most instances it was apparent that the above criteria were not always adhered to. This is further discussed in the observation results. Non-compliance to policy was a prominent theme identified in the investigation files reviewed, the interviews and the observations. Table 7.8 highlights the number of CSO investigations conducted for the reporting period of 1 April 2014 to 31 March 2015.

Table 7.8 The total number of investigations completed by the CSO

Level of investigation	Number of investigations
Level 1	17
Level 2	18
Level 3	120
Total	**155**

During this period, TFR had 2282 operational occurrences (RSR, 2015). In terms of the total number of operational occurrences for all the operators in South Africa; TFR contributed 49% (RSR, 2015). TFR and PRASA, the two major operators contributed 90% to the total number of operational occurrences in South Africa (RSR, 2015). Operational occurrences vary in severity which determines the level of investigation. Therefore the CSO will not investigate all 2282 occurrences, but every occurrence must be investigated by Line Management. The researcher was informed by a participant in the interviews that the CSO is not able to investigate every occurrence that it should be investigating due to a

number of constraints, for example staffing and time availability. This is discussed further in the interview results.

A number of level crossing investigations were also evident in the TFR files. The CSO's investigations displayed similar findings, immediate causes, root causes, and recommendations for level crossing accidents compared with the RSR investigations. The common finding was that the root cause could not be determined due to the driver of the motor vehicle not being interviewed. This was the same for the RSR's investigations. The high profile level crossing accident discussed in the RSR's investigation files was also an investigation conducted by the CSO. This accident resulted in the death of four minors and eight injured minors. The occurrence was investigated by the RSR separately and received the attention of the Minister of Transport given the death of children. Hutchings and Barker (2016) in an analysis of this level crossing identified it to be a hot spot site. In the five years prior to 2014 when this occurrence happened, seven fatalities had occurred at this crossing. In 2013 seven occurrences took place and three in 2012. Furthermore, the crossing is congested with approximately 8000 vehicles crossing it daily (Hutchings & Barker, 2016). Given the repeated number of occurrences at this level crossing, the TFR investigation did not demonstrate any different causes to other level crossing accident investigations. However one finding from the investigation report stated: *"A high level intervention is recommended with Government to understand how trains operate"*. This statement not only emphasises the seriousness of the accident, by mentioning that Government needs to be involved, but also suggests that the Government (and its agencies) do not understand train operations. This is an example of a systemic factor. Different levels in the socio-technical system, especially higher up in the system, need to be aware of the system's actual state of affairs. In the investigation system, the same principle applies. Information about the functioning of the system needs to be available for decision makers to effect control. If feedback between the levels in the system hierarchy is non-existent, or the channels for feedback are ineffective, this impacts on the performance of the investigation system achieving its objectives. The bigger rail socio-technical system is further affected. Reducing the number of level crossing occurrences is dependent on thorough investigations with recommendations that are achievable and realistic.

Despite multiple fatalities, injuries, and repeated occurrences at this high risk level crossing, the Board could still not determine the root causes. This begs the question as to

the effectiveness and thoroughness of the CSO's investigations for level crossings, and other types of occurrences. Evidence of the following findings from the reviewed TFR files may offer explanations for why the CSO is unable to determine the causes of certain occurrences:

- Not using accident causation methods or tools, except in two investigations, impacts on the investigation team's ability to accurately identify what happened;
- Not having an investigation team that includes a combination of experts, for example Human Factors Specialists, influences the team's ability understand the bigger picture of what occurred; and
- Time delays between the event and the inquiry impacts on witnesses' memory where they may forget significant details about the event.

The systemic view of why an event occurred is important to identify the various actors in the system and how different role players can contribute to such events, and also help prevent recurrences. A member of the Provincial Government was quoted in one report: *"You Transnet people…why do you kill our kids? Last year our kids were also killed."* Shifting of responsibilities and accountability between the various role players in the system adds little value in preventing recurrences. This was apparent in many level crossing accidents, especially between the rail and road stakeholders. Furthermore, this encourages a blame culture where learning from previous events is unlikely. Le Coze (2013) claims that for learning to occur, strategies are needed to cope with conflict of interests between different actors including between different state agencies. In the high profile level crossing accident discussed above, a recommendation to build a bridge was suggested by the TFR investigation team. Due to the issue of costs and who should pay for the bridge, this was an ongoing debate between TFR, the Municipality, Local Government and the Road Traffic Department as nobody had the budget to fund the bridge. The continuous shifting of accountability and bureaucracy at the expense of ensuring the public's safety questions the entire transport system's commitment to public safety.

Recommendations post an occurrence need to be effective to prevent a recurrence. More importantly is the implementation of the recommendations for real change to take place. In the level crossing example (and in many others) a recommendation such as *"increase*

public awareness of level crossing risks" may be futile and irrelevant given the repeated occurrences. Furthermore, it also illustrates shifting blame to the public and road authorities away from TFR. In the same level crossing investigation the following findings were identified by the TFR Board, however were not mentioned in any of the recommendations to be addressed.

"Tree obstructs road signage"
"Last inspection of the level crossing conducted in June 2013"
"Level crossing report after the accident not completed"
"No risk assessment as per SANS requirements after an accident"
"Not enough traffic officials"
"No traffic officials on site when the train approached"
"Road markings wearing away"

The findings above suggest that there were many contributing factors but that these were not explored further by the Board. The results indicate that level crossing incidents in particular are not thoroughly investigated. The shifting of accountability to the motorist appears to be a sufficient outcome for the Board, with the Operator and the others actors in the rail socio-technical system not held responsible. This is an example of a systemic factor impacting on the effectiveness of the investigation process.

An additional finding in the CSO investigation files was the delay between the date of the occurrence and commencing with the investigation. This was acknowledged by the Board in one report: *"The Board acknowledges it didn't have the benefit of conducting a site visit immediately after the incident and therefore relied on photos of the site and the description provided by the witnesses' testimony"*. Given that the BOI team is established by the CSO to be independent, relying on the witnesses' testimony and photos may lead to biased evidence. If the evidence on site is tampered with, the Board would not be able to establish this. What could have been observed as opposed to what is told to the Board needs to be carefully considered. This is where investigators need to be experienced and skilled to identify any inconsistencies.

In one investigation the delay in conducting the investigation was due to the Line Management investigation not being done in time as there was confusion as to whose area of jurisdiction the incident took place in. This was due to operational areas being restructured within the organisation. Consequently nobody investigated these incidents as each business unit was under the impression the incident was not in their area of jurisdiction. The entire investigation process was compromised due to this dispute. The train crew had been suspended despite no Line Management investigation taking place, and at the time of the Board's investigation, had not been reinstated. These factors influence the effectiveness of the investigation process and add to the complexity of the investigation system. The terms of reference for investigations state that the purpose of the investigation is not to apportion blame. Witnesses were on suspension following a disciplinary hearing despite no accident investigation commencing. This does little to create a just culture. Instead witnesses become fearful and weary of what information to share when they acted as informants in the investigation for fear of any further disciplinary action. The sharing of information regarding safety and mutual trust should be encouraged so as to create a learning culture without fear of punishment thereby facilitating a just culture (Jeffcott et al., 2006). Learning from events helps to prevent recurrences.

In summary the review of the investigation files at both the RSR and TFR demonstrated similar findings, especially with level crossing investigations. The purpose of this research is to focus on the system of accident investigations rather than the accident itself. The results illustrate a number of systemic factors that create the complex system of accident investigations impacting on the effectiveness of the investigation process. The next section discusses the results from the interviews.

7.4 Interviews at the DoT, RSR and TFR results

To determine what barriers outside of the organisational system and human system contribute to the manner in which occurrences are investigated, interviews were conducted at the DoT, the RSR and TFR. The results from the interviews are separated for the *Government, Regulator* and *Operator* in keeping with the different levels of the investigation system.

7.4.1 Government interview

A representative from the Rail Branch in the DoT was interviewed. Twelve themes emerged from the data and are illustrated in Figure 7.2 (a full list of the themes with sub-themes can be provided upon request).

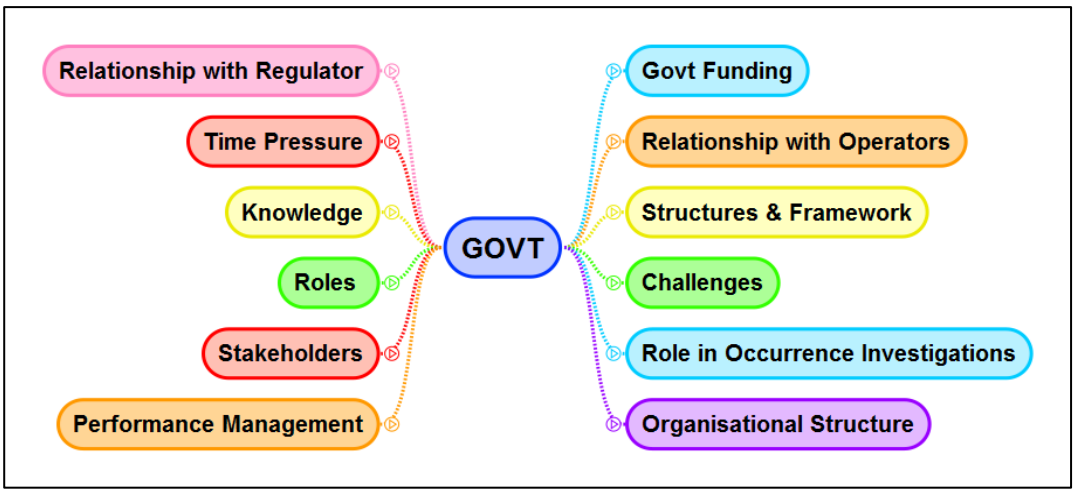


Figure 7.2 The main themes from the DoT interview

The themes identified highlight a number of factors, challenges, pressures, and obstacles (systemic factors) that influence the overall occurrence investigation system. The purpose of the Rail Branch in the DoT is:

- *Rail regulation* (rail policy and strategy, rail economic regulation, and railway safety regulation)
- *Rail infrastructure* (projects)
- *Oversight and business operations* (including PRASA and the RSR to ensure that rail is safe and affordable)

At the time of the interview, the Rail Branch had only been in existence for two years, with two staff members in the railway safety regulation division. The participant explained that the DoT does not get involved in occurrence investigations directly, unless there are social and economic impacts. This is because all South African Government institutions need to adhere to the *"Batho Pele Principles"*. This literally translates to *"putting people first"* and consists of ten principles; for example transparency and improved service delivery. This may explain why the Minister of Transport features more prominently in level

crossing occurrences and in occurrences involving passengers. Both TFR and the RSR governance documents stated that occurrences that attract media attention increases the seriousness of the occurrence and may attract the attention of the Minister of Transport. The DoT participant stated that the Minister rarely goes to the scene of an occurrence, and if the Minister does go onsite, it gives the community a sense that the Minister is doing something. It was admitted by the participant that this is more of a *"publicity show"*. The following are two comments from the participant at the DoT in relation to the Minister visiting occurrence sites:

"This one I will just give you my own point because, um, I wouldn't know, but I just have a feeling that if it's, it's a really fatal accident where people lose their lives and it's been recurring, that's when I think the Minister steps in because I've noticed on some other ones it comes, we just get notified, and, you know, it goes like maybe, uh, spillage of dangerous goods, if there were people nearby then it would become a big issue."
"It's the severity again. If it's just a Mickey Mouse one it's like, no."

The findings from all the data methods indicate that the Government has retreated from active participation in railway safety efforts, there is no National Rail Policy, provides weak legislation and does little to ensure rail is a safe mode of transport. Consequently there is no national 'referee' who determines the acceptability of the investigation of accidents and the accident themselves to protect society. Roed Larsen & Stoop (2012) state that this is problematic as power becomes distributed with no formal safety assessors who are independent to make substantive judgements.

The participant at the DoT was not familiar with the type of railway occurrences, the reporting of these and the different levels of severity. Furthermore, there was no system in place for the RSR to report occurrences to the DoT. It was explained that the DoT could learn about accidents through the media first, prior to being informed by the RSR. This further confirms that the media is an important decision maker in the system of accident investigations. The DoT is not always aware when occurrences take place. Furthermore, the interviewee had never been to the site of an occurrence and had not been provided with a copy of any occurrence investigation reports. This is described in the following example:

"...and it happens that I don't know about this accident. And you will see people at the Regulator, they don't even report this thing and the reason maybe we are unable to participate in these things is because they keep it to themselves, they don't share it with us."

Communication and information about the systems actual state of affairs does not flow upwards from the RSR to the Government level, illustrating that the investigation system and the rail socio-technical system are examples of a disjoined system. The exchange of information in both directions is important for improving railway safety and reliability. Vertical feedback, integration between the levels, openness and mutual trust in the hierarchy were identified as problematic. It was explained that there was no transparency and that people at the RSR were not open and honest with the DoT. A lack of transparency and flow of information between the Government and its own agency (the RSR) propagates down the system, impacting on relationships between the RSR and the Operators. Furthermore, feedback and information about the actual state of railway safety needs to be provided to the Government from the levels below. If not, then the ability of the Government to control safety in the form of laws, regulations and policies is hindered. Furthermore, if the Government is uninformed this impacts on the flow of information to the public. This offers an explanation for why the media underreports occurrences as the public are not informed to generate pressure and attention for Government to effect change. These intricacies illustrate the complexity of the system of accident investigations. In order for effective investigations to enable systems to be safe, this is dependent on the activities of *individuals at every level in the system* and the *interactions between these levels* (Branford, 2011).

The relationship between the DoT and the RSR was a prominent theme. Sub-themes included a lack of independence, transparency and no formal reporting lines between the RSR and the Rail Branch in the DoT. The RSR was viewed as not being fully independent because of PRASA and the RSR both reporting to the Minister of Transport. This is explained in the following example. A similar finding was confirmed in the interviews with the RSR and TFR.

"From my own view, the Regulator should not be belonging to the DoT. Um, I feel it

should be a standalone independent body, um, which could get, um, guidance and some form of limited guidance from the DoT, then it would be able to run through with…, because from my own perspective, having PRASA under our umbrella, it, it looks like we giving them favour against the others."

In terms of funding, the RSR is funded by the Government, through the DoT. Annually the funding is reduced leaving the RSR to source its own funds. This is challenging for the RSR as they are limited in terms of income and what special projects they are able to implement. Furthermore, the participant explained that the limited funding also impacts on how many BOI investigations the RSR is able to complete, given the costs associated with using external specialists. For example:

"*I look at the APP (Annual Performance Plan) and say, okay, they're saying they're going to do 10 investigations…but given the amount of money we don't think it's going to be enough, so what happens? The Regulator gets told, go revise your APP, reduce the number of accidents, reduce the number of this, reduce the number of this."*

A reason for the RSR only conducting a few BOI's is attributed to the reduced Government funding. To counter this, the RSR has had to find ways to generate its own income. The participant explained that the permit system for Operators to run trains has become a source of funding for the RSR. The permit fees have increased with the participant acknowledging that the increased adjustments are being used to fund the RSR. Limited funding constrains the system as a whole, including the investigation system, and the ability to improve railway safety. The issue of the increased costs for the permit fees emerged as a theme in TFR's interview findings.

In terms of time pressure and performance management, the participant explained how there was pressure to meet targets and key performance indicators in the division of the Rail Branch. The DoT itself is also constrained by staff shortages and high work demands. There only two staff members in the rail regulation division. The participant explained that it would therefore not be possible for the DoT to be involved in accident investigations. Shorrock et al. (2014) believe that the success of a system depends on adequate resources and appropriate constraints to meet the demands. Unavailable and inadequate resources,

including people and funds impacts on the Government's ability to cope with demands as is explained in the following examples:

"Unfortunately we don't have capacity, in my directorate; it's only the two of us."
"It's really hectic, it's difficult … you're always under pressure. Like every day you're always chasing targets which you never meet. So I think, for me, that is number 1, the biggest hurdle for us. Like literally everything that can be done by 100 people lands on 2 people. So, ja, that's how hectic it is. So that's why I'm saying to you we're always chasing targets."

The participant at the DoT stated that the RSR in striving for *"zero tolerance"* has also become target driven. The reader will recall that the RSR's vision for 2015-2020 is zero occurrences. The participant felt that the focus of the RSR is centred on the number of investigations that they need to conduct rather than about preventing accidents. For example:

"The RSR has limited scope and it's a gap in the system that needs addressing. They chase the numbers instead of really preventing accidents."

Although an important declaration, the irony of the statement is that the RSR only conducts a very small percentage of investigations. Whether the numbers are significant enough to prevent accidents is unlikely given the systemic factors already highlighted. This was discussed in 7.3.1. The DoT's perception of the RSR is that the RSR has little control over railway safety as they threaten to close Operators down and revoke their permits but that nothing ever happens. The authority of the RSR and its commitment to safety was discussed in 7.2.1 and was acknowledged by the DoT participant as a *"gap in the system"*.

In terms of Government structures and frameworks, bureaucracy was apparent from the interview. In order to achieve any initiatives there were a number of processes, hierarchies and red tape to overcome. The participant explained how the Government has lacked a formal rail structure, with the Rail Branch having only existed for two years (at the time of this interview) and no National Rail Policy and only the Green Paper published by the DoT

(DoT, 2015). The lack of a legislative framework and no formal rail policy indirectly contributes to the number of railway occurrences. This is because safety is not prioritised in terms of Government's responsibilities despite developing legislation such as Act 16. Legislation is necessary for conflicting goals and sets boundaries for acceptable conditions; the responsibility of Government. The implementation and interpretation of legislation is the responsibility of the RSR, who through rules controls the activities of the system. Given the high number of occurrences and poor railway safety performance in South Africa, the priorities and commitment of the South Africa Government and the RSR are doubtful. The participant confirmed that rail has been not been regarded as a serious sector in South Africa:

"Honestly speaking, given that it's a baby, a new kid on the block (rail), I don't think everyone gives it…it's like, so what! I think people are more focused on, you know these thriving industries."
"The concept of rail is still a distant something to the people. I don't think it's taken as seriously as it should, and by virtue of, of the inadequacy or absence thereof, of the rail policy then it, it means, it seems, it says a lot to me. It says you are not taking this thing seriously. I mean, if railways has always been there before all the other things, you've got policies and legislative framework for all the other things, this one is always lagging behind, how serious do you take this thing, you know?"

In terms of the DoT's opinion of railway Operators, the view was that smaller Operators feel they do not need to be regulated as rail isn't their core business and bigger Operators become rebellious and feel they are overregulated. This creates a negative relationship between Operators and the Regulator. A lack of trust and openness between the two levels in the system was identified in the interviews. Furthermore, the bigger Operators feel that they fund the Regulator (with their permit fees) and that this entitles them to more power and authority. Conflicting goals for the RSR include overseeing railway safety but also generating funding to sustain themselves. This dichotomy impacts on the relationship between the RSR and the Operators as highlighted below by the participant:

"Maybe that's why they're getting that, the rebellion back from the Operators because they're pushing so hard because remember, when, when you've also got a target then

you start pushing me as well and then you get that ugly reaction from me and then, now it becomes a sour relationship."

Of the twelve themes that emerged from the interview data, the theme with the most sub-themes was that of *challenges*. Challenges include the pressures, issues and constraints that the DoT is confronted with. Figure 7.3 illustrates these challenges.

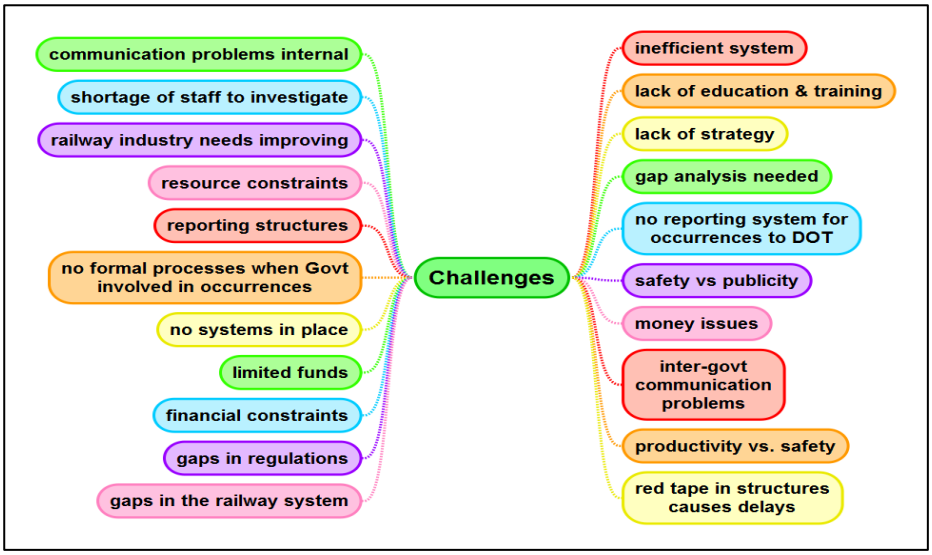


Figure 7.3 The theme challenges from the DoT interview

An example of one of the DoT's challenges is the lack of education and training and no knowledge and skill transfer within the DoT. These have impacted on the DoT achieving its mandates. These factors were attributed by the participant to South Africa's political situation post 1994 (in 1994 South Africa transitioned to a democratic country ending Apartheid). Furthermore, the lack of expertise is a contributing factor in the delay of establishing a National Rail Policy. For example:

I don't know if I'm politically correct but I just feel how this country has approached things, for me, um, is wrong… and you take away all the expertise, it's going to fall. You're taking away all the brains, all the intellectual property and you hope to establish something, but there's, there's no knowledge transfer. When I get to work there's no one who can transfer all that knowledge."

In terms of the gaps in the railway system, the participant stated that the authority of the RSR is limited. This is not only due to staff capacity and funding, but also in terms of authority to really enforce safety. The issue of the doors of the PRASA trains not closing was used as an example. The lack of authority of the RSR to revoke PRASA's permit due to violating a basic safety requirement was discussed. The RSR has a conflict of interest because of the structure and reporting lines in the railway system. The participant confirmed that *"they never will"* and that if the Operator's permit was revoked *"this would impact on the economy of the country".* It was further explained that Act 16, the legislation that gives the RSR its *"power"*, is not well enforced nor understood at a Government and RSR level impacting on the state of railway safety. If at the highest levels of the investigation system, legislation is not understood by those who develop it, then the expectations on the lower levels of the system to adhere to its requirements may result in differing interpretations. This was confirmed in the results previously discussed. The consequence of this is a disjointed system, where a lack of coherence hampers the system's ability to achieve its goals of safe, reliable and efficient rail transport.

The issue of the RSR increasing the permit fee costs has impacted on the work demands of the DoT as Operators have legally challenged the regulations. The comment below emphasises how easily Operators are prepared to legally take on the RSR and the Government. This demonstrates the dominance of the Operator, or conversely the weakness of the state.

> *"This development of this new, uh, safety permit fee model. It's been a nightmare and Operators have been complaining about the escalating fee, so we're dealing with battle after battle and, you know, Transnet's, um, legal team, so, ja, when you start dealing with that, I promise you, everything you park aside and then you start to get, we need to get state law advisors, we need to do legal opinions like we really, so I think, for now, that had taken so much of our time, we could not focus on anything."*

The reporting structures were also a factor with Transnet reporting to another Ministry in the DPE, who is the main shareholder. PRASA reports to the DoT. The different Government reporting structures have conflicting goals themselves. The DoT is concerned with safety of all modes of transport while the DPE is primarily concerned with economic

development, infrastructure and productivity. The participant explained that there is a lack of integration between the different agencies in the Government structures. For example:

> *"The DPE does not understand the dynamics of TFR, like at all. We get there and DPE knows literally … knows nothing related to the operations of Transnet, uh, the dynamics and everything."*

In the DoT's limited interactions with the DPE regarding railway safety and regulation, the participant explained that the DPE does not understand the dynamics associated with railway safety and rail regulation. Because systems are nested within systems, shifts in one complex system impact on functioning of other systems. The lack of integration and flow of information in the bigger rail socio-technical system (apparent within the Government structures and between the Government and the Regulator) impacts on the complexity of the accident investigation system.

Lastly, the final comment from the participant is worth noting. One of the outcomes of this research is to provide industry with ways in which they can improve the investigation of railway occurrences. The participant felt that the types of questions asked by the researcher warranted further work in the railway industry to improve the way in which occurrences are managed. Furthermore, the participant alluded to the Government playing a more active role in railway occurrence management:

> *"I think it's just awakened me. I think this, we've parked this type thing and it's, it's, it's a very important aspect and the only time we get active is when this thing is being prepared, then everyone gets into a hype, you know, accidents, occurrences, accidents, and then after it dies down. So it's one of those things that maybe we should start taking seriously and see what, um, the direction or the role that the department wants to play, uh, especially within this aspect, ja."*

Overall the findings from DoT interview illustrate that the rail socio-technical system is fragmented with a lack of integration and flow of information within and between the various levels of the system. The Government does not play a significant role in occurrence management and it was acknowledged that the railway industry has been

overlooked. The interview findings for the next level in the system, the RSR, are discussed in the following section.

7.4.2 RSR interviews

The interviewees from the RSR provided a number of systemic factors that influence the effectiveness of the investigation process, and the findings and recommendations. In total 24 themes emerged from the interview data each with a number of sub-themes. Figure 7.4 illustrates the themes emanating from the interviews (a full list of the themes and sub-themes can be provided on request).

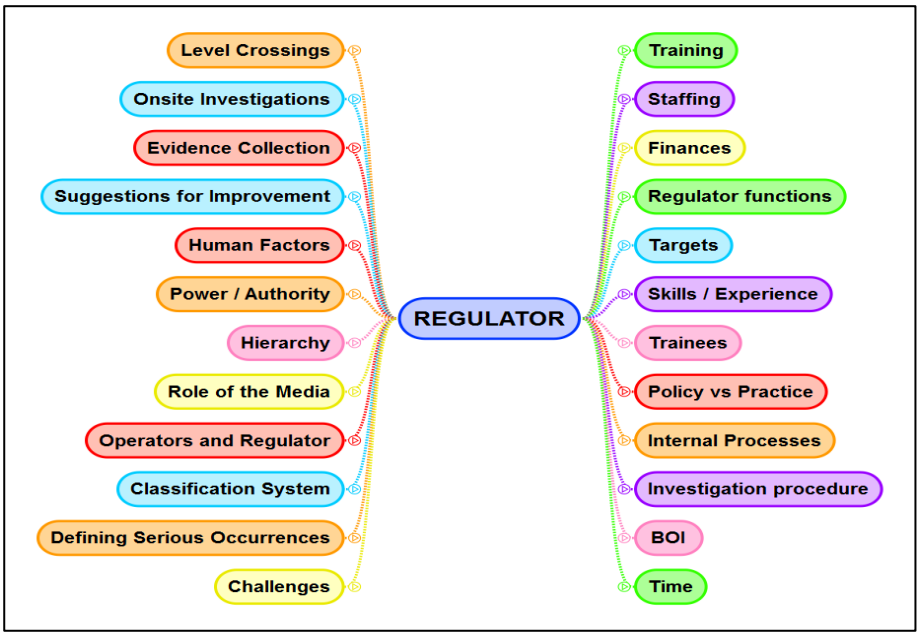


Figure 7.4 The main themes from the RSR interviews

Only a few themes will be discussed in detail as others will be discussed in the observations. The themes selected include: defining serious occurrences, classification system, targets, staffing, finances, trainees and skill/experience.

Defining serious occurrences: All the participants gave different definitions for what a *"serious occurrence"* was and the distinction between a major and a minor occurrence was often ambiguous. The seriousness of the occurrence determines the level of investigation and also whether the event is classified as major or minor. In trying to determine how the RSR selects occurrences to be investigated from the 4500 occurrences that are reported, the following explanation was given:

"It's based on man power and the resources that we have. It's truly that. We could, because we like this year, we have 4500 operational occurrences. And if, I, I was telling the guys there, you see, they were, they wanted to compare, um, in percentage you take 30 that we have done, you divide by 4500, you get a 0, then you can't do that. Rather you take, you take that, um, 30 and you divide it by the very serious ones, then it might give you some answer."

Ascertaining what classified an occurrence to be *"very serious"* was difficult as a number of participants provided different definitions. Given that a number of occurrences resulted in fatalities and injuries, it was necessary to probe further to distinguish between a major and minor occurrence. Again none of the interviewees could provide the same answer and struggled themselves to differentiate between major and minor events. A participant stated that the 32 occurrences selected for investigation from the 4500 were *"very, very serious"* occurrences, but could not explain what separated these from other similar incidents. In trying to establish whether the RSR was investigating a significant number of occurrences to prevent recurrences, and therefore have any impact on improving railway safety, the following explanation was provided:

"I'm saying the very, very serious. We can say maybe of the 4500, I can say maybe which ones we were supposed to, maybe close to 1000, if you check where there was an injury and all that, uh, but in the very serious ones, we, we've we even pass the 32."

The above comment is contradictory as the RSR suggests it needs to investigate more than the 32 occurrences in order to improve railway safety performance, despite justifying the small number of occurrences investigated. The seriousness of an event influences the level of investigation and determines whether the RSR or a BOI will be conducted. The next theme is the classification system used by the RSR.

Classification system: Participants explained that Level 1 and 2 investigations were the same. The RSR conducted Level 2 investigations with BOI's a separate investigation altogether. BOI's were different as these were chaired by external people outside of the RSR. The number of BOI's that the RSR conducts is constrained by financial costs. This is an example of a systemic factor and an extract supporting this is given below:

"Ah, there's no, no, there's no difference. But now, what you need to understand is the very serious occurrences should be, should be done through a BOI but obviously we can't. If we have 5 or 10 of those, there's no way we can do BOI's on them, but, um, actually, there's not much, the only difference now that you can say there's, a BOI is done by, it's chaired by an external person and then, um, even though the occurrence look like it's similar to that of a, of a Level 2."

The decision of which occurrence to investigate was based on the experience and decision making of the RSR's Principal Inspector. The Principal Inspector does not use any formal matrix to select the occurrences for investigation. Many of the inspectors were unaware of how the Principal Inspector selected occurrences to be investigated. One participant stated that the classification system adopted by the RSR was *"confusing"*. The allocation of occurrences to the RSR inspectors to investigate was also not known to the inspectors. As there was no rostering system for who would be investigating what occurrence, and when, the inspectors would wait to be informed by the Principal Inspector. In one instance two inspectors were investigating the same occurrence but did not know until they were chatting amongst themselves. This finding illustrates a lack of integration and feedback within the RSR Occurrence Department.

Furthermore a challenge experienced by the Principal Inspector was receiving communication of occurrences as they happen. The information is not immediately communicated to the Occurrence Department but gets received in the call centre first and then relayed to another department in the RSR. This contributes to the delay in commencing with an investigation as the Principal Inspector may find out about the occurrence after some time. This was attributed to there being no formal communication and information system in the RSR for reporting of occurrences. An example is given below:

"You see, the way we're working now, we don't have an information system, a working manual. Excel, that's what we use to store the occurrences that have been reported. And then how do I get to know about (the occurrences) because the dailies, it's only the ones that they call by phone, the very same, because they come, well, the call centre calls me, but those others, the dailies, those other occurrences there's, they e-mail them to XXX,

he puts them in a database. ***I was talking to one of XXX's guys to e-mail me what happened the whole of last week so that I can see whether there are occurrences that we can investigate.*** *You see, that's how we work it, but now, once the information system is working then I will be able to just check by myself."*

This example further illustrates the lack of integration within the RSR impacting on the flow of information and feedback about the systems performance. The next theme that emerged as a prominent category was that of achieving targets.

Targets: The RSR is not required to investigate every occurrence. Given the costs associated with instituting BOI's, the RSR focusses mainly on Level 2 and 3 occurrences. Limiting the number of independent investigations because of financial constraints is an example of a systemic factor that influences the objectivity and effectiveness of the investigation process. The researcher was informed that as part of the RSR's operational plan, each financial year targets are established for the number of investigations to be conducted. The following statements relate to the theme of targets:

"The number of BOI's is supposed to be two this year"
"32 Level 2 investigations"

A few participants stated that Level 3 occurrences are not really investigations but more of a review or audit of the Operator's investigation files. For example *"Operators give us their report, we review it, and if we accept we treat it like it's ours and then we conduct follow-ups"*. SPADs were also classified as a level 3 occurrence. The perception created is that SPAD events are not serious railway occurrences and therefore only warrant a review of the Operator's investigation report. These incidents have the potential to cause serious harm and not investigating them independently could contribute to recurrences. The targets for the RSR Occurrence Department were based on the limited manpower and resource constraints. Furthermore, the participants explained that there were *"serious constraints to meet the targets"*, that the department shouldn't be *"focussing on targets"*, that the targets were for *"control purposes"*, and that focussing on targets could jeopardise the quality of the reports. The targets and the small number of occurrences investigated by the RSR are examples of systemic factors impacting on the effectiveness of the investigation system.

Shorrock et al. (2014) argue that by managing individual functions, parts of the system compete. In striving to achieve individual goals, goal conflicts are introduced where individuals compete at the expense of the system. Instead, the focus should be on the systems purpose, i.e. achieving effective accident investigation for safe railway operations.

Staffing: In terms of resources, the RSR only had four inspectors and is supposed to have 26 inspectors in the theoretical Occurrence Department structure. There were a few trainee inspectors and interns, but these were not considered as part of the 26 inspectors in the structure. Therefore the lack of capacity, together with the workload experienced by the investigators, results in only a small number of occurrences being investigated. This constraint was acknowledged as a *"challenge"* that impacted on the workload of the inspectors who were *"worked up"*.

The issue of the removal of the stand-by system to enable inspectors to conduct occurrence investigations after hours and on weekends was raised in the interviews. As discussed previously, the removal impacts on the RSR releasing staff to attend to the scene of an occurrence immediately. For example:

"We don't have standby here. We don't have somebody who's standing … I don't have enough human resources. The finance part also is a challenge."
"We pray accidents don't happen on the weekends"

The last comment above illustrates the seriousness and implications of not having a stand-by system. This impacts on the comprehensiveness of the RSR's investigations as the RSR only attends the scene sometime after the occurrence and is unable to ensure that the evidence is preserved at the scene. This is because Operators need to clear the railway line in order to resume operations, illustrating the conflicting goals of the two organisations. The onsite investigation is an important stage of the investigation process that is not performed by the RSR. The RSR relies on the Operator for footage, compromising the independence of the RSR's investigations. The inspectors highlighted that the delay in conducting occurrences, impacts on the credibility of the witnesses' testimony as they were unable to recall information.

Finances: The shortage of staff, lack of resources, no stand-by system, not always getting to the site, and the number of investigations conducted are attributed to financial constraints. As already mentioned, the RSR's funding from the DoT is reduced annually. This impacts on their budget and expenditure. The researcher was informed that more BOI's would be done if there was the financial means to afford external specialists. One participant explained that to generate income, the RSR implemented the Penalty Fee Regulations while another participant suggested that the RSR should charge Operators to investigate their occurrences. Examples of quotes relating to finances are summarised below:

"We are choked financially"
"If we have 5 - 10 very serious occurrences, no ways we can do BOI's"
"We can't hire more people"
"We do more occurrences at the beginning of the financial year because there is budget"
"We were supposed to do two for the year but the money's gone"

Finances also impacted on what locations in South Africa the RSR would investigate occurrences, as travel and accommodation costs needed to be considered. Furthermore, the RSR as an organisation only had one company vehicle that was shared with the other departments, limiting travel. Equipment such as cameras and voice recorders were shared amongst the investigators, where at any one time more than one team would require the tools to perform their job effectively. Shorrock et al. (2014) state that in order to meet demands it is only possible with adequate resources and appropriate constraints. The examples illustrate that the RSR does not have the resources to investigate the number of occurrences (demands), and conduct these effectively. This is because they are constrained financially. The inherent systemic factors in the investigation system impact on the systems performance.

Trainees: Given the resource constraints, the RSR uses interns who, as part of a Government initiative, are provided to the RSR to gain work experience. The trainees have no railway knowledge but are recent graduates with a technical discipline for example, civil engineering. One participant explained that after four months of starting at the RSR

the intern had commenced with their own investigations, despite no rail experience and investigation training. The trainees help as a resource but in terms of competency they are not adequately trained, find the role of inspector as *"difficult"*, and have to learn on the job with no investigation manual provided to them. One participant explained that when interviews are conducted with witnesses *"this gives me a headache because I don't know what to ask"* as there are no checklists or examples of interview questions provided. Interns were assigned a mentor (senior investigator) to help teach them, but most felt that they needed training to help them. The interns interviewed were all surprised to be conducting their own investigations and writing reports so early on. One participant explained: *"It's difficult. Like now I was doing my own investigation alone, to write a report is difficult, it's, it's not easy."*

In the RSR, the trainees are used to alleviate the work pressure and fill in the gaps created by the vacancies. The quality of the investigation is compromised as the trainees themselves admitted to not being adequately trained or experienced. The interns added that to teach themselves they rely on *"Google"* and past investigation reports. Roed-Larsen & Stoop (2012) assert that investigating requires qualified, knowledgeable and competent individuals, which the trainees were not. As discussed in the previous sections, the investigation reports have gaps and don't always address the bigger picture. The amount of learning required by the interns or trainees is substantial in order to effectively conduct an investigation, provide accurate findings and recommendations that address the findings sufficiently to prevent a recurrence. The researcher was informed that the trainees would only go on courses after a year when they would then be on the payroll system, reiterating the impact of the RSR's financial constraints on the effectiveness of the investigation process.

Skills and Knowledge: The training, knowledge and experience of the RSR's investigators influence how they conduct an investigation. Furthermore, it also impacts on the accuracy of the findings and whether the appropriate recommendations are proposed. Two RSR inspectors had previous experience in the aviation industry. Both inspectors explained how significantly different the railway industry was in conducting accident investigations. The training received to be an investigator in the aviation industry was far more advanced whereas at the RSR, there was no internal investigator training, no training on how to establish the root causes of accidents, or how to interview witnesses. The two inspectors

added that they were *"lucky"* to have their aviation experience and that anyone who did not have prior investigation training, experience and knowledge would not be able to do the job effectively. One participant acknowledged that there was a railway skills gap as the RSR competes with the Operators for skilled railway personnel. This results in the RSR recruiting people who do not have a background in rail and was a reason for why none of the inspectors had railway knowledge prior to their appointment at the RSR. The railway skills shortage in South Africa is acknowledged as problem in the DoT's Green Paper for a National Rail Policy (DoT, 2015). This illustrates how systemic issues in the bigger rail socio-technical system influence the system of accident investigations nested within.

Most of the participants explained that it was not only the skills, knowledge and experience of the RSR inspectors and trainees that was limited, but also the attorneys who chair the BOI's. The participants felt that many of the attorneys lack railway knowledge and were inexperienced in conducting accident investigations. This contributes to the effectiveness of the investigation process and impacts on the quality, objectivity, accuracy and validity of the investigation reports. This was evident in one of the BOI observations instituted by the RSR where the attorney was chairing a railway investigation for the first time and did not understand railway terminology.

The above results suggest that there are a number of systemic factors at a RSR level within the investigation system. These not only influence the effectiveness of the investigation process, but also the comprehensiveness of the reports, the accuracy of the findings and appropriateness of the recommendations in trying to prevent recurrences. Some of the systemic factors propagate from the level above the RSR i.e. the South African Government. Decisions and actions at the top filter down the levels in the system with side effects felt at each level that may not be anticipated. Other agents in the system, in trying to achieve their goals have to act in order to restore balance to the system. These actions may also lead to unintended and intended consequences. The accident investigation system is therefore an example of a complex system in its own right. Figure 7.5 summarises the findings from the RSR interviews and depicts the relations between the various themes.

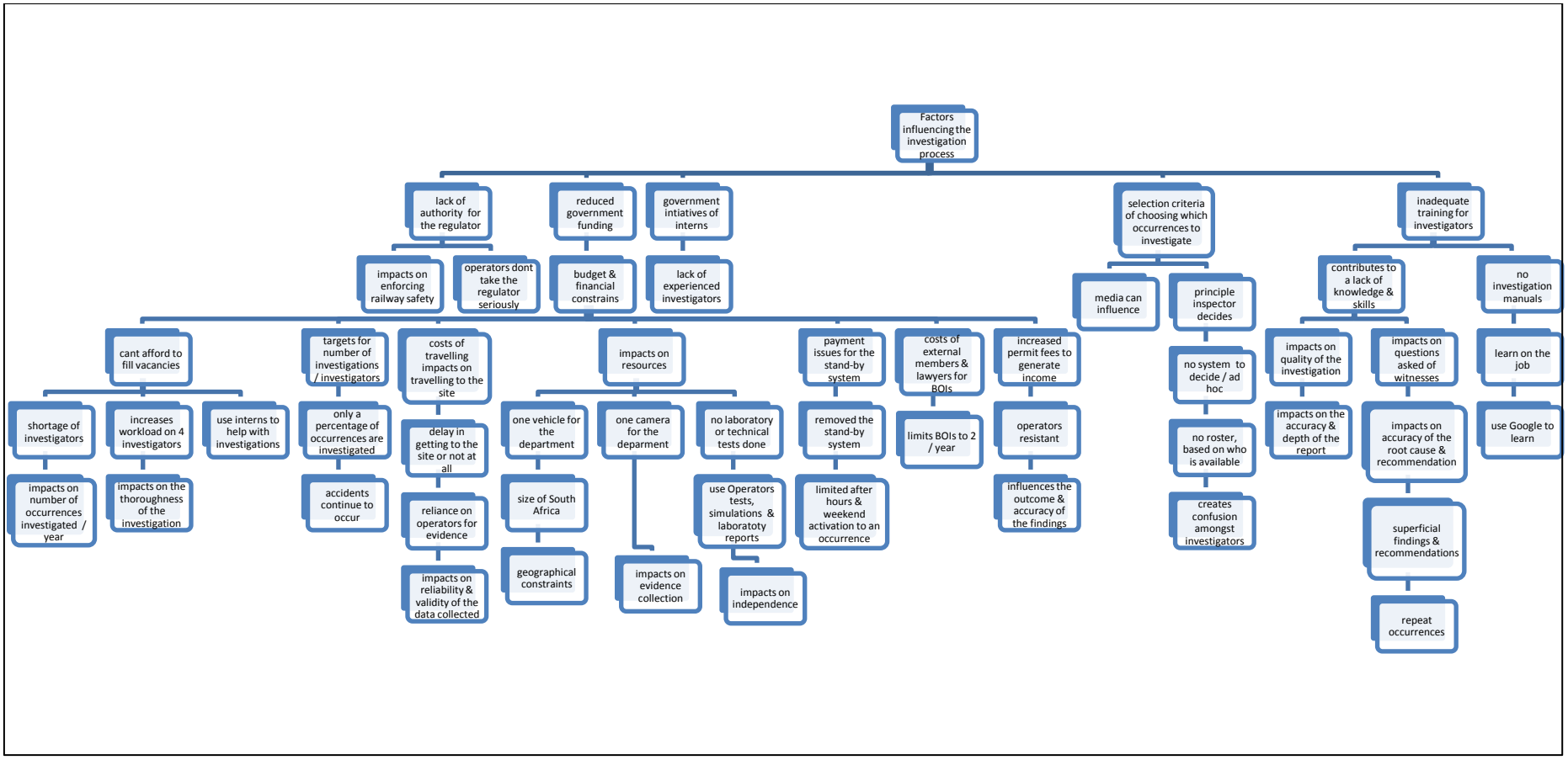


Figure 7.5 Summary of the RSR interview findings

7.4.3 TFR interviews

This section details the findings from the next level in the investigation system, the Operator represented by TFR. This level of the system is split into two levels: Management and Staff and includes both the CSO and Line Management. TFR does not have people appointed as investigators; therefore interviews were conducted with Managers responsible for occurrence management. The results are separated for the CSO and Line Management.

7.4.3.1 CSO results

In total 27 themes emerged from the CSO interview data. Some of the data has already been discussed therefore only nine of the themes will be elaborated on further. These are: the safety permit fee, RSR and TFR's relationship, the RSR penalty system, the perception of the Regulator, capacity to investigate, competence/experience, the Occurrence Policy, non-compliance and the dichotomy of safety and productivity. These themes were selected as they were discussed in the most detail by the participants and also provided the context to describe the organisations approach to occurrence investigations. Figure 7.6 provides an illustration of the themes overall (each theme has sub-themes which can be provided upon request).

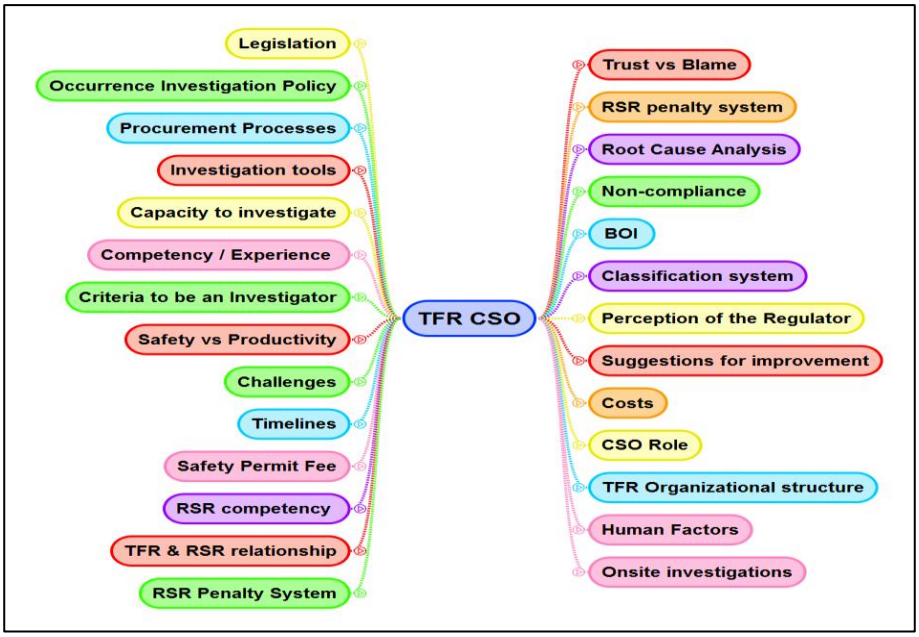


Figure 7.6 The main themes from the CSO interviews

Safety Permit Fee: Annually TFR has to reapply for a safety permit fee from the RSR. This is a source of income for the RSR (as already discussed) and in essence is a 'licence' for the Operators. However, it was explained that TFR had not paid this fee due to a legal battle over the drastic increase in the fees. This finding was also identified in the interview with the DoT representative. TFR participants felt that the RSR's motivation for increasing the annual fee would result in Operators taking the RSR more seriously. The consequence of the increased fees has resulted in strained relationships between the RSR and TFR. The seriousness of the matter was escalated to the CEO level of both organisations and also to the two different Government ministries. TFR did not agree to the criteria set by the RSR for the drastic fee increase (the fees increased from R2.754 million in 2005 to R61 million in 2014). TFR disputed the drastic increase in the safety permit fee because the safety permit fee used to be an annual fee, then it changed to be based on the Operator's activity, and at the time of the interview was based on the Operator's income. Again this illustrates the dominance of the Operators and supports Thompson (2009, p. 11) who states that "*the regulatory frameworks are incapable of resolving problems in the industry"*. The RSR's lack of authority is evident in this example where an Operator is able to challenge the RSR even at the highest level. Political influence was evident in matters that created disagreements between the RSR and TFR. The effective functioning of the bigger rail socio-technical system is impacted by strained relationships and little integration between the two levels in the system. This was identified as its own theme that emerged from the data and is discussed next.

RSR and TFR's relationship: It was mentioned that at a CEO level the relationships are tense given the above mentioned safety permit fee. One participant explained: "*You can see it and feel it!"* Further up the system, it was admitted that at a strategic and political level, the relationships are strained between the two organisations; however at an operational level there is no problem between the two levels of the system. However, one participant explained that the RSR in their communication with TFR, for example when the RSR requests information from the Operator for an investigation, adopted a harsh tone emphasising their authority. The participants acknowledged that there is *"room for improvement"* in terms of rebuilding the relationships. One participant stated that the conflicts are healthy and there would always be robust discussions especially when interpreting Act 16, regulations and standards. Strained relationships do not facilitate creating a just culture where organisations and individuals have a mindset of openness,

trust and fairness. The intent of the RSR may be for the betterment of the railway industry, however the approach and the understanding of the RSR's actions in context may not have been well thought out. If the highest levels of the system do not establish a mutual understanding between the actors then this will result in little cooperation and unnecessary interference. Given that systems are dynamic, the behaviours of the higher levels of the system filter to the lower levels shaping the systems performance. Therefore the lack of a just culture at the highest levels may be a reason why in this research, at an operational level, a blame culture was evident. This is discussed further on.

RSR Penalty System: Not only are Operators required to pay a safety permit fee to operate trains, they are also required to pay a penalty fee in instances where a safety rule was transgressed. The Penalty Fee Regulations are instituted by the RSR (stipulated by Act 16) as part of their mandate to oversee safe railway operations. Participants at TFR in the CSO described how the penalty fees have also had a bearing on the relationship between TFR and the RSR. It emerged from the interviews that TFR is threatened with a penalty if they do not adhere to the RSR's requests for example, not submitting a corrective action plan (post an occurrence investigation) on time. Despite being threatened with the penalty clause, TFR has often appealed and disputed these. The matter is then escalated to each organisation's legal department to resolve. One participant stated: *"We have the sword of the penalty looming over our heads"* which the participant admitted made the organisation uncomfortable. This again speaks to creating a just culture where openness, mutual trust and fairness are encouraged. The opposite, a punitive culture, leads to fear and resistance. Shorrock et al. (2014) claim that a just culture helps to understand how the system behaves by creating opportunities for sharing and learning. Understanding the context in which work is done, and respecting that goals of various levels in the system may conflict one another are important system concepts. TFR felt that the RSR was not fair as often the focus of the RSR was on *"nailing the bigger Operators"*. TFR also felt that the RSR was lenient towards PRASA and was not impartial to be fair given the reporting lines, conflict of interests, the need to generate revenue to be self-sustaining and the means of going about this.

The authority and autonomy of the RSR was questionable as participants felt that the RSR's use of the penalty system was to impose their authority rather than to ensure railway safety. A comment by one of the participants: *"they don't really the have teeth to*

enforce safety" illustrates that in reality the RSR is unable to fulfil its mandate. This could be due to being under-resourced and not having a strong legislative mandate to be able to follow through. Another participant described the RSR as *"playing the person not the ball".* The participant described how the RSR is unfair in how it treats TFR and has a vendetta against the organisation. In one instance TFR refused to pay a penalty as there was a technicality in the Penalty Fee Regulations that was identified by TFR's Legal Department. In another example, it was agreed between the two organisations, at a CEO level, that a penalty issued was no longer payable. Figure 7.7 provides examples of statements that grouped together formed the RSR penalty system theme.



Figure 7.7 RSR Penalty fee system as a theme from the CSO interviews

The ability of the Operator to assert their authority over the RSR questions how influential the RSR is. Furthermore, the Penalty Fee Regulations if ambiguous result in decision makers at the next level of system having to decide how to carry out the functions. The way this is done might be different to how the rule makers anticipated this to be. Rasmussen (1997) states that changes in legislative strategy brings about substantial changes in the structure of the distributed decision makers. Delegating decisions to the next level creates distributed organisations where communication about the systems performance is imperative. The impact of these decisions on all stakeholders needs to be formally considered (Rasmussen, 1997). The implementation of the Penalty Fee

Regulations by the RSR may have been decided with good intent but unintended consequences. It appears that the penalty fees and prohibition notices are idle threats given that the Operators do not have their permits revoked, questioning both the RSR's and TFR's commitment to safety. The next theme discussed relates to how TFR perceives the RSR in how it conducts occurrence investigations.

Perception of the Regulator: Participants expressed their concern with regards to the manner in which the RSR conducted occurrence investigations. Examples provided included: the RSR arriving at the depot unannounced for an investigation, the spelling in the reports was poor, that some of the inspectors were not trained or knowledgeable in accident investigations and *"do not have a clue about train control and train operations"*. A participant stated that these issues impacted on the quality of the RSR's investigations. The TFR participants' perception of the RSR is that the RSR relies heavily on their investigation reports, documents, evidence and information. It was explained that this was because the RSR inspectors are not experienced in occurrence management and do not have the operational knowledge to determine what happened. The participants felt that they trusted the quality of their reports more, especially because the RSR does not have a laboratory for any technical tests. It was acknowledged that there were some investigators at the RSR who *"do a great job"* and that the *"experienced investigators'"* reports correlated with TFR's reports.

The overall perception of the RSR was that the different ministerial reporting lines for TFR and PRASA resulted in political interference in their relationships, in particular, between the RSR and PRASA. The perception of the participants interviewed was that there was a certain element of bias towards PRASA, creating a conflict of interest. The RSR was seen to be more lenient of PRASA due to both organisations reporting to the Minister of Transport and that this impacted on the objectivity of the RSR's investigations. Examples of statements made by the TFR participants include:

"The Regulator doesn't make noise for PRASA"
"When PRASA acts negligently the RSR does nothing"
"PRASA and the Regulator are brothers and sisters"

The interviewees not only shared their perception of the RSR but also shared what they felt in terms of how the RSR perceived TFR. Many of the interviewees felt that the RSR had a negative opinion of TFR with the following comments highlighted:

"They have a vendetta against TFR"
"RSR is built on a foundation with ulterior motives"
"They have missed the point"
"Regulator does not act in good faith"
"It is to show these Operators"
"…likes to be difficult"

The participants explained that when the RSR was formed, a number of TFR employees were recruited to the RSR. The TFR interviewees felt that some of these employees were *"disgruntled ex-TFR employees"* who had a point to prove when they moved to the RSR. One participant stated that compared to international regulators, the RSR was not helpful, did not create an *"enabling environment"* and instead were *"wanting to penalise us"*. TFR is the biggest freight operator with operations all over South Africa. The participants described how the RSR do not understand the size and complexity of TFR, often imposing unrealistic timelines or deadlines for information. This statement is contradictory, because on the one hand the participants suggest that the RSR is made up of ex-TFR employees who would therefore understand how TFR operates, and conversely state that the RSR doesn't understand TFR. One participant suggested that there is a need for the RSR to be more like the South African Civil Aviation Authority (SACAA). Furthermore, TFR felt that they were penalised for level crossing occurrences and felt that the RSR did not put enough pressure on the Minister of Transport to get the road authorities (who also report to the Minister of Transport) to play an active role in preventing level crossing occurrences. The relationship and perceptions between the RSR and TFR influence the ability to create a just culture. The next theme that is discussed is that of the capacity to investigate.

Capacity to investigate: TFR does not have employees whose sole job it is to investigate occurrences. Investigations are done by Managers who have other responsibilities, namely running operations. In terms of the CSO's structure, a participant described it as being *"seriously inadequate"* as there are a number of occurrences and *"you can't cope"*. It was

acknowledged that a weakness of the organisation was that the CSO and Line Management do not have capacity. One participant stated that *"people are pulled from their normal job to investigate"*. Another interviewee explained that it was stressful to keep up with the number of investigations and this resulted in:

> *"Those that are grey / borderline we discard them. They have potential to be major but we discard and they disappear into thin air"*

The statement above suggests that not all occurrences and near misses are investigated due to capacity. This admission contributes to a recurrence of accidents as the purpose of an investigation is to identify what happened and to put in place recommendations to prevent recurrences. The participants at the CSO stated that in some of the Line Management investigation reports, the quality of the reports and the accuracy of the findings was a problem. Quality issues result in a large amount of inconsistency in the investigation reports submitted to the CSO and increased work demands on the person responsible for quality assurance. Quality assurance of investigation reports is performed by a single individual who has to review investigation reports for the entire company. Furthermore, this individual is also required to monitor the implementation and effectiveness of the recommendations from the investigation reports. It was acknowledged that the workload of this individual to review, monitor and follow up for every investigation was too demanding. It was not always possible to follow up whether every recommendation was implemented or effective. Le Coze (2013) states that it is not the investigation of accidents that prevents them but the implementation of the recommendations that result in improvements. A reason for the poor safety performance trends is that not all of the recommendations are implemented or monitored for effectiveness. This is an example of a systemic factor, including the lack of capacity to investigate. The next theme discussed is competency/experience and how this impacts on the accuracy, quality, validity, reliability and effectiveness of the investigation process, the findings and recommendations.

Competency/experience: This theme and the statements highlight important systemic factors that influence the effectiveness of the investigation process. A lack of skilled railway professionals in the country has a direct impact on TFR employing people who have experience. As a result TFR is required to utilise available resources within the company to conduct occurrence investigations. However, the company offers little to no

training for employees on occurrence management and how to conduct accident investigations. A further constraint is that TFR does not have formally appointed qualified and skilled investigators. These factors contribute to the efficacy of the occurrence investigation process. A participant described the use of external attorneys for BOI's as a factor that impacts on the quality and comprehensiveness of the reports as they do not always have railway knowledge. For example: *"CSO has to help external people a lot (in investigations)"*. An additional contributing factor that impacts on the effectiveness of the investigation process was inexperienced employees. It was explained that this was attributed to the high turnover of staff and accelerated promotions of employees who were in positions for a short period of time, especially at a Line Management level. One statement illustrated that the knowledge of inexperienced employees is rudimentary. For example: *"New people you have to start with the four modes of transport"*. Figure 7.8 summarises the statements from the competency/experience theme.

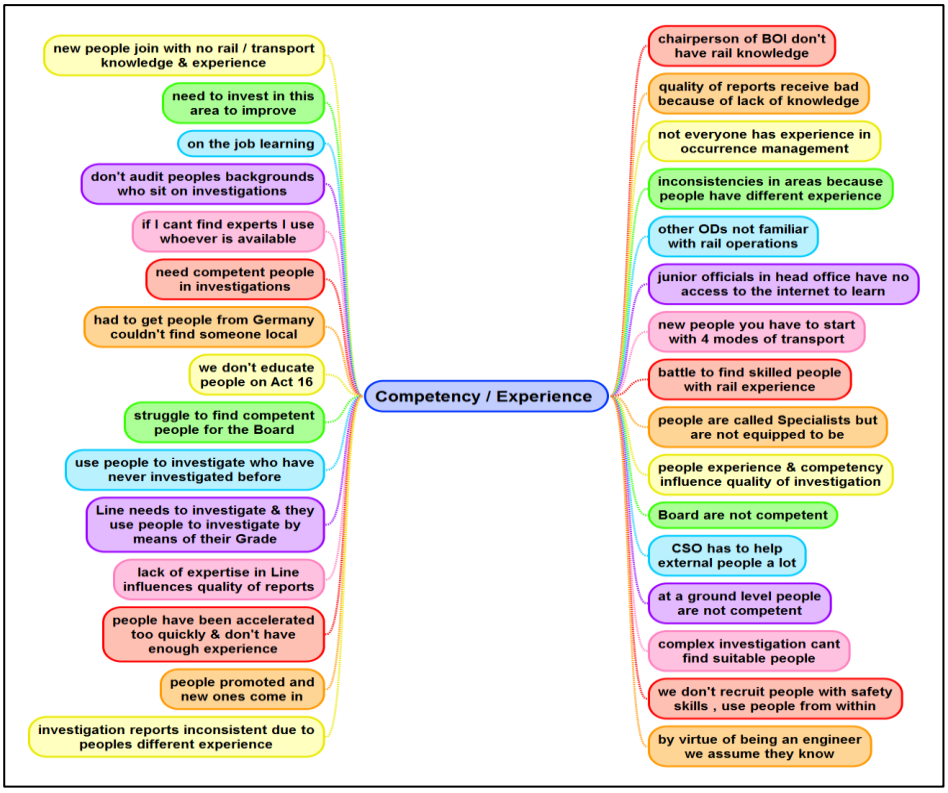


Figure 7.8 Competency / experience a theme from the CSO interviews

Another factor that impacted on obtaining competent/experienced investigators from outside the company to conduct BOI's relates to company procurement processes. The following comments illustrate how bureaucracy and internal processes hinder the

organisation from achieving its safety objectives and the ability to conduct thorough investigations:

"There are so many challenges with our processes"
"Procurement policies are a stumbling block"
"We approached people who had gone on pension to assist us on the Board. Pensioners couldn't apply because of the procurement processes"
"We went on an open tender for people with expertise and only four companies applied"

The complexity of the accident investigation system is due to the limited integration, flow of information and feedback within the organisation. Actions taken at higher levels propagate and impact on the decisions of other actors in the system. This results in side effects that are not always anticipated. For example the procurement policies and bureaucracy impact on the organisation's commitment to safety and therefore the effectiveness of the investigation process. The next theme relates to the Occurrence Policy that emerged from the interview data.

Occurrence Policy: As discussed in the governance document results, the Transnet Group BOI Policy was not always adhered to by TFR. The participants felt that this policy was too generic, had many gaps, was not specific to the railway environment and was not practical to implement. The following are examples of the participants' concerns:

"There are serious problems with the policy"
"We can't comply to the policy for practical reasons"
"We need to do away with the BOI policy"
"It's a company policy but I have my views"
"The words in the policy are used loosely"
"The policy prevents us from using internal people so this takes time to find people"
"Sometimes violate the policy to move forward"
"Circumstances force you to not comply"
"Couldn't comply to the policy so ended up not complying"

The interviews results, the review of the investigation files and the governance document results illustrated that what happens in practice is not as per the policy. Local rationality is a systems principle that explains how work that is done needs to be understood from the local perspectives of those doing the work (Shorrock et al., 2014). TFR does things that make sense to them given their goals and understanding of the context. Therefore Transnet Group needs to also have this understanding and acknowledge that TFR's goals may be different to the formal declared system goals reflected in the policy.

Non-compliance: Non-compliance emerged as its own theme. Issues included non-compliance to: procedures, time frames, not investigating all occurrences, not enforcing the Transnet Group BOI Policy, randomised quality assurance, defying the RSR's non-compliance certificates, non-adherence to standards and not paying penalties. Non-compliance may be due to deliberate violations by the organisation but may also be attributed to factors already identified that impact on the organisation's ability to meet the demands. In a big organisation like TFR it is expected that there are conflicting goals. As a result, work involves trade-offs where certain decisions or actions are sacrificed (Shorrock et al., 2014). In these examples, safety might be sacrificed for efficiency, production or cost reduction. Furthermore, the demands and pressures relating to capacity and resource constraints also contribute to non-compliance and have a fundamental effect on performance, i.e. the effectiveness of the investigation process. An example of another conflicting goal is that of safety and productivity.

Dichotomy of safety and productivity: The dichotomy of safety and productivity was evident in most of the participant's interviews. Most of the participants felt that safety is not prioritised in TFR with the company's top agenda *"pushing volumes"*. Furthermore, employees' performance management is affected by the number of occurrences in the organisation, directly impacting on bonuses paid out each year. The CSO agreed that incidents shouldn't be used for performance management as *"people think about their own pocket"* rather than on the systems performance. This also contributes to underreporting of occurrences. The lack of seriousness towards railway safety was evident in that "*safety is talked about but not practised"* and that having the number of incidents as targets *"drives the wrong behaviour".* The lack of seriousness towards safety is a major systemic factor that impacts on a number of factors already discussed. Furthermore, it influences the effectiveness of the investigation process and the recurrence of accidents.

The following results detail the findings from the interviews at the next level of the system, Line Management. Line Management are responsible for investigating all occurrences in their jurisdiction.

7.4.3.2 Line Management results

The themes that emerged from the Line Management interviews are detailed in Figure 7.9. Twenty three themes were identified, with many themes similar to those identified for the CSO and RSR. The themes selected for discussion include: lack of independence, quality of Line Management investigations, 7-day timeline, root cause analysis, training, classification system, lack of accountability, punitive culture and opinions of the CSO and RSR (a full list of themes and the sub-themes can be provided upon request).

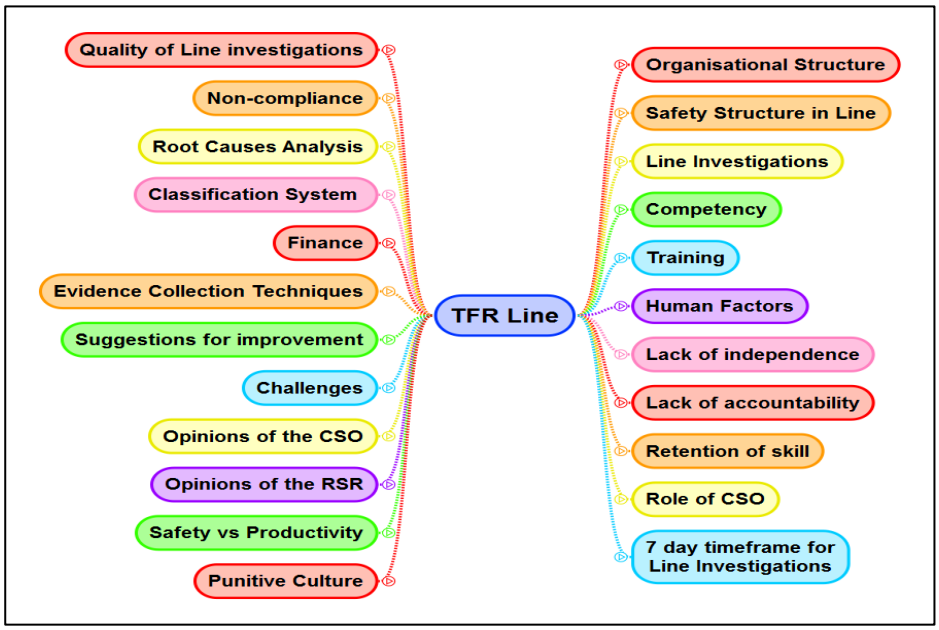


Figure 7.9 The main themes from the Line Management interviews

Lack of independence: When an incident occurs in the Line Management's jurisdiction the Line Manager becomes the chairperson and establishes a panel made up of Managers to investigate. At a Line Management level there is no independence as Managers investigate themselves. This finding also emerged from the CSO interviews. Statements relating to the lack of independence at a Line Management level include:

"A lack of officially appointed investigators is a gap as we don't have independent teams"

"Being player and referee you will not get the correct answer"
"We cannot be independent. We work together day-in and day-out. We are so intertwined"
"This results in biased investigations as people are not impartial"

Contrary to the company's investigation procedure, where it is stated that a Manager from another area should investigate the incident, the participants explained that this never happens. Some of the participants were not even aware that the procedure detailed this clause. Participants explained that the lack of independence impacts on the quality of the Line Management investigation as *"nobody wants to admit their own wrongdoings"*. A lack of impartiality can lead to recommendations that are ineffective as people try and *"cover up"* for their own wrongdoings. The next theme relates to the quality of Line Management investigations. The lack of independence is an example of a systemic factor.

Quality of Line Management investigations: Line Management acknowledged that their investigation reports were not always of a high standard. This was also the view of the CSO when reviewing Line Management investigation reports. Factors such as the following emanated from the interviews.

"We don't go about things in the right way"
"People don't go deeper"
"See the same findings over and over, especially for level crossings"
"Reports are of poor quality"
"We can finish an investigation in one day from 8 to 4pm"
"We don't do investigations properly"
"Line investigations are hogwash"
"Occurrence investigations now don't add value"
"Do an investigation more for formality to close it out"

Poor quality, not doing a thorough investigation and rushing to finish investigations are examples of systemic factors that impact on the effectiveness of the investigation process and the accuracy of the findings. Furthermore, the duties and responsibilities of Line Management who spend most of their time *"running operations"*, suggests conflicting

goals and different priorities to that of the organisation's safety. The trade-off to meet the operational demands is that occurrences are investigated, but not thoroughly, contributing to a recurrence of events. Line Managements' performance is measured against *"volumes"* and *"tonnages"* with safety an aside function. Safety is one of the multi criteria that Line Management are responsible for, however is often not prioritised due to conflicting goals that determine individual's' performance management. These factors are additional examples of systemic factors that add to the complexity of the investigation system

7-day timeline: The poor quality of Line Management investigation reports was also attributed to the 7-day timeline. The Occurrence Investigation Procedure stipulates that Line Management investigations need to be *completed* within seven days. The participants explained that the consequence of the time pressure was that they rushed their investigation reports as quickly as possible to meet the deadline. One participant stated: *"God forbid you miss the deadline"*, as the CSO monitors that Line Management adheres to this. The deadline also impacted on Line Management not adhering to the procedure where it is stated that another Manager from a different depot should investigate an occurrence. This is because the seven days was too short notice for the Managers to stop their normal activities to conduct an investigation. Furthermore, the travel and accommodation costs associated with this were another reason for not complying with this clause. The 7-day timeline was also unrealistic as participants stated that they could not always gather all the evidence in time. Moreover when equipment was sent to the laboratory or witnesses were absent from work as a result of the occurrence. Examples of statements about the 7-day timeline include:

"The 7-day deadline is difficult for us to comply with"
"We don't have all the evidence in seven days"
"The deadline puts pressure on managers to find the quickest solution"

Compromising on the accuracy and quality of the investigation report, impacts on the effectiveness of the investigation process and also the findings and recommendations. This contributes to the recurrences of accidents. Furthermore, this illustrates how decisions made higher up the system result in unintended consequences at lower levels of the system where safety is compromised. The next theme discusses root cause analysis.

Root cause analysis: In terms of identifying the most basic reason for why the occurrence happened, Line Management admitted that they did not use any root cause analysis methods. This is despite the BOI Policy and the annexure in the Occurrence Investigation procedure suggesting this. A few participants explained that when they are on the scene of the accident, they establish the *"root cause"* and that this does not change for the rest of the investigation process. This suggests that a thorough investigation is not always performed as the ability to determine the *"root cause"* immediately; especially for major accidents such as collisions would require investigators who were experienced, trained and qualified. Furthermore, the resources to conduct a proper investigation, including time, tools and techniques would be necessary. TFR did not always have access to these resources and resource constraints were identified to be a limiting factor at a Line Management level. Examples of participants' comments include:

"Find the cause at the scene the rest is contributing factors"
"Most times we don't come up with the root causes"
"Cause at the scene doesn't really change"

Training: As highlighted in the previous section, trained investigators are a limiting factor at a Line Management level. Most of the participants had not received any occurrence investigation training. A few of the participants had attended a training course that was for three days and was only theoretical. A participant explained that once the course was completed there was no practical training and no real life simulations or mentors assigned to the Managers thereafter. The participant elaborated to say: *"Only once you are called out to the scene for your first accident that this is where you learn what to do".* The same participant further explained that due to a lack of training and experience the participant often forgot what to do when investigating. Furthermore, it was identified that TFR used to offer a Train Accident Prevention (TAP) training course, however this had been discontinued. Participants were disappointed as this course was very popular and was the only in-house training course offered by TFR. In terms of being a chairperson or a panel member of an occurrence investigation, no training or experience was required. By virtue of being a Manager this counted for experience. Training was also affected by finances as one participant added *"there is no training in this year's financial plan"*. TFR therefore not does not only have no appointed investigators in the organisation, but has Managers

who lack training, knowledge and skill to investigate accidents. Competency and a lack of training are examples of systemic factors that impact on the entire investigation process.

Classification system: In terms of the types of occurrences that are investigated by Line Management, some participants admitted that their focus is primarily on derailments. One participant stated that level crossings *"even get investigated"* implying that they do investigate these types of occurrences but more for compliance purposes. This is because the cause is always attributed to the vehicle driver with the organisation believing that they have little part to play in causing the accident. This was a similar sentiment identified in the RSR and in the CSO interviews and in the review of the investigation files. Some participants were unsure of how occurrences were classified, stating that the costs and monetary value of the occurrence determined the level of severity. One participant did not remember the different levels of investigation despite being a Line Manager who was expected to conduct investigations. Comments from some of the participants included:

"Level 3 and 4 are the same"
"Level 3 is not critical"
"Level 4 is the biggest occurrence, most serious"
"Eish I can't remember the difference between the levels"
"Not looked at the criteria lately"

The comments suggest that the organisation's occurrence policy and procedure are not well understood at an operational level, or are not enforced by the CSO. Furthermore, Line Management are required to investigate every occurrence, irrespective of the level, and therefore may not be concerned by the classification system.

Lack of accountability: It was evident from all the interviews at TFR, both at the CSO and Line Management levels, that there was a lack of accountability within the organisation. Blame was a common theme with many different departments in the organisation blaming the other for the occurrence. Participants stated that *"pointing fingers"* with nobody wanting to accept responsibility happened often during Line Management investigations. The following comments emerged from the data:

"Recurrences because we don't address the root causes. We are too busy protecting ourselves"
"When you arrive at the scene you pray it wasn't your driver"
"We protect ourselves that's why we don't get the right answers"
"When you arrive at the scene you want to save your department"
"Big fights between department for who accepts responsibility"
"Everyone is covering their own failures"
"No Ops Manager is going to expose himself for the things he was supposed to see to"
"Lack of Management accountability"

The lack of accountability and responsibility for an occurrence, together with rushing the investigations and completing them more for formality, questions the accuracy and comprehensiveness of the entire investigation process. Ineffective investigations impact on organisational learning and contribute to a recurrence of accidents. Furthermore, blame does little to facilitate a just culture. It was evident that at a Line Management level, between the various departments that there was little mutual trust. These are examples of systemic factors that influence the investigation process and hence the recurrence of accidents. This theme was also observed during the observations with witnesses shifting accountability to other departments.

Punitive culture: Following from the theme above, a punitive culture was evident at a Line Management level. Blame, failing to accept responsibility and operational employees' charged in disciplinary hearings while investigations were in process are examples of a punitive culture. With Managers not accepting accountability and responsibility, this was shifted to the employees at an operational level, for example train drivers. One participant stated that *"witnesses feel they are being crucified"*, and that people don't want to get into trouble because *"then you will pay"*. This punitive culture creates an environment where one Manager affirmed that *"you have to plea with the witnesses to give the correct evidence"* indicating that witness's testimonies are inaccurate or incomplete. Participants explained that some witnesses asked to bring their union representative with them to ensure they were treated fairly. Some depots admitted that *"if a person admits to a boo-boo it will lower their sanction"*. A punitive culture, where a lack of trust and fear was evident may explain why many of the interviewees did not know what a just culture was in

the interviews. A lack of trust was acknowledged to be evident between the operational employees and Management, and within Management of the different departments. One Line Manager affirmed that *"we need to shift the blame away from employees to management"* and *"we need to ask ourselves as managers what did we do to prevent this"*. Furthermore, the investigations focussed on the individual at the sharp end and not on the system and its performance. The punitive culture contributed to witnesses being scared to open up for fear of negative consequences. These systemic factors impact on the accuracy and reliability of the findings.

Opinions of the CSO and RSR: Line Management displayed mixed views regarding the role of the RSR. One participant viewed the RSR as a "*colleague"* while others used terms such as *"cocky"* and *"they want to nail us"* to describe the RSR. With regards to level crossing occurrences, the participants felt that the RSR placed too much emphasis on TFR to do more to prevent these types of occurrences, supporting the results obtained from the CSO's interviews. Line Management felt that the RSR was not doing enough to work with the Road Traffic Department and municipalities to minimise level crossing accidents. Given that the RSR reports to the DoT, and that the Minister is also responsible for road safety, it is questionable whether these interfaces are acknowledged in terms of overall safety for road and rail users. Furthermore, 'passing the buck' from one level to another in the system, also illustrates a lack of a systems approach to these types of occurrences. The results illustrate that while one layer of the rail system expects the other to 'fix this', other stakeholders, for example municipalities and road authorities have the same expectations. This conundrum results in no further action as all the stakeholders wait for the other to take action. In the meantime safety is compromised. Furthermore, one would expect the Ministers to intervene in situations such as this, given their mandate is to ensure safe transportation; however this was identified from the interview results to not happen. These challenges do not only illustrate the complexity of the railway accident investigation system but also the bigger *transport* socio-technical system.

In terms of Line Management's opinions of the CSO, there were also mixed views. Some of the participants suggested that the CSO adopts *"a high and mighty position"* and that *"they are scared when the CSO comes to investigate"*. Other participants stated that they had a good relationship with the CSO. Again these findings illustrate that a culture and mindset of fairness, openness and trust is not apparent within the organisation. Shorrock et

al. (2014) believe that these are prerequisites necessary for understanding how things work and why things work in the way they do.

In summary, the themes and results for both the CSO and Line Management level were fairly similar. There were also similarities with the themes identified from the interviews at the RSR. The complexity of the accident investigation system and the bigger rail socio-technical system are indeed influenced by systemic factors inherent within the railway system. Furthermore, the impact of a lack of integration between, and within the different levels of the system of accident investigations is especially felt at an operational level where the accidents take place. The decisions and actions of the higher levels of the system shape the behaviour of the system and its performance. Demands, constraints, a lack of resources and conflicting goals impact on the effectiveness of the investigation process and the bigger rail socio-technical systems ability to achieve safe railway operations.

The following section highlights the results from the observations of actual inquiries. The findings in the above sections are verified against the information collected in the observations.

7.5 Observations of occurrence inquiries results

The inquiry step of the investigation process was observed for both the RSR and TFR. The observations provide the final verification of the triangulation process to improve the validity of the data collected. The results collected in this section are verified against the findings already discussed in the previous results. The outcomes are documented separately for the RSR and for TFR as the DoT does not conduct investigations.

7.5.1 RSR's observations

Three inquiries were observed at the RSR. One was a Level 2 investigation and two were BOI's. The results are documented separately for the Level 2 and BOI investigations.

7.5.1.1 RSR Level 2 investigation

Two investigators from the RSR's Occurrence Investigation Department conducted the investigation. As it was a Level 2 investigation, external specialists and attorneys were not required. The Level 2 investigation was for a derailment that resulted in R33 million in damages. The sitting (inclusive of the site visit and interviews) occurred 49 days after the

occurrence and took place at the depot of the Operator. This delay impacts on the reliability of the witnesses' testimony as they may forget certain details or recall may be difficult. Not conducting the onsite investigation immediately after the occurrence, impacts on the validity of the process, the quality of the evidence collected and the effectiveness of the entire investigation process.

In the letter submitted by the RSR to the Operator informing them of the RSR investigation the only information requested was photographs of the scene, written statements from the train crew, TCO and the Rail Incident Commander (RIC). Further details about the train crew and TCO; for example their training, shift roster and proof of substance abuse testing were requested. Considering the type of occurrence it was peculiar that no technical evidence from the locomotive, wagon or infrastructure departments were obtained. Selective evidence may be due to having a preconceived idea of the outcome of the investigation prior to actually investigating the incident. Lundberg et al. (2009, p. 1297) state that this is referred to as *"What-You-Look-For-Is-What-You-Find"* suggesting that the RSR only addresses superficial findings with others remaining unnoticed in the system. The results are detailed separately for the arrival at the inquiry, the site visit and the interviews with the witnesses. Table 7.9 highlights the results from the arrival stage of the investigation prior to commencing with the site visit.

Table 7.9 RSR Level 2 occurrence investigation: observations on arrival

Stages of the Investigation	Observations
Arrival	The RSR arrived late at the depot, resulting in some witnesses having left to resume their operational duties
	Some witnesses were not available or rostered for the inquiry
	The RIC, a primary witness, was on leave and was not available to be interviewed or to accompany the RSR to the site. The RSR was not informed about this prior to the inquiry
	The RSR was informed that the train driver would not be present and had gone to hospital. This was only mentioned on arrival
	Some of the personnel at the depot did not know who the RSR was

Upon arriving at the depot, the depot appeared disorganised with many of the employees at the Operator not knowing who the RSR was. The RSR's arrival appeared to be a surprise, with TFR stating that the RSR can arrive unannounced. Identification of the inspectors would have been useful and sets a precedent that the investigation is being conducted by the Regulator. The level of authority that is assumed with being the RSR was not acknowledged at a depot level. The observations support the interview findings that the Operator does not take the RSR seriously and this was evident in the non-availability of personnel to be interviewed, the delays in sourcing transport to take the inspectors to the occurrence site (despite advanced notification of the inquiry), and that witnesses were not rostered or released from their operational duties to be interviewed. A lack of integration between the various levels of the rail socio-technical system was evident. Furthermore, the Operator's commitment to safety is also doubtful. Table 7.10 highlights the observations from the onsite investigation.

Table 7.10 RSR Level 2 occurrence investigation: observations onsite

Stages of the Investigation	Observations
Onsite Investigation	The scene was cleared as the occurrence occurred over a month ago
	The RSR inspectors did not have a camera to take any photographs
	There was no formality on site. No introduction upon arrival, no induction as to the RSR's purpose and no order of proceedings. The inspectors randomly asked questions
	Witnesses accompanied the RSR onsite
	No notes were captured by the inspectors onsite
	Various witnesses started sharing their thoughts about what happened
	The RSR asked witnesses questions about the occurrence prior to the interviews in the presence of other witnesses

The observation verified the interview findings that the RSR Inspectors do not have adequate resources to do their job effectively. The inspectors did not have a camera because the RSR Occurrence Department only has one camera. With all the inspectors investigating occurrences at different places at any given time, the unavailability of resources makes it difficult to meet the demands of the investigation system effectively. Shorrock et al. (2014) affirm that meeting demands is only possible with adequate

resources and appropriate constraints. Resources are needed to fulfil a function, to ensure efficiency and maintain the systems performance. Mobile phones were used to take photographs, contradicting railway safety policies relating to the use of mobile phones while on the rail track. One of the inspectors stated: *"I don't do photographs"*. As identified from the results in the previous sections, the RSR relied on photographs and evidence collected by the Operator during the Operator's investigation.

A number of different Line Management departments were present onsite with each giving their view of what happened to the RSR's inspectors. This leads to bias and again questions the reliability of the information collected by the RSR. Each department gave their own opinion of what happened, often conflicting the other departments information. The reliability, validity and effectiveness of the investigation process are compromised as the objectivity is affected. This finding confirms the information given to the researcher during the interviews where at a Line Management level shifting the blame from one department to the other and pointing fingers was common practice. After the site visit, one of the witnesses asked the RSR inspector: *"Where were you from the start?* The delay in the RSR commencing with the investigation and arriving onsite 49 days later confirms the information collected during the interviews and the review of the investigation files. The reliance of the RSR Inspectors on the Operator was obvious; raising the question of whether the RSR investigation was more for formality purposes.

One of the RSR inspectors stated during the inquiry *"I didn't realise this was a serious one … spending two days here"*. The investigation was classified as a Level 2 inquiry and is initiated for serious occurrences. Therefore the seriousness of the investigation is evident in the level of classification. The above statement confirms the interview findings and the review of the investigation files that the classification system in the governance documents is not understood and not applied in practice. Furthermore, the inspector's competency and experience may be doubtful given that the inspector did not think that the occurrence was serious, verifying the interview findings that the inspectors had different ideas of what a serious occurrence was. The level of preparedness of the investigator before commencing with the investigation was doubtful as the inspector was not aware of the seriousness of the incident. General practice would require that investigators are familiar and prepared with the event prior to commencing with the investigation. This would require analysis of prior documentation, analysis of the Operator's evidence and a review of previous investigation

reports to determine what to look for when on the scene and what questions to ask the witnesses. The ramifications are that the validity of the interview process with the witnesses, the writing of the report by the investigators and the outcomes of the investigation are impacted. Table 7.11 highlights the findings from the interviews conducted with the witnesses.

Table 7.11 RSR Level 2 occurrence investigation: observations from the interviews

Stages of the Investigation	Observations
Interviews	The RSR Inspectors had no evidence, documents, reports etc. with them
	The RSR Inspectors did not read the remit nor did they introduce themselves or the observer to the witnesses
	Inspectors let the witnesses decide who to go first
	Interviews were recorded with a mobile phone as the Inspectors did not have a voice recorder
	Interviews started off with a standard question: introduce yourself, your responsibility and involvement in the occurrence
	One of the Inspectors only had a few questions jotted down
	Inspectors didn't know who was going to be interviewed and only requested certain people by grade
	Inspectors requested evidence while interviewing the witnesses
	Only a few notes were captured by the Inspectors
	Over reliance by the RSR Inspectors on witnesses evidence rather than an independent view of the causes
	A mix of open and leading questions were asked to the witnesses
	Interviews were conducted back-to-back affording no opportunity for the inspectors to debrief after each testimony

There was very little structure given to the interviews. Not all of the witnesses requested to be available were present on the day. This confirms the findings identified in earlier results regarding the lack of authority of the RSR to enforce Operators during investigations to provide information and witnesses. It also verifies that the Operator does not take the RSR seriously. The inspectors' level of preparedness was questionable given that they did not

have all the evidence prior to preparing their questions. One witness had brought a file with them to the interview containing all the previous investigations (conducted by the Operator) and evidence. The Inspector requested a copy of the file as the RSR did not have all of the evidence prior to the inquiry. The question that can be asked is; if the witness wasn't so well prepared how would the RSR have obtained this information? Furthermore, how then does the RSR make accurate and reliable findings and recommendations in their reports without all the available evidence *prior* to commencing, and during the inquiry?

The lead RSR Inspector during the introduction with the all witnesses stated that the interviews would be no longer than 30 minutes. The interviews were fairly short in duration with the longest being 42 minutes and shortest 13 minutes. Although longer interviews do not necessarily yield additional findings, the interview lasting 13 minutes provided very little substantial evidence. Considering the occurrence warranted a Level 2 investigation, it is questionable whether the duration of the interviews, together with the underprepared Inspectors, resulted in significant information to prevent a recurrence. One of the RSR Inspectors admitted to only preparing the questions the night before the investigation. This was evident in one of the questions to the interviewees: *"What shall I ask you now?"* Not having all the evidence prior to the inquiry and being underprepared impacts on the thoroughness of the investigation, the accuracy of the findings and appropriateness of the recommendations.

The Inspectors did not appear to have an in-depth understanding of the rail environment and rail terminology. One Inspector had only been at the RSR for less than a year. The Inspector would often stop the witnesses during their testimony and ask the witness to define or explain a term. To understand the behaviour of a system requires field experts who are experienced, knowledgeable and competent (Roed-Larsen & Stoop, 2012; Shorrock et al., 2014). Specialists are important for improving the systems performance, and in the accident investigation system railway inspectors fulfil this function. Shorrock et al. (2014) affirms that without this expertise the validity and usefulness of data gathering, analysis and improvement is limited. Rasmussen (1997) affirms that competence of decision makers is extremely important to understand the systems functioning. The two Inspectors (the decision makers in the system of accident investigations) were inexperienced and admitted this during their interviews. The RSR Inspectors need to be competent to communicate information up, down and horizontally in the system, with the

investigation report the output of their decision making. To prevent repeated occurrences and to establish learning, the reports need to be accurate and thorough. In addition the reports need to be disseminated within and between the levels of the investigation system for effective implementation and organisational learning. The observations confirm that the inexperience and competency of the RSR inspectors influences the effectiveness of the investigation process.

The observations also confirm that operational employees were not aware of the RSR and also the different levels of investigation in the system. For example, the witnesses did not know the purpose of the RSR investigation and two separate investigations had already been conducted within the Operator. A witness asked: *"So what happens now?" Is there a disciplinary process?"* The RSR Inspector stated that the RSR is independent and is not about apportioning blame, but trying to prevent a recurrence. A lack of integration between and within the various levels of the investigation system was evident, confirming the previous findings already identified. Communication and education about the RSR, its duties and responsibilities in terms of railway safety did not appear to reach employees at an operational level. The investigation system, like any other system, has a number of interactions between human, technical, social, political and organisational elements. Information and feedback need to flow from end to end through the system (Shorrock et al, 2014). In the accident investigation system, the organisational elements are disjointed. This has a fundamental effect on performance, i.e. in achieving accurate, reliable, thorough, valid and objective investigations. If the parts of the socio-technical system do not function as a whole this impacts on the nested systems within the bigger system. Preventing occurrences and improving safety is hindered when the system doesn't function holistically.

Following the inquiry the inspectors were required to complete an investigation report. The researcher enquired as to when this needed to be completed, with the inspector replying that they did not know the timeframes *"Our policy says something but I am not sure"*. The observations confirm that not all of the RSR inspectors are familiar with their own company policies. This was identified in some of the interviews. After some consideration the inspector mentioned that the investigation was part of the Inspectors' targets and that it had to be completed by the end of the financial year. At the time of the observation this was in 2 months' time. The investigation report is compiled by the two investigators from

the RSR and then submitted to the RSR's Principal Inspector for quality control. Thereafter it is sent to the Operator for implementation. The observer was not provided with the final copy of the report. The observations validated the theme of *targets* from the interviews. The inspector was required to complete eight Level 2 investigations for the financial year.

The observation findings support the interview findings where themes such as the relationships and perceptions between the Operator and the RSR, the lack of integration within and between the levels of the system, and the authority of the RSR were identified during the observations.

7.5.1.2 RSR BOI investigations

The Board members of the BOI consisted of external specialists and an attorney who chaired the investigation. A representative from the RSR was part of the inquiry but stated that the RSR's role was to coordinate the Board members, witnesses, logistics and organisational processes. The occurrences were both rear-end collisions with one of the incidents resulting in a derailment. The results are compared in Table 7.12 (the researcher was only able to attend the site visit for Occurrence B).

Table 7.12 Observations from the RSR BOI's

Observation	**Findings**	
	Occurrence A	**Occurrence B**
Time between date of occurrence and the date of the Board's site inspection	54 days	122 days
Time between date of occurrence and the date of the inquiry	77 days	123 days
Duration of the inquiry	3 days	2 days
Resources used to capture and record evidence	Voice recorder for the interviews	Voice recorder for the interviews

Processes and procedures during the site visit	Researcher did not attend the site	Walkabout of the scene and a visit to the TCO's signal cabin
Board member composition	1 Technical expert 2 Legal experts 1 RSR (coordinator) 1 RSR representative	1x RSR representative 1x Technical expert 1x RSR Human Factors Specialist 2x Legal experts 1x Signalling expert 1x RSR (coordinator)
Chairperson of the BOI	External attorney	External attorney
What methodologies / root cause techniques were used to analyse the occurrence?	None	None
Questioning of the witnesses	Mix of open and leading questions	Mix of open and leading questions
Compilation of the report	Compiled by the Chair and then circulated to the Board members for their input and rail expertise. Once completed by the Board it is submitted to the RSR for approval	Compiled by the Chair and then circulated to the Board members for their input and rail expertise. Once completed by the Board it is submitted to the RSR for approval

An initial observation was the length of time between the date of the occurrence and the date of the inquiry. Although the RSR does a preliminary investigation, the BOI's appointment and commencement with the inquiry is some time after the occurrence. This finding supports the information collected during the investigation files where a noticeable delay between the inquiry and the event was evident. One Board member shared that the time delay results in the Board not obtaining all the facts that are required for the investigation and suggested that the BOI commence within a month after the incident occurred. Both the inquiries took place later than the stipulated timeframe in the RSR

Occurrence Investigation Policy, confirming the theme of non-compliance to governance documents already identified in the results.

The BOI's are chaired by external lawyers and it was explained that this is to give the inquiry independence. However, the researcher was informed that besides independence, the purpose of having the lawyers chair the RSR inquiry was also for legal protection for the RSR or other criminal implications that may arise. In terms of the Chairpersons railway background, neither of the attorneys had extensive knowledge of the railway environment. One attorney had chaired only a few occurrences for the RSR and the other Chair was participating in a railway occurrence investigation for the first time. As discussed earlier, competent, qualified and experienced investigators are important for conducting thorough investigations, especially for complex socio-technical systems such as rail. Experience and competency are required to be able to identify exactly what happened, and to recommend suitable corrective actions to prevent recurrences. The interview results relating to the knowledge and competency of the attorneys in BOI's were verified in the observations.

There were differences in how the terms of reference and remit of the BOI was shared with the witnesses. In one BOI the witnesses were sworn in, informed that they were under oath, had to raise their right hand and swear to tell the truth. The other Chairperson did not swear the witnesses in. Both Chairs informed the witnesses that the BOI was as per Section 38 of the Railway Safety Act (Act 16). The differences in approach may be attributed to experience in conducting railway investigations.

At the start of both inquiries there was no briefing amongst the Board members as to the process of the inquiry, a discussion around the occurrence, who was going to be interviewed, what did the Board want to obtain from each witness or any other deliberations. Each BOI commenced with interviewing the witnesses. The observer was informed that the Board members for one of the BOI's did have a 'kick off' meeting when they were appointed, but at that time had not received all the evidence or conducted the site visit. In Occurrence B, the Chairperson explained that there *"was no hard and fast procedure to this inquiry"*. The Chairperson continued to inform the Board members that the inquiry centred on each panel member's discipline or expertise. The Chair stated that the panel should guard against confusing the witnesses. One panel member asked *"What is our objective and what do we want to clarify"* suggesting that the aims of the inquiry were

not understood by all of the Board members. A discussion of the events and an introductory briefing prior to commencing with the interviews perhaps would have minimised any confusion and clarified the Boards intentions. The response by the Chair was "*we are here to identify what happened and to see what can be done to prevent this"*. Amongst the Board members, a lack of cohesion and planning was evident and can be attributed to not having consolidated as group prior to commencing with the interviews. In Occurrence B, the Board members met each other for the first time at the onsite investigation.

In terms of interviewing the witnesses, not all of the Board members had a schedule or list of witnesses, resulting in some members repeatedly asking who would be interviewed. This was interesting to observe as it questions how well prepared the panel was in terms of any prepared interview questions other than those relating to their expertise. Many of the witnesses arrived late and some witnesses had their union representatives present. One witness informed the Board: *"I was only told yesterday when I was home to come to the BOI"*. Other witnesses did not arrive on their scheduled day as they were not released from their operational duties for the RSR investigation. A Board member explained that this portrayed a level of disrespect for the RSR's processes. The observations confirmed the interview findings and the review of the investigation files that Operators do not take the RSR seriously. Furthermore, evidence requested prior to the inquiry was not always provided by the Operator, resulting in the Board often requesting the witnesses to submit documents directly to the Board during the interviews. One Board member commented: *"It is a nightmare requesting information from the Operator"*. Again if the Board is not informed of all the events and contributing factors leading to the occurrence, how well prepared are the members when they commence the inquiry, and how does this inform the types of questions asked of witnesses? Board members who have operational and investigation experience may rely on this, but not all of the Board members were experienced. This is an example of a systemic factor and impacts on the effectiveness of the investigation process and its outcomes.

The investigation system is impacted by the lack of integration between the various levels in the system, in particular between the RSR and the Operators. This is attributed to conflicting goals of the various actors in the investigation system, where the RSR's mandate is to oversee railway safety and the Operators are required to run trains.

Operators' allocation of resources, in this instance sending witnesses to the RSR BOI, is impacted on by differing priorities of the Operators. Operators need to relieve staff which interferes with their operational rostering and the train schedules adding further constraints on this level of the system. This is exacerbated by a shortage of safety critical staff within the Operators furthering constraining the investigation system as people are unavailable to attend investigations. At the same time the RSR needs to maintain the safety of the bigger rail socio-technical system, but due to a lack of authority are unable to ensure that investigations are thoroughly investigated due to the unavailability of witnesses. Therefore both actors commitment to safety is doubtful. These factors increase the complexity of the investigation system impacting on the effectiveness of the investigation process and its outcomes.

The Chair who was participating in a railway investigation for the first time, demonstrated a lack of understanding of the railway environment. The attorney's inexperience was obvious because on a number of occasions witnesses were interrupted to clarify or define information. The RSR inspector on the Board, who is only required to coordinate the inquiry, was required to participate in the interviewing of the witnesses to ask questions relating to processes and procedures. For example: *"I am not part of the Board, but to assist the Board I will ask some questions"*. The purpose of using external experts is to give the BOI independence, however in both observations, the RSR representatives participated as Board members. The observations confirm that the RSR BOI's are not completely independent, impacting on the objectivity of the investigation process, the findings and recommendations. Le Coze (2013) states that independence in investigations is important in order to challenge both the state and industry. Contrary to Le Coze (2013), in the observations at the RSR it appears one sided in that only the Operators (industry) are challenged. Other parts of the socio-technical system that can also contribute to poor railway safety, for example the Regulator, are not challenged. There was no evidence of a systems approach in both observations and the performance of the system was not investigated but rather its components. Furthermore, with no independent investigating body in South Africa, like the NTSB in America, the state (inclusive of the RSR as a government agency) is not challenged.

The BOI's appeared to be unstructured in terms of questioning witnesses and the Board did not have a set of prepared questions. One Chairperson commented: "*The Board should*

find a sequence of questions so we don't go off track. We don't have questions prepared. Our questions are informed from the responses of the witnesses". These factors could also be reasons for why many interviews were longer than the Board had planned, given the lack of structure and specifically prepared questions. After each witness was interviewed, there was no debriefing or discussion amongst the Board members, consolidation of the evidence, summary of the findings, or preparation for the next witness. Witnesses also did not know why the RSR was investigating the occurrence when it had already been investigated by the Operator some time ago. This suggests employees, particularly those at an operational level in the Operators, are unaware of the role of the RSR and Act 16. One witness stated: *"I was shocked to be invited to a BOI"*. This further illustrates a lack of integration and a disjointed system where the flow of information regarding the investigation process and its purpose does not propagate down the system to the level of the witnesses at an operational level. Witnesses act as informants in the system of accident investigations and are important stakeholders.

An inability to recall the events relating to the occurrence was a common theme identified during the observations. For example, *"I can't remember"* or *"I don't know"* were frequent statements. This can either be interpreted as the witnesses not wanting to answer the question or may be due to the time delay since the incident (especially Occurrence B where the BOI took place 4 months after the event). This, together with any trauma experienced during the event, could be a plausible explanation. A witness objected to being sworn in and stated: *"Yes because I can't remember. It was a long time ago"*. The interview continued despite this statement. These findings are important as they impact on the reliability and validity of the testimony and therefore the effectiveness of the investigation process. The observations confirm the findings relating to this theme from the interviews.

During the interviews the researcher was informed that it is not common practise to have a Human Factors Specialist as a Board member, questioning how human factors issues get identified. Limited human factors expertise in the RSR BOI's was also verified in the investigation files. However, a Human Factors Specialist from the RSR was a Board member for Occurrence B, but in Occurrence A there was no Human Factors Specialist. This finding confirms the interview and investigation findings that it is not consistent to include human factors experts in the RSR BOI's. During the observation a Board member

commented that the human element is considered during the investigation, but nobody goes deeper and looks into the psychological part as to why, for example, the driver passed the signal at danger. This finding is an example of a systemic factor that suggests that incidents are not thoroughly investigated. Superficial findings being addressed and latent conditions not being identified signifies the ineffectiveness of the investigation process, but also the accuracy of the findings and appropriateness of the recommendations. This finding was supported by one of the Board members who commented: *"We don't drill deeper, we need to go deeper"*. No accident causation methodologies, tools and root cause analysis techniques were evident in both observations. This supports the findings from the interviews with the inspectors and confirms that the governance documents are not implemented in practice.

A comment made by one of the Chairpersons to a witness was: *"We are trying to help you have a safe working environment. We have the power to assist you".* Although this indicates the authority given to the RSR's inquiries, many of the witnesses appeared to be dejected and did not believe that anything different would be done given the repeated number of accidents. One witness commented: "*We are not out of danger yet. We lost a colleague in a previous incident like this. Something is going to happen; a big bang is coming soon."* The findings identified thus far in this research suggest that repeated occurrences are likely given the systemic factors already identified impacting on the effectiveness of investigation process. Furthermore, the organisational learning of the railway system as a whole is influenced by the delay in commencing with the investigation, as during this time a number of repeated occurrences could have happened. The concern of a *"big bang coming soon"* after a similar incident, demonstrates that the recommendations from previous investigations are either inappropriate and/or not implemented contributing to a recurrence of events.

Despite the RSR asserting its power to try and help the witnesses, the dejection of the witnesses is attributed to a lack of a just culture and mutual trust within and between the levels of the system. The observations therefore highlight that a just culture approach to occurrence investigations is not adopted by Operators as per SANS (2009) impacting on the effectiveness of the RSR's investigations. The lack of a just culture was evident in the witnesses' responses. Blame and a punitive culture at an operational Line Management level was a common thread in many of the witnesses' testimonies, despite the purpose of

the BOI not about apportioning blame. For example, *"I hope this is confidential, as this will get me fired"*; *"I am too scared to talk about my company"*, and "*I am going to lose three train drivers as they are all on 12 month sanctions"*. Such comments impact on the system's ability to learn from occurrences as fear and a lack trust inhibit witnesses from participating in giving evidence. A reporting culture is necessary so that any vulnerability within a system can be understood and rectified before an accident occurs (Weigmann, Zhang, Von Thaden, Sharma & Gibbons, 2004). Furthermore, learning from accidents requires that information and feedback about an occurrence is provided to members of the organisation, to educate members and to develop and maintain safety (GAIN, 2004). A reporting and learning culture was not evident in the whole accident investigation system.

The word *"system"* was mentioned on a few occasions in the BOI inquiries. This finding was not evident in the review of the investigation files and some of the interview findings. The context of most of these sentences was the need to shift the focus away from the actions and events at an individual level, to include the broader system; i.e. factors outside of the human and organisational boundary. Despite the use of the word *system*, there was no evidence of a formalised systems approach adopted in accident investigations to determine the causes. This is likely due to this not being identified by the organisation and documented in governance documents. Examples of the word *"system"* include:

"We are frustrated with the system"
"People held accountable are usually the train driver or train control officer. Nobody from a system's point of view is held accountable"
"The system contributes"
"The abnormal system we have to work with"
"What's wrong with the system"
"We must focus on system issues"

To the contrary, one witness testified that *"most of the causes are human factors and it's not the system that is the cause"*, attributing blame back to the sharp end. A Board member acknowledged that the findings emanating from one of the occurrences *"was a bigger problem than anticipated"*, suggesting that the Board needed to adopt a systemic view rather than just focussing on what went wrong at the time of the occurrence. The lack of

any systemic accident causation models and no methods in general to identify the causes of the occurrences, impacts on the validity and accuracy of the findings. This has a direct impact on the suitability of the recommendations necessary to prevent repeated occurrences.

The appropriateness of recommendations to prevent a recurrence, and more importantly the implementation of them was questioned by one of the Board members. The question was directed to both the Operator and the RSR. *"Do you get recommendations from all the BOI's as there have been more than three incidents and why is it still happening even when there is a recommendation?"* Commitment to safety and the ability of both the RSR and Operators to control safety is doubtful considering the number of repeated occurrences, similar findings and the same recommendations being suggested. A witness explained *"If Operator X continues to do things as they do, these things will reoccur"*. These comments suggest a number of concerns. Firstly, the purpose of an investigation is to identify what went wrong and how to prevent a recurrence. If there are repeated occurrences, this questions the ability of the investigation team to successfully identify what transpired. Secondly, the Operators may not implement the recommendations from the RSR's investigations as there are no consequences, despite the threats of the penalty regulations. Thirdly, the RSR may not enforce the implementation of the recommendations as it does not have the power in reality to do this despite its legislative mandate. Fourthly, the investigations may be mere formalities for compliance and achieving targets rather than about actually preventing recurrences. Lastly, the recommendations suggested by the RSR and the Operator's own investigations may not be appropriate, realistic and achievable for the causes of the event. These factors add to the complexity of the investigation system. The overall quality of the RSR investigation process was raised as a concern by witnesses during one of the observations and was acknowledged during the interviews. Examples of some of the comments relating to the quality of investigations include:

> *"The Regulator finishes their investigation and gives the report to a person in Operator X and it ends there. We don't hear anything. We may see something about recommendations but otherwise nothing. We are just junior employees who request incident recommendations, we complain, it frustrates us we don't get anything"*

"We must be overlooking something … we get the Regulator's reports and corrective actions, but the human element is fundamental and we overlook it. Our investigations don't look at this"
"We fire people and our incidents still keep happening"

The comments above further support no systems approach in accident investigations and suggest that the recommendations are not implemented. It is identified that actors and decision makers within the system do not give feedback. Information needs to be communicated both from a top down and from a bottom up to inform the actors of the systems performance and the actual state of affairs. Feedback is an important system requirement as the flow of decisions and information connects the levels of the system (Branford, 2011). The exchange of information is essential for safety because if recommendations from the higher levels are not implemented, for example from the RSR to the Operator, or information is not conveyed upwards from the Operator to the RSR about whether the recommendations are effective or even implemented, then the balance or control of the investigation system is impacted. The success of the investigation system in achieving its objective to prevent repeated occurrences therefore depends of the activities of *individuals at every level* in the system and the *interactions between these levels*. The ability of the RSR to enforce recommendations and to act with authority was raised as a concern by the Chair in one of the observations, for example *"We need to help you. We need the Regulator to get the recommendations to be done. We need power as the Board, otherwise we just talk shop"*. This was confirmed in the interviews that the RSR does not have enough power and is also not taken seriously by the Operators.

Witnesses were interviewed back-to-back in both observations. Reasons for this were because a number of witnesses were scheduled for each inquiry, there were time constraints to finish the inquiry in the scheduled days and because of the costs associated with using the external Board members. Time, as recognized in the interviews, was a theme identified during the observations. Time impacts on the credibility of the investigation process as it resulted in:

- Rushing the interviews in the interests of time
- Rushing the process may affect Board members concentration and attention

- No debriefings after and before each witness was interviewed
- Sparing costs at the expense of conducting a thorough investigation

Examples of how time constraints were a common theme that emerged from the observations include:

"Colleagues we are pressed for time"
"In the interests of time we need to move on"
"There are interviews we need to accelerate, we are dwelling too much on sequence"
"We are running way out of time"
"It shouldn't be more than one hour per person"
"We are pressed for time. We have lots of witnesses to get through"
"Please can you just ask pertinent questions"

Interviews were often longer than an hour resulting in the Board reducing the time allocated for other witnesses. After each of the statements above it was evident that the interviews with subsequent witnesses were considerably shorter in duration than previous interviews. The accuracy of the findings and suitability of the recommendations is influenced by rushing the witnesses and also the inquiry. Furthermore, given the time delay between the occurrence and the start of the BOI this adds additional pressure for the Board members to complete the inquiry so that the report can be distributed. This is because the RSR Occurrence Department is under pressure to account to its Executive Board. On one occasion it was discussed that the BOI had to provide a report within 20 days due to the approaching Christmas break. In a system, each level is constantly anticipating, responding and adapting to demands or events in order to maintain control. The stability of the investigation system however is comprised due to a lack of flexibility, the unavailability of resources and unnecessary constraints such as time pressure to rush a report. These factors influence the effectiveness of the entire investigation process.

No accident investigation tools or methods to identify the causes of accidents were used; for example, fault trees or event diagrams. The Board relied mainly on the documents provided by the Operator, emphasising the RSR's reliance on the Operator, and impacting on the objectivity of the investigation. Roed-Larsen and Stoop (2012) state that the

absence of accident methods not only weakens the analytical rigour of the investigation process, but also jeopardises the drafting of recommendations.

At the end of the last interview, both BOI's did conclude with a debriefing of the events. However, this was conducted fairly quickly due to the time of day being the close of business. Upon conclusion of the interviews a draft report was compiled by the Chairperson and then circulated to the Board members for their comment and subject matter inclusion. The RSR inspector requested that the Board report should be specific, with short, medium, and long-term recommendations. The researcher was informed after the observation that one report was submitted five times before the RSR was satisfied with it. It could not be established whether this was due to the poor quality of the report or whether the RSR did not approve of the content.

7.5.2 TFR observation

The occurrence observed was a run-away train that collided with a stationary load on the tracks and then derailed resulting in injuries to the train crew. A BOI was instituted by the CSO and Line Management had conducted their separate investigation. Contrary to the BOI Policy, the Board was chaired by a Senior Manager from another railway company and not an external attorney. This was a new initiative implemented between TFR and another Operator so that lessons learnt could be shared. This was the first time this initiative was trialled. Subsequent discussions with the Board inferred that the use of attorneys does not provide value as they lack railway knowledge and are expensive. This confirms the interview findings. The question that arises is whether this new initiative is due to cost saving or added value? Non-compliance to governance documents was also evident in the observation. Table 7.13 highlights the observations from the TFR BOI.

Table 7.13 Observations from theTFR BOI

Observation	Finding
Time between the date of the occurrence and the date of the Board's site inspection	5 months, 7 days
Time between the date of the occurrence and the date of the Board's sittings (interviews)	1st sitting – 5 months, 7 days 2nd sitting – 6 months, 11 days 3rd sitting – 7 months

	4th sitting – 7 months, 20 days
Duration of the Board's sittings (excl. report writing)	1st sitting – 2 days 2nd sitting – 2 days 3rd sitting – 1 day 4th sitting – 1 day
Resources used to capture and record evidence	Onsite no cameras were used Voice recorder for the interviews
Processes and procedures during the site visit	Walkabout, familiarisation with the scene
Board member composition	1 Chairperson 1 Risk Manager 1 Senior Manager, Resource Management 1 Technical Investigations Manager 1 Fleet Manager (different operating division) 1 CSO Secretary & Coordinator
Chairperson of the BOI	Senior Manager, another Operator
What methodologies / root cause techniques were used to analyse the occurrence?	None
Questioning of the witnesses	Mix of open and leading questions
Compilation of the investigation report	Drafted by the Board's Secretary with inputs from all Board members

A notable observation was the time delay between the date of the BOI and the date of the occurrence. The first sitting of the BOI took place 5 months and 7 days after the incident. This is a lengthy delay and impacts on the reliability and validity of the evidence and hence the effectiveness of the investigation process. The delay in commencing with the BOI was attributed to the non-availability of the Chairperson, witnesses and Board members. In total, four sittings of the Board took place. This was due to:

- Line Management not rostering operational employees to attend the BOI

- Line Managers not availing themselves to be interviewed despite numerous requests from the CSO
- Line Management not responding to emails sent by the CSO
- The time taken to interview all the witnesses during the BOI was longer than the scheduled times
- The Board requested additional witnesses as the inquiry proceeded

The Secretary of the Board informed the observer that these factors were serious frustrations experienced regularly for any BOI, especially Line Management ignoring requests from the CSO. As discussed in the previous section, the lack of integration between the RSR and Operators is similar to the next levels in the system. That is, within the company level there is a further disjointed system between the CSO level and the Line Management level. Parts of the system operating in isolation of each other, and the conflicting goals of these parts, impact on the successful performance of the investigation system. Line Management are required to run trains but are also responsible for railway safety. The CSO is responsible for maintaining the organisations safety but has to compete with production and tonnage output. Aggressive competitive environments, political pressure and economic pressure are external influences that influence organisational behaviour and the stability of a system. Line Management in the system are under pressure to work in a cost-effective manner but at the same time need to ensure safety by conducting thorough investigations. Migration in the system between these conflicting demands occurs and is influenced by decision makers and activities of other people, at different times, in different parts of the system. The accident investigation system has to balance its resources and constraints to cope with complexity, with the observations at TFR indicating that meeting production pressures is favoured at the expense of conducting effective investigations and improving railway safety. This was confirmed in the interviews at TFR.

For effective investigations, competent and skilled investigators are important. The researcher asked the Board members if they had undergone any accident investigation training. One member had completed a five-day course RCAT course, but admitted this was some time ago. The rest of the Board members acknowledged that they relied on their experience and were not trained. The Board members were selected based on their

operational expertise relevant to the occurrence as TFR does not have appointed investigators. Table 7.14 highlights the researcher's observations for the pre-inquiry and arrival stage of the inquiry.

Table 7.14 TFR BOI: observations pre-inquiry and arrival

Stages of the Inquiry	Observations
Pre-inquiry and Arrival	The RSR & Line Management had already conducted their separate investigation
	Board members arrived late
	Some witnesses had their union representatives present
	Disciplinary hearings had already been completed
	One Board member had photographs that other members did not have

During a discussion between the researcher and a Board member, the Board member stated that he did not know why he was attending the inquiry: *"Not sure why I am here. I thought all the questions had already been asked. We will find out now why we are here. No idea why I am here".* The Board members had not communicated prior to the BOI and no alignment meeting or pre-inquiry discussions were held. The Board members had not met at any stage prior to the inquiry and commenced with the site visit and the interviews. These factors influence the Board's preparation and illustrated a lack of cohesion. Both the Line Management and RSR's investigations had already been conducted with some of the witnesses querying why there was another investigation. Disciplinary processes had also concluded. Table 7.15 indicates some of the observations of the onsite investigation by the Board.

Table 7.15 TFR BOI: observations onsite

Stages of the Inquiry	Observations
Onsite investigation	No evidence onsite (accident happened 5 months and 7 days) ago
	No investigation equipment was used onsite or any photographs captured
	One witness accompanied the Board to the site

The site visit served as a means of orientation. The site visit was brief and included a walkabout and an explanation of what happened. No measurements or photographs were captured. Upon returning from the site, the Board commenced with the interviewing of witnesses. Table 7.16 highlights some of the interview observations.

Table 7.16 TFR BOI: observations from the interviews

Stages of the Inquiry	Observations
Interviews	Chairperson asked the Board to identify root causes, observations, findings, immediate causes, contributing factors and recommendations
	Terms of reference read out to each witness
	Initial questions started with what is your grade, what are your duties, and take us through what happened on that day
	Interviews were recorded for the Board Secretary to write up the report
	Board requested documentation from the witnesses
	Witnesses were encouraged to feel free and be open
	No summary / consolidation amongst the Board after each interview
	Some witnesses did not know why they were attending another investigation
	No prepared questions. Questions were asked as the interviews progressed

Similarly to the RSR BOI, time pressure also emerged as a theme during the TFR observations. The same findings identified during the RSR's observations, were also evident in the TFR observations. The delay in commencing with the BOI was acknowledged by the Chairperson and resulted in time pressure on the Board to complete the investigation. For example comments included: *"in the interests of time"*, *"so that we don't spend a long time on this afterwards"* and "*we need to be quicker with our questions"*. Similarly to the results from the RSR's observations, witnesses' ability to recall information was also affected by the time delay in commencing with the interviews. Within in the entire investigation system, rushing in the interests of time to complete the investigation was a common finding. Investigators are under pressure due to decisions and actions made at higher levels in the system that impact on the lower levels of the system,

namely the staff (investigators) required to do the work of investigating. Investigators therefore have to make trade-offs, and in this example the quality and thoroughness of the investigation process is substituted for a report that is submitted for compliance purposes. In turn this does little to prevent recurrences of railway occurrences.

The observations verified the findings from the interviews that blame is prominent at an operational level in TFR. Different departments pointed fingers in order to shift accountability. The Board members felt that many of the witnesses were intimidated as they were required to give evidence after they had already been disciplined by their Line Management disciplinary processes. These factors impact on the reliability of the evidence provided to the Board with one witness stating: *"I'm scared"* in reference to giving evidence. Witnesses were fearful of the consequences once the BOI report was made available to Line Management. Despite the CSO BOI being *"independent"* of Line Management, one witness stated*: "I don't want to say something that I'm not supposed to say"*, while another didn't want to continue unless there was a union representative present. The Board resumed interviewing this witness once the union representative arrived. Similarly to the RSR observations, a just culture was also not evident in the next level of the system. This further impacts the effectiveness of the investigation system and creating a reporting and learning culture.

In light of the above finding, the Board reiterated the need to *"find out what happened from a systems point of view"*. The Chairperson informed the Board to focus on job factors, management issues, and the system rather than on an individual. One Board member stated "*Management are excused but need to be accountable as they issue instructions to their subordinates"*. The Board acknowledged that there is a gap in the TFR system in terms of how occurrences are investigated with one participant stating: *"Blame is apportioned to train drivers which impacts on trust and creating an open culture. This impacts on the reliability of the evidence and hence the effectiveness of the inquiry"*. The Board further added that the way investigations were currently done at TFR needed to be revised, as accidents would continue to occur. A suggestion was made to the observer that there is a need for independent and specialised BOI teams in TFR to ensure standardised processes, as investigations were not the Board members' core function. These are important statements, confirming that the effectiveness of the investigation process is influenced by systemic factors. Although a systems approach to accident

investigations was mentioned, there was no evidence of applying this in the BOI to determine what happened from a systems perspective.

In response to focussing more on the system, comments such as: "*We need to drill down to the root causes. We must not sugar coat the incident. We need the causes of what happened, the root causes, and we must drill down to it"* and "*We need to peel the onion to get down to the root cause"* were shared by the Chairperson to the Board to ensure that the Board fulfilled its mandate. Although important to ensure effective investigations, no systemic models or methods were adopted to achieve this. Furthermore, no Human Factors Specialists formed part of the Board, limiting the number of human factors related questions. The observation confirms the findings from the interviews and review of the investigation files that Human Factors Specialists are not used in investigations conducted by TFR.

The questioning style adopted by Board members can impact on the reliability and objectivity of the evidence. The union representative of one of the witnesses interrupted a Board member who was asked to change their questioning style and not to interrogate the witness. This inquiry was the Board member's first. Inexperience and no investigation training therefore impacted on how the questions were phrased. Some of the Board members appeared aggressive towards a witness, pushing them in a certain direction. The Chairperson did intervene and reminded the Board to not interrupt witnesses and stated: "*We are missing the ground rules"*. However, at the start of the BOI no ground rules were established. The Chairperson was from another Operator and therefore assumed Board members, by their appointment to sit on the Board, would be familiar with the processes. This is a result of no formally appointed investigators.

Witnesses explained that since the accident, there had already been seven near misses of the same type of incident. These near misses could have resulted in seven more occurrences. The accuracy of the findings, suitability of the recommendations and whether the recommendations were implemented by Line Management post their investigation is questionable. Furthermore, learning from previous incidents appears to not have received any significance. The purpose of an investigation is to determine what happened to prevent a recurrence. For seven near misses of the same occurrence to continue, raises an important question as to the effectiveness of the previous investigation and the whole

investigation system. One witness admitted that the Line Management investigation: *"is not addressing the real root cause. I am happy the BOI is happening because the Line investigation has not addressed the problem. The events keep reoccurring so clearly the recommendations are ineffective"*. A Board member also commented that the BOI itself is a compliance exercise, done on paper and if the BOI was really effective, there wouldn't be so many repeated findings over and over. This is an example of a systemic factor and if neither the Line Management investigation nor the BOI are taken seriously by the organisation, then the investigation process adds little value to improving railway safety.

Commitment to safety, of which accident investigations are one way of managing safety, requires adequate resources (Rasmussen, 1997). TFR does not have appointed investigators to conduct occurrences, and with the number of occurrences, increases the delay in investigating accidents as soon as possible after the event. During this time delay it is not surprising that repeated near misses occur as learning has not taken place. The investigation of accidents is an example of a complex system. Like in any other complex system people need to make trade-offs to cope with variable demands and pressures (Shorrock et al., 2014). This is what gives systems flexibility. To cope, individual performance is adjusted which can result in unwanted consequences. In the investigation system, systemic factors such as resource and time constraints impact on the performance of the investigators to conduct a thorough investigation. Although an investigation is conducted, the trade-off is the quality, reliability, validity and objectivity of the investigation process. Limited controls to keep the investigation system stabilised i.e. appointed investigators, further exacerbates the system from achieving its objectives in addition to the bigger rail socio-technical system.

As discussed Line Management are required to run operations but are also responsible for safety. The conflicting interests increase the demands at a Line Management level, with production demands preceding the need to conduct effective investigations. The Board identified that the Line Management investigation report (submitted as evidence) had a number of mistakes and was poor. A witness, who was part of the Line Management investigation team admitted to not having read the Line Management investigation report before signing acceptance of it. Another witness stated: *"We have the same mistakes keep happening since this accident. Line is about finding quick fixes"*. This finding was also identified during the Line Management interviews. The objectivity of the Line

Management investigations was identified as a problem due to witnesses who were also on the Line Management investigating team. A witness admitted that as management: *"we do not hold ourselves accountable"*. The Board acknowledged that it was common practice for Line Management investigations to not be impartial, contributing to discrepancies between the findings in the CSO report and Line Management reports. One witness stated: *"if you put that in the BOI recommendations then there will be more pressure"* emphasising that Line Management investigations are completed more for compliance and are not taken seriously. Appointed investigators whose sole job it is to investigate, who have the authority to make recommendations and can ensure that these are implemented, would improve the effectiveness of the investigation process throughout the company.

In summary, the observations verified the information obtained in the interviews and the review of the investigation files, confirming the validity of the results. In addition the observations and the interviews highlighted that what is stipulated in governance documents does not always happen in practice. Triangulation and the use of multi-methods in this qualitative research provided a comprehensive understanding of the phenomena of the system of accident investigations. This is a complex system influenced by a number of systemic factors inherent with the system of accident investigations but also in the bigger rail socio-technical system, extending into the transport system of South Africa. The following section summarises the findings in an Accimap.

7.6 Accimap of the accident investigation system

An Accimap was created providing a graphical representation of the systemic factors, decision, events and conditions that together illustrate that the accident investigation system is a complex system in its own right. Levels or stakeholders include societal, governmental, regulatory and organisational factors. This is illustrated in Figure 7.10.

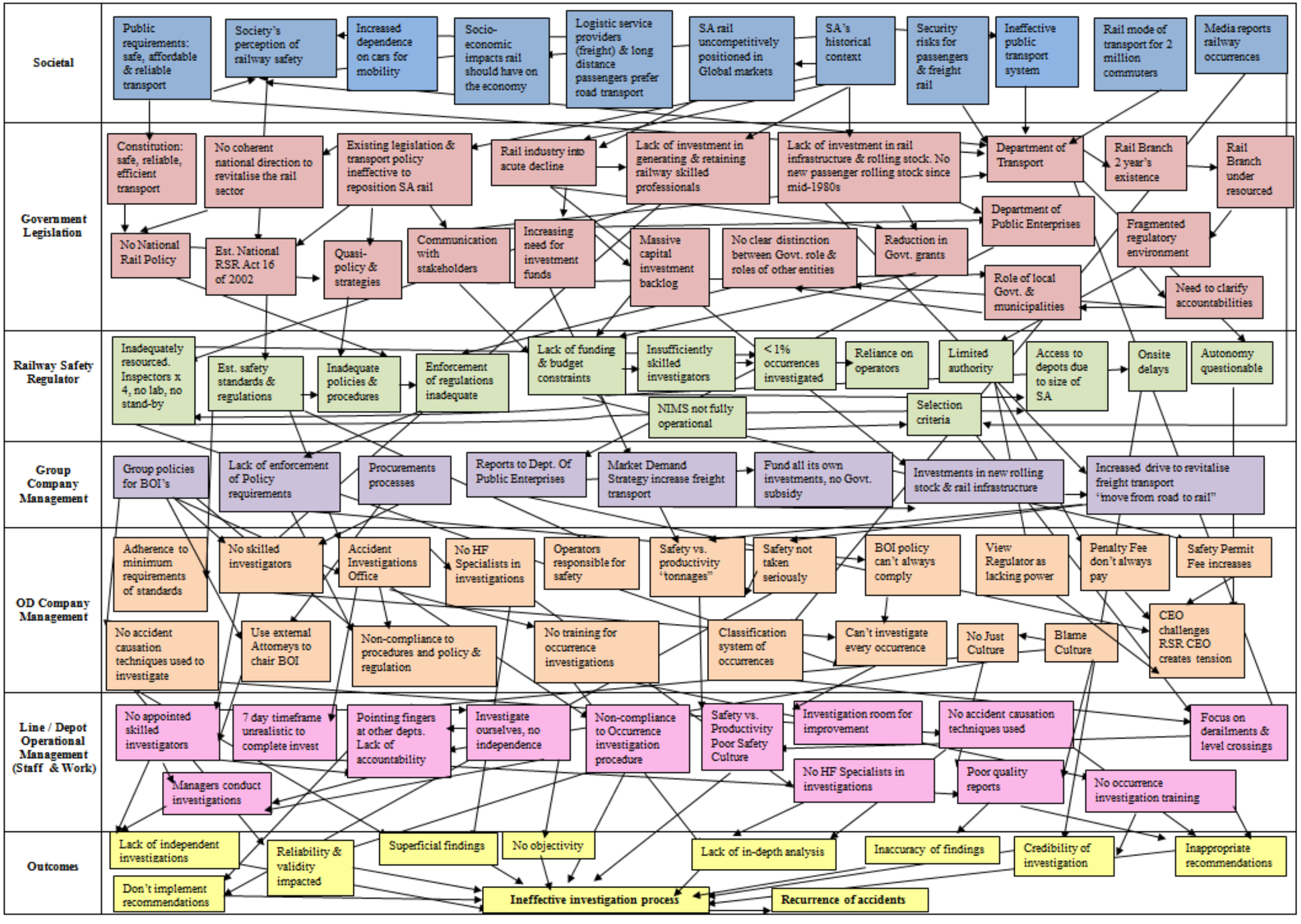


Figure 7.10 Accimap of the system of accident investigations

The Accimap was created to illustrate the context and events that influence the complex system of accident investigations and impact on the effectiveness of the investigation of accidents. The Accimap consists of seven levels. The first six levels of the framework include: Societal, Government and Legislation, Railway Safety Regulator, Group Company Management, Company Management, and Operational / Line Management. The decisions, actions, events, conditions, flow of information, feedback, integration, constraints, resources, demands, trade-offs and interactions of the stakeholders at the top six levels of the system of accident investigations result in a number of systemic factors. This includes the flow within and between the levels of the system of accident investigations. The seventh level refers to the impact of the systemic factors on the accident investigation system and is called *Outcomes*. The outcomes of the systemic factors on the system of interest are an *ineffective investigation process* resulting in a *recurrence of accidents.* The Accimap depicts each level using a separate colour in order to highlight the impact and events of that level on the next level of the system. The level above the outcome level reflects the immediate precursors to the ineffective investigation process. The Accimap summarises the results from this research and these are explained in the next chapter in detail.

7.7 Summary of the results

The media provides a platform for the public to be informed about the state of railway safety. In this research the public formed part of the investigation system, with the public having an important role to play in influencing Government and its agencies to improve the state of railway safety. The public rely on rail to commute to work and also for goods to be transported, therefore the system needs to safe and reliable. If the public are unaware about the safety performance of the railway system, then efforts to put pressure on the Government to effect change are minimal. One way of increasing public awareness is through the reporting of railway accidents by way of the media. The role of the media was acknowledged by the both the RSR and TFR as a stakeholder who can influence the level of severity of an investigation by way of media attention. The media, representing the public, are an important decision maker in the system of accident investigations. The media analysis illustrated that although railway accidents are reported, the number of reports were substantially fewer than the number of occurrences reported annually by the RSR State of Safety reports. Therefore the public (and the media) are not acceptably

informed about the state of railway safety in order to pressure the Government to improve railway safety.

The Government (represented by the Rail Branch in the DoT) in the investigation system plays no role in the actual investigation of occurrences, and in general does not actively participate in railway safety. Constraints and challenges at this level in the investigation system impacted on the next level of the system, the RSR. No National Rail Policy in South Africa and generic legislation that is not well understood at the highest levels of the system are examples of systemic factors. Furthermore, little vertical integration between the different levels below the Government level and also up to the Public level impacts of the investigation systems performance in addition to that of the bigger rail socio-technical system.

The RSR lacks autonomy and is not an independent investigating body. The reporting structures in the DoT are a contributing factor to why Operators do not take the Regulator seriously. A number of systemic factors were identified that impact on the effectiveness of the investigation process but also the validity, reliability, objectivity and accuracy of the findings and recommendations from the investigation reports. A lack of resources, both in terms of staff and financial resources, impacted on the quality of the RSR's investigations exacerbated by investigators who did not have the necessary competency and experience.

Similar findings to those demonstrated at the RSR level were identified for the next level in the system, the Company. In TFR, at both the CSO and Line Management level comparable themes impacting on the effectiveness of the investigation process were identified. Systemic factors included no formally appointed investigators, lack of training, conflicting goals, time pressures, time delays in commencing with the inquiry and the relationships within and between the different levels of the system. At the both the RSR and TFR level in the investigation system it was evident that a just culture does not exist despite this being a requirement of SANS (2009).

The Accimap summarises the results from this research, illustrating that the accident investigation system is a complex system and this is discussed in the next chapter. The interviews, observations, review of the governance documents and the review of the investigation files demonstrated similar results. The process of triangulation confirms that

the findings established in one method were verified in more than one of the methods adopted in this research. This increases the validity and reliability of the data collected in this research.

7.8 Concluding remarks

The results indicate that there are a number of systemic factors influencing the effectiveness of the investigation process of railway occurrences in South Africa. The systemic factors, displayed in an Accimap, are inherent within and between the different levels of the investigation system. The accident investigation system is an example of a complex system in its own right with system principles such as integration, feedback, demands, resources, constraints and flow of information all evident from the results in this research. It can be concluded that the investigation system's complexity is influenced by disjointed system of systems where the performance of other systems, the context, conflicting goals and organisations' commitment to safety influences the investigation system from achieving its objectives. That is objective, valid, reliable, accurate and quality investigations. Thorough investigations should lead to the establishment of accurate findings and recommendations that are appropriate and are implemented for change to occur. A learning culture needs to be encouraged in order to maintain safety and to prevent recurrences.

The final chapter of this research, chapter 8, is the discussion of the results with the Accimap integrating all the systemic factors influencing the effectiveness of the investigation process. Directions for future research, the limitations of this research and the recommendations for the railway industry are highlighted in the following chapter. The final conclusions and confirmation of the research hypothesis are provided.

CHAPTER 8: DISCUSSION, RECOMMENDATIONS AND CONCLUSION

Chapter 7 detailed the results from the media analysis, the governance documents analyses, the review of the investigation files, the interviews and the observations. The results illustrate that the investigation process of accidents is an example of a complex system on its own nested within the bigger rail socio-technical system. A number of systemic factors inherent in both systems influence the effectiveness of the investigation process, and impact on the accuracy of the findings and suitability of the recommendations. An Accimap provided a summary of the results highlighting the complexity of the system of accident investigations. This final chapter discusses the Accimap and the findings in relation to Rasmussen's (1997) Risk Management Framework, highlighting the theoretical contribution of this research. In addition, the limitations of this study, the recommendations for the South African railway industry and the directions for future research are discussed. The conclusions of this research are provided at the end of the chapter.

8.1 Accimap of the system of accident investigations

Chapter 4 described Rasmussen's work and its application in accident causation theory. In this research Rasmussen's work has been extended to demonstrate how factors within the South African rail socio-technical system and the context contribute to the effectiveness of the investigation process of railway occurrences. These factors are referred to as *systemic* as they are deep rooted and have existed for some time. The popularity of Rasmussen's work has been widely used in determining why accidents occur illustrating accidents are the result of the dynamics of complex systems. In this research the results demonstrate that the *accident investigation process* is in itself an example of a complex system and not just the accidents. The context and dynamics of the South African rail socio-technical system have contributed to the accident investigation system being a complex system of systems. The different levels described in Rasmussen's (1997) Risk Management Framework served as the foundation for this research. Furthermore, it provided a framework to explore the role that each level in the *system of accident investigations* has in influencing the following:

- Whether all railway occurrences are investigated

- How are occurrences investigated
- What factors impact on the credibility of the evidence collected
- What factors impact on the objectivity of the investigation process
- What factors hinder the investigation process from the time the accident occurs to the submission of the report
- What factors influence the quality and thoroughness of the investigation reports, including the findings and recommendations
- Whether recommendations from the investigation reports are implemented

To illustrate the findings of this research and its contribution to Rasmussen's work, an Accimap was created. The Accimap approach (discussed in chapter 4) has traditionally been used as a means of modelling the socio-technical context to identify the combination of events and decisions that produced an accident (Branford, 2011). However, for the purposes of this research the Accimap demonstrates that it can be used as a technique to model the decisions, interrelationships and events that influence the system of *accident investigations* and not only to determine the causes of accidents. Furthermore, this study suggests that the investigation process also is a reason for why accidents recur. Ineffective investigations impact on the accuracy and credibility of the outcomes, namely the findings and recommendations. Identifying only superficial findings, akin to the 'tip of the iceberg' analogy, results in the real reasons for why the accident happened remaining unnoticed within the system. Likewise, inappropriate recommendations, the failure to implement recommendations post an occurrence and not following up on the value of these can also be influenced by the systemic factors in the investigation system. In South Africa, the decisions of the various role-players, the context and the complexity of the accident investigation system impacts on railway safety performance trends. In this research the Accimap provides a systemic view of the factors influencing the system of accident investigations but also the bigger rail socio-technical system.

In chapter 6 adjustments were made to Rasmussen's (1997) Risk Management Framework. This was necessary to make the Accimap specific to the context of the South African rail socio-technical system, of which the system of accident investigations is a part of. The adjustments included extending Rasmussen's (1997) Risk Management Framework to include the *Public* as a level rather than as an external pressure. South Africa's historical

context has impacted on the socio-political and socio-economic climate of the country. Since 1994, post-Apartheid, there has been a need to redevelop and revitalise the country. Before 1994 rail was underdeveloped and international sanctions imposed on South Africa hindered the railway industry's ability to grow. The South African Government has acknowledged that the railway industry has been neglected and the consequences of this were discussed in chapter 2. In the Green Paper for a National Rail Policy (DoT, 2015), South Africa is in the process of revitalising the railway industry as part of the rail renaissance to improve the safety, efficiency and reliability of rail transport. The public represented by society in the Accimap includes both customers and users of rail, either for freight transport or commuting to and from work. The public have an important role to play in terms of the bigger rail socio-technical system in addition to the system of accident investigations. This is because of the Constitution of South Africa of 1996 that requires the Government to legislate policies to ensure that the South African transport system provides safe, reliable, efficient and effective transport operations (South African Government, n.d.). Furthermore, the South African Government states that in order to achieve this, policies need to be shaped by the needs of society in general, of the users or customers of transport and the economy that transport supports (South African Government, n.d.). By including the public as a level of the hierarchy, an adaption of Rasmussen's (1997) Risk Management Framework, it gives more significance to the role of society in the system of accident investigations.

An additional adjustment to Rasmussen's (1997) Risk Management Framework for this research occurred at the Management, Staff and Work level. As was explained in chapter 6, in the accident investigation system the *Staff* level refers to the individuals who conduct investigations i.e. investigators. However, the difficulty experienced in identifying the staff for this level was because investigators can also be *Management*, as was identified in TFR who did not have appointed investigators. By virtue of being a Manager at TFR this meant that any Manager could investigate occurrences. At the RSR level there were appointed investigators, however the shortage of staff resulted in the RSR using interns to assist with the investigations. At TFR, the Management level also included Managers who were policy and procedure decision makers including those responsible for the overall management and implementation of the occurrence investigation process. Operational front line staff (for example, train drivers) would normally be at the staff level in the traditional Risk Management Framework. However, in the accident investigation system

they are not included in the staff level as their role is to act as witnesses or informants and provide information. Operational front line staff are not responsible for the investigation process. They do not play any role in the administration and organisation of investigations. At the both the RSR and at TFR, the competencies and skills of the investigators was identified as a systemic factor due to the inclusion of interns as investigators with no knowledge or background in accident investigations and no formally appointed investigators at TFR. The *Work* level in the system of accident investigations refers to the activities of conducting investigations rather than the hazardous processes as illustrated in Rasmussen's (1997) Risk Management Framework.

8.2 Accimap discussion

The Accimap in Figure 7.10 at the end of the previous chapter is discussed in this section highlighting the integrations and relationships between the levels, or stakeholders of the accident investigation system, events and conditions that influence the effectiveness of the investigation process. The levels, or stakeholders include societal, regulatory, governmental and organisational factors. The Accimap illustrates how the accident investigation system is an example of a complex system because of the number of interacting elements that are dynamic and change as conditions of the system change. From the perspective of the stakeholders in the system, for example the RSR and TFR the system appears ordered, but the Accimap illustrates how the system is fragmented. Moreover, at a Government level, represented by the DoT, there is very little understanding of the complexities of the railway system. Furthermore, rail has not been a priority of the Government indicative of the lack of adequate resources for its agencies to effect change, and with the focus of the Government centred on road transport. The behaviour of the accident investigation system is determined by the dynamics of the complex system where changes in one part of the system have an effect on another that is non-linear. The performance of the accident investigation system is measured by the credibility, objectivity, quality, thoroughness and effectiveness of incident investigations. What happens in one level of the system impacts on the next, and with little information about the state of affairs flowing back to the higher levels, the effectiveness of the investigation system is compromised. The Accimap depicts how circumstances, for example South Africa's historical context can result in disproportionally larger effects than was expected. For example the underinvestment in rail, socio-economic impacts, and rail uncompetitively positioned in the global markets. Furthermore, time and changes in the

environment, together with the interactions of the stakeholders of the bigger rail socio-technical system have also impacted on the accident investigation systems behaviour. A further outcome of the Accimap is that the ineffectiveness of the investigation process also contributes to the recurrence of accidents. This is because the accuracy, reliability and validity of the findings and recommendations emanating from the investigation are questionable, minimising the likelihood of reducing future occurrences, and compromising the safety of the bigger rail socio-technical system.

Nyman and Johansson (2015) affirm that the overall goal of investigating accidents is to learn and prevent. However in order to achieve this, the accident investigation process needs to be effective i.e. objective, reliable, thorough, valid and credible. This is to ensure that the findings and recommendations are able to acceptably address the cause(s) of occurrences. Investigators need to look beyond the obvious and can only achieve this by adopting a systems approach in accident investigations. As was evident from the results chapter there is minimal improvement of adverse events in South Africa's railway system supported by the number of occurrences and repeats of similar events. This is largely because of the industry's methods of approaching change that are ineffective. Investigations of accidents, albeit a reactive method, are important for improving railway safety and bringing about change. If the process is ineffective, change in the form of safety improvements is unlikely. Furthermore, recommendations that are proposed to effect change are not always directed at robust system level improvements and/or are not implemented for change to occur. A systems approach in accident investigations is not applied at the level of the RSR, CSO and Line Management level. Furthermore, an integrated system where system principles are understood was not evident. Instead the components of the bigger rail socio-technical system act in isolation rather than holistically.

The Accimap illustrates the relationships and effects of various decision makers, events, conditions and processes beyond the most obvious actors in the system. It provides a fuller picture, and a more useful understanding, of the systemic factors influencing the investigation process of railway occurrences in South Africa. The effectiveness of occurrence investigations is influenced by decisions makers, events, conditions and integrations from all levels of the socio-technical system and this was clearly indicated in the Accimap. Underwood and Waterson (2014) state that the Accimap approach

demonstrates key system thinking and system theory concepts. The Accimap in Figure 7.10 illustrates the system thinking approach. The whole system hierarchy is responsible in some way or form for the ineffectiveness of the investigation process. The components of the system were analysed holistically, where the interactions between the various elements of the system were examined. The outputs of these relationships and how they negatively impact on system safety (in terms of ineffective investigations) were shown in the Accimap. The Accimap demonstrates system behaviour via the caption boxes and the arrows illustrating the inputs and outputs of the various decision makers and events. Each of the causal factors in the Accimap is linked to its effects. For example the public require safe and reliable transport, but there has been an underinvestment in rail infrastructure and rolling stock, impacting on the safety and reliability of rail transport. This together with no national direction to revitalise rail has resulted in no National Rail Policy. Without this policy there has been little Government investment in creating skilled railway specialists and a general lack of involvement in rail safety. This has impacted on the RSR's ability to perform its work effectively, due to under funding and the shortage of railway skilled professionals. The RSR is unable to fulfil its mandate of overseeing safe railway operations. In turn this impacts on the number of investigations conducted by the RSR resulting in not every occurrence being investigated, and those that are, the effectiveness is doubtful. The outcome is an ineffective investigation process and a recurrence of accidents. This is only one example of the causal links in the accident investigation system, with the Accimap illustrating multiple casual links leading to the same outcomes. This is discussed further in the following paragraphs. The Accimap therefore illustrates how one factor, event or action influences other factors. All of the decisions, actions, events and conditions in the Accimap come together to produce outcomes. In the system of accident investigations these are ineffective investigations and a recurrence of accidents. The goals of the system of accident investigations are implicit in that the principal goal of the system is to have effective investigations and therefore the avoidance of occurrences. The context in which decisions and activities take place in the various system levels is depicted in the Accimap and extends as far back in the system hierarchy as South Africa's historical context.

South Africa's historical context refers to the disinvestment in rail during the Apartheid era and the effects of Apartheid felt post 1994 when South Africa became a democratic country. International sanctions and social divisions within the country resulted in the

democratic Government post 1994 trying to redress the wrongdoings of the Apartheid Government. The Apartheid Government disinvested in railways resulting in railway skills, education and work opportunities in rail being non-existent (DoT, 2015; Mathebula et al., 2014). Post 1994, the democratic Government introduced affirmative action with the aim of creating equal employment opportunities in the workforce and to redress the long history of racial and sexual discrimination to create a diverse society (Mathebula et al., 2014). The implementation of affirmative action also brought with it consequences such as skilled white people resigning, being disgruntled and others migrating overseas (Mathebula et al., 2014). Mathebula et al. (2014) further state that as a result of these factors, together with black people job hopping because of their high demand in the market, the skills gap widened. In the Green Paper for a National Rail Policy (DoT, 2015) it is acknowledged that the South African Government has neglected investing in the development of professionals with critical railway skills and attributes this to (amongst others), South Africa's historical context. The shortage of railway skilled professionals in South Africa still exists today and was evident in the results from this research. The struggle to find experienced railway investigators was admitted in all of the interviews. The RSR acknowledged that this has had an impact on the safety of railway operations. The RSR struggled to recruit skilled railway professionals because of the short supply, but also because of the added competition of other railway stakeholders competing for the same resource. This is why the RSR used the interns to compensate for the shortage of staff in the RSR Occurrence Investigation Department. The system principle of *trade-offs* is clear in this example (Shorrock et al., 2014). The South African context requires that the RSR make trade-offs, i.e. using inexperienced, untrained interns who have no rail and accident investigation knowledge because of the shortage of staff. This is in order to cope with the demands. For example, maintaining railway safety while trying to cope with the number of accidents that need investigating.

In terms of societal influence, both passenger and freight logistic users of rail require that it is safe, reliable and efficient. This is an example of a demand on the railway system, where the public require the performance of the system to meet such pressures. However, the underinvestment in rail infrastructure and rolling stock, the lack of security for passengers and freight and inefficient operations has further exacerbated the use of rail as a chosen mode of transport with road transport being the preferred option (DoT, 2015). *Demand and pressure* are a further example of a system principle (Shorrock et al., 2014)

that has a fundamental effect on system performance. Furthermore, the globally competitive environment and South Africa's endeavour for economic development further constrains the bigger rail socio-technical system. Added to this the skill shortages already discussed in the previous paragraph, makes it challenging for the country to meet the demands of globalisation. The socio-economic and socio-political environments of South Africa have contributed to South Africa lagging behind in the rail renaissance compared to its compatriots in the BRICS countries (DoT, 2015). South Africa is therefore uncompetitively positioned in the global market because of the underdevelopment and inefficient system, the historical context and the lack of railway skilled professionals. This was acknowledged in the interview at the DoT where the loss of skilled railway people has contributed to why South Africa's National Rail Policy is absent. The absence of a National Rail Policy further contributes to why there is no proper direction in terms of Government policy on railway safety, and why the Government plays an inactive role in railway safety in general. Mathebula and Sopazi (2016) confirm that a shortage of critical skills and the underinvestment in rail have compelled South African railways to operate in a degraded mode of operation. The ramification of this is that safety performance of the bigger rail socio-technical system is impacted, and by implication the nested systems performance also. The activities of the system of accident investigations in trying to prevent a recurrence are hampered because of problems inherent in the system. Therefore to improve railway safety it is necessary for organisations to view the investigation of accidents as a system i.e. holistically where the interactions between the elements or parts are considered rather than in isolation. The systems concept of 'the whole is bigger than the sum of its parts' must be considered by system actors and decision makers in how accidents are investigated throughout the process. As is evident in the Accimap the elements of the system influence each other and are interconnected characterising the system and shaping its performance.

The role of the public as a level on its own was included in the system as the public and the media are important decision makers in the accident investigation system. In order to determine if the public are aware of the state of railway safety, a media analysis was conducted. In the Accimap the media and the public are incorporated into the societal level. The print media was found to report on railway occurrences, albeit the number of media reports was substantially fewer in comparison to the number of occurrences reported by the RSR. According to the literature on newsworthiness, operational

occurrences would be perceived by the media to hold more risk to the public due to resultant fatalities and injuries (Cotter, 2010, MacDougall, 1977; Pape & Featherstone, 2005). Loss of life or injury heightens public attention increasing the likelihood for the media to report on such events. Vasterman (2005) explains how reporting on fatalities and injuries would trigger media attention by evoking social responses of fear and vulnerability, stimulating the current news event and increasing media attention. This phenomenon is known as *journalistic sensationalism*. In essence, journalistic sensationalism considers the manipulation of content or language to portray an event that will evoke public emotions (González, 1993). For example, an event resulting in environmental damage will be sensationalised by the media to instil anger within the community. Other events that have the potential to be sensationalised include those that have resulted in greater financial implications, greater disruption to rail services, and greater damage to infrastructure and technology (González, 1993). The researcher hypothesised that if the media reported more on railway safety performance trends, that this would increase public attention thereby placing pressure on the South African Government and its agencies to improve the state of railway safety. The results illustrated that the media do report on railway occurrences but not enough to generate the public outcry or interest required to influence the Government, and its agencies.

The top levels of the system need to be aware of the actual state of affairs of the system to determine if the situation is compatible with the decision makers' objectives (Rasmussen, 1997). In addition to the public and media not being aware of the state of railway safety in South Africa, the participant in the DoT was also not aware of the actual state of affairs. Given that the RSR produces an annual report and the State of Safety report, the DoT cannot be oblivious of the state of affairs of the railway system. Instead it indicates that there is an inherent dearth of urgency by the DoT to 'fix' the system, given the number of occurrences and the consequences of these for society in general. Within the Government level there is a little to no integration including between the Government and its agencies to effect change. For example the DoT and DPE both have railway Operators reporting to them, but there is no integration to improve railway safety performance for the betterment of everyone in the system. The Government level in the bigger rail socio-technical system, and even beyond this into the transport system, is fragmented contributing to the entire system being disjointed. This is a likely reason for why the public, the next level up in the system of accident investigations are unaware of the state of railway safety in South

Africa. The intricacies in one level of the system therefore influence the level below *and* above highlighting no 'holism' in the system of systems, but in particular in the system of interest of this research that is the accident investigation system.

In the interviews it was highlighted at both the RSR and the DoT that the Government is rarely involved in occurrence management, given that no formal communication system exists between the two levels, and the reduced funding for the RSR to perform its mandate. The Government appears to have retreated from any active participation in occurrence management leaving the RSR to be referee in determining which of the major accidents warrant investigating, or conversely what accidents are publically acceptable to not investigate. The separation of power to the RSR, in the absence of an independent investigating body has contributed to political conflicts between government agencies and the Operators. Furthermore, TFR reporting to a completely different Ministry further exacerbates the effective functioning of the system. The lack of cohesion between the two Ministries in terms of railway safety further compounds the integration, flow of information and feedback between the system elements. It is therefore observable that the higher echelons of the system are disjointed and operate in isolation. Between the Government level and society there is also minimal *flow of information and feedback* about the poor state of affairs and the inability of the accident investigation system to cope with the demands or number of occurrences needing to be investigated. Rasmussen (1997) and Shorrock et al. (2014) state that flow of information; feedback and integration are important system principles. Society and the public (whether a commuter, customer or community member living adjacent to the rail network) require feedback about both problems and opportunities for improvements. The lack of vertical integration in both directions is an example of a systemic factor impacting on the overall performance of the system.

In this research, print media represented the public as the media is one way that the public can be informed about railway safety. In this research the public was seen to be more significant than just an outside pressure as illustrated in Rasmussen's (1997) Risk Management Framework. This is because the media and the public are decision makers in the system of accident investigations as they influence the type of occurrences that the RSR and the CSO at TFR will investigate. In the system of accident investigations, both the RSR and TFR need to adjust to the variability in the demands of the media (and the

public). Changes in conditions, for example increased media attention, impacts on the classification system of occurrence investigations. Public outcry or interest in an occurrence, portrayed via the media requires the RSR and TFR to adjust the level of investigation to meet the demands of society. Adjusting to cope with variability in demands and conditions is another example of a system principle referred to as *performance variability* (Shorrock et al., 2014). Both the RSR and TFR account for performance variability in the system of accident investigations because of their policies and procedures that address media and public attention as criteria for determining the severity. This allows for flexibility in the system. In this example, variability is fairly predictable for both the RSR and TFR. However should the demands change, for example the media report more on railway occurrences or similarly the public become more aware of the state of railway safety, then this changes the systems behaviour and the ability of the system to cope with the demands. The ability of the RSR to cope with increased media and public attention (demands) is doubtful. This is because of the present constraints and insufficient resources to meet the existing demands, where the RSR currently investigates less than one percent of the total number of occurrences on South Africa's railway. An increase in media and public attention is an example of emergent behaviour within the system of accident investigations. Should this increase then the variability may be inherently unpredictable. Making continuous adjustments are necessary in order to adapt to system conditions. The RSR and TFR will require more capacity and resources than just their procedures to account for an increase in media and public attention. For example, more staff and equipment to ensure accidents are effectively investigated. Shorrock et al. (2014) affirm that performance variability is necessary and without it success would not be possible. However, success is dependent on adequate resources and appropriate constraints which was found wanting in the RSR and TFR. Both the RSR and TFR need to be cognisant of variability and account for any drift into a state where the demands exceed the capacity. Currently, the number of occurrences (demands) exceeds the capacity to investigate i.e. the number of investigators impacting on the number of investigations. This observation impacts on the system's ability to operate within its boundaries. Dekker (2011) refers to this as a *drift into failure*, commonly used in accident causation but in this context it is also relevant. Investigating a few occurrences at the RSR, and not investigating every occurrence thoroughly by TFR's Line Management, does little for establishing a learning culture and preventing recurrences. Ineffective investigations and the consequences of

these can also result in the investigation system's drift into failure with detrimental consequences for the railway system as a whole.

The Government does not provide sufficient resources (both financial and in terms of people) to develop effective rail safety regulation. Both the RSR and the Rail Branch in the DoT had inadequate resources (including staffing, equipment, competency, information and governance documents) impacting on a number decisions, events and conditions. Legislation was not enforced in terms of the requirements of Act 16, despite the requirements documented in the RSR Occurrence Investigation Policy. The absence of a National Rail Policy contributes to the status quo observed in terms of the state of railway safety and the underdeveloped rail safety regulation. The DoT (2015) in the Green Paper on the National Rail Policy advocates that the absence of this policy has resulted in no coherent direction to guide the development and revitalisation of the rail sector. The result of this absence has meant that existing legislation and transport policy are not conducive to repositioning South Africa's railway in today's globally competitive market (DoT, 2015). Existing legislation was also found to be ambiguous. Rasmussen (1997) believes that generic legislation is not easily enforceable or effective because it leaves so much up to the companies. This was evident in the RSR's results where their own policies were ambiguous, and the standards developed by the RSR for the Operators were also generic. Given that generic legislation is not easily enforceable, it would appear in this research that the issuing of penalties is used instead to ensure compliance. The end result is that companies do not comply and relationships become strained as was evident by the CEO's of the RSR and TFR debating penalties and the safety permit fee regulations. Furthermore, the issue of competence, as discussed by Rasmussen (1997), plays a crucial role in interpreting generic regulation when this is delegated to the decision makers at the next level. Having the formal knowledge, practical skills, being thoroughly familiar with the requirements to investigate effectively and the ability to make the appropriate risk management decisions are important for local decision makers (Rasmussen, 1997). Given that the Rail Branch had only existed for two years, staffed with one employee, and in the next level at the RSR using interns as investigators, and TFR not having formally appointed investigators; the issue of expertise and competence was a prominent finding. Roed-Larsen & Stoop (2012) confirm that in modern investigations, competent, experienced and qualified investigation staff are required who not only have operational expertise but are trained as investigators at an academic level. Competence, experience and

training were identified as systemic factors at the Government, RSR and TFR levels impacting on the effectiveness of the investigation process and its outcomes.

The DoT (2015) acknowledges that in order to achieve successful rail revitalisation in South Africa, robust and drastic interventions are required. Furthermore, the DoT (2015) emphasises that the implementation of these will require strong leadership from National Government and clear direction through the National Rail Policy to drive and fund this. It was apparent in this research that strong leadership was found wanting at a Government level illustrated by the general lack of involvement in railway safety as a whole. Furthermore, the inability to intervene during debates over level crossing recommendations where various agencies of the DoT and other Government organisations were involved, demonstrates that *transport safety* is not prioritised. The diminishing funding from the Government to the RSR impacted on a number of factors influencing the value of the investigation process. Examples include:

- The shortage of staff
- Lack of equipment
- The number of BOI's
- The number of investigations
- The ability to be on site soon after the occurrence
- The unavailability of proper investigating equipment once the investigators were on site and during the inquiry, for example laboratories

The findings from this research illustrate how the decisions of higher level decision maker's impact on the ability of the next level of decision makers to implement change and ensure safety. It was also evident how actions of actors, and the effects of these, lower down in the system were not conveyed to the higher levels of the system. Rasmussen (1997) asserts that in order for decision makers to control safety adequately, they need to act properly. This speaks to whether their priorities are right; for example are they committed to safety? If the South African Government was really committed to safety, then the RSR would be appropriately independent, fully resourced, equipped, powerful and have the freedom to go about ensuring that railways are safe. Furthermore, the Government would be open with public about the state of affairs and do everything

possible to ensure rail is safe, reliable and efficient, proving their commitment to public safety. This may include establishing a truly independent body to investigate accidents. The consequence of establishing this body is that it would reveal that the Government is liable itself in some respects, a possible reason for why this body hasn't been established in South Africa. At the Company level, it was clear that TFR's commitment to safety is also questionable and it was admitted that safety was not a priority in the organisation. Examples include:

- The unavailability of appointed inspectors to conduct investigations
- Not equipping Line Management (who are mandated to investigate) with the necessary skills and training to do investigations properly
- Bureaucracy in procurement processes limiting the recruitment of expert investigators
- Emphasising volumes (productivity) over safety

Furthermore, Rasmussen (1997) states that another factor to consider is whether decision makers are made aware of safety constraints and the implications on the business and everyday work. Most of the participants acknowledged the importance of safety and its implications; however it was always secondary to production. In terms of occurrence investigations, it was admitted at a Line Management level that investigations were poor and didn't address the causes of the incident acceptably. This is another example of where the system principle of *trade-offs* was evident. Conflicting goals of safety and production were identified at all levels in the system, but was particularly evident at a Line Management level. Line Management are responsible for operations with safety as a support function. Rushing to complete investigation reports within seven days and acting as both the player and referee impacted on the independence of the investigations, its findings, and the suitability of the recommendations. TFR's Occurrence Investigation Procedure acts as a *constraint* as Line Management is rushed to complete an investigation in seven days. Line Management therefore have to work around constraints in order to meet the pressures of the procedure, but also to resume operations as soon as possible given the demands of their core functions. Safety is a support function not a core function. The implication of this constraint is an incomplete and poor investigation report impacting on the performance of the system of accident investigations. The practicality and

feasibility of the 7-day deadline (constraint) to complete an investigation requires careful review by the CSO at TFR.

The purpose of an investigation is to uncover the contributing factors and inform changes that redress the circumstances that went wrong (Dekker, 2006; Salmon et al., 2017). Furthermore, Rasmussen (1997) and Salmon et al. (2017) state that investigations are important for organisational learning. The data collected should address the contributing factors from across the whole system rather than from just the sharp end, and the interactions or interrelationships between the factors within and across the different system levels needs to be gathered. However, in practice, Salmon et al. (2017) argue that investigations do not often focus on the overall system, even in organisations with a mature safety management system. The results in this research, particularly the investigation reports and observations provided evidence that a systems approach is not adopted in railway occurrence investigations in South Africa despite reference to the word 'system' in some of the results. Apportioning blame at individuals at the sharp end, mention of human error as the cause of accidents, and acknowledgement by management that they do not accept accountability for occurrences were common findings in the results. *Just culture* is an example of a system principle, however in this research openness, mutual trust and fairness was identified to be absent. In the accident investigation system within and between the levels a lack of mutual trust was evident. This is despite SANS (2009) requiring Operators to create a just culture when the RSR responsible for overseeing railway safety of the whole system was unaware of this clause and could not define a just culture in the interviews. Furthermore, the RSR also investigates occurrences but just culture is not stipulated in the RSR's own policies. The expectations are on the Operators to implement this but not the higher levels of the system. A just culture helps to facilitate a learning culture but in this research the investigation process is hindered from achieving this due to a lack of trust between:

- Operational staff and Line Management
- Line Management and the CSO
- CSO and the RSR
- RSR and the DoT

It can also be said that a lack of trust and openness exits between the Government and the public where the media analysis revealed that the public are not acceptably aware of the state of railway safety. The lack of transparency can lead to suspicion. This is created due to a lack of integration and flow of information both from bottom up and top down in the system of accident investigations as the system does not function as a whole. A disjointed rail socio-technical system has implications for the nested systems within the bigger system impacting on improving railway safety performance. Rasmussen (1997) states that accidents are typically caused by multiple contributing factors and not just a single action or decision. In this research the Accimap illustrates how multiple decisions, events and conditions cause the ineffectiveness of investigations and a recurrence of accidents. The wider context has a significant impact on how accidents are investigated, and not only on the causation of accidents. The Accimap demonstrates that decisions and actions outside of the organisational and human system also play a role in influencing the behaviour of the accident investigation system i.e. the efficacy of the investigation process. These included societal, governmental and regulatory factors in addition to organisational factors.

8.3 Summary of the Accimap outcomes

The contribution of this research to existing theory was to provide a different perspective to accident causation by focusing on the investigation process as a complex system in itself. The system of accident investigations is only one system of the bigger rail socio-technical system. The context, goals, demands, constraints and performance of the rail socio-technical system influences its nested systems of which the accident investigation system is one of. In summary the outcomes of the Accimap illustrate a unique approach to the investigation of accidents and emphasise that accident investigations are indeed a complex system. The arrows demonstrate that every part of the system is connected to something and that nothing is completely independent.

The public require safe, reliable and efficient transport and their needs are fundamentally important in defining the systems purpose. However, conflicts and tensions between the different parts of the system were evident due to conflicting goals, in particular safety and productivity. This occurred across the different levels. The conflicts and tensions in the bigger rail-socio-technical system have a direct influence on the accident investigation system. The system of accident investigation's common purpose is to ensure every occurrence is investigated in order to identify what happened and what can be done to

prevent recurrences. Furthermore, the implementation of the recommendations plays a far more important role, however the effectiveness of these is dependent on the relevance and practicability of the recommendations.

Exploring the system of accident investigations in this research, the Accimap provides a clear picture that the accident investigation system is a disjointed system that does not operate as a coordinated whole to achieve the same objectives i.e. a safe, reliable and efficient railway. In reality, the various system actors as a whole do not have this understanding, although there is acknowledgement that safety, and in particular the investigation of accidents needs improvement. The behaviour of a system emerges from a collection of circumstances and interactions. South Africa's historical context and the socio-economic and socio-political climates have contributed to the performance of the bigger rail socio-technical system, and by implication its nested systems. While this may not be obvious from the outside, these factors have contributed to how the accident investigation system has evolved over time. The repercussions are evident in the unavailability of skilled, competent and qualified experts necessary to be accident investigators. From an outside view the system and its behaviour appear to be harmonised. Once deconstructed as performed in this research, the findings (graphically demonstrated in the Accimap), indicate that the behaviour of the accident investigation system is in fact erratic and increasingly fragmented. This is what makes the system of accidents a complex system.

Integration between and within the levels is required in order for the system to be adaptive to organisational learning and to function holistically. While there is a desire for railway safety, and in some parts of the system this was evident, the ability to achieve this is prevented by decisions made in other parts of the system. For example, the Government may believe its decisions are appropriate and necessary for improvements; however the effects of these are felt by other aspects of the system with the systems performance not necessarily improving as intended. The Accimap illustrates how the decisions and actions in one part of the system affect the other parts with the end outcomes resulting in ineffective investigations and a recurrence of accidents. The accuracy, quality, validity, reliability and objectivity of the whole investigation process, its findings and the recommendations are compromised as a result of the dynamics of the system. It is therefore not surprising why railway accidents continue to happen.

Accimaps have traditionally been used to identify why a particular accident occurred. In examples in the literature of where Accimaps have been used, the causes of the accidents are interestingly similar to some of the systemic factors influencing the effectiveness of the investigation system in this research. Examples of similar findings include:

- Led outdoor activities incidents (Salmon et al., 2015): staffing and recruitment, communication, compliance with procedures.
- Sewol ferry accident (Lee et al., 2017): Government and Regulatory bodies not having adequate oversight and enforcement mechanisms, inexperience and competency and profits over safety.
- Grayrigg train accident (Underwood & Waterson, 2014): staff training, staff recruitment and staff competence.
- Esso Australia gas plant explosion (Hopkins, 2000): inadequate regulatory system, market forces, cost cutting and inadequate training and procedures.

The similarity in the findings suggests that the factors that contribute to accidents, however remote, can also influence the effectiveness of the investigation process. The advantages of using the Accimap is in its ability to illustrate the chain of events and decision making of the socio-technical system and is therefore a logical and useful tool for anyone interested in accident prevention.

The theoretical contribution of this research is indicative of the novelty in the application of Rasmussen's (1997) Risk Management Framework and the Accimap in the *system of accident investigations* and not the traditional application in accident causation. The findings from this research illustrate that accident investigations are not just a process but a complex system on its own. The rail socio-technical system is designed as an integrated system but there is little understanding of the constraints of the other systems on the accident investigation system. Systems within the rail socio-technical system operate functionally separately where the top needs are not propagated further down the system, and the bottom needs are not encompassed further up by the decision makers. In fact it was evident further down the system at a *Company* level that the company, represented by TFR is more dominant and powerful than the higher echelons of the system. This illustrates the intricacies and complexity of the system of accident investigations. The RSR relied on

TFR for their investigation reports, laboratories and expertise. TFR was able to assert its dominance over the Regulator by refusing to pay penalties and ignoring the requests for information and evidence from the RSR. This worked to their advantage as there were no consequences. The diversion of power to the company level further emphasises the need for an independent investigating body in South Africa. Roed-Larsen & Stoop (2012) state this body needs the organisational freedom, legal freedom, financial freedom, adequate resources, appropriate expertise, transparency and the ability to follow up. These criteria were not afforded to the RSR or any other agency in the rail system.

The railway industry is a policy driven system from the top down but the inability of people who develop policy to implement, disseminate and enact is doubtful as evident in this research. The disparity between the different levels and parts of the system influences the vertical integration of information. Cassano-Piche et al. (2006) state that without vertical integration systems lose control of the processes that they are designed to control. The results in this research confirm that the investigation system is not in control given that the decisions made at the top levels and the state of affairs at the lowers levels of the system are not coordinated.

A further contribution of this research to theory is that Rasmussen's (1997) Risk Management Framework can be extended to include the *Public* as an important decision maker in a system and not just an outside pressure along with the competitive environment and fast pace of technological change. In this research, the public formed another level in the system hierarchy. In addition, the *Work* level, in this research was adapted to represent the actual work of conducting an investigation compared with the hazardous processes in Rasmussen's (1997) Risk Management Framework. Waterson et al. (2017b, p. 500) refer to this as *"remixing"* Rasmussen's work.

In chapter 4 it was stated that Rasmussen's (1997) Risk Management Framework originated to model risk management in a dynamic society and included looking at the cause of accidents from a systemic viewpoint. This research confirms that both Rasmussen's (1997) Risk Management Framework and the Accimap are useful methods and tools to determine what influences other systems of interest behaviour and performance. Traditionally the Accimap is used to account for the role that the socio-technical levels play in shaping the course of an accident as it happens over time

(Waterson et al., 2017b). What we know now is that the Accimap can also model the accident investigation system by shaping the events, conditions and decisions that also happen over time ultimately influencing the effectiveness of the investigation process. The similarities in the findings of researchers who used the Accimap for accident causation and the findings emanating from this research illustrate the system of systems concept where nested systems are influenced by the effects of other systems. Furthermore, the systemic approach adopted in this research is unique to accident investigations because it is the system of accident investigations that was examined and not the accident itself. This research therefore provides a systemic account of the factors contributing to the effectiveness of the investigation process. As a result of this research we now know that the entire investigation system is an example of a complex system on its own. System theory principles were recognised confirming the complexity of understanding why accidents do not get investigated thoroughly. The deconstruction of the railway accident investigation process demonstrates the causal factors and relationships across and between the levels of analysis in this research. Together with the context, these contribute to the complexity of the accident investigation system.

The Accimap addresses the research questions stated in chapter 1. The levels of the socio-technical system illustrate that barriers outside of the human and organisational system contribute to the manner in which occurrences are investigated. This was evident in the number of systemic factors identified at a societal, governmental and regulatory level, including organisational factors. Examples include: financial constraints, Government retreating from participating in railway safety, limited independence and regulatory control, competency, no integration between the different stakeholders, workload pressures, bureaucracy, insufficient resources, ambiguous governance documents, ineffective communication and no just culture. These are only a few of the systemic factors influencing the effectiveness of the investigation process. These combined with the constraints, demands and conflicting goals of other systems add to the complexity of the system of accident investigations. In terms communication of the results of an investigation to effect change, occurrence investigation results are communicated from a top down by those conducting the investigation in a report. However, in terms of the communication from a bottom up about the effectiveness of the interventions, this process was hindered by the challenges, pressures, frustrations and obstacles of the accident investigation system but also the systems surrounding it. This was an important

observation further contributing to South Africa's poor railway safety performance. The recommendations in the reports and what is implemented in practice did not always materialise as the recommendations were unrealistic, inappropriate and ambiguous to prevent recurrences. This feedback is necessary to the higher levels of the system in order for organisations, the Regulator and the Government to systematically and critically evaluate previous performance. This is not only important for organisational learning but is also a policy requirement of the South African Government to ensure that rail transport is safe.

The following sections address the limitations of this research, recommendations for the industry and the directions for future research.

8.4 Limitations of the research

The discussion of limitations is important in any research as it highlights potential aspects that could limit the quality of the findings and the ability to effectively answer the research questions. Limitations of the current research are discussed in terms of the nature of the sample, challenges in obtaining information from the Government level, and researcher bias due to familiarity with the topic and field of research.

In terms of the sample, the researcher only selected one Operator and therefore this could have had an impact on the findings. The Operator selected represents one sector of rail transportation (freight transport) and it would have been interesting to compare findings to that of a passenger Operator. The transportation of people emphasises the need to ensure safety is of the utmost priority. As explained in the results chapter, the Government, in particular the DoT, has both the Regulator and PRASA reporting to it. This conflict of interest would have been interesting to explore had the Operator been part of the selected sample. Having had an understanding of the different reporting lines and differing priorities, particularly in the case of safety would have provided a different perspective. Bearing in mind that Transnet reports to a different ministry, the DPE, inter-government relationships and varying priorities would have also made a worthwhile study. Although this research did demonstrate that complexities higher up the system influence how the next level of the system implements, advises, directs or instructs, a horizontal / inter-government perceptive could have provided a deeper interpretation of the findings. This limitation would possibly have given further insight into whether safety, in this case

railway safety, is really seen to be a priority at a Government level. The opportunity to explore this would have allowed the researcher to gain a deeper understanding of the reasons for the absence of the National Rail Policy, especially given the high number of fatalities and injuries and the increased focus on rail as a mode of transport. Furthermore, increased participation from a Government level would have allowed the researcher to explore whether the *"Batho Pele"* principle of *"putting people first"* is genuinely a concern of the South African Government. However, this finding only emerged from the data provided in this research and at the time of conducting this research was unknown to the researcher. Given the treacherous state of the South African railway system, access to the Minister of Transport would have provided a more holistic understanding of the integration between the various modes of transport, in particular how rail is overseen by two different ministries.

A further limitation was access for the researcher to interview senior Government officials. The researcher was informed in the interview with the Government participant that access to interview senior people would be a struggle given these employees' work demands and time availability. Furthermore, the researcher was informed that in terms of obtaining data relating to railway safety and rail regulation that the Rail Branch consisted of only two employees, the participant had only been at the DoT for a year and that the Rail Branch had only been in existence for two years. Therefore obtaining an historical view of railway safety in general would have been a challenge. The researcher instead had to rely on the availability of Government documentation from the South African Government website, the Green Paper for a National Rail Policy (DoT, 2015) and the National Railway Safety Regulator Act No.16 of 2002 (2009). Furthermore, the Director General (DG) of Transport at the time of the data collection was new and did not have an in-depth understanding of the DoT, especially with regards to rail safety. This may have influenced the accuracy and reliability of the data in addressing the research questions had the researcher been able to interview more senior officials. Although limitations of this research, these further illustrate that skill, experience and knowledge transfer through continuity is also prominent higher up the Government level. The DoT participant explained that interviewing the DG would be a *"duplication of effort"* and that *"I would have to sit in and brief the DG any way"*. This suggests that the information collected from the DoT participant would be more reliable and the participant was also the only employee in the Rail Branch with knowledge of railway safety.

The researcher did have prior work experience and was well versed with the railway industry and its challenges. The idea for conducting this research was due to the challenges that the researcher experienced in the field with accident investigations and having participated in BOI's personally. This may be perceived to be a limitation due to elements of researcher bias. The interview questions were developed based on the researcher's familiarity with the railway industry and in particular human factors, however the literature review also provided the researcher with additional questions. In terms of the selection of the Operator this was based on ease of access to information, however obtaining access to the information was a difficult and a time consuming process. Given the sensitivity of the information and the topic of this research it did take a long time to obtain permission to commence with this research. Obtaining permission from just one Operator impacted on the longitudinal effects of this research and therefore was a reason for only collecting data from one Operator and not including a passenger Operator. In order to minimise any bias in the methods and findings, the researcher adopted a multi-method design with results indicating similarities in the findings between the various methods, minimising bias and improving the reliability and validity of the findings.

In terms of the media sampling, the limitation is that only print media was sourced and not any other forms of media for example, social media. Furthermore, it may have been useful to also interview reporters to understand how they as the media hear about railway occurrences and to what extent they are made aware of railway safety given the number of railway occurrences in South Africa. In addition, not conducting any interviews or questionnaires with users of rail, both commuters and freight customers may also be a limitation of this research. Given the time consuming nature of qualitative research, this would also have impacted on the longitudinal effects of this research.

It is the author's view that the theoretical contribution of this research can be generalised to other rail contexts in Africa. Wadongo (2014) explains how Africa is rising and striving to meet the demands of globalisation and a global economy. However, many developing countries in Africa are faced with similar, if not far worse challenges than the South African context. This would make for an interesting comparison. The limits to generalising the theoretical contribution of this research may require adapting the levels of the socio-technical system in an Accimap to be more representative of the African context.

While there are limitations to this research, this study also provides recommendations for industry to improve the accident investigation system with the intention of improving railway safety.

8.5 Recommendations for the South African railway industry

The purpose of this research was two-fold. To contribute to theory and to provide the railway industry with recommendations on how best to improve the investigation of railway occurrences, thereby improving railway safety. Branford (2011) contends that the big picture approach that the Accimap provides is useful for determining corrective actions (with reference to being used in accident causation). The Accimap in this research provided a number of recommendations for improving the effectiveness of occurrence investigations. Examples of these are discussed in more detail.

Firstly, the lack of a National Rail Policy has influenced the status quo of railways both economically and from a safety perspective. The Green Paper for the National Rail Policy (DoT, 2015) highlights the impacts of the absence of a rail policy, with the purpose of a Green Paper being a tentative Government report of a policy proposal. The DoT reported that the National Rail Policy should be implemented with high priority as the DoT acknowledged the significant contribution it would make in terms of the revitalisation of the rail sector, promotion of rail as a mode of transport, and the positive impacts on the country's socio-economic development (DoT, 2015). The finalisation of the National Rail Policy regarding rail transport would bring certainty and a formal policy position of the DoT regarding the governance of the rail transport sector in South Africa. The DoT (2015) affirms that the policy would further seek to facilitate the social and economic objectives of the South African Government by providing an efficient rail system that should cater for both freight and passenger needs. It is recommended that railway safety and the implications of failing to address this, is included in the National Rail Policy, and not just the economic benefits of developing rail in South Africa.

Secondly, standards, policies and procedures relating to occurrence management and accident investigations need to be clear, specific, and comprehensive for all the levels in the rail socio-technical system. Although the RSR standards provide the minimum requirements for Operators, the minimum requirements in terms of occurrence investigations need to be comprehensive enough to ensure no loopholes can be bypassed.

Employees and stakeholders of these documents need to be educated and trained on the contents in order to effectively carry out the requirements. As an example, *just culture* was a requirement in SANS (2009) however very few people knew how to define the term and all of the participants did not know the term existed in the standard. The just culture clause is invalid as it is not defined in the national standard and expectations around training and expertise are not provided either. The importance of understanding a just culture will assist in ridding the blame culture that was evident in all the levels highlighted in the investigation system. Reason (1997) describes a just culture as a sub-component of safety culture along with a reporting culture, learning culture and a flexible culture. Dekker (2006) and Jeffcott et al. (2006) state that the purpose of a just culture is meant to support a safety culture through improving the communication of safety related information and therefore contributing to a learning culture used to improve organisations safety management. Furthermore, the word *encouraged* was used as opposed to *shall* in the instruction made by the RSR, with most of the other requirements written with the prefix *shall*. This indicates that Operators have a preference as to whether they wish to foster a just culture as part of their safety management systems. It is therefore recommended that just culture is clearly defined and ways to achieve it are detailed. Furthermore, a just culture must be implemented in the highest levels in the system and not only at an Operational level.

Shorrock et al. (2014) in a White Paper for Systems Thinking for Safety, define just culture as a culture in which front line staff and others are not punished for actions, omissions, or decisions taken by them. By establishing a just culture an environment of openness, trust and fairness is created where people's actions are understood in context and non-judgemental behaviour and non-blaming is adopted (Shorrock et al., 2014). The investigation reports revealed elements of a blame culture and in the observations witnesses were openly fearful to divulge information for fear of negative consequences. The investigations disclosed that people and their performance were being investigated rather than the system and its performance. Judgemental and blaming language, for example *human error* and *driver's fault* were also evident in the investigation reports. In the interviews, participants did not feel that their superiors *trusted them* and the acknowledgements by Line Management that *everyone blames everyone else* are examples of a lack of a just culture throughout the railway system. Evidence of disciplinary charges being laid before even concluding the investigation suggests that a just culture has not

been operationalised at the various levels of this complex socio-technical system. There is a need to establish a clear mutual understanding, trust and openness between staff, management, the Regulator, Government and the Public in order to build trust.

Thirdly, investigations should be conducted by trained and qualified experts who are *independent* in order to eliminate bias and blame (Lindberg et al., 2010; Roed-Larsen & Stoop, 2012). It is recommended that the RSR and the Operator employ experienced, skilled and trained investigators whose sole job it is to investigate occurrences. Van Vollenhoven (2002) states that independent investigations are the only way to establish exactly what happened and put an end to any public concerns in the aftermath of an accident. Independent investigations demonstrate transparency and if the Board conducting the inquiry is not independent, attempts to apportion blame are not the right instrument for finding out exactly what happened. By apportioning blame only the direct causes are identified and the underlying causes are often neglected. Van Vollenhoven (2002) argues that for independent investigations there is a need for statutory guarantees to ensure witnesses are free to tell the truth without fear of legal consequences. In the observations, witnesses demonstrated this fear and many had already suffered disciplinary charges before the 'independent' investigation. Furthermore, the RSR reporting to the DoT as well as an Operator results in a conflict of interest when it comes to investigations impacting on the 'independence' of the RSR. Given the dichotomy of safety and productivity, as was evident from the results, safety often plays a secondary role, resulting in conflicting interests for the company. If the true causes of an accident are never revealed then this fact alone is sufficient to justify the need for independent investigations. Van Vollenhoven (2002) states that some parties stand to gain from safety not being a priority as this allows companies to push productivity or refrain from implementing recommendations post an occurrence as there is no enforcement or consequences. Furthermore, Van Vollenhoven (2002) believes that if the real reasons for why an accident happened are never revealed, some individuals may also benefit from this. The lack of management accountability, evident in the interview and observation results, is a further reason why independent investigations are needed. The DoT and the media were not acceptably informed about the state of railway safety illustrating a lack of transparency at the highest levels of the system. In the system of accident investigations none of the investigations were truly independent influencing the accuracy of the findings and ability to prevent recurrences.

Following on from independent investigations, it is recommended that in South Africa an organisation similar to the NTSB is established. This recommendation would allow for a truly independent body, separate from the Government, the RSR, and the Operators. The NTSB in America is viewed by Van Vollenhoven (2002, p. 18) as the *"godparent of independent investigations"* with countries such as Australia, Canada, New Zealand, Netherlands, and Sweden following suit. Lindberg et al. (2010) support Van Vollenhoven's view of the NTSB and claim that the NTSB has had a significant positive impact on the safety of the USA's transportation system saving thousands of lives with its recommendations. The NTSB was established as a permanent, autonomous organisation and its independence guaranteed. Van Vollenhoven (2002) states that this body is never questioned in terms of impartiality; the recommendations have great authority, and because it is a permanent independent organisation, are able to ensure that recommendations are followed up. In the results, the CSO acknowledged that one person is responsible for following up with corrective actions and with the number of occurrences; it was not possible to follow up every recommendation instituted. By means of establishing a similar organisation to the NTSB, this would create capacity to produce reports of the highest standard from independent investigations. The RSR and TFR acknowledged that investigation reports were not always of the highest quality. Furthermore, the lack of skilled and trained railway investigators emphasises the need for a multi-modal independent Board representing all the transport sectors. This would help in terms of training, educating and sharing lessons learned to increase the pool of investigators in South Africa. This would also assist in creating more resources to improve the percentage of occurrences investigated. Van Vollenhoven (2002) states that multi-modal Boards offer an integrated approach to safety rather than separate boards that are often poorly equipped to do the job properly. This would help especially with level crossing accidents to address the challenges identified between the road and rail interfaces.

There is a need in South Africa to invest and fund accident investigation boards and committees sufficiently. The findings from the RSR illustrated how being under resourced impacted on the ability of investigators to do their job properly. One vehicle, no laboratory and one camera for the group are inadequate for a thorough investigation. These are examples of the basic necessities needed for investigations. In comparison to accident investigation organisations internationally, South Africa appears to lag behind in ensuring that investigators have the necessary resources to carry out effective investigations. The

researcher was able to visit the Rail Accident Investigation Branch (RAIB) in the UK, which was established after Ladbroke Grove, a serious rail accident in 1999. The inquiry recommended that an independent organisation that investigates railway accidents be established to improve safety. In comparison to the RSR and TFR the researcher noted how 'advanced' the RAIB was. Sophisticated surveillance and measuring equipment, drone technology, equipment that was able to detect fraudulent documentation, a laboratory, sophisticated cameras, a dedicated fully stocked investigation vehicle and a workshop were observed. It is recommended that as part of the Government's rail renaissance (DoT, 2015) that cognisance be given to funding and equipping investigation organisations sufficiently. Effective investigations result in improved safety and therefore improved productivity.

Lastly there is a need to train current and future investigators in how to adopt a systems approach in accident investigations to provide a holistic view of all the contributing factors, and the importance of using accident causation models to underpin incident reporting systems. The absence of systemic models and accident causation models in the investigations analysed in this research influenced the type of data collected, the approach used to analyse the data, and the remedial actions proposed. It is recommended that those responsible for safety management are kept up to date educated and trained on modern accident causation theory. Salmon et al. (2017) criticise incident reporting systems for not having developed with modern thinking and in line with a systems thinking approach to accident causation. It is recommended that the academic literature in this field, for example the work of Rasmussen, and many others be disseminated into industry. Investigators must be educated on how to investigate and report incidents from this viewpoint to improve their value in the investigation system.

8.6 Directions for future research

It is recommended that future work in the field of accident causation explore the impact that the actual investigation process (inclusive of the data gathering, inquiry and report writing) has on the recurrence of events. Further work can also explore the system of accident investigations as a complex system and its relevance in other industries and in other countries. The literature review highlighted that a gap exists where the majority of accident theory concentrates on accident causation methods and techniques, however very little critical analysis of the literature was found that focusses on the investigation process

as a complex system on its own. As stated in the problem statement in chapter 1, if accidents do get investigated, why are there still a number of repeated accidents if the purpose of an investigation is to prevent a recurrence? While some might argue that this is because recommendations don't get implemented, (which was evident in this research), it is rather the ineffectiveness of the entire investigation process that contributes to repeated occurrences. This is because the accident investigation system is an example of complex system where a number of systemic factors influence the accuracy, quality, relativity, objectivity and validity of the process but also the outcomes of the report. Consequently, the appropriateness and reliability of the recommendations are also impacted influencing the effective implementation of these.

It would be useful for future work to explore whether the findings identified in this research are similar for other developing countries across the different continents, in addition to including BRICS countries of which South Africa is a part of. It is the researcher's view that developing countries (countries less industrialised than its first world counterparts) have had to adjust to the fast pace of global technological changes with limited funding and underdeveloped infrastructure. With the phenomenon of globalisation, the developed countries have been able to innovate and invent while the likes of Africa, a developing continent dominated by natural, social, welfare and economic phenomena, has become more primitive (Wadongo, 2014). Wadongo (2014) refers to this as *"Africa Rising"*, the notion of a giant continent awakening from poverty and disaster and now bursting with hope and opportunity (Wadongo, 2014, para. 1). A comparative study looking at other developing countries may provide an even greater theoretical contribution.

Future work in this field, in particular continuing this work in South Africa, could include other Operators for example a passenger Operator as already discussed in the limitations section. This would create a more holistic picture of the status quo of South Africa's railway system.

Furthermore, future research might explore the possibilities of generalising the theoretical contribution of this research in other contexts. For example, in South Africa the methods adopted in this research, together with Rasmussen's (1997) Risk Management Framework and Accimap could be applied in the education and healthcare system. This is because the

systemic factors, for example the historical context and the socio-economic and socio-political circumstances of the country are not only unique to the railway industry but has had an impact on every sphere of the country. Although many systems are designed to be integrated, the education and healthcare systems performance and behaviour indicate signs similar to those identified in this research for the railway industry.

An extension of this research into other transport sectors in South Africa may also prove to be useful given the interest expressed from peers in the field. Sectors such as the aviation industry may illustrate similar systemic challenges as identified in this research. In the initial scoping of this research, the researcher explored including the SACAA as a means of comparison between the rail and aviation authorities. The aviation industry is perceived to be the safest mode of transport, and in comparison to the railway industry this perception can be confirmed by comparing the number of occurrences, fatalities and injuries. The intention of comparing the two authorities is because the aviation industry is so well regulated (*and* internationally regulated) that this may be a reason for why the aviation sector is so safe, or conversely why the railway industry is less so. Preliminary discussions were held with Managers at the SACAA who provided similar responses in terms of the systemic challenges identified in this research. For example, issues such as skill and competency, insufficient training and limited human factors knowledge of their inspectors resemble the findings from this research. In this study, interviewees at the RSR emphasised the need for the railway industry to benchmark against the aviation sector, especially with regards to onsite investigations and evidence preservation. It is the researcher's objective for future work to explore the comparisons between the rail and aviation sectors in South Africa.

8.7 Conclusion

The aim of this research was to identify the systemic factors influencing the effectiveness of the investigation process of railway occurrences in South Africa. In order to this a systems approach was required. The researcher's experience in the field, and having conducted railway occurrences investigations, has identified that the manner in which accident investigations are performed requires significant improvements to truly effect change and create safe railways. This is important so that the underlying causes of events are successfully identified and the appropriate recommendations implemented. To determine what prevents the investigation process from being achieving this, the

researcher deemed it necessary to focus on the rail socio-technical system. In particular the focus was on the various decision makers and stakeholders within the higher echelons of the system (societal, government, regulatory and organisational levels) and how they influence the effectiveness of the investigation process. The researcher wanted to demonstrate how different elements of the system play a role in impacting on the effectiveness of accident investigations, and by implication accident causation.

The literature review highlighted that in the field of accident causation the focus has largely been dedicated to what causes accidents with a multitude of methodologies to determine and assist in identifying what happened. The purpose of this research was not identity why accidents happen, because this is already addressed, but rather how does the *investigation of accidents* contribute to a recurrence of events. Viewing the system of accident investigations as its own system has also not been explored. The purpose of conducting an investigation is to identify what happened and to determine what can be done to prevent the accident from happening again. It was suggested in this research that if organisations do not conduct a thorough, in-depth analysis then only direct causes would be identified and the underlying issues remain unnoticed. As Reason (2000) stated, these often remain as latent conditions that at any given time could result in a catastrophic event. Despite railway Operators and the RSR in South Africa investigating occurrences, the state of safety remains a concern for the industry given the high number of railway occurrences. Therefore this research proposed that the manner in which occurrences are investigated impacts on the authenticity of the findings emanating from an occurrence investigation. Similarly these would also effect the appropriateness of the recommendations and hence the recurrence of incidents. The results confirm that the investigation process is indeed flawed, and despite what recommendations are suggested by the various investigating bodies, these do little to solve the inherent problems. More importantly, this research highlights how the investigation of accidents is an example of complex system in its own right and not the just accident itself. A particular level crossing incident was highlighted as an example to illustrate the inherent complexities of the investigation system and the ineffectiveness of the investigation process to prevent recurrences.

Rasmussen's (1997) Risk Management Framework provided the theoretical framework for this research to structure the South African railway accident investigation system. The framework is well used in accident analyses and the work of Rasmussen has been many

applied in a number of different industries. Waterson et al. (2017a) state that the work of Rasmussen over the last half century represents some of the most influential contributions to the field of human factors, cognitive science and safety science. In this research adjustments were made to Rasmussen's (1997) Risk Management Framework in order to contextualise the system of accident investigations. In particular the public were included as another level incorporated within the system and the work level represented the work of conducting accident investigations. The different levels, based on Rasmussen's (1997) Risk Management Framework, for this research included:

- The Public represented by the media analysis
- The Government represent by the DoT
- The Regulator (RSR)
- TFR as the Company
- The CSO and Line Management representing both Management and Staff
- Work being the actual investigation

The theoretical contribution of this research is identified by the addition of the public as important decision maker in the system and therefore was a level on its own within the system of accident investigations. Furthermore, the theoretical contribution of this research confirms (by using Rasmussen's [1997] Risk Management Framework) that the accident investigation process is in fact a complex system in its own right. Deficiencies and disparities within and between each level in the investigation system and a number of systemic factors contribute to the complexity of the investigation system. This study is a useful and novel application of Rasmussen's (1997) Risk Management Framework that will add to the value of accident causation theory.

A qualitative multi-method approach was conducted in this research and included an analysis of print media to determine how the public are informed about railway occurrences, an analysis of governance documents, a review of completed investigation files, interviews with participants responsible for occurrence management and observations of occurrence inquiries. The multiple data sources not only contributed to a deeper understanding of the system of accident investigations, but verified and validated that the findings were robust and comprehensive.

An Accimap was developed to model the findings from this research, highlighting the context and complexities of the system of accident investigations. The Accimap was used to graphically represent the integration of the data collected from this study. The graphic illustrates the bigger rail socio-technical system deconstructed into different levels that emerged from the findings. These included: Society, Government/Legislation, RSR, Group Company Management (Transnet), Operating Division Management (TFR) and Line/Depot Management. The last level of the Accimap are the *Outcomes* which are the ineffective investigation process resulting in a recurrence of accidents. The Accimap illustrates how the bigger rail socio-technical system when deconstructed, demonstrates the intricacies, relationships, constraints and demands that impact on the complexity of the nested systems within. The advantage of using the Accimap was that it provided a visual diagram that illustrated the multiple contributing factors, events, decisions, conditions and interrelationships within the system of accident investigations. These impact on the effectiveness of the investigation process and contribute to a recurrence of accidents. The Accimap is a useful technique to demonstrate that while a system is designed to be integrated, and that it may be perceived by those inside it to be so, from the outside it is in fact inherently fragmented. The decisions of the top level of the system are not propagated to the bottom and information about the state of the affairs at the bottom does not flow to the higher levels. This confirms that vertical integration (in both directions) is necessary to achieve performance but was not apparent in the system of accident investigations.

The results of the research highlighted that a number of systemic factors do influence the occurrence investigation process and exist as far back as South Africa's historical context. The media and the public, if incorporated within the system, can play a more significant role in influencing the South African Government and its agencies to effect change. Examples of some of the systemic factors identified included: budgeting and financial constraints, ambiguous and inadequate legislation and policy, shortage of competent investigators, inadequate resources to investigate properly, absence of independent investigating body, non-compliance to governance documents and the dichotomy of safety and productivity.

This study provides greater insight into accident causation theory and safety science, with particular reference to the investigation of accidents. This research acknowledges that railway occurrences in South Africa are investigated; however the effectiveness of the

investigation process is fundamentally flawed. The research hypothesis can therefore be confirmed that there are systemic factors impacting on the effectiveness of the investigation process and its outcomes. Furthermore, findings from this research illustrate the complexity inherent within the rail socio-technical system and that the investigation of accidents is in itself a complex system. Nested within the bigger rail socio-technical system, the system of system concept was clearly evident. The rail socio-technical system in practice is a disjointed system. The complexities, constraints, demands of the bigger system influence the entire investigation process where the parts operate functionally separate. Systems theory principles were evident supporting the main outcome of this research that the *investigation of accidents*, and not only the accident, is a complex system.

The investigation system needs to meet the demands of the 4500 railway occurrences annually in South Africa. While trying to balance conflicting goals, such as the need to continue running operations, this contributes to the dynamic nature of the investigation system. In order to adapt to the situation and environment, the investigation system makes a number of trade-offs as evident in the findings. These result in the performance of the system fluctuating which is necessary to cope with the varying demands. However, the findings illustrated that accident investigation system is not balanced due to the resources necessary to counter the constraints. Furthermore, it was evident that higher levels in the system rely extensively on the levels below to maintain the balance of the system under all the circumstances.

Shorrock et al. (2014) believe that to understand the system of interest, it needs to be seen from the perspective of the people who are part of the system. In this research, the interviewees at the DoT, RSR, and TFR provided their perspectives of the accident investigation system. The media analysis also provided a perspective of the public's view of the system. The data clearly indicated that the investigation system has a number of challenges, pressures, obstacles and frustrations that need to be overcome in order to truly ensure railway safety.

The investigation process of railway occurrences is an example of a complex system consisting of a number of stakeholders, operating in varied environments, with numerous interactions and both external and internal influences. These factors affect the reliability, accuracy, validity, quality and objectivity of the outcomes and the process itself. The

current study has provided insights into the factors that shape the accident investigation system and contribute to the investigation process being flawed. Furthermore, this has an impact on the ability to identify what happened and what can be done to prevent a recurrence. The success of the investigation system is dependent on its parts functioning coherently and holistically. In order for the sustainability of railway transport in South Africa, the effectiveness of the investigation system needs to be overhauled.

The research has highlighted important factors that should guide future research and has provided insights into recommendations for industry to explore. It is hoped that this research will encourage the railway system in South Africa to invest in the occurrence management process of railway incidents in order to improve the state of railway safety. The novel approach of this study has contributed to a deeper understanding of the nature of accident investigations and confirms that there are systemic factors inherent within the rail socio-technical system that contributes to the complexity of the system of accident investigations.

REFERENCES

Anden-Papadopoulos, K., & Pantti, M. (2013). Re-imagining crisis reporting: Professional ideology of journalists and citizen eyewitness images. *Journalism, 14(7)*, 960–977. doi:10.1177/1464884913479055

Ayeko, M. (2002). *Integrated Safety Investigation Methodology (ISIM)-Investigating for Risk Mitigation*. Paper presented at the First Workshop on Investigation and Reporting of Incidents and Accidents (IRIA 2002), Glasgow, July, pp. 115-126. Retrieved from http://www.cirs.ch/Report%20Studie%20D%C3%A4nemark.pdf#page=115

Barbour, R. S. (2001). Checklists for improving rigour in qualitative research: A case of the tail wagging the dog? *British Medical Journal, 322*, 1115-1117. doi:10.1136/bmj.322.7294.1115

Bar-Yam, Y. (2003, October). When systems engineering fails-toward complex systems engineering. Paper presented at the *IEEE International Conference on Systems, Man and Cybernetics* (pp. 2021–2028). Washington, DC: IEEE. doi:10.1109?ICSMC.2003.1244709

Bathembu, C., & Vos, G. (2009, February 03). Gauteng carnage as train collides. 131 hurt in springs, 171 in Lenasia. *Citizen*, p.3.

Baysari, M. T., McIntosh, A. S., & Wilson, J. R. (2008). Understanding the human factors contribution to railway accidents and incidents in Australia. *Accident Analysis & Prevention, 40*(5), 1750–1757. http://doi.org/10.1016/j.aap.2008.06.013

Baysari, M. T., Caponecchia, C., McIntosh, A. S., & Wilson, J. R. (2009). Classification of errors contributing to rail incidents and accidents: A comparison of two human error identification techniques. *Safety Science, 47*(7), 948–957. http://doi.org/10.1016/j.ssci.2008.09.012

Berg, B. (2004). *Qualitative research methods for the social sciences* (5th ed.). London, England: Allyn and Bacon.

Besnard, D., & Baxter, G. (2003). Human compensations for undependable systems. *Technical Report Series University of Newcastle Upon Tyne Computing Science.* Retrieved from http://www.cs.ncl.ac.uk/publications/trs/papers/819.pdf

Blanchard, S., & Fabrycky. (2011). *Systems engineering and analysis* (5th ed.). Indiana, USA: Prentice Hall International Series in Industrial and Systems Engineering

Blockley, D. I. (2011). Engineering safety. *Forensic Engineering*, *164*(FE1), 7–13. http://doi.org/10.1680/feng.2011.164.1.7

Boudana, S. (2011). A definition of journalistic objectivity as a performance. *Media, Culture & Society*, *33*(3), 385–398. doi:10.1177/0163443710394899

Bouwer, D., & Hubinger, S. (2014, October 12-17). Methods and options for preserving railway safety knowledge in a changing environment. The importance of human factors management in train operations. Paper presented at the International Railway Safety Council, Berlin, Germany. Retrieved from http://rsr.org.za/wp-content/uploads/2014/09/methods-and-options-for-preserving-railway-safety-knowledge-in-a-changing-environment-%e2%80%93-the-importance-of-human-factors-management-in-train-operations.pdf

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Branford, K. (2011). Seeing the big picture of mishaps: Applying the AcciMap approach to analyze system accidents. *Aviation Psychology and Applied Human Factors*, *1*(1), 31–37. https://doi.org/10.1027/2192-0923/a00005

Branford, K., Naiker, N., & Hopkins, A. (2009). Guidelines for Accimap analysis. In A. Hopkins (Ed.), *Learning from high reliability organisations* (pp. 193-212). Sydney, Australia: CCH Australia.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77-101.

Cacciabue, P. (2004). Human error risk management for engineering systems: a methodology for design, safety assessment, accident investigation and training. *Reliability Engineering & System Safety*, *83*(2), 229–240. http://doi.org/10.1016/j.ress.2003.09.013

Campbell, D. (2016, December 13). Hospitals fail too often to investigate deaths, NHS watchdog finds. *The Guardian*. Retrieved from

Carayon, P. (2006). Human factors of complex sociotechnical systems. *Applied Ergonomics*, *37*(4), 525–535. http://doi.org/10.1016/j.apergo.2006.04.011

Carayon, P., Wetterneck, T. B., Rivera-Rodriguez, A. J., Hundt, A. S., Hoonakker, P., Holden, R., & Gurses, A. P. (2014). Human factors systems approach to healthcare quality and patient safety. *Applied Ergonomics*, *45*(1), 14–25. http://doi.org/10.1016/j.apergo.2013.04.023

Cassano-Piché, A., Vicente, K. J., & Jamieson, G. A. (2006). A sociotechnical systems analysis of the BSE epidemic in the UK through case study. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 50, pp. 386–390). SAGE. Retrieved from http://pro.sagepub.com/content/50/3/386.short

Catino, M. (2008). A review of literature: Individual blame vs. organizational function logics in accident analysis. *Journal of Contingencies and Crisis Management*, *16*(1), 53-62.

Cedergren, A., & Petersen, K. (2011). Prerequisites for learning from accident investigations – A cross-country comparison of national accident investigation boards. *Safety Science*, *49*(8-9), 1238–1245. http://doi.org/10.1016/j.ssci.2011.04.005

Celik, M., Lavasani, S. M., & Wang, J. (2010). A risk-based modelling approach to enhance shipping accident investigation. *Safety Science*, *48*(1), 18–27. http://doi.org/10.1016/j.ssci.2009.04.007

Central Intelligence Agency. (2012). *The world factbook*. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/rankorder/2121rank.html

Cherian, J., & Jacob, J. (2013). Analysis of Attitude towards Online and Print Publications: A Case Study among University Students. *Asian Social Science*, *9*(1), 52–59. https://doi.org/10.5539/ass.v9n1p52

Cicmancova, S. (2013). Safety and Risk as part of railway system. *Safety Engineering Series*, *VIII*(2), 33–38.

Clarke, S. (1998a). Organizational factors affecting the incident reporting of train drivers. *Work & Stress*, *12*(1), 6–16. http://doi.org/10.1080/02678379808256845

Clarke, S. (1998b). Safety culture on the UK railway network. *Work & Stress*, *12*(3), 285–292. http://doi.org/10.1080/02678379808256867

Cotter, C. (2010). *News Talk: investigating the language of journalism*. Cambridge, England: Cambridge University Press.

Creamer, T. (2013, February 11). Transnet teams up with CSIR to raise yearly R&D spend to R150m. *Engineering News*. Retrieved from http://www.engineeringnews.co.za/article/transnet-teams-up-with-csir-to-raise-yearly-rd-spend-to-r150m-2013-02-11

Dekker, S. (2002). *The field guide to human error investigations*. Aldershot, England: Ashgate Publishing Limited.

Dekker, S. (2006). *The field guide to understanding human error* (2nd ed.). Hampshire, England: Ashgate Publishing Limited.

Dekker, S. (2009). Just culture: who gets to draw the line? *Cognition, Technology & Work*, *11*(3), 177-185.

Dekker, S. (2011). Drift into failure: From hunting broken components to understanding complex systems. Surrey, England: Ashgate Publishing Limited.

Dekker, S. (2012). *Just Culture: Balancing safety and accountability*, (2nd ed.). Hampshire, England: Ashgate Publishing Limited.

Dekker, S. (2014). The bureaucratization of safety. *Safety Science, 70*, 348-357. http://dx.doi.org/10.1016%2Fj.ssci.2014.07.015

Dekker, S., & Laursen, T. (2007). From punitive action to confidential reporting. *Patient Safety & Quality Healthcare, 5*, 50-56. Retrieved from http://www.humanfactors.lth.se/fileadmin/lusa/Sidney_Dekker/articles/2007/Dekker___Laursen.pdf

Dekker, S., Cilliers, P., & Hofmeyr, J.H. (2011). The complexity of failure: Implications of complexity theory for safety investigations. *Safety Science, 49*(6), 939–945. http://doi.org/10.1016/j.ssci.2011.01.008

Dekker, S., & Nyce, J. M. (2012). Cognitive engineering and the moral theology and witchcraft of cause. *Cognition, Technology & Work*, *14*(3), 207–212. http://doi.org/10.1007/s10111-011-0203-6

Department of Public Enterprises. (2014). *About DPE*. Retrieved from http://www.dpe.gov.za/about-us

Department of Transport. (2012). *Welcome to Department of Transport South Africa-Online*. Retrieved from http://www.transport.gov.za/

Department of Transport. (2015, August). *National Rail Policy: Green Paper*. Pretoria, South Africa: Department of Transport. Retrieved from http://www.transport.gov.za/LinkClick.aspx?fileticket=0MTIGeNPZ8s%3D&tabid=334&mid=1800

Department of Transport. (2016, June 17). *National Transport Master Plan 2050*. Pretoria, South Africa: Department of Transport. Retrieved from http://www.transport.gov.za/IntegratedPlanning/NATMAP2050.aspx

Dien, Y., Dechy, N., & Guillaume, E. (2012). Accident investigation: From searching direct causes to finding in-depth causes – Problem of analysis or/and of analyst? *Safety Science, 50*(6), 1398–1407. http://doi.org/10.1016/j.ssci.2011.12.010

Dlamini, A. (2009a, August 12). Regulator to impose hefty fines for poor rail safety. *Business Day*, p. 2.

Dlamini, A. (2009b, August 24). Rail watch dog to impose stricter safety regulations. *Business Day*, p. 2.

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., van der Doelen, B. (2012). A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics, 55*(4), 377–395. http://doi.org/10.1080/00140139.2012.661087

European Union Agency for Railways. (2016). *Railway safety performance in the European Union Biennial Report*. Retrieved from https://erail.era.europa.eu/documents/SPR.pdf

Eurostat. (2016). *Railway safety statistics*. Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Railway_safety_statistics

Falasca, K. (2014). Political news journalism: Mediatization across three news reporting contexts. *European Journal of Communication, 29(5)*, 583–597. doi:10.1177/0267323114538853

Farrington-Darby, T., Pickup, L., & Wilson, J.R. (2005). Safety culture in the railway maintenance. *Safety Science, 43*, 39-60.

French, S., Bedford, T., Pollard, S. J. T., & Soane, E. (2011). Human reliability analysis: A critique and review for managers. *Safety Science*, *49*(6), 753–763. http://doi.org/10.1016/j.ssci.2011.02.008

Geach, C. (2013, November 05). The big story near-misses at Buttskop. Dicing with death. Impatient road users ignore booms. Oncoming train. Businessman says its the wild west out here. *Cape Argus*, p. 4.

Ghosh, S., Banerjee, A., & Ganguly, N. (2012). Some insights on the recent spate of accidents in Indian Railways. *Physica A*, *391*(9), 2917–2929. http://doi.org/10.1016/j.physa.2011.12.061

Global Aviation Information Networking. (2004). *Roadmap to a just culture: Enhancing the safety environment*. GAIN Working Group E: Flight Ops/ATC Ops Safety Information Sharing Working Group. Retrieved from https://flightsafety.org/files/just_culture.pdf

Goh, Y. M., Brown, H., & Spickett, J. (2010). Applying systems thinking concepts in the analysis of major incidents and safety culture. *Safety Science*, *48*(3), 302–309. http://doi.org/10.1016/j.ssci.2009.11.006

González, A. (1993). Journalism and the development of Spanish American narrative. England: Cambridge University Press.

Government Communication and Information System. (2015, March). Revitalising South Africa's rail sector. *Insight Newsletter Issue 18*. Retrieved from http://www.gcis.gov.za/insight-newsletter-issue-18

Grosvenor, T. (2000). *Qualitative research in the transport sector*. Workshop on Qualitative/Quantitative methods. Retrieved from http://onlinepubs.trb.org/onlinepubs/circulars/ec008/workshop_k.pdf

Grote, G. (2014). Adding a strategic edge to human factors/ergonomics: Principles for the management of uncertainty as cornerstones for system design. *Applied Ergonomics, 45*(1), 33–39. http://doi.org/10.1016/j.apergo.2013.03.020

Havenga, J. (2015). Macro-logistics and externality cost trends in South Africa – underscoring the sustainability imperative. *International Journal of Logistics Research and Applications, 18*(2), 118-139. http://doi.org/10.1080/13675567.2015.1015509

Havenga, J. H., Simpson, Z. P., & De Bod, A. (2014). South Africa's freight rail reform: A demand-driven perspective. *Journal of Transport and Supply Chain Management, 8*(1), 1-7. http://doi.org/10.4102/jtscm.v8i1.153

Hignett, S. (2005). Qualitative methodology. In J.R Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (3rd ed., pp. 114-128). London: Taylor and Francis.

Hollnagel, E. (2014). Human factors/ergonomics as a systems discipline? "The human use of human beings" revisited. *Applied Ergonomics, 45*(1), 40–44. http://doi.org/10.1016/j.apergo.2013.03.024

Hollnagel, E., & Goteman, O. (2004). *The functional resonance accident model*. Proceedings of Cognitive System Engineering in Process Plant (pp. 155–161). Sendai, Japan. Retrieved from http://www.skybrary.aero/bookshelf/books/403.pdf

Hollnagel, E., Leonhardt, J., Licu, T., & Shorrock, S. (2013). *From Safety I to Safety II: A White Paper*. European Organisation for the Safety of Air Navigation (Eurocontrol). Retrieved from http://www.skybrary.aero/bookshelf/books/2437.pdf

Hopkins, A. (2000). *An AcciMap of the Esso Australia gas plant explosion*. In Julkaisussa: Proceedings of the 18th ESReDA seminar on: Risk Management and Human Reliability in Social Context, Karlstad-Sweden. Retrieved from http://www.qldminingsafety.org.au/_dbase_upl/03_spk003_Hopkins.pdf

Hovden, J., Albrechtsen, E., & Herrera, I. A. (2010). Is there a need for new theories, models and approaches to occupational accident prevention? *Safety Science*, *48*(8), 950–956. http://doi.org/10.1016/j.ssci.2009.06.002

Hovden, J., Størseth, F., & Tinmannsvik, R. K. (2011). Multilevel learning from accidents – Case studies in transport. *Safety Science*, *49*(1), 98–105. http://doi.org/10.1016/j.ssci.2010.02.023

Human error may have caused Tembisa train crash: Metrorail. (2016, October 24). *eNCA*. Retrieved from https://www.enca.com/south-africa/human-error-may-have-caused-tembisa-train-crash-metrorail

Hutchings, J., & Barker, J. (2016, June 13-15). Are the root causes of errors and violations at level crossings universal? A comparison between level crossing risk in South Africa and Great Britain. Paper presented at the14th Global Level Crossing Safety and Trespass Prevention Symposium, Helsinki, Finland. Retrieved from https://www.trafi.fi/filebank/a/1465989532/d67eb929d02af6dd554d9fe47c55636e/21834-1_Jessica_Hutchings_John_Barker_SESS3.pdf

Hutter, B. M., & Lloyd-Bostock, S. (1990). The power of accidents. The social and psychological impact of accidents and the enforcement of safety regulations. *British Journal of Criminology, 30(4),* 409–422.

International Council on Systems Engineering. (2011). Systems Engineering handbook. A guide for system life cycle processes and activities. San Diego: INCOSE.

International Council on Systems Engineering South Africa Chapter. (n.d.). *About INCOSE South Africa chapter*. Retrieved from https://www.incose.org.za/About

International Ergonomics Association. (2016). *What is Ergonomics?* Retrieved from http://www.iea.cc/whats/index.html

Jeffcott, S., Pidgeon, N., Weyman, A., & Walls, J. (2006). Risk, trust, and safety culture in UK Train Operating Companies. *Risk Analysis*, *26*(5), 1105–1121. http://doi.org/10.1111/j.1539-6924.2006.00819.x

Jørgensen, K. (2011). A tool for safety officers investigating "simple" accidents. *Safety Science*, *49*(1), 32–38.

Kaboub, F. (2008). Positivist paradigm. *Leong, Encyclopedia of Counselling, Thousand Oaks*, 786–787. Retrieved from http://personal.denison.edu/~kaboubf/Pub/2008-Positivist-Paradigm.pdf

Karsh, B.T., Waterson, P., & Holden, R. J. (2014). Crossing levels in systems ergonomics: A framework to support "mesoergonomic" inquiry. *Applied Ergonomics*, *45*(1), 45–54. http://doi.org/10.1016/j.apergo.2013.04.021

Katsakiori, P., Sakellaropoulos, G., & Manatakis, E. (2009). Towards an evaluation of accident investigation methods in terms of their alignment with accident causation models. *Safety Science*, *47*(7), 1007–1015. http://doi.org/10.1016/j.ssci.2008.11.002

Kee, D., Jun, G. T., Waterson, P., & Haslam, R. (2017). A systemic analysis of South Korea Sewol ferry accident – Striking a balance between learning and accountability. *Applied Ergonomics*, *59*, 504–516. https://doi.org/10.1016/j.apergo.2016.07.014

Khatri, N., Brown, G. D., & Hicks, L. L. (2009). From a blame culture to a just culture in health care. *Health care management review*, *34*(4), 312-322.

Kim, D. S., & Yoon, W. C. (2013). An accident causation model for the railway industry: Application of the model to 80 rail accident investigation reports from the UK. *Safety Science*, *60*, 57–68. http://doi.org/10.1016/j.ssci.2013.06.010

Kinnear, J. (2012, July 13). Cameras hoped to make level crossings safer. CCTV will reduce reckless driving. *Cape Argus.* Retrieved from http://www.iol.co.za/capeargus/cameras-hoped-to-make-level-crossings-safer-1.1098353#.VFh6pjSUdIk

Kleiner, B. M. (2006). Macroergonomics: Analysis and design of work systems. *Applied Ergonomics, 37*(1), 81–89. http://doi.org/10.1016/j.apergo.2005.07.006

Kletz, T. (1994). Are disasters really getting worse? *Disaster Prevention and Management: An International Journal, 3*(1), 33-36. doi: 10.1108/ 09653569410049649

Klockner, K., & Toft, Y. (2014, May 28-30). *Accident modelling using social network analysis for complex socio-technical systems*. Paper presented to the Australian Systems Safety Conference, Melbourne, Australia.

Korolija, N., & Lundberg, J. (2010). Speaking of human factors: Emergent meanings in interviews with professional accident investigators. *Safety Science*, *48*(2), 157–165. http://doi.org/10.1016/j.ssci.2009.07.004

Kubheka, T. (2016, October 25). Tembisa train crash: driver skipped red signal light. *Eyewitness News*. Retrieved from http://ewn.co.za/2016/10/25/Metrorail-train-driver-charged-with-culpable-homicide

Kumanyika, S. K., Parker, L., & Sim, L. J. (2010). *Bridging the evidence gap in obesity prevention*. Washington, D.C.: The National Academies Press.

Lawton, R., & Ward, N. J. (2005). A systems analysis of the Ladbroke Grove rail crash. *Accident Analysis & Prevention*, *37*(2), 235–244. http://doi.org/10.1016/j.aap.2004.08.001

Le Coze, J. C. (2013). What have we learned about learning from accidents? Post-disasters reflections. *Safety Science, 51*(1), 441–453. http://doi.org/10.1016/j.ssci.2012.07.007

Lee, S., Moh, Y. B., Tabibzadeh, M., & Meshkati, N. (2017). Applying the AcciMap methodology to investigate the tragic Sewol Ferry accident in South Korea. *Applied Ergonomics, 59*, 517-525.

Lerer, L. B., & Matzopoulos, R. (1996). Meeting the challenge of railway injury in a South African city. *The Lancet*, *348*(9028), 664–666.

Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, *42*(4), 237–270. http://doi.org/10.1016/S0925-7535(03)00047-X

Leveson, N. G. (2011). Applying systems thinking to analyze and learn from events. *Safety Science*, *49*(1), 55–64. http://doi.org/10.1016/j.ssci.2009.12.021

Lewis, J., Ritchie, J., Ormston, R., & Morrell, G. (2014). Generalising from qualitative research. In J. Richie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative research practice: A guide for social science students & researchers* (2nd ed., pp. 347-366). London, England: Sage.

Lindberg, A. K., Hansson, S. O., & Rollenhagen, C. (2010). Learning from accidents–what more do we need to know? *Safety Science*, *48*(6), 714-721.

Loftus, E. F. (1979). *Eyewitness Testimony*. Massachusetts: Harvard University Press.

Lundberg, J., Rollenhagen, C., & Hollnagel, E. (2009). What-you-look-for-is-what-you-find – The consequences of underlying accident models in eight accident investigation manuals. *Safety Science*, *47*(10), 1297–1311. http://doi.org/10.1016/j.ssci.2009.01.004

Lundberg, J., Rollenhagen, C., Hollnagel, E., & Rankin, A. (2012). Strategies for dealing with resistance to recommendations from accident investigations. *Accident Analysis & Prevention*, *45*, 455-467.

MacDougall, C. (1977). *Interpretative reporting* (7th ed.). New York, NY: Macmillan

Mahuza, E. (2008, September 17). Transnet loses appeal on liability ruling in Cape train accident. *Business Day*, p. 4.

Maluleke, K. J. (2013). Instilling safety culture in the passenger rail transport industry within the South African context. *Journal of Transport and Supply Chain Management, 7*, 1 – 6.

Marks, D., & Yardley, L. (2004). Research methods for clinical and health psychology. London: Sage.

Masemola, L. (2009, December 08). City schoolgirls relive rail accident terror. Six pupils taken to hospital for treatment, while other athletes are bought back to Pretoria by bus. *Pretoria News*, p. 3.

Mathebula, M., Poya, N., & Makwela, M. (2014, October 12-17). *Leading safety on the edge of chaos: Creating a repository of knowledge in the era of dwindling critical railway skills*. Paper presented at the International Railway Safety Council, Berlin, Germany. Retrieved from http://rsr.org.za/wp-content/uploads/2014/10/Summary-Leading-Safety-on-the-Edge-of-Chaos-2014.pdf

Mathebula, M., & Sopazi, P. N. (2016, May 18-19). *Degraded modes of operation: Antecedents for railway accidents*. Paper presented at the Sixth SARA International Conference & Exhibition, Midrand, South Africa. Retrieved from http://rsr.org.za/wp-content/uploads/2016/05/SARA-Conference-paper-2016-3.pdf

McNaughton Nicholls, C., Mills, L., & Kotecha, M. (2014). Observation. In J. Richie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative research practice: A guide for social science students & researchers* (2nd ed., pp. 243-268). London, England: Sage.

Metrorail and those doors. (2016, January 14). *Railways Africa*. Retrieved from http://www.railwaysafrica.com/news/metrorail-and-those-doors

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). London, England: Sage.

Mposo, N., & Bester, J. (2011, October 29). Metrorail to go data dotty: Thieving to become more difficult. *Saturday Argus,* p. 2.

Moray, N. (2000). Culture, politics and ergonomics. *Ergonomics, 43*(7), 858–868. http://doi.org/10.1080/001401300409062

Moves to improve rail safety. (2011, May, 27). *SA News.* Retrieved from URL http://www.sanews.gov.za/south-africa/moves-improve-rail-safety

Mthethwa, T. (2009, April 09). Rail safety drive starts. *Daily News,* p. 5.

Myburgh, P. L., & van Rensburg, D. (2014, March 23). Questions over R50bn Transnet tender. *Fin24.* Retrieved from http://www.fin24.com/Companies/Industrial/Questions-over-R50bn-Transnet-tender-20140323

National Railway Safety Regulator Act No.16 of 2002. (2009, September 21). Retrieved from http://rsr.org.za/wp-content/uploads/2014/09/RSR-Act.pdf

News24. (n.d.). *About us.* Retrieved from http://www.news24.com/SiteElements/Footer/About-Us-20090703-4

Nolan, C. (2016, January 20). PRASA train doors left open while in motion. *SABC News Online*. Retrieved from https://social.shorthand.com/SABCNewsOnline/n2UP49ZPXY/prasa-train-doors-left-open-while-in-motion

Nyman, M. R., & Johansson, M. (2015). Merits of using a socio-technical system perspective and different industrial accident investigation methods on accidents following natural hazards – A case study on pluvial flooding of a Swedish railway tunnel 2013. *International Journal of Disaster Risk Reduction, 13*, 189-199. http://dx.doi.org/10.1016/j.ijdrr.2015.06.004

105 Tons of railway lines stolen near Steynsburg, police say. (2008, August 14). *Cape Times,* p. 7.

Ouyang, M., Hong, L., Yu, M.-H., & Fei, Q. (2010). STAMP-based analysis on the railway accident and accident spreading: Taking the China–Jiaoji railway accident for example. *Safety Science*, *48*(5), 544–555. http://doi.org/10.1016/j.ssci.2010.01.002

Pape, S, & Featherstone, S. (2005). *In Newspaper Journalism: A Practical Introduction*. Thousand Oaks, CA: SAGE

Passenger Rail Agency of South Africa (2013). *About us*. Retrieved from http://www.prasa.com/About.aspx?d=1

Pepe, J., & Cataldo, P. (2011). Manage risk, build a just culture. *Health Progress-St Louis*, *92*(4), 56.

Perrow, C. (1999). *Normal Accidents. Living with high-risk technologies* (2nd ed.). New Jersey: Princeton University Press.

Pienaar, W. J. (2003). Rail or Road? An overview. *Civil Engineering*, *11*(9), 18–21.

Pienaar, W. J. (2010). Railway corporate governance in a free-functioning freight transport market: A South African position. *Corporate Ownership & Control*, *7*(3), 448–453.

Qureshi, Z. H. (2007). A review of accident modelling approaches for complex socio-technical systems. In Proceedings of the twelfth Australian workshop on Safety critical systems and software and safety-related programmable systems-Volume 86 (pp. 47–59). Australian Computer Society, Inc. Retrieved from http://dl.acm.org/citation.cfm?id=1387046

Railway Safety Regulator. (2011a). *Annual Report 2010/2011*. Retrieved from http://rsr.org.za/wp-content/uploads/2014/08/Annual-Report-2010-11.pdf

Railway Safety Regulator. (2011b). *South African Railway State of Safety Report 2010/2011*. Retrieved from http://rsr.org.za/wp-content/uploads/2014/08/State-of-Safety-2010-11.pdf

Railway Safety Regulator. (2012). *South African Railway State of Safety Report 2011/2012*. Retrieved from http://rsr.org.za/wp-content/uploads/2014/08/state-of-safety-20112012.pdf

Railway Safety Regulator. (2013). *South African Railway State of Safety Report 2012/2013*. Retrieved from http://rsr.org.za/wp-content/uploads/2014/08/state-of-safety-20122013.pdf

Railway Safety Regulator. (2014). *State of Safety Report 2013/2014*. Retrieved from http://rsr.org.za/wp-content/uploads/2014/09/State-of-Safety-2013-14.pdf

Railway Safety Regulator. (2015). *State of Safety Report 2014/2015*. Retrieved from http://rsr.org.za/wp-content/uploads/2015/11/RSR-State-of-Safety-Report-2015-web-Part-A.pdf and http://rsr.org.za/wp-content/uploads/2015/11/RSR-State-of-Safety-Report-2015-web-Part-B.pdf

Railway Safety Regulator. (2016). *State of Safety Report 2015/2016*. Retrieved from http://rsr.org.za/wp-content/uploads/2016/11/RSR_SafetyReport_PART-1.pdf and http://rsr.org.za/wp-content/uploads/2016/11/RSR_SafetyReport_PART-2.pdf

Rail Safety and Standards Board (2014). *Investigation Guidance: Part 3 Practical support for accident investigators*. London, England: Rail Safety and Standards Board Ltd.

Rao, D. B. V., & Prasad, D. J. D. (2013). Indian railways: Trends in accidents and safety measures. *International Journal of Logistics & Supply Chain Management Perspectives*, *2*(4), 709–714.

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. *Safety Science*, *27*(2/3), 183–213.

Rasmussen, J. (2000). Human factors in a dynamic information society: where are we heading? *Ergonomics*, *43*(7), 869-879.

Rasmussen, J., & Svedung, J. R. I. (2000). *Proactive risk management in a dynamic society*. Karlstad, Sweden: Swedish Rescue Services Agency.

Read, G. J. M., Salmon, P. M., & Lenné, M. G. (2013). Sounding the warning bells: The need for a systems approach to understanding behaviour at rail level crossings. *Applied Ergonomics*, *44*(5), 764–774. http://doi.org/10.1016/j.apergo.2013.01.007

Reason, J. (1990). *Human error*. Cambridge, England: Cambridge University Press.

Reason, J. (1997). *Managing the risks of organisational accidents*. Aldershot, England: Ashgate Publishing

Reason, J. (2000). Human error: models and management. *Western Journal of Medicine*, *172*(6), 393.

Reinach, S., & Viale, A. (2006). Application of a human error framework to conduct train accident/incident investigations. *Accident Analysis & Prevention*, *38*(2), 396–406. http://doi.org/10.1016/j.aap.2005.10.013

Rivera, S. S., Baziuk, P. A., & Nunezmcleod, J. E. (2011). Fuzzy uncertainties in human reliability analysis. In *Proceedings of the World Congress on Engineering* (Vol. 2, pp. 970–975). London, England. Retrieved from http://www.iaeng.org/publication/WCE2011/WCE2011_pp970-975.pdf

Roed-Larsen, S., & Stoop, J. (2012). Modern accident investigation – Four major challenges. *Safety Science*, *50*(6), 1392–1397. http://doi.org/10.1016/j.ssci.2011.03.005

Ryan, B., Hutchings, J., & Lowe, E. (2010).An analysis of the content of questions and responses in incident investigations: Self reports in the investigation of signals passed at danger (SPADs). *Safety Science*, *48,* 372 – 381.

S.A. Media. (n.d.). *S.A. Media at your service*. Retrieved from http://www.samedia.uovs.ac.za/

Saleh, J. H., Marais, K. B., Bakolas, E., & Cowlagi, R. V. (2010). Highlights from the literature on accident causation and system safety: Review of major ideas, recent contributions, and challenges. *Reliability Engineering & System Safety*, *95*(11), 1105–1116. http://doi.org/10.1016/j.ress.2010.07.004

Salmon, P. M., Cornelissen, M., & Trotter, M. J. (2012). Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP. *Safety Science*, *50*(4), 1158–1170. http://doi.org/10.1016/j.ssci.2011.11.009

Salmon, P. M., Goode, N., Taylor, N., Lenné, M. G., Dallat, C. E., & Finch, C. F. (2017). Rasmussen's legacy in the great outdoors: a new incident reporting and learning system for led outdoor activities. *Applied Ergonomics*, *59*, 637-648.

Saurin, T. A., Formoso, C. T., & Cambraia, F. B. (2008). An analysis of construction safety best practices from a cognitive systems engineering perspective. *Safety Science*, *46*(8), 1169–1183. http://doi.org/10.1016/j.ssci.2007.07.007

Shorrock, S. (2016, December 5). The varieties of human work [Blog post]. Retrieved from https://humanisticsystems.com/2016/12/05/the-varieties-of-human-work/

Shorrock, S., Leonhardt, J., Licu, T., & Peters, C. (2014). *Systems Thinking for Safety: A White Paper*. European Organisation for the Safety of Air Navigation (Eurocontrol). Retrieved from http://www.skybrary.aero/bookshelf/books/2882.pdf

Singer, E., & Endreny, P.M. (1993). Reporting on risk: How the mass media portray accidents, diseases, other hazards. New York: Russell Sage Foundation.

Sklet, S. (2004). Comparison of some selected methods for accident investigation. *Journal of Hazardous Materials*, *111*(1-3), 29–37. http://doi.org/10.1016/j.jhazmat.2004.02.005

Smart, K. (2004). Credible investigation of air accidents. *Journal of Hazardous Materials*, *111*(1-3), 111–114. http://doi.org/10.1016/j.jhazmat.2004.02.018

South African Government. (n.d.).*Transport*. Retrieved from http://www.gov.za/node/71

South African National Standard. (2009). *Railway Safety Management. Part 1: General* (SANS 3000-1:2009). Pretoria, South Africa: South African Bureau of Standards (SABS) division.

South African National Standard. (2011). *Railway Safety Management. Part 4: Human factors management* (SANS 3000-4:2011). Pretoria, South Africa: South African Bureau of Standards (SABS) division.

South African Press Association. (2009a, January 07). Zille 'deeply saddened' by DA trio's deaths in train accident. *Cape Times,* p. 1.

South African Press Association. (2009b, January 09). Unsafe level crossings blamed for recent deaths. *Cape Times,* p. 4.

South African Press Association. (2009c, August 11). Rail safety under spotlight. *News24*. Retrieved from http://www.news24.com/SouthAfrica/News/Rail-safety-under-spotlight-20090811

South African Press Association. (2010a, April 21). Minister Ndebele says Rovos Rail accident will not impact on 2010 Transport preparations. *Mail & Guardian.* Retrieved from https://mg.co.za/article/2010-04-22-runaway-luxury-train-claims-lives

South African Press Association. (2010b, April 25). Tracks clear of Rovos coaches. *News24.* Retrieved from http://www.news24.com/SouthAfrica/News/Tracks-clear-of-Rovos-coaches-20100425

South African Press Association. (2010c, August 25). Reckless' driver killed kids – MEC. *News24.* Retrieved from http://www.news24.com/SouthAfrica/News/Reckless-driver-killed-kids-MEC-20100825

South African Press Association. (2012a, May 22). Arrest of 3 cable thieves applauded. *News24*. Retrieved from http://www.news24.com/SouthAfrica/News/Arrest-of-3-cable-thieves-applauded-20120522

South African Press Association. (2012b, July 13). Horror crash: 26 dead, driver faces murder charge. *News24.* Retrieved from http://m.news24.com/news24/SouthAfrica/News/Horror-crash-26-dead-driver-faces-murder-charge-20120713

South African Press Association. (2013, May 21). More rail freight needed: Motlanthe. *Sowetan*. Retrieved from http://www.sowetanlive.co.za/news/business-news/2013/05/21/more-rail-freight-needed-motlanthe

South African Press Association. (2014, February 3). New rail network to bring relief to roads. *Fin24*. Retrieved from http://www.fin24.com/Economy/New-rail-network-to-bring-relief-to-roads-20140203

Spencer, L., Ritchie, J., Ormston, R., O'Connor, W., & Barnard, M. (2014). Analysis: principles and processes. In J. Richie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative research practice: A guide for social science students & researchers* (2nd ed., pp. 269-294). London, England: Sage.

Strangor, C. (2007). *Research methods for behavioral sciences*. United States: Wadsworth Cengage Learning.

Svedung, I., & Rasmussen, J. (2002). Graphic representation of accident scenarios: mapping system structure and the causation of accidents. *Safety Science, 40*(5), 397-417.

Tau, P. (2009, February 04). Action stations after rail crashes. *Star*, p. 2.

Tau, P. (2011a, May 23). Driver in train collision had been warned about speeding. *Star*, p. 3.

Tau, P. (2011b, May 26). Metrorail commuters to get millions of rand. R20m for passengers injured in accidents where driver was negligent. *Star*, p. 2.

Tau, S. (2016, July 27-31). Analysing the impact that lack of supervision has on safety culture and accident rates as a proactive approach to curbing the South African railway industry's high incident occurrence rate. Paper presented at the Applied Human Factors and Ergonomics Conference, Orlando, Florida. Retrieved from http://rsr.org.za/wp-content/uploads/2016/09/Paper_-Impact-of-lack-supervision-July-16.pdf

The Times. (2009, December 08). Transportation could derail world cup experience. *The Times*, p. 10.

Thompson, L. S. (2009, February 5-6). *Railway and ports organization in the Republic of South Africa and Turkey: The integrator's paradise?*. Paper presented at Organisation for Economic Co-Operation and Development and the International Transport Forum Joint Transport Research Centre, Leipzig, Germany. Retrieved from http://www.econstor.eu/handle/10419/68753

Transnet. (2015.). *About us*. Retrieved from http://www.transnet.net/AboutUs/Affiliates.aspx

Transnet Freight Rail. (2010a). *Company profile*. Retrieved from http://www.transnetfreightrail-tfr.net/Aboutus/Pages/Company-Profile.aspx

Transnet Freight Rail. (2010b). *Coal*. Retrieved from http://www.transnetfreightrail-tfr.net/BU/Coal/Pages/Overview.aspx

Underwood, P., & Waterson, P. (2013). Systemic accident analysis: Examining the gap between research and practice. *Accident Analysis & Prevention*, *55*, 154–164. http://doi.org/10.1016/j.aap.2013.02.041

Underwood, P., & Waterson, P. (2014). Systems thinking, the Swiss Cheese Model and accident analysis: A comparative systemic analysis of the Grayrigg train derailment

using the ATSB, AcciMap and STAMP models. *Accident Analysis & Prevention, 68*, 75–94. http://doi.org/10.1016/j.aap.2013.07.027

Underwood, P., Waterson, P., & Braithwaite, G. (2016). 'Accident investigation in the wild'–A small-scale, field-based evaluation of the STAMP method for accident analysis. *Safety Science, 82*, 129-143.

Van der Mescht, J. (2006). Revisiting the road versus rail debate. In *Proceedings of the 25th Southern African Transport Conference (SATC 2006)* (pp. 485–494). Pretoria, South Africa. Retrieved from http://www.repository.up.ac.za/bitstream/handle/2263/6100/093.pdf?sequence=1&isAllowed=y

Van Vollenhoven, P. (2002). Independent accident investigation -The right of each citizen and society's duty. *Japan Railways & Transport Review, (33),* 14-19. Retrieved from http://www.jrtr.net/jrtr33/pdf/f14_vol.pdf

Vasterman, P. L. M. (2005). Media-hype: Self-reinforcing news waves, journalistic standards and the construction of social problems. *European Journal of Communication, 20(4),* 508–530. doi:10.1177/0267323105058254

Vicente, K. J., & Christoffersen, K. (2006). The Walkerton E. coli outbreak: a test of Rasmussen's framework for risk management in a dynamic society. *Theoretical Issues in Ergonomics Science, 7*(02), 93-112.

Wadongo, E. (2014, November 7). Africa rising? Let's be Afro-realistic. *The Guardian*. Retrieved from https://www.theguardian.com/global-development-professionals-network/2014/nov/07/africa-rising-lets-be-afro-realistic

Waterson, P. (2009). A critical review of the systems approach within patient safety research. *Ergonomics*, *52*(10), 1185–1195. http://doi.org/10.1080/00140130903042782

Waterson, P. (2015). Sociotechnical design of work systems. In J. R. Wilson & S. Sharpels (Eds.), *Evaluation of Human Work* (4th ed., 753-772). London, England: CRC Press.

Waterson, P., Le Coze, J. C., & Andersen, H. B. (2017a). Recurring themes in the legacy of Jens Rasmussen. *Applied Ergonomics, 59*, 471-482.

Waterson, P., Jenkins, D. P., Salmon, P. M., & Underwood, P. (2017b). 'Remixing Rasmussen': The evolution of Accimaps within systemic accident analysis. *Applied Ergonomics, 59*, 483-503.

Wiegmann, D. A., Zhang, H., Von Thaden, T. L., Sharma, G., & Gibbons, A. M. (2004). Safety culture: An integrative review. The International Journal of Aviation Psychology, 14(2), 117-134.

Williams, D. (2010, July 09). Rail safety beyond the Gautrain. *Financial Mail,* p. 44.

Williams, D. (2011, April 29). White-knuckle ride. *Financial Mail,* p. 40.

Williams, M. (2011, February 15). Crackdown on boom-dodgers: Transport minister rolls up sleeves at deadly railway level crossing. *Cape Argus,* p. 3.

Wilson, J. R. (2000). Fundamentals of ergonomics in theory and practice. *Applied Ergonomics, 36*(6), 557–567.

Wilson, J. R. (2014). Fundamentals of systems ergonomics/human factors. *Applied Ergonomics, 45*(1), 5–13. http://doi.org/10.1016/j.apergo.2013.03.021

Wilson, J. R., & Norris, B. J. (2005). Rail human factors: Past, present and future. *Applied Ergonomics, 36*(6), 649–660. http://doi.org/10.1016/j.apergo.2005.07.001

Wilson, J., Farrington-Darby, T., Cox, G., Bye, R., & Hockey, G. (2007). The railway as a socio-technical system: human factors at the heart of successful rail engineering. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 221*(1), 101–115. http://doi.org/10.1243/09544097JRRT78

Wilson, J. R., & Carayon, P. (2014). Systems ergonomics: Looking into the future – Editorial for special issue on systems ergonomics/human factors. *Applied Ergonomics, 45*(1), 3–4. http://doi.org/10.1016/j.apergo.2013.08.007

Yeo, A., Legard, R., Keegan, J., Ward, K., McNaughton Nicholls, C., & Lewis, J. (2014). In-depth interviews. In J. Richie, J. Lewis, C. McNaughton Nicholls & R. Ormston (Eds.), *Qualitative research practice: A guide for social science students & researchers* (2nd ed., pp. 177-210). London, England: Sage.

Zink, K. J. (2014). Designing sustainable work systems: the need for a systems approach. *Applied Ergonomics, 45*(1), 126-132.

Zwetsloot, G. I., Aaltonen, M., Wybo, J. L., Saari, J., Kines, P., & De Beeck, R. O. (2013). The case for research into the zero accident vision. *Safety Science, 58*, 41-48.

APPENDICES

APPENDIX A:RSR OPERATIONAL OCCURRENCE CATEGORIES

Table A1 Railway occurrence categories
(Adapted from the RSR, 2011b)

Operational Occurrence Categories	
Category	**Category Description**
A	Collisions during movement of rolling stock
B	Derailments during movement of rolling stock
C	Unauthorised movements including rolling stock movements exceeding limit of authority
D	Level crossing occurrences
E	People struck by trains during movement of rolling stock
F	People-related occurrences: trains outside station platform areas or in section
G	Passenger-related occurrences: travelling outside designated area of train
H	People related occurrences: platform-train interchange
I	People related occurrences: station infrastructure
J	Electric shock
K	Spillage/leakage, explosion or loss of dangerous goods
L	Fires

APPENDIX B: EXAMPLE OF THE INTERVIEW QUESTION PROTOCOL

	Participant Number:
INTERVIEW QUESTIONS	
A	**Demographics**
1	Organisation
2	Age
3	Location
4	Job Title
5	Gender
B	**General**
1	How long have you been working at this company?
2	How long have you been in your current position?
3	Are you involved as an investigator in occurrence investigations?
4	Have you been an investigator at this company in your tenure?
5	How many investigations have you been involved in?
6	Describe the structure and functions of your department
C	**Investigations**
1	What is the purpose of a Line Investigation?
2	Describe the different Levels of Investigation
3	Are all Level 3 & 4 investigated?
4	What is your role when it comes to occurrence management?
5	Are there appointed investigators whose sole responsibility is conducting investigations?
6	Who determines who is involved in an occurrence investigation?
7	What methods/techniques are used when investigations are done to identify what went wrong?
8	Who chairs the Line Investigation? What are the criteria? Policy states multidisciplinary functions depending on the occurrence?
9	Who selects the panel/members for Line Investigations? What are the criteria? Policy states multidisciplinary functions depending on the occurrence?
10	How are witnesses selected?
11	How long does the actual Line Investigation generally last for?
12	Where do the investigations take place?
13	Describe the investigation process from the time an occurrence occurs until the incident is closed out?
14	What is the role of the CSO vs Line's responsibilities in terms of investigations?
15	Are there times where the CSO and Line differ in terms of outcomes if the CSO does a Level 1 or 2 investigation?
16	Are all occurrences investigated?
17	Are there different levels of occurrence management in relation to the severity of the occurrence?
18	Who generally makes up the panel/members for a BOI & Line Investigations?
19	Is the panel always the same people i.e. a team or do different people form part of the panel?

20	When an occurrence takes place what are the steps in terms of how the incident becomes investigated
21	Does every occurrence involve some form of governance structure in terms of what people do before the start an investigation
22	How are differences amongst members dealt with?
23	Who oversees that corrective actions are implemented?
24	What do you think are the reasons or causes of TFR's accidents?
25	Are investigation reports audited in some way to ensure quality?
26	How do you find the quality of the Line Investigation reports?
27	How do you find the quality of the CSO Investigation reports?
28	When the CSO does their investigation do you get interviewed? If yes what questions do they ask you?
29	The BOI policy and Occurrence Investigation procedures mention certain tools/techniques e.g. RCAT, SWIFT, HAZOP. Are these used at all levels? If yes what training was done?
30	What are the criteria or requirements needed to investigate e.g. experience, grade/seniority?
31	Would you say the investigations are more about just investigating or about prevention? In other words are investigations done just to comply or are they thoroughly investigated
32	Are you familiar with TFR's Occurrence Procedures
33	How well is ACT 16 understood within TFR?
34	Are investigations completed in the specific time frames e.g. Line investigations after 7 days of an occurrence?
35	How does the CSO monitor & oversee Line safety by enforcing safety compliance?
36	How are the corrective actions put in place by Line monitored by the CSO?
37	The procedure states that where possible investigation team for Line should be from another area to remove bias and allow for independence. Does this occur? If so how to describe this?
38	What is meant by system failure as a cause of occurrences?
39	Investigation reports from Line are submitted to the BOI as evidence. Would this not result in bias?
40	How do the reports for an occurrence differ between the CSO and Line investigations?
41	Do you have access to resources such as laboratories etc. for testing equipment?
42	Why would the nature of the occurrence determine who is involved as experts. Is the panel not always a set number of experts?
43	What happens if there is no consensus on the implementation of corrective actions and agreed timeframes
44	How many Level 1,2,3,4 investigations are done a year
45	How often are reports from Line rejected by CSO or GM?
46	How you have any interaction with the RSR?
47	Is there a template as to what types of questions to ask in an investigation interviews
48	What is the general length of time for a BOI sitting e.g. 1 or 2 days?
49	Do you feel under pressure and can you keep up with the number of occurrences vs the number of investigations vs number of investigators?
D	**Training**

1	What training are those who are involved in investigations given?
2	The training is it in-house or external?
3	Is the training beneficial?
4	Is there anything you would improve with regards to the training of those involved in investigations?
5	Are investigators trained on Human Factors?
6	If external people are used to do an occurrence investigation do they require any training from TFR or an induction?
E	**Challenges**
1	What would you say are the challenges, if any, that you experience when it comes to investigations?
2	What would you say are the challenges, if any, that you experience when it comes to occurrence management in general?
F	**Suggestions for improvement**
1	What would you suggest for improving the investigation process?
2	What would you suggest for improving the occurrence management process?
G	**Human Factors**
1	What is your understanding of Human Factors?
2	What tools or techniques are used to identify the causes of an occurrence?
3	What role does Human Factors play in incident investigations?
4	Are Human Factors Specialists involved as part of the panel for a Line Investigation?
5	Do occurrence reports have a section specifically dedicated to Human Factors?
6	Is the Human Factors Specialist involved in all Levels of investigations including Line?
H	**Safety**
1	Is safety a priority in your organisation?
2	Are there times when productivity and safety are in conflict?
3	How would you describe the safety culture within your organisation?
4	How seriously is safety taken in your organisation?
5	Are there vacancies amongst the occurrence department?
6	Do you find that in many of the occurrence reports that human error is found to be the cause?
I	**Political**
1	Do you have good relations with the CSO Occurrence Investigations Dept.?
2	Do you have good relations with the RSR?
3	Do you have any involvement with the Department of Public Enterprises?
4	Do you have any involvement with the Rail Branch in the Department of Transport? What is their role?
5	How often does the CSO audit your occurrence investigation reports?
6	Does politics play a role in the way in which occurrences are managed?
7	How independent is the Regulator from Government in your opinion?
8	What ministerial interventions occur in terms of occurrence investigations
9	Are there times with the Inspectors from the DOL are involved?
J	**Financial**

1	Are investigations costly to put in place?
2	Are there ever times when finances / costs impact on the occurrence management process?
K	**Communication**
1	Are there communication channels in place to report back to the organisation what happens after an inquiry has been closed?
2	Are there good communication channels between management and employees regarding occurrence investigations?
3	In terms of communication channels with the CSO are these effective?
4	When the RSR does investigate any of your occurrences how do you find their communication and your relationship
5	How is knowledge gained from one investigation transferred to other investigations "lessons learned"
L	**SANS 3000:1**
1	SANS states that seniority and experience are required to be an investigator. Is this the case and how is this enforced and how does this occur in the real world? *Persons appointed to investigate occurrences shall have the necessary competence and seniority, both in relation to the nature and seriousness of the occurrence, and the scope and level of the investigation.*
2	What is your understanding of a "just culture" mentioned in SANS 3000-1 in 8.1

APPENDIX C:ETHICS PROTOCOL

Wits Transnet Centre of Systems Engineering, University of the Witwatersrand, Private Bag 3, Wits 2050
• Tel: +27 11 717 7449 • Fax: +27 86 7655580 • Jessica.Hutchings@wits.ac.za

To whom it may concern,

Hello. My name is Jessica Hutchings. I am currently a student, and employed as an Associate Researcher in the Faculty of Engineering in the Transnet Centre of Systems Engineering at the University of the Witwatersrand, Johannesburg. I am currently conducting research for my Doctor of Philosophy (PhD) degree between the Faculty of Engineering and the Faculty of Humanities in the Psychology Department. My background is in the field of Human Factors and I have worked in the railway industry before being employed by the University of the Witwatersrand, Johannesburg. My passion is in accident investigations and trying to understand what went wrong and what can be done to prevent future recurrences.

The title of my research is: ***Systemic factors in the investigation of South African railway occurrences***. The purpose of my research is to understand why railway occurrences remain high given interventions and regulations that are put in place by railway Operators and the regulator in order to reduce and prevent a recurrence. This research intends to investigate what factors may be influencing the actual investigation process of railway incidents and perhaps this process may be a factor that indirectly contributes to the number of railway occurrences. It is not my intention to find fault or blame anyone, but to assist railway Operators and the Regulator in improving railway safety by providing suggestions for improvement.

I would like to invite you to participate in this study. Your name was provided to me as you are in some way or other involved in Railway Safety. I have an agreement that has been signed between the University of the Witwatersrand, Johannesburg and the RSR and between the University of the Witwatersrand, Johannesburg and Transnet Freight Rail. The purpose of this agreement is to allow me to conduct my research with the said organisations, to ensure your anonymity, and confidentiality of your information and that of the organisation you represent.

As part of my research I will need to conduct interviews. I would therefore like to invite you to participate in a 1 hour interview where I will interview you. The reason why I would like to

interview you is because of your role in Railway Safety and your knowledge of railway occurrence investigations. Please note that participation is voluntary and you will not be advantaged or disadvantaged in any way for choosing to go through with the interview or your refusal to participate.

Everything you say during this interview will be kept confidential. Although I know who you are, confidentiality will be maintained by not disclosing any information that is of a personal nature in the report i.e. I will not disclose your name or location to protect your anonymity. I will assign a pseudonym to your information in the report, for example, Participant A or Respondent B. Individual quotes may be used, however no personal information will be given and only the pseudonym used. I would also like to request your permission to tape record the interview so that I can refer back to our interview at any stage and that I am therefore able to speak to you and not have to write at the same time. Only my supervisors and I will have access to the tapes. The tapes and transcripts will be kept at the University of the Witwatersrand, Johannesburg in a locked cupboard for five years after which they will be destroyed. You have the right to withdraw from the study at any time. You also have the right to refrain from answering any questions should you wish to do so.

All the information that I will be collecting as part of my research will be reported on in a thesis and publications, and will not contain any personal information and only the findings of the group as a whole. At the end of my research feedback will be provided to the RSR in the form of a presentation and/or summary of the study and its findings.

Before beginning the interview I will need you to read through and sign these two consent forms. The one form is that you consent to being interviewed and the other is that you consent to having the interview recorded. In addition these forms just confirm that you are aware of everything that we have discussed concerning confidentiality, feedback and privacy. Please detach and keep this sheet for your records.

Should you at any stage wish to contact me for any clarity, questions or any further information please do not hesitate to contact me or my supervisors. Our details can be found below.

Kind Regards,

Jessica Hutchings
Associate Researcher

University of the Witwatersrand, Johannesburg
Tel: 083 978 9299
Email: Jessica.Hutchings@wits.ac.za

Professor Ian R Jandrell (Supervisor)
Dean: Faculty of Engineering and the Built Environment
University of the Witwatersrand, Johannesburg
Tel: +27 (11) 717 7012
Email: Ian.Jandrell@wits.ac.za

Professor Andrew Thatcher (Co-Supervisor)
Chair Industrial & Organisational Psychology
Department of Psychology, School of Human & Community Development
University of the Witwatersrand, Johannesburg
Tel: +27 11 717 4533
Email: Andrew.Thatcher@wits.ac.za|

APPENDIX D:THEMES AND SUB-THEMES FROM THE MEDIA ANALYSIS

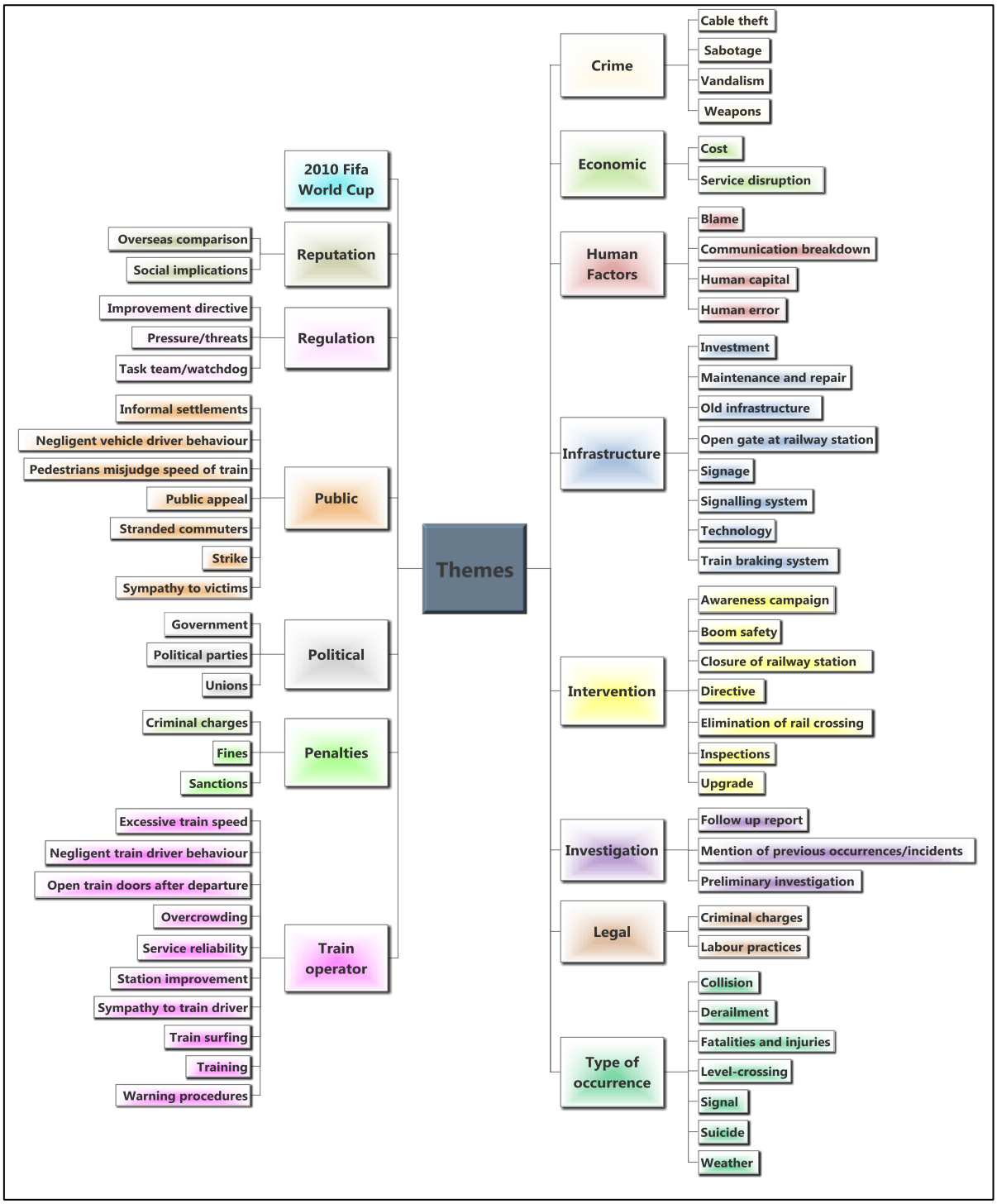


Figure D1 Themes and Sub-Themes from the Media Analysis

APPENDIX E: DISCUSSION OF THE THEMES FROM THE MEDIA ANALYSIS

Crime

Media reports relating to cable theft, sabotage, vandalism and weapons were grouped under this theme. The impact of crime, in particular cable theft is a major problem in South Africa impacting on operational occurrences. For example: *"we are looking at 20 incidents a month, which seriously impacts on our ability to operate trains. This is taking away money we should be using to enhance parts of our services*" (Mposo & Bester, 2011, p. 2). Safety of commuters at stations and whilst on moving trains is also of concern "*acts of violence, intimidation, vandalism and malicious damage to assets have become a daily occurrence and undermine the operator's ability to provide a safe service"* (D. Williams, 2010, p. 3).

Economic

Media articles that considered the *costs* (both direct and indirect) associated with railway occurrences were grouped under the theme of *economic*. For example, *"We lose about R150 million to theft each year, but the consequential losses, due to the knock-on effects, runs into many millions more"* ("105 Tons of Railway Lines Stolen near Steynsburg, police say", 2008, p. 7). Another sub-theme was *service disruption* as train occurrences result in delayed operations, impacting on productivity, for example: *"The social and economic implications of these incidents are massive as they result in line closure, expensive repair costs, delays for freight trains and passenger trains, train cancellations as well as huge consequential costs to the economy"* (SAPA, 2012a). Maluleke (2013) explains the cycle of rail inefficiency whereby rail occurrences lead to the perception that rail services are unreliable and unsafe. In turn unreliable and unsafe rail services lead to overseas investors and the general public considering alternative means of transport with this negatively impacting on the operator's profits. The negative spiral continues as a decrease in profits means that there is less money available to improve rail services and reliability resulting in a cycle of rail inefficiency. In terms of frequency of reporting, this theme was the third most reported in all the articles sourced. A majority of the security articles centred on this theme given the costs associated with cable theft and resultant impacts.

Human Factors

The theme of *human factors* emerged from the media analysis with acknowledgment of the introduction of the Human Factors Standard by the Regulator. Following an operational occurrence that injured hundreds of commuters, the article reported on the introduction of the SANS 3000-4: 2011 Human Factors Management Standard ("Moves to improve rail safety", 2011). The article was able to articulate the definition of Human Factors well, and demonstrated safety management as a complicated task requiring an in-depth consideration into all workplace conditions. This finding illustrates the media's ability to successfully report on current affairs in a way that allows the public to connect to larger societal concerns.

The sub-theme of *blame* dominated articles reporting on rail occurrences. It is suggested that in order to appeal to public interest, the media may be exaggerating the attributed blame of the event. Reporters use the "latest scandal" to their advantage by exaggerating blame to the different actors involved in the event. Alternately the media reports on what is provided to them by the operator in media briefings where initial findings suggest blame, often apportioned at drivers. For example *"Calls for Metrorail to be stricter on its drivers who 'put thousands of lives at risk'"* (Tau, 2011a, p. 3). Furthermore the media may not be aware of Human Factors as a scientific discipline that supports the view of focussing on the system rather than apportioning blame at the sharp end following an occurrence. It is believed that if the media were educated on systemic accident causation, then pressure would increase on government to tighten up its policies relating to safety. Rasmussen's framework highlights how this information would filter down to the next level in the system through feedback loops, ultimately increasing pressure on the Regulator and Operators to investigate railway occurrences thoroughly. The modern literature supports a move away from linear accident causation approaches to adopting a systemic view. The valuable role of the media here would be to report on the recurring features that caused the occurrence in a manner that gradually reshapes the way the public thinks and behaves about rail occurrences.

Infrastructure

Investment in rail infrastructure is recognised by the government as an important aspect influencing the state of the country's economic affairs and was a common sub-theme identified. Improved infrastructure allows train Operators to meet the increased demand of

rail transportation, as well as to mediate pressure to provide safe and reliable services. Despite the number of sub-themes for investment a number of sub-themes for old infrastructure, signage and train braking systems were evident and contributed to the rate of operational occurrences. A political union's spokesman illustrates how old infrastructure and a lack of investment in upgrading the railways impacts on rail safety: *"It is totally unacceptable that human life is disregarded by failing to upgrade and maintain necessary infrastructure in our country"* (SAPA, 2009b, p. 4). A lack of upgrades and investment has resulted in the rail industry suffering an estimated investment backlog at around R60bn, resulting in un-serviced coach fleets and signalling systems impacting on railway safety and efficiency.

Interventions

The attention received by a news event is influenced by how it is portrayed to society. Media-hype i.e. the way the media portrays an event as a crisis posing as a threat to the public (Vasterman, 2005), will increase the amount of attention it attracts. Subsequently, the event becomes a catalyst to questioning social constructions, which forces authorities to intervene. This is where the theme *intervention* becomes relevant in the construction of newsworthy events. Interventions are crucial measures aimed at improving the rail industry's safety. Le Coze (2013) explains that the media can play a role in spreading information of an event to the public, thereby establishing public interest and concern, and play a role at a policy level. Furthermore investigations of accidents can shape (or not) changes in public policies on the basis of interactions between interest groups, government leaders, policy makes, news media and members of the public.

After the 2011 Soweto train collision, the media reported on interventions to improve rail safety for example, refresher training programmes specifically designed for train drivers with safety violations and a review of training programmes for train drivers before they specialise (Tau, 2011b, p. 2). Reporting such interventions would instil confidence in the public knowing that Operators are doing something to improve rail safety. This is supported by Vasterman (2005) who states that the word 'intervention' implies action directed to improving a problem which triggers media attention and public concern. One article quoted the Transport Member of the Executive Council (MEC) in the Provincial Government promoting a sense of urgency to a problem *"We could not simply wait for a tragedy to occur"*(M. Williams, 2011, p. 3) triggering public attention.

Investigation

Overall this theme was the most dominant as many articles discussed the topic of *investigations.* In the operational occurrence articles the dominant sub-theme was *preliminary investigation.* It was common practice for media articles to include that the event was under investigation; however no further information emanating from the inquiry was communicated with the public. For example *"An in-depth investigation into the incident will be conducted but is expected to take two to three weeks"* (SAPA, 2010b) and *"In this investigation, our principle objective is to look at the root cause and evaluate this against similar incidents in recent months"* (SAPA, 2009a, p. 1). It is hypothesised that the inclusion of additional information would present readers with an opportunity to get more involved and interested in the outcome/s of the event. Furthermore, this research suggests that by presenting the public with more information on an event's investigation process, a deeper understanding and appreciation for railway safety would be achieved.

However what is concerning, and no doubt will not instil confidence in the public, is the lack of inspectors at the Regulator to conduct the number of investigations. For example an article stated that *"In 2009/2010 only four of its 12 inspection posts were filled with permanent staff"* (D. Williams, 2011, p. 40).

Legal

The theme *legal* pertained mainly to consequences of rail incidents. The sub-theme, *criminal charges* (including charges of murder and culpable homicide), was dominant with specific reference to level crossing occurrences as the main rail event reported on in the media. A number of reports included the likelihood of the vehicle drivers involved in the incident facing criminal prosecution if found guilty of negligence. MacDougall (1977) wrote that reader interest is evoked when it comes to the reporting of crime and that by including legal implications; suspense is created thereby increasing media attention.

One article reported on the 2012 level crossing incident in Mpumalanga where a truck driver transporting 25 workers was arrested and faced 25 murder charges (SAPA, 2012b). This is an example where c*riminal charges* increase public interest by creating emotion in the reader. By graphically depicting the scene, for example *"the train dragged the truck, leaving bodies with limbs missing scattered on the ground"* public resentment and debate is fuelled resulting in greater public interest (SAPA, 2012b). Vasterman (2005) contends

that when an event results in serious consequences the public tends to deliberate on whom is to blame. Knowing this, the media aims to increase readership by reporting on the event in light of one party being more, or solely, responsible for the occurrence.

Type of occurrence

Overall this theme was the second most captured. The sub-theme of level crossings was frequently reported with 33 articles, followed by *collisions* with 12 articles. Interestingly, this differs to what the RSR contends is the lead contributor to most occurrences and that is collisions during movement of rolling stock. An explanation for level crossings being the most frequently reported occurrence could be due to the attention that fatalities and injuries receive and due to the damages to infrastructure. For example *"the recklessness and irresponsiveness acts seen at level crossings not only endanger lives, but cause very costly damages to property"* (Geach, 2013, p. 4), thereby making it a newsworthy event for the media to report (Vasterman, 2005). Another explanation may be that the public are the users of level crossings, the same audience that news media rely on to sell, relating to their behaviours at level crossings.

The 2010 Buttskop level crossing incident was the only incident to have had follow up reports in 2011, 2012 and 2013. The Buttskop incident involved child fatalities. MacDougall (1977) contends that articles on the welfare of children often receive more interest because the public views it as their responsibility to promote and defend child safety. The driver of the vehicle also faced a number of counts of murder thereby significantly increasing public interest and attention. The event resulted in sympathy to the deceased children and questioning of authorities to mitigate railway risks, a positive finding for this research.

Train operator

A number of articles mentioned specific *train Operators* which is an expected finding. Many of the sub-themes identified related to safety aspects of these Operators for example, *excessive train speed*, *open train doors*, *overcrowding of stations*, *training surfing* and *warning procedures*. Train Operators are required to manage safety to ensure no injury or death to its employee's and commuters; however the issue of passenger trains with open doors has existed for some time. In 2008, the Business Day newspaper published a follow up report on a 2002 incident where open doors of a moving train resulted in an injury to a

passenger. The article quoted a rail operations expert who stated that: *"it was a basic requirement for the safe operation of a passenger train that it should not depart with an open door"* (Mahuza, 2008, p. 4). Although it may be perceived by experts as a basic requirement, the departure of certain passenger trains with open doors resurfaced in 2012. A newspaper reported on a fatality that occurred as a result of open train doors. Four years after the publication of the article it is evident that there is either a lack of concern and/or accountability for commuter safety from the higher echelons of the system. Trains departing with doors open still exist today. This is because the infrastructure is beyond its maintenance lifecycle and Operators await new fleet. It is concerning to the researcher that what would appear to be a major safety risk can be justified by the Government, Regulator and Operator to wait for new infrastructure to be procured whist this risk remains in the system. It is suggested that if the media was aware of this common practice, it would increase pressure (through the public) towards the hierarchies accountable for public safety.

Penalties

In many of the regulation articles the issue of *penalties* was reported with sub-themes of *fines* and *sanctions.* An example is where train Operators are issued with penalties by the Regulator for not complying with rail safety requirements, operating permits may be suspended and criminal charges instated. Semantics (such as harsh words or expressions directed at a specific target) were evident in the penalty articles. The media utilises words to create a desired reaction from the public, making it topical, informative and interesting to the readers (Pape & Featherstone, 2005). For example, it was found that regulation articles frequently made reference to the role of the "watchdog" (the Regulator) in ensuring safety compliance. For example *"Watchdog intends to introduce hefty fines"* (Dlamini, 2009a, p. 2). The use of the adjective "hefty" denotes a strong warning that the fines hold serious consequences, increasing the importance and urgency of the article, thereby increasing the attention of the article.

Political

The theme *political* contributed to interesting observations in this method. Operational occurrences saw the most political figures quoted creating the perception by the media that this would result in higher interest levels for the reader and increased credibility of the articles content. For both operational and regulation articles, if political figures were

quoted, the article was considerably longer in length compared to the average word length of the categories. Three sub-themes were identified under the main theme: *government*, *political parties* or *unions*. For example, a quote from one of the unions "*Fedusa perceives the lack of regard for safety to be totally unacceptable"* (Bathembu & Vos, 2009, p. 3) increases the importance given to the article as the union is the largest politically non-aligned trade union federation in South Africa with the ability to put pressure on government to ensure railway safety.

Public

The reader will recall that not all railway occurrences are reported in the media inferring that the public may not be aware of the state of railway safety, the frequency of accidents and potential dangers. A lack of awareness (through news media) regarding the dangers associated with level crossings may lead to an increase in negligent vehicle driver behaviour. Even though moving trains have the right of way, vehicle drivers misjudge the speed of the train and as such engage in risky behaviours at level crossings. An example of public appeal is: *"We have to change the mind-sets about road safety. We can just get insides people's heads and make them think twice before trying to beat the train, we can save lives"* (Kinnear, 2011).

The sub-theme *informal settlement* provided an alternative view into the role of the public as actors contributing to rail occurrences and incidents. One article quoted a Transnet spokesman on the effects of informal settlements: *"We are worried about people who build shacks next to the railway because it is not safe as children love playing on the tracks"* (Mthethwa, 2009, p. 5). By stating the concern for the lives of children, the article was effective in that it appealed to human interest (MacDougall, 1977), and depicted how the actions of the public were hindering railway safety. This article together with others, demonstrate that the ability of train Operators to provide safe and reliable services may either be hindered or enhanced by the public. As such, this research suggests a co-dependence between the public and the rail Operators in promoting and establishing rail safety and reliability.

Regulation

The RSR is a crucial actor in promoting the well-being of the public, the environment and the train Operators through regulatory frameworks and legislation. This theme links to

most of the other themes already discussed. Sub-themes included *improvement directives*, *pressure/threats* and *task team/watchdog*. The articles used strong and descriptive language with an authoritative stance, for example *"Watchdog insists on zero tolerance"* (Dlamini, 2009b, p. 2). According to Pape and Featherstone (2005), this sentence is an example of effective reporting because the sentence implies action, creates tension and is simple to understand. The tone of most of these article were top-down, for example "*PRASA was instructed to make sure that the doors of commuter trains were closed before departure from a station"* (SAPA, 2009c). The hierarchy of the Regulator in the system is evident in terms of the word "instructed" however evidence that the doors remain to be open questions how seriously the Regulator is taken by both Operators and the government.

Reputation

The media analysis found that both international and local reputation was considered a concern for the train Operators. Due to the high statistics of railway occurrences train Operators are perceived as being unreliable and untrustworthy by the public, impacting on Operator's reputation. For example, *"It could take decades for this country to recover from the negative images that would result from such a tragedy"* (The Times, 2009, p. 10). The shift to using road to transport freight over rail has received quite a bit of media attention. This results in a knock-on effect impacting on operator productivity and profit, and ultimately on improving safety.

2010 FIFA World Cup

2010 was an important year for South Africa. The country hosted the Soccer World Cup. Despite the economic advantages of hosting an international event, the influx of tourists in the country increased pressure on the government to make sure transport systems were safe and reliable. This added pressure is evident in a statement released by the Transport Minister at the time after the 2010 Rovos Rail train derailment (this is a prestigious passenger train): *"We want to assure South Africans, as well as our international visitors, that this accident is an isolated incident ... that doesn't impact the Department of Transport is in the process of operationalising ahead of the 2010 FIFA World Cup, or the country's ability and readiness to host the tournament"* (SAPA, 2010a). However, what the Transport Minister viewed as an "isolated incident" contradicts the 895 derailments

reported in the RSR State of Safety Report (RSR, 2011b) and illustrates how the public may be selectively fed with biased information.

APPENDIX F: CAPTIVE HEADINGS FROM THE MEDIA ANALYSIS

Table F1 Captive headings from the media analysis

Type of reporting	Media report heading
Operational occurrence reports	"'Metrorail is to blame for accident'"
	"Unsafe level crossings blamed for recent deaths"
	"Gauteng carnage as train collides. 131 hurt in springs, 171 in Lenasia"
	"'Neglect caused rail accidents'. DA AND COSATU: Maintenance sacrificed for 'prestige projects'"
	"Residents flee as train derails. Wreak: Crew injured as timber train crashes near homes"
	"City schoolgirls relive rail accident terror. Six pupils taken to hospital for treatment, while other athletes are bought back to Pretoria by bus"
	"Transportation could derail World Cup experience"
	"Another death on the tracks"
	"Minister Ndebele says Rovos Rail accident will not impact on 2010 Transport preparations"
	"'Driver passed 9 cars to cross boom' in crash. Van breached licence terms – MEC"
	"Crackdown on boom-dodgers: Transport minister rolls up sleeves at deadly railway level crossing"
	"The big story Near-misses at Buttskop. Dicing with Death. Impatient road users ignore booms. Oncoming train. Businessman says its the wild west out there"
	"Train track death tap 'open day and night'"
	"Soweto train crash injury toll now 857: Rail accident is the second this year"
	"Driver in train collision had been warned about speeding"
	"Survival after train crash next to zero"
	"Driver 'ignored order to stop'. Five pupils injured in another level crossing accident"

	“Horror crash: 26 dead, driver faces murder charge”
Security occurrence reports	“200 crimes, injuries on Cape railways in 2 months”
	“Rail traffic strung up by cable thieves. Cancelled trains cost Transnet millions of Rands, writes Paul Ash”
	"’We will hunt you down and imprison you'"
	“Call for help to stop rail ‘sabotage’. Plea comes as Metrorail thrashes out security plan to counter ‘deliberate vandalism’”
	“Unreliable trains hitting firms’ profits. Frequent cancelations and delays are taking a heavy toll on productivity and jobs”
	“Copper theft costs SA R7bn, hits city hard. Declared act of economic sabotage”
Regulation reports	“Rail safety under spotlight”
	“Regulator to impose hefty fines for poor rail safety”
	“Rail watch dog to impose stricter safety regulations”
	“Rate of derailments ‘unacceptably high’”
	“Rail safety incidents costs operators R480m”
	“The many dangers of being a commuter”