A Case Study of Industrial Injury Reduction:
New Zealand Aluminium Smelters Limited

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Abstract

Research aim: To assess the safety performance of New Zealand Aluminium Smelters Limited (NZAS), 1971-2011. Research objectives sought 1) to quantify the NZAS safety improvement, and 2) to describe interventions used to achieve that improvement.

Method: NZAS quantitative data was interrogated for statistical significance. Qualitative data was gathered from NZAS staff (N=23) to substantiate the decrease in lost-time injuries (LTI) and to identify the interventions used.

Results: The LTI decrease was significant. Key interventions identified were automation, personal protective equipment, incident investigation resulting in workplace alterations, and proprietary behavioural programmes. The interventions were consistent with hierarchy of controls methodology. An ergonomic focus was the most prominent moderating effect on the success of the interventions. This was demonstrated by plotting interventions on a hazard intervention effectiveness matrix.

Summary: NZAS achieved a significant decrease in LTI’s primarily through ergonomically-focused interventions, representing a successful manifestation of the hierarchy of controls methodology.
# List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACC</td>
<td>Accident Compensation Corporation</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>AUT</td>
<td>Auckland University of Technology</td>
</tr>
<tr>
<td>BHP</td>
<td>Broken Hill Proprietary Limited</td>
</tr>
<tr>
<td>BLS</td>
<td>Bureau of Labor Statistics (United States of America)</td>
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<tr>
<td>BMJ</td>
<td>British Medical Journal</td>
</tr>
<tr>
<td>BMJUSA</td>
<td>United States of America’s issue of the British Medical Journal</td>
</tr>
<tr>
<td>Comalco</td>
<td>Commonwealth Aluminium Corporation Proprietary Ltd</td>
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<tr>
<td>CBP</td>
<td>Current best practice</td>
</tr>
<tr>
<td>CRA</td>
<td>Conzinc Rio Tinto Australia</td>
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<tr>
<td>CTU</td>
<td>(New Zealand) Council of Trade Unions</td>
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<tr>
<td>EC</td>
<td>(European) Economic Community</td>
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<tr>
<td>FTE</td>
<td>Full-time equivalent (employees)</td>
</tr>
<tr>
<td>GM</td>
<td>General Manager</td>
</tr>
<tr>
<td>HFO</td>
<td>Heavy fuel oil</td>
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<tr>
<td>HSE</td>
<td>Health and Safety in Employment Act 1992 (New Zealand)</td>
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<td>HSEQ</td>
<td>Health, safety, environment and quality</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organisation</td>
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<tr>
<td>IMS</td>
<td>Integrated management system</td>
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<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
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<tr>
<td>JAMA</td>
<td>Journal of the American Medical Association</td>
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<tr>
<td>LDI</td>
<td>Lost day injury</td>
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<tr>
<td>LTI</td>
<td>Lost time injury</td>
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<tr>
<td>LTIR</td>
<td>Lost time injury rate (usually (LTI x numerator)/total hours worked)</td>
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<tr>
<td>LTIFR</td>
<td>Lost time injury frequency rate (also LTFR)</td>
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<td>LTISR</td>
<td>Lost time injury severity rate</td>
</tr>
<tr>
<td>MRU</td>
<td>Mutual Recognition Unit (NZAS departmental division)</td>
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<tr>
<td>MSS</td>
<td>Management system standards</td>
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<tr>
<td>NIHL</td>
<td>Noise-induced hearing loss</td>
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<tr>
<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health (USA)</td>
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<tr>
<td>NOASA</td>
<td>National Occupational Safety Association (South Africa)</td>
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<tr>
<td>NZAS</td>
<td>New Zealand Aluminium Smelters Limited</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
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<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration (United States of America)</td>
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<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
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<td>PPI</td>
<td>Positive performance indicators</td>
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<tr>
<td>RWD</td>
<td>Restricted work day</td>
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<tr>
<td>RWDI</td>
<td>Restricted work day injury</td>
</tr>
<tr>
<td>SAP</td>
<td>Systemanalyse und Programmentwicklung (System Analysis and Programme Development)</td>
</tr>
<tr>
<td>SMR</td>
<td>Standardised Mortality Ratio (in France)</td>
</tr>
<tr>
<td>SOP’s</td>
<td>Standard Operating Procedures (NZAS)</td>
</tr>
<tr>
<td>TQM</td>
<td>Total quality management</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom of Great Britain and Northern Ireland</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
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To my friend and mentor, Dr. John Wallaart, thank you for your support in the early days at the smelter and for all your subsequent encouragement. Your significant contribution to New Zealand safety has yet to be adequately recognised.

To my adult kids, Liz, Tom, Stu and Joe, you make me proud... you steer my course through chaos where once I charted order. And to my wife, Ngaire… in my life to date I have pursued many exciting and serendipitous quests, and I am proud of my achievements, but it is you who lights the way.

Steve Young
December 2012
Chapter One: Introduction

1.1 Purpose and intent

More than 6,000 people notify New Zealand’s Ministry of Business, Innovation and Employment\(^1\) of a serious harm incident in their workplace each year (Independent Taskforce on Workplace Health and Safety, 2012). In 2011 in New Zealand, there were 189,117 new work-related claims on the Accident Compensation Corporation (ACC), New Zealand’s universal no-fault accident compensation and rehabilitation scheme (Accident Compensation Corporation, 2011). Aside from the humanitarian considerations of all injury, these work-related claims cost New Zealand employers and employees more than one billion New Zealand dollars per annum in insurance levies (ACC, 2011). This does not include the personal costs of injuries to employees and their families, public health costs, or the costs to the employer of production disruption and replacement staff.

New Zealand’s only aluminium smelter is situated near Invercargill, the country’s southern-most city. New Zealand Aluminium Smelters Limited (NZAS) has been named as the safest aluminium smelter in the world of its class (International Aluminium Institute, cited in New Zealand Aluminium Smelters Limited, 2007). It is unusual for a New Zealand company to be recognised internationally for its safety record: New Zealand’s workplace injury rates are twice those of Australia and almost six times those of the U.K. (Independent Taskforce on Workplace Health and Safety, 2012). NZAS’ reputation as a relatively safe workplace is especially surprising considering the potentially hazardous nature of the process of smelting aluminium. Aluminium smelting presents workers with the potential for severe trauma as a result of exposure to well documented hazards including molten metals, electrical currents, machinery, vehicles, confined spaces, and working at heights\(^2\). As an indication for the potential of an aluminium smelter to injure its workers, a study analysing accidents at an Indian smelter,

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\(^1\) New Zealand’s Ministry of Business, Innovation and Employment incorporated the Occupational Safety and Health Service (OSH) of the former Department of Labour.
\(^2\) See Appendix D for an outline of the aluminium smelting process and its potential hazards.
with approximately 2100 employees, similar in both size and production methodology to NZAS, reported a total of 465 lost-time injury accidents, including 5 fatalities, between January 1989 and December 1991 (Das & Chaudhury, 1995). Over the same period, with a workforce of approximately 1700 people, NZAS recorded 116 lost-time injuries and no fatalities. In the 11 years since 1991, no fatalities have been recorded at NZAS, and lost-time injuries have been confined annually to single figures.

Within the New Zealand context, the hazards inherent in the smelting operation present the potential for people working at NZAS to be subjected to a high rate of lost-time injury. Yet the lost-time injury rate at NZAS appears to be declining at a significantly faster rate than other aluminium smelters. The apparent superiority in NZAS’ safety record over that of other smelters internationally operating in a country with a relatively high workplace injury rate, is therefore worthy of investigation. If the improving safety record of NZAS can be substantiated and described, then others may be able to learn from this success and prevent serious injuries in their respective workplaces, both within New Zealand and overseas. This, then, is both the purpose and intent of this research project.

1.2 Research objectives

Case studies of large, dynamic industrial worksites are not common, partly perhaps because the companies are often preoccupied by production considerations, and partly due to the possible commercial sensitivity or a mistrust of the researcher’s intent. One notable study determined the effectiveness of interventions on return to work after injury at an Australian aluminium smelter (Viljoen, Guest, Boggess, & Duked, 2010), but did not consider the effect interventions may have had on the incidence of injury per se. The opportunity to undertake this case study of NZAS’ safety record and the interventions introduced will therefore contribute materially to the important field of industrial safety knowledge in New Zealand and beyond.

This research project has two research objectives.
1 To quantify the safety improvement record at NZAS by examining lost-time injury rates, 1971-2011.

2 To describe safety interventions associated with the reduction in lost-time injury rates at NZAS, 1971-2011.

1.3 Restriction to acute injury

If a person’s ability to work is compromised by the very undertaking of that work, then deterioration of work ability constitutes harm or injury to the employee. Work ability is a reflection of the relationship between the worker’s capacity and the occupational demands of the worker (Ilmarinen, 2009). Any acute injury that reduces or removes the capacity of a worker to perform his/her normal occupation is a compromise of work ability. This study focused exclusively on acute injury as an indicator of reduced or removed work ability, and therefore as an indicator of NZAS’ safety performance.

Chronic injury and disease are more difficult to relate to work ability, simply because they occur over an extended period of time and etiology is sometimes disputed. In addition, the reduction or removal of work capacity is gradual and usually progressive. Chronic injury and disease such as occupational asthma\(^3\) (O'Donnell, Welford, & Coleman, 1989, O'Donnell, 1995) has been recorded at NZAS, and can eventually be more debilitating to a worker than acute injury. However, the progressive nature of chronic injury and disease, often taking decades to become manifest in a reduction or removal of work ability, does not lend itself to a determination of safety improvement over a period of years. Ultimately, they may be the most important indicators of reduced work ability, but for the purposes of this study, the apparent decrease in chronic injury and disease is difficult to measure, and was therefore excluded.

1.4 Thesis organisation

Before embarking on the NZAS case study, a context for the research was identified by undertaking a literature review of acute injury in the workplace. The literature review

\(^3\) In an aluminium smelter, occupational asthma is sometimes known as ‘potroom asthma’.
identifies a dichotomy between writers who have focused on management of energy, and those who have emphasised human behaviour change as a basis for injury prevention. The apparent lack of reconciliation between these very different approaches, outlined in Section 2.2, has important ramifications for the positioning of this research project. Having contextualised the research with this introduction and the literature review, a mixed method investigation is proposed, using both quantitative and qualitative methods to meet the first objective, and qualitative methods to meet the second. Chapter Three describes the methods employed for both the quantitative and qualitative investigations.

The results are presented in two chapters: Chapter Four assesses NZAS’ ‘40-year safety journey’ and thereby meets research objective one; while Chapter Five describes safety interventions introduced at NZAS, and thereby meets research objective two. A discussion of these results follows in Chapter Six. This discussion sets out the key results of the study, relates the results to existing literature, noting strengths and limitations of the research, and offers the researcher’s observations on the efficacy of NZAS safety interventions. Chapter Seven presents a conclusion, summarising the key findings of the project and making recommendations drawn from the research.
Chapter Two: Literature Review

2.1 Introduction

This chapter reviews the source of commonly cited industrial safety knowledge, and discusses the basis for industrial workplace safety practice.

‘Accidents’ have customarily been regarded as purely random events, communicating a mixture of ideas: injury, property loss, unexpected events, and unintended results (Loimer & Guarnieri, 1996). Religion, myth, and magic have driven popular interpretation of injury causation as manifestations of divine punishment and retribution (Haddon, 1973; Loimer & Guarnieri, 1996). Anthropological texts have referred to groups of people reverting to superstition where their comprehension of new fields of knowledge exceeds their understanding of their known world (Malinowski & Redfield, 1948). It is important to identify the current evidence-based knowledge of industrial injury in order to provide a context for this case study.

Throughout the 20th century, theories of workplace injury etiology were developed by drawing from the scientific disciplines of physics and behavioural psychology. It is apparent that the resulting explanations of industrial injury became polarised towards two viewpoints: the energy-exchange/ergonomic approach which attributes damage and injury to an unintended exchange of energy, represented by writers such as Haddon and Robertson; and the human-error/egocentric approach which attributes damage and injury to perceived lapses in workers’ behaviour, represented by writers such as Heinrich, Rasmussen, and Reason. This dichotomy of theoretical approach to accident etiology, highlighting the most influential writers in each approach, is represented in Figure 1.
The persistence of fatalism and supernaturalism in workers’ interpretation of workplace injury complicates this theoretical dichotomy. Together, these three drivers of industrial injury analysis represent a fragmentation of theory and belief resulting in considerable confusion in the workplace. Section 2.2 provides the background to both the ergonomic and egocentric streams; section 2.3 considers the contemporary pragmatic concerns of a modern industrial complex; and section 2.4 briefly examines eight of the key frameworks used to interpret injury in an industrial context. The evaluation of the effectiveness of safety interventions is considered in section 2.5. A summary in section 2.6 will draw together the elements of this contextualising literature review to provide a platform for proceeding with the case study.

2.2 Background to the dichotomy in industrial injury etiology

2.2.1 The ergonomic approach

During World War II, the mechanics of survivability of falls were investigated and evidence of the significant increase in safety provided by design was identified (De
Haven, 1942). This has since been described as “…the beginning of injury science…” (Winston, 2000). Gordon (1949) identified that, while deaths from communicable disease had been falling for more than 100 years in response to public health initiatives, death rates from accidents and violence remained at 1900 levels. He postulated that in parallel with a germ causing a disease in a host, injury is a combination of forces from at least three sources: the host, the agent, and the environment in which the agent and the host find themselves. He concluded that the same principles hitherto applied to eliminating or decreasing community disease could work equally well for eliminating or decreasing injuries. (Gordon, 1949). These writers demonstrated that comprehensive taxonomies were as essential for industrial safety as they were for public health.

Building on the taxonomic approach, Haddon (1980) linked epidemiology, energy exchange, damage, and injury, pointing out that, “…known injury distributions are highly nonrandom in time, place, and person, just as one would expect from the nonrandomness of their causes”. Haddon cites the work of Gibson, (1961, cited in Haddon, 1980): “Injuries to a living organism can be produced only by some energy interchange. Consequently, a most effective way of classifying sources of injury is according to the forms of physical energy involved”.

Haddon (1980) ascribed the work of De Haven as being “…the first to focus competently on understanding – and thereby reducing – the actual problem, the occurrence of injury per se, rather than concentrating on finding the initiating shortcomings of the people involved”. Haddon (1970, 1973) had previously specified techniques and strategies for managing energy sources and reducing injuries. Robertson (1992) strengthened Haddon’s argument by distinguishing the agents of injury into unique forms of energy: mechanical, thermal, chemical, electrical, ionising radiation; or too little energy in the case of asphyxiation.

2.2.2 The egocentric approach

The rising casualty statistics from the industrial revolution, the increasing popularity of psychiatry as a presumed solution to the problems of mankind in the 19th century, and
even the temperance movement, all began to focus on the worker as the cause of accidents: “People were responsible for their own safety, and the victim shared the guilt for his or her injury.” (Guarnieri, 1992). In the 19th century, and well into the 20th century, British factory inspectors were primarily concerned with the technical breakages involved in any accidents, since they regarded that any other causes could not be reasonably prevented (Hale & Hovden, 1998).

Many of these egocentric concepts were included in Heinrich’s influential work Industrial Accident Prevention (Heinrich, 1931). The enduring legacies of this book and its 1941, 1950, and 1959 reissues are two ratios that prevail throughout safety management. The first is Heinrich’s causation theory: 88:10:2, where the causes of accidents are identified as: 88% unsafe acts of persons; 10% unsafe mechanical or physical conditions; and 2% unpreventable. The second is Heinrich’s loss control triangle: 300:29:1 which indicates that the existence of a ‘base’ of 300 nil-injury accidents will portend 29 minor injuries in a workplace which will in turn, portend 1 major injury. Heinrich stated that, “…psychology lies at the root of any sequence of accident causes…”, and, having delivered his 88:10:2 causation model, he advocated prevention through “…identifying the first proximate and most easily prevented cause in the selection of remedies” (Heinrich, 1931). Since Heinrich deems 88% of accidents to have been caused by human error, he is clearly focusing on human error as the key preventive measure.

Writers in the behavioural sciences continued to work on their interpretation of the relationship of human beings to their work environment insofar as it relates to safety (Hale & Hovden, 1998; Rasmussen, Duncan, & Leplat, 1987; Rasmussen, 1982; Rasmussen & Jensen, 1974; Reason, 1990). In his multi-edition book Human Error, Reason (1990) pointed out that errors mean different things to different people: to cognitive theorists, they offer “…important clues to the covert control processes underlying routine human action…” while to “…applied [safety] practitioners, they remain the main threat to the operation of high-risk technologies”. He identified three types of human behaviour that influenced safety: errors, slips, and mistakes. Perhaps with
the realisation that ‘human error’ is often an ill-defined or vague expression, Rasmussen (1982) pointed out that, “…the analyst will not have the information – or psychological background – which is necessary to trace through the human performance in the explanatory backtracking process to find a possible causal input”. He suggests, “…a more fruitful view [would be to] consider human error as instances of man-machine or man-task misfits”.

Notwithstanding this moderation, the writing of the behaviouralists influenced much of accident prevention work in the late 20th century. From 1990 however, two trends become apparent in their work. Firstly, when referencing the condition termed ‘human error’, both Rasmussen and Reason moved to split their analyses into two distinct categories: personal error and organisational, or latent, error. Secondly, their writing started to provide more preventive safety-oriented solutions, rather than analysing underlying psychiatric determinants. Reason (2000) introduced a distinction between the ‘person’ approach and the ‘system’ approach. He notes that, “The person approach has serious shortcomings and is ill-suited to the medical domain. Indeed, continued adherence to this approach is likely to thwart the development of safer healthcare institutions”. In contrast, he notes that in the system approach, “Errors are seen as consequences rather than causes” and, “When an adverse event occurs, the important issue is not who blundered, but how and why the defences failed” (Reason, 2000). Rasmussen (1982) called for “…a reconsideration of human error: research should be focused on a general understanding of human behaviour and social interaction in cognitive terms in complex, dynamic environments, not on fragments of behaviour called ‘error’”.

It can be seen here that Reason and Rasmussen are increasingly focusing on analyses of organisational factors and solution-oriented measures for injury prevention, rather than on personal factors and individuals’ propensity for error, previously regarded as causation. Reason (2000) points out that “…(although) we cannot change the human condition, we can change the conditions under which humans work”. Rasmussen (2003) writes “The ‘error’ is a link in the chain, in most cases not the origin of the course of
events.” Nevertheless, a large number of papers written towards the end of the 20\textsuperscript{th} century continued to build on the causal construct of ‘human error’, often without any definition of what was meant by the term\textsuperscript{4}.

2.3 Contemporary industrial environment

2.3.1 Introduction

Industrial safety has become politically important in New Zealand in recent times (Independent Taskforce on Workplace Health and Safety, 2012). The Organisation for Economic Cooperation and Development (OECD), and increasingly, developing nations, have high expectations that governments and corporations should ensure the protection of working people (Reason, Hollnagel & Paries, 2006). Communities are also rejecting the notion that ‘accidents happen’, or that a working life will always be vulnerable to chronic wear and tear and acute trauma (Roberts, Bea & Bartles, 2001). People increasingly expect that their working life will be remunerated without compromise to their health and wellbeing (James, 1987).

All industrialised OECD countries have over-arching legislation and regulatory departments intended to protect their citizens from workplace injury. In New Zealand, the Health and Safety in Employment Act (1992) (HSE Act, 1992) is overseen by the Department of Business, Innovation and Employment. This Act, along with other pertinent legislation, is discussed in section 2.3.2 following. In addition, section 2.3.3 contextualises workplace safety within the international industrial relations perspective, identifying the differing views about who is responsible for workplace safety. Finally, the acceptability of the word ‘accident’ and a working definition of the word ‘injury’, including the issues surrounding ongoing measurement of workplace injuries, are examined in section 2.3.4.

\textsuperscript{4} See section 2.4.2, Heinrich’s triangle for a more in-depth consideration of the ‘human error’ writers.
2.3.2 The legislative framework

2.3.2.1 Health and Safety in Employment Act (1992) and Hazardous Substances and New Organisms Act (1996)

Before the 1980s, New Zealand workplace safety was directed by 14 statutes, 50 sets of regulations, and overseen by six government agencies. A coordinated approach to injury prevention was difficult. This fragmentation was partially resolved in the 1980’s with the introduction of the Factories and Commercial Premises Act 1981 which widened provisions for the safety, welfare and health of people in places of work. In the same year, the Walker Report recommended that New Zealand should adopt the approach of the 1972 Robens Report from the United Kingdom. The Robens Report recommended that the law surrounding safety should be simplified and that the balance between ‘prescriptive’ and ‘goal setting’ legislation needed to shift towards the latter. This devolution of workplace safety from overarching prescriptive solutions to workplace self-management was adopted by most OECD countries (Allan & Clarke 2006).

In 1992 in New Zealand, almost 100 statutes and regulations were repealed and replaced with the Health and Safety in Employment Act, (1992). The HSE Act (1992) was enacted to promote “…excellence in health and safety management…” by employers (Health and Safety in Employment Act, 1992). It required employers to take “…all practicable steps to ensure the safety of employees while at work…” while requiring employees to use a “…duty of care…” in the performance of their work (Health and Safety in Employment Act, 1992).

Essentially based around the ‘hierarchy of controls’ framework for hazard mitigation, the legislation in the United States of America (USA), United Kingdom (UK), European Community (EC), Australia and New Zealand now requires employers “…as far as practicable…” (Health and Safety in Employment Act, 1992) to: 1) identify and eliminate significant hazards; 2) isolate such hazards where they can not be eliminated; and 3) minimise hazards where they cannot be eliminated or isolated. Employers are placed in
charge of their employees’ safety; with substantial punitive measures imposed if they are shown to be negligent, usually demonstrated by a serious accident or accident trend.

As a further manifestation of the Robens approach, in 1988 the Interagency Co-ordinating Committee on Pollution and Hazardous Substances recommended that a new legislative framework for controlling hazardous substances and pollution be developed. Therefore, in addition to the HSE Act (1992), the Hazardous Substances and New Organism Act (HSNO Act) (1996) was enacted to provide guidance for the management of hazardous substances and new organisms in the workplace. The HSNO Act (1996) repealed and consolidated a wide range of legislation including the Toxic Substances Act (1979), the Explosives Act (1957), the Dangerous Goods Act (1974) and parts of other legislation such as the Pesticides Act (1979), the Animal Remedies Act (1967) and the Plants Act (1970). The HSNO Act is administered by New Zealand’s Ministry for the Environment with support from the Environmental Risk Management Authority New Zealand (ERMA New Zealand). (Allan & Clarke (2006).

2.3.2.2 Accident Compensation Act (1972)

In 1967, Woodhouse Report, recommended a completely new ‘no-fault’ approach to compensation for personal injury, based on five basic principles: community responsibility, comprehensive entitlement, complete rehabilitation, real compensation, and administrative efficiency. As a result, the Accident Compensation Act (1972) and its 1973 amendment were enacted and the Accident Compensation Commission (ACC) was established.

The ACC provided compulsory, state-administered, ‘no-fault’ accident insurance for all New Zealanders. It is unique in the world in that New Zealanders forfeit their right to dispute injury causation and pursue damages in exchange for ACC-paid rehabilitation and wages compensation when they suffer an injury at work, at home, or at leisure. It is universal and pays 80% of earnings if more than five days are required off work. It also pays for associated medical and rehabilitation services.
Successive governments commissioned a variety of reviews which resulted in a series of amendments including a widening of coverage (1973), and cost reduction (1982). In 1992, the Accident Rehabilitation and Compensation Insurance Act (1992) was enacted which, among other changes, introduced experience rating discounts and loadings for employers. Further amendments were enacted in 1996 and 1998 before the act was repealed and replaced with the Accident Insurance Act (1998). This act retained the basic principles of ACC, but opened the market for work-related injury insurance to private insurers.

In 2000, ACC was restored as the sole provider of all injury insurance and the accredited employer scheme (ACC Partnership Programme) was re-introduced through the Accident Insurance Act (2000). The accredited employer programme provides for the accreditation of employers\(^5\) to self-manage and fund work injury claims arising out of their workplace. The programme offers up to 20% discount on employer levies when the employer can demonstrate an advanced level of health and safety management.

Among other changes, accident prevention was given greater priority in the The Injury Prevention, Rehabilitation, and Compensation Act (2001), mental injury arising from sexual abuse was included in the 2005 amendment, and coverage for those who experience mental trauma at work was included in the 2008 amendment. The most recent amendment, the Accident Compensation Amendment Act (2010) moved to improve ACC flexibility, contain rising costs, and to encourage closer working relationships between government agencies and ACC (ACC, 2013).

2.3.2.3 Employment Contracts Act (1991) and Employment Relations Act (2000)

In 1991, New Zealand employment law was reformed by the Employment Contracts Act (1991) which was subsequently repealed and replaced by the Employment Relations Act (2000). These acts represented a considerable shift from the labour environment in place at NZAS from 1971 until 1991. Previously, the Industrial Conciliation and Arbitration Act (1894) had proscribed how unions were organised and their relationship with

\(^5\) This programme is generally suitable for large employers whose levies exceed $250,000 per year.
employers. The 1936 amendment required compulsory unionism. While the 1961 amendment abolished compulsory unionism, unions remained the basis of workers’ and employers’ relationship with each other until 1991 (Bray & Walsh, 1998).

When the smelter at Tiwai Point was established in 1971, the main unions negotiated a site-wide broad and wide-ranging composite agreement which covered all waged employees (Lind, 1996). This agreement eliminated demarcation issues that had plagued other large industrial sites in New Zealand. It is worthy of note that the site was split into two categories: ‘wages employees’, covered under the composite agreement; and ‘staff’, or salaried workers. But the Employment Contracts Act (1991) effectively dispensed with compulsory negotiations with unions and replaced them with individual contracts. The Employment Relations Act (2000) reworked rules around how contracts were negotiated, and reintroduced the concept of collective bargaining and the collective agreement as an alternative to the individual contract in New Zealand employment.

### 2.3.3 The industrial relations context


On the other hand, internationally, the perennial power struggle between capital and labour continues, and some believe that industrial safety is the battleground. Gray (2009)

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⁶ Compulsory unionism
argues that workers are being forced to adopt a rights-defined identity where they are regarded not only as the victims of industrial injury, but also the key offenders in causing accidents by not working safely. He attributes this to the neo-liberal concept of ‘individual responsibility’, highlighting Ontario’s ticketing system for worker violations, and safety-oriented behavioural programmes, such as DuPont’s ‘STOP’.

Furthermore, in the analysis of occupational incidents as a means of identifying interventions, an often subjective attribution of causation becomes central to blame and ‘responsibilisation’ (Gray, 2009). The theory of causal attribution explains how one’s position in an organisational structure can adversely affect the way safety is perceived or analysed within that organisation. In particular, incident analysis may be prone to errors and bias commensurate with one’s position in the organisational structure (DeJoy, 1994; Gray, 2009; Gyekye, 2010). For instance, DeJoy (1994) explains that attributing poor performance to individual workers absolves the supervisor from blame, and may also avoid the need for costly re-engineering to remove the hazard.

In summary, the possible influence of stakeholders such as employers, managers, directors, and shareholders, wishing to present a favourable safety report, must be considered when assessing interventions based on historical causation data. This is particularly important when considering definitions of injury and injury etiology.

2.3.4 Interpretations and comparisons of ‘accidents’ and injuries in industry

It is almost universally agreed that the word ‘accident’ is inadequate as a descriptor of workplace injury (Doege, 1978, 1999; Gibson, 1961; Haddon, 1970, 1973; Haddon, Suchman & Klein, 1964; Heinrich, 1931; Langley, 1988; Robertson, 1992). These writers condemned the word ‘accident’ in a modernist understanding of the science of safety, free of superstition and prejudice, suggesting that such an understanding could advance the cause of injury prevention. The evident failure of these calls can be seen in the term ‘an accident waiting to happen’ which continues to prevail in explanations of catastrophic
injurious events. In a 2012 article on the Pike River coal mining enquiry\(^7\), the Otago Daily Times newspaper quoted an ‘expert’ using this term (Laxton, 2012), demonstrating the failure of these writers to effect a more accurate descriptor of workplace injury, even by safety experts.

Alternatively, many writers have called for the term ‘injury’ to be used in a more pro-active manner, as in either ‘injury control’ or ‘injury prevention’ (Cryer & Langley, 2008; Doege, 1978; Haddon, 1980; Kamerow, 2004; Langley & Brenner, 2004; Robertson, 1992), but there are some differences in the definition of the word ‘injury’. Langley and Brenner (2004) define injury simultaneously by the causative event and by the resulting pathology, whereas Robertson (1992) distinguishes between descriptive epidemiology which describes the incidence and severity of injury, and analytic epidemiology which attempts to describe the causes of the injury. McDonald (2003) and Kahler & Ellis (2002) prefer to use the word ‘damage’ rather than injury. But despite the differences, these writers all eschew the amorphous ‘accident’ and prefer to focus on personal damage or injury as an outcome in a time continuum.

Nevertheless, in Australasia, a ‘workplace injury and disease recording standard’ has been established which enables comparison of injury trends between and within organisations. The Australian/New Zealand Standard 1885.1-1990 was published by Worksafe Australia in 1990, providing consistent definitions for injury recording and reporting. The standard defines ‘time lost from work’ as, “The total number of complete working days or shifts lost from work as a result of the injury/disease” (Safework Australia, 1990).

Australasian industrial plants typically use ‘lost-time injury’ (LTI) as specified in the Australia/New Zealand Standard 1885.1-1990 as a measurement of their safety effectiveness. (Safework Australia, 1990). Accordingly, the fewer LTI’s a company records, the safer it may claim to be. Conversely, a company with a high LTI rate

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\(^7\) A royal enquiry into the 2010 Pike River coal mine disaster in New Zealand in which 29 men lost their lives.
compared to other companies in a similar industry would draw unfavourable attention to itself by regulatory bodies, unions, shareholders and the public. Lost-time injury rates (LTIR) or lost-time injury frequency rates (LTIFR) are usually calculated as the number of occurrences of injury, divided by the total number of hours worked by all workers in the recording unit, for each one million hours worked: (LTIs/total hours) x 1,000,000 (Massey, Lamm, & Perry, 2007).

However, the LTI measurement system has inherent potential for manipulation through under-reporting. For instance, Oleinick et al., (1993) demonstrated a case of significant under-recording by manipulation of the time of measurement or recording of the LTI’s. Probst, Brubaker, & Barsotti, (2008) demonstrated that companies with a poor safety climate are more likely to under-report their injury rate whereas those with a good safety climate were more likely to report accurately.

The association of LTI’s with remuneration, either in injury compensation levies or in bonus reward systems, has also been shown to distort the accuracy of the LTI measurement. Robertson and Keeve (1983) noted, “Lost work time is a misleading indication of severity because it is strongly related to maximum compensation in a given state for certain injuries”. One writer related an anecdote involving a container being dropped as it was lifted, without any serious injury, and was therefore ignored; yet a relatively minor injury resulted in the loss of safety awards to staff: “There is no doubt that the lifting incident was much more serious” (Hopkins, 1994).

There has been a call for a movement away from LTI towards the development of positive performance indicators (PPI) (Emmett, 1994). This is consistent with the call by Flin, Mearns, O’Connor, & Bryden (2000), for forward-looking ‘leading indicators’ for safety rather than the retrospective ‘lagging indicators’ such as the LTI. At the 1994 Worksafe Australia conference, Hopkins (1994) questioned the often-lauded, presumed link between declining lost-time injury frequency rates (LTIFR) and increasing productivity in Australian mines, demonstrating that there is no causal connection. He

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8 Safety ‘climate’ is discussed in section 2.4.8.
stated, “It is well known in the industry that some of the best LTIFR’s have been achieved by strenuous efforts to keep the injured at work, on alternative duties if necessary” (Hopkins, 1994). Other writers have concurred and called for a better data system to become the major driver of the prevention of death and permanent disabling injury (Hale & Hovden, 1998; Stiller, Depczynski, Fragar, & Franklin, 2008). In particular, Coyle (1985) and Flin et al., (2000) have called for a greater accuracy and use of safety climate measurements to determine workplace safety.

Nevertheless, despite these criticisms and calls for more appropriate measures, LTI and LTIFR remain the de facto standard for benchmarking safety performance at large industrial plants in Australasia and beyond. Thus, LTI measurement, with all the inherent weaknesses noted, will remain the outcome measurement in this case study of industrial safety.

2.4 Frameworks and strategies utilised for understanding industrial injury

2.4.1 Introduction

This section will identify and review the literature surrounding frameworks and strategies most frequently used in workplace safety. Table 1 identifies eight of the most common techniques for defining, determining and describing industrial incidents.
Table 1. Frameworks and strategies utilised for understanding industrial injury.

<table>
<thead>
<tr>
<th>Framework</th>
<th>Brief description</th>
<th>Pre-eminent writers</th>
</tr>
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<tbody>
<tr>
<td>Heinrich’s triangle</td>
<td>A focus on lesser incidents as a predictor of more serious incidents.</td>
<td>(Heinrich, 1931)</td>
</tr>
<tr>
<td>Goal theory</td>
<td>Prioritisation of resources in pursuit of a singular goal.</td>
<td>(Locke &amp; Latham, 1990, 2002)</td>
</tr>
<tr>
<td>Total quality management</td>
<td>The pursuit of organisational excellence through management practice.</td>
<td>(Evans, 2008; Foster, 2007)</td>
</tr>
</tbody>
</table>

2.4.2 Heinrich’s triangle

Heinrich’s 300:29:1 ratio proposed that attention to small workplace events like near-misses would ultimately prevent a serious injury or a fatality. This perceived relationship is usually represented as Heinrich’s triangle.
While Heinrich’s work is often cited in safety literature and management texts, Heinrich offered no evidence to support his ratios, and his data was never made available for examination (Manuele, 2011). Moreover, his influence grew with each edition as his claim that human error was the cause of most accidents became more assertive: “…it is apparent that man failure is the heart of the problem; equally apparent is the conclusion that methods of control must be directed toward man failure” (Heinrich, cited in Manuele, 2011). Indeed, Heinrich (1941) writes of his methods in the preface to his second edition, “They have been proved to be sound in principle and practicable of application. That which was at one time regarded as theory is now recognized as fact” (p v).

It is more than 80 years since Heinrich’s landmark book on industrial safety was first published. While some of his harshest critics have praised him for focusing industry’s attention on accident prevention in general, and more specifically, on the importance of near-miss reporting (Collins, 2011; Manuele, 2011; Ojanen, Seppälä & Aaltonen, 1988), there has been very little confirmation or validation of his work. This is surprising when considering the influence that Heinrich has had on safety practitioners around the world. Salminen, Saari, Saarela, & Räsänen (1992), discussed the 1986 work of Bird and Germain who found the model to be true, but with varying proportions, and the 1989 work of Petersen who claimed that different circumstances produced minor and major
injuries. Salminen et al., (1992) then analysed all serious occupational accidents in Southern Finland and produced data that supported Petersen’s work. They demonstrated differences between fatal and non-fatal accidents, both in the type of accident and the distribution of the accident causation factors examined. Their analysis of their data set therefore contradicted Heinrich’s model. The American National Safety Institute’s (ANSI) Z10 Safety Management Standard clearly states that the hazards that create the potential for serious injuries and fatalities are inconsistent with those that produce minor injuries; that there is no frequency correlation between minor and serious injury causal factors; and that reducing the total number of hazards or incidents does not guarantee a reduction in serious injury risk (Occupational Safety and Health Administration, 2005). Nevertheless, Heinrich’s emphasis on ‘human error’ has seldom been challenged and is frequently cited in the literature (Barkan, Zohar, & Erev, 1998; Korolija & Lundberg, 2010; Murphy, DuBois, & Hurrell, 1986; Reason, et al., 2006; Shappell & Wiegmann, 1997, 2007; Sheridan, 2008; Simard & Marchand, 1995; Wright & van der Schaaf, 2004; Zohar, 2000).

Manuele carefully compared equivalent, but changing, quotations from Heinrich across the four editions pointing out inconsistencies and vacillation between editions. Ultimately, as well as referring to the United States’ National Council on Compensation Insurance data that contradicted the 300:29:1 ratio, Manuele (2011) pointed to the absurdity of Heinrich’s observation that 329 lesser events will occur prior to one major event happening. Subsequently, the lack of a relationship between the hazards and causal factors that lead to minor injury or near-misses, and those leading to serious injury, has been established (Manuele, 2011; Ojanen, et al., 1988). Therefore, despite Heinrich’s important early contribution to 20th century injury prevention, ‘Heinrich’s triangle’ is of limited use for injury analysis.
2.4.3 Haddon matrix

Haddon introduced his ‘matrix’ as a framework to be used to investigate an injurious event by analysing the dynamic circumstances surrounding that event i.e. before, during and after the occurrence of the injury. The circumstances are divided into human, equipment, environment, and social/economic factors (Haddon, 1973, 1974, 1980; Haddon, et al., 1964; Reza, Homayoun, Nasrin, Shahnam & Reza, 2012; Runyan, 1998, 2003).

<table>
<thead>
<tr>
<th></th>
<th>Human</th>
<th>Equipment</th>
<th>Environment</th>
<th>Social/Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-event phase</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Post-event phase</td>
<td></td>
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</table>

The Haddon matrix offered the first model to consider the multi-factorial circumstances surrounding an injury in a time-based context. While there is a lack of robust epidemiological evidence demonstrating its effectiveness for injury prevention, Haddon’s work and his ‘matrix’ have been shown to be a useful framework for incident analysis (Robertson, 1992; Runyan, 1998, 2003). Its particular strength lies in prompting users to consider all factors inherent in an injurious event, both in understanding the time continuum surrounding the injury, and in considering a full range of conditions and circumstances surrounding the event.

2.4.4 Hierarchy of control

Also drawing from Haddon’s work and his fellow ergonomists, the hierarchy of control model proscribes a sequential consideration of controls for hazard reduction: the hazard should be eliminated; if it cannot be eliminated, it should be isolated; if it can neither be eliminated nor isolated, the hazard must be minimised through administrative measures
such as personal protective equipment (PPE), work organisation, and training (Barnett & Brickman, 1986; Ellenbecker, 1996; Manuele, 2005). The hierarchy of control is the basis for the New Zealand Health and Safety in Employment Act (1992) and many of the United States of America Occupational Safety and Health Administration’s (OSHA) standards and guidelines. Figure 3 represents an effectiveness vector, showing that elimination of hazards provides the most effective control, whereas minimisation of hazards provides the least control.

<table>
<thead>
<tr>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminate</td>
</tr>
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Figure 3. The hierarchy of control effectiveness vector. Safety Institute of Australia (2012).

However, the hierarchy of control model is often misunderstood or misinterpreted. Ellenbecker (1996) notes that in many workplaces, the bulk of industrial hygiene resources is not devoted to engineering controls, but to measuring worker exposures and comparing the results to legislative standards. Furthermore, the model focuses solely on a hazard in a static context, whereas effective changes made to the dynamic work environment may produce a more positive effect on workplace safety (Ellenbecker, 1996).

The strength of the hierarchy of Control model lies in its ability to identify the most effective intervention for hazard amelioration. However, the propensity for users to dismiss the higher level controls too readily in preference for lower level controls, is an inherent weakness.

### 2.4.5 Human behaviour

Many texts considering injury are presaged with the declaration that the majority of injuries are caused by ‘human error’, yet substantiation of this claim is notably absent.
The limitations of Heinrich’s work, claiming ‘88% of accidents are caused by human error’, has been noted above. Other estimates vary between 80% and 96%, all with limited definition of what is meant by ‘human error’, and usually with no supporting data.

The inference usually drawn from these estimates is that changes in human behaviour will lessen risk of an injury. Accordingly, writers have drawn from the field of behavioural psychology to explain human behaviour and how it may be altered to increase safety levels. Rasmussen (1982, 2003) and Reason (1990, 1997, 1998, 2000; Reason et al., 2006) have elucidated the concept over time, and contributed to an understanding of how workers interact with their workplace, yet substantiations of the effectiveness of behavioural interventions in safety are few. The difficulty is perhaps best represented by Wagenaar (1998), who wrote, “The general belief that psychologists can cost-effectively change person-related factors, such as attitude or personality, and indirectly the behaviour that follows from them, even when situational factors invite the wrong behaviours, is totally unfounded. In most situations it is more practical to remove the latent failures that elicit the unwanted behaviour” (p125). Most frameworks and strategies necessarily include the behaviour of people involved in their consideration of an incident. However, the effect of ‘causal attribution’ has been noted above, and models focusing primarily on human error must be treated with caution.

An egocentric intervention based on the assumption that human behaviour change is feasible may therefore be regarded as less likely to be effective than an ergonomic intervention such as automation. This effectiveness vector is illustrated in Figure 4.

<table>
<thead>
<tr>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ergonomic intervention</strong></td>
</tr>
<tr>
<td>e.g. Automation</td>
</tr>
</tbody>
</table>

Figure 4. The ergonomic-egocentric effectiveness vector.
2.4.6 Goal theory

The theory of goal setting is an important framework for analysing focused safety objectives (Locke & Latham, 1990). While much of the so-called motivational ‘goal-setting’ in sports and business management is of dubious worth, the peer-reviewed literature on goal theory is strongly rooted in the field of cognitive behaviour in contemporary psychology study. Locke and Latham have contributed to the field for some years, and link their work to cognitive psychologist, Albert Bandura (Bandura & Cervone, 1986; Locke & Latham, 1990, 2002).

A goal may serve as a benchmark against which performance feedback can be evaluated. Goal setting theory assumes that human action is directed by conscious goals and intentions. It specifies the factors that affect goals, including their relationship to action and performance. In particular, conscious goals can constitute an intervention towards a measureable outcome (Locke & Latham, 1990, 2002). Specific, difficult goals consistently lead to higher performance than those urging people to ‘do their best’. ‘Do-your-best’ goals are defined idiosyncratically and therefore allow a wide range of acceptable performance levels, whereas goal specificity reduces variation in performance by reducing the ambiguity about what is to be attained (Locke & Latham, 2002). Locke & Latham (2002), specify four characteristics of goal effectiveness:

1. Goals serve a directive function, avoiding distraction from goal-irrelevant activities (Rothkopf & Billington, 1979, cited in Locke & Latham, 2002).
2. Goals have an energising function, leading to goal-related effort greater than that for alternate goals with lower aspirations (Bandura & Cervone, 1986, cited in Locke & Latham, 2002).
Locke and Latham (2002) also identify three moderators on the relative success of goals: commitment, feedback, and task complexity. Goal-performance is strongest when people are committed to their goals (Tubbs, 1993). Two factors of commitment to a goal have been identified as: 1) The importance of the goal – in particular, a public commitment to a specific goal by leaders (Hollenbeck, Williams, & Klein, 1989); and 2) self-efficacy – the belief that the goal can be attained (White & Locke, 2000). Feedback to people on progress relating to their goals is important; the pursuit of a goal accompanied by feedback is more effective than the singular existence of that goal (Bandura & Cervone, 1986). Task complexity has a varied effect on achievement of goals (Locke & Latham, 2002). However, high goals lead to significantly higher performance on a complex task when a specific learning goal, rather than a performance goal is set (Winters, 1996).

Together, these components of goal setting theory offer evidence-based components of goal theory against which the effectiveness of the specific safety goal can be measured.

2.4.7 Total quality management (TQM)

TQM is a group of management analysis and action concepts based on American, W. Edwards Deming’s work in the 1970s, which was itself largely based on his perception of Japanese cultural precision and single-mindedness. In its earliest and simplest manifestation, the TQM process proposes a continuous cycle of improvement in all aspects of company operation. This cycle of improvement is represented in Figure 5 by the Deming cycle: ‘plan, do, study, act’: a perpetual process of quality advancement. Other contributors such as Juran, Ishikawa, and Taguchi are also credited with significant contributions to the TQM ethos of constant improvement (Foster, 2007).
Other TQM techniques, briefly described in Table 3, are used in most large industrial plants in developed countries.

Table 3. Common TQM techniques.

<table>
<thead>
<tr>
<th>TQM technique</th>
<th>Brief description</th>
<th>Originating company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean production</td>
<td>The technique of absolute focus on the defined process – without waste or distraction</td>
<td>Toyota</td>
</tr>
<tr>
<td>The 5 S’s</td>
<td>‘Sort, stabilise, shine, standardise, and sustain’; a further focusing tool for the prescribed task</td>
<td>Toyota</td>
</tr>
<tr>
<td>Six sigma</td>
<td>Processes characterised by specifications within 6 standard deviations from the process mean – virtually 100% specification compliance</td>
<td>Motorola</td>
</tr>
</tbody>
</table>

Businesses have moved to meet rising social expectations by adopting international management system standards (MSS) such as International Standards Organisation (ISO) ISO9001 quality assurance, ISO14001 environmental management, and OHSAS18001 safety. Integrated Management Systems (IMS) is a model that provides guidance on the integration of sustainable development into every level of the organisation (Rocha, 2007). There can be problems associated with introducing multiple MSS, including complexities of internal management, lowering of management efficiency, and cultural incompatibility (Beckmerhagen, 2003). Nevertheless, a study of Chinese organisations, pointed to early successes with IMS, including the facilitation of continuous improvement (Zeng, Xie, Tam, & Shen, 2011). Another study of the implementation of IMS into three large Australian companies found similar successes in integration, “…accompanied by
barriers…” (Zutshi & Sohal, 2005). A merger of Strategic Safety Management (SSM) into TQM was demonstrated by Rahimi (1995).

The literature on IMS is mixed, but perhaps this is not surprising for an organisational initiative that has arisen relatively recently. At the very least, the integration of the management of safety with well-established quality assurance management systems has been well signaled. The improvement of risk evaluation of design changes through the integration of safety design into quality management has been demonstrated at a Norwegian aluminium smelter (Kjellén, Boe, & Hagen, 1997).

Quality assurance is a predictive, rather than an historical management tool (Foster, 2007). Flin et al., (2000) noted that, “There has been a movement away from safety measures purely based on retrospective data or ‘lagging indicators’ such as fatalities, lost time accident rates and incidents, towards so called ‘leading indicators’ such as safety audits or measurements of safety climate” (p177). The success of TQM in contemporary organisational management appears to have much to contribute to safety management, particularly in predictive methodology. However, the multiplicity and complexity of TQM techniques may discourage some organisations from employing TQM in a safety capacity.

2.4.8 Culture and climate

In recent decades, there has been a move to identify and measure safety culture and safety climate as a predictor of an organisation’s performance (Cooper, 2000; Cox, et al., 1998). Organisational culture may be defined as an embodiment of values, beliefs and underlying assumptions, while organisational climate is a descriptive measure reflecting the workforce’s perceptions of the organisational atmosphere (Cooper, 2000; Flin, et al., 2000; González-Romá, Lloret, Peiro, & Zornoza, 1999; Zohar, 1980, 2000).

Reason’s (1998) paper examined previous definitions of safety culture and asked “can a safer culture be engineered?” (p294). He concluded that a safe culture can be acquired
through the day-to-day application of practical down-to-earth measures; that an informed culture is one in which people, at all levels, do not forget to be afraid (Reason, 1998).

Cox et al., (1998) utilised structural equation modeling to examine the relationship between attitudes to safety and perceived organisational commitment to safety, concluding that individual’s attitudes to personal actions for safety do not seems to be influencing their appraisal of the organisation’s commitment. When considering safety culture and its relationship to management, Guldenmund (2010) concluded, “The motor that drives the system to its desirable end will always be particular idealistic individuals, not the system alone or the convictions it promulgates”.

Safety climate is a snapshot of the state of safety providing an indicator of the underlying safety culture of a work group, culture, or plant (Flin et al., 2000). An early study determining safety climate dimensions noted five characteristics of successful factory safety programmes: a strong management commitment to safety, a high rank and status of safety officers, frequent safety inspections, good housekeeping, a stable work force, and distinctive ways of promoting safety (Zohar, 1980). However, Coyle’s (1985) paper on safety climate called Zohar’s thesis into question in an Australian context, and called for future research into the relationship between safety climate analysis and other positive performance indictors.

Subsequently, Flin, et al. (2000) noted the recent movement away from safety measures purely based on retrospective data such as fatalities or lost-time injury rates towards ‘leading indicators’ such as safety audits or measurements of safety climate. Their review of 18 published reports of safety climate surveys attempted to reveal the validity of such surveys to reveal the level of site safety. While they noted some encouraging results, they also called for further comprehensive meta-analyses of such studies before any conclusive validation could be established. (Flin, et al., 2000)
However, many writers have cautioned that the definitions of safety culture and safety climate vary widely, and may often be inaccurate or ill-defined (Cooper, 2000; Coyle, Sleeman, & Adams, 1995; Flin, et al., 2000; Guldenmund, 2010; Mearns, Whitaker, & Flin, 2003). The ability to measure safety culture and climate empirically is regarded as central to their utility as evaluators of organisational safety performance (Cooper, 2000; Cox & Jones, 2006; Cox & Cox, 1996; Cox et al., 1998; Guldenmund, 2010; Oliver, Cheyne, Tomäš, & Cox, 2002).

Cooper (2000) argues that the ‘product’ of safety culture has been overlooked, and therefore the lack of ongoing evaluative data in a company would make it difficult, if not impossible, to determine the quality of its ongoing safety culture. He therefore suggests goal setting theory as a means of strengthening the concept of safety culture by providing “…the requisite scientific utility…” for helping an organisation attain its super-ordinate goal (Cooper, 2000). The management of safety may be divided into a series of sub-goals to direct people’s attention and actions towards a singular goal (Cooper, 2000).

The measurement of safety culture within an organisation is frequently used as a barometer of safety performance. However, without a clear organisational goal, interventions intended to change culture may have limited use for injury reduction.

**2.4.9 Incident analysis**

In a combination of many of the above frameworks and strategies, companies often focus on historical incidents they have experienced, either injuries or near-misses, in order to learn from the experience and to impose measures to prevent a recurrence. The ‘Swiss cheese’ model of causation, represented in Figure 6, uses a time-based concept and the metaphor of holes in slices of Swiss cheese through which the “trajectory of accident opportunities” progresses; when these holes all align, the ‘accident’ occurs (Reason, 1990, 1997, 1998, 2000; Reason, et al., 2006).
However, it has been shown that despite becoming the dominant paradigm for analysing medical errors and patient safety incidents, understanding of Reason’s model is not consistent among safety professionals, and is often misunderstood (Perneger, 2005). Moreover, the model changes significantly with each of Reason’s publications (Perneger, 2005; Reason, 1990, 1997, 1998, 2000, Reason et al., 2006). In a recent report for the European Organisation for the Safety of Air Navigation, when discussing the ‘Swiss cheese’ model, Reason himself states that, “…the pendulum may have swung too far in our present attempts to track down possible errors and accident contributions that are widely separated in both time and place from the events themselves” (Reason, et al., 2006).

The ‘Swiss cheese’ model portrays a sequence of ‘triggers’ which, when aligned by chance, allow the incident to progress. The model seldom appears to be used in modern incident investigation. Reason himself indicates that it may not be sufficiently thorough for retrospective incident analysis.

### 2.5 Evaluation of interventions

Evaluating the effects of occupational health and safety intervention has become central to ongoing safety improvement (Zwerling et al., 1997; Goldenhar & Schulte, 1994).
Intervention research may be defined as the study of planned and applied activities designed to produce designated outcomes (Windsor, Baranowski, Clark, & Cutter, 1984). Prevention effectiveness research includes identifying efficacious and effective strategies to reduce morbidity and mortality (Goldenhar & Schulte, 1994). The effectiveness of evaluation relates directly to the ‘assess’ stage of Deming’s cycle of improvement (Evans, 2008). Further, Zwerling et al. (1997) called for inclusion of a qualitative component in quantitative studies in order to understand how and why specific interventions may contribute to injury prevention.

However, the literature proposing theoretical frameworks for devising or assessing safety interventions is limited (Goldenhar & Shulte 1994; Goldenhar, LaMontagne, Katz, Heaney & Landsbergis, 2001; Rivara & Thompson, 2000; Roelofs, Barbeau, Ellenbecker, Michael, & Moure-Eraso, 2003; Shannon, 1999; Zwerling et al., 1997). Goldernhar and Schulte’s (1994) review of 36 occupational health and safety intervention studies called for increased measurement of reliability and validity of intervention data.

Ojanen et al. (1988) pointed out that accident reports and statistics usually form the basis for the evaluation of the final effects of safety programmes; however, they also stressed that the consequences of an accident may vary even when the type of accident is the same.

Existing intervention research is too often based on individual researchers’ intuition and experience rather than on theory and evidence (Goldenhar & Schulte, 1994; Shannon, 1999). Since Rivara & Thompson, (2000) opined more than 11 years ago that few randomised trials had been conducted evaluating occupational injury interventions, very little appears to have been added in the literature. Smith and Shannon (2003), stated that the near total absence of controlled trials, randomised or otherwise, is indeed an issue of concern for the field of injury prevention research.

In 2001, the (USA) National Institute for Occupational Safety and Health (NIOSH) set out to address this lack of safety intervention models by engaging health and safety
stakeholders to establish a national occupational research agenda (NORA). In their overview of the intervention research process, Goldenhar et al. (2001) specified that an intervention must meet three criteria to be evaluative:

1. the intervention should be operating or have been implemented as intended;
2. the intervention should be relatively stable;
3. the intervention should seem to be achieving positive results.

In general, literature reviews of occupational injury intervention studies have commented on the reviewed studies' limitations (Goldenhar & Shulte, 1994; Roelofs et al., 2003; Zwerling et al., 1997). The intervention studies in these reviews are classified into intervention characteristics: engineering, behavioural (or personal), administrative, or multiple; although Zwerling et al. (1997) point out that many interventions are multi-factorial. Moreover, Goldenhar & Schulte (1994) caution that causal phenomena are complex, and advise that intervention research should focus more on the ongoing process of interventions as well as studying the outcomes. Goldenhar et al. (2001) also point out that, “…although ‘Does it work?’ is the ultimate question that must be answered, the broader view of the intervention research process includes research to evaluate the development (or adaptation) and implementation of interventions”. These statements are consistent with the multi-factorial nature and complexity of a large industrial plant. Stake (1995) points to the complex and dynamic nature of an existing organisation, stating that case study research “…champions the interaction of the researcher and phenomena”. Case study methodology is therefore suited to evaluating the performance of a goal-oriented, ‘real-world’ industrial plant.

2.6 Summary

This literature review has set the scene for the case study. It has identified the dichotomy between writers who propose workplace management of energy sources as a means of injury prevention, and writers in behavioural science who advocate modification of human behaviour as the means of injury prevention. This dichotomy is complicated by a latent belief in predetermined drivers for safety underlying the lay understanding of
industrial safety. In this case study considering interventions leading to an apparent improvement in safety, any description of identified interventions will require a contextualisation of which ‘branch’ of injury etiology has been used.

The literature review then outlined the current industrial environment insofar as it is determined by legislation, the industrial relations environment, and the issues concerning current definitions of relevant data. It also identified and assessed the frameworks currently used to interpret the etiology of injury in industrial worksites, highlighting the strengths and weaknesses of each. Finally, the review considered the issues surrounding the evaluation of safety interventions in injury management. It pointed to the complexity and multi-factorial nature of interventions in ‘real-world’ organisations, supporting the choice of case study methodology for this research project.
Chapter Three: Methods

3.1 Study design

This chapter will describe the methods of investigation intended for this study. The need to learn from the apparent reduction in NZAS’ record of LTIs recorded was recognised in Section 1.1. Since this research project was focused on one particular industrial site, an intrinsic case study was chosen as the research framework (Stake, 1995). The examination of NZAS’ 40-year safety record meets Stake’s (1995) description of a case study framework as, “…bounded by time and activity… researchers collect detailed information using a variety of data collection procedures over a sustained period of time”. The research project aimed to assess the safety performance of NZAS over the period 1971-2011 as represented by LTI incidence.

A mixed methods mode of investigation supports case study methodology. Mixed methods uses the strengths of both quantitative and qualitative research where either quantitative or qualitative research alone is inadequate to address the complexity of the study subject (Creswell, 2009). Collecting qualitative data can help advance the field of occupational health and safety research by identifying underlying factors related to behavioural and organisational change (Goldenhar & Shulte, 1994).

The study therefore proposed two objectives:

- Objective 1: to quantify the safety improvement record at NZAS by examining lost-time injury rates, 1971-2011.
- Objective 2: to describe safety interventions associated with the reduction in lost-time injury rates at NZAS, 1971-2011.

The first objective required the use of both quantitative and qualitative research i.e. empirical data indicating an improvement in NZAS’ safety record, corroborated by
qualitative statements from NZAS staff. The second objective used qualitative research to describe interventions used to produce the improved NZAS safety record.

Section 2.4.6 examined goal theory as a framework for analysing focused safety objectives. Therefore, since NZAS uses the slogan ‘Our Goal is Zero’, goal theory was selected as a means of assessing NZAS’ safety performance. Both the qualitative and quantitative components of this project were undertaken concurrently.

In qualitative research, the researcher necessarily becomes part of the research and therefore must reveal his/her profile insofar as it may influence the collection and interpretation of data (Creswell, 2009; Patton, 2002). Section 3.2 will therefore outline the researcher’s perspective, including his experience in serving the smelter as a contractor, and the expertise he has drawn from NZAS safety initiatives. Section 3.3 describes the ethical consent acquired for the research. Sections 3.4-3.7 describe respectively, the qualitative sample selection and recruitment of participants, interview protocol, data collection and administration procedures, and the analysis of the qualitative data. The quantitative data analysis method is described in section 3.8.

In summary, this research project comprises a mixed method case study, with a pragmatic worldview, using a concurrent strategy of inductive enquiry. The method of enquiry will employ semi-structured interviews seeking responses to open questions and analysis of data collected by both qualitative and quantitative means (Creswell, 2009).

3.2 The researcher’s perspective

I established Vidmark Productions Limited, an independently owned video production company, in Dunedin in 1984. The following year, an NZAS staff member requested that I visit the smelter to be briefed on the production of a video on safety lock-out tags. The resulting production was well-received and established a successful and long-standing relationship between the two companies. I subsequently produced more than 40 safety-related videos for the smelter between 1985 and 2012, delivering an area of competitive
specialty for my company and a series of world-class productions to the smelter (Coughlin, 1992; Lind, 1996).

I absorbed the information supplied to me by NZAS on each safety topic and wrote and directed each safety production. The 28 years of visiting the NZAS has provided me with a familiarity with all areas of the plant, an historical perspective on changes over that time, and an insight into the safety issues associated with the respective hazards and injuries being addressed by each production. For the purposes of this research, I therefore had a participatory observer role in the inductive analysis (Gold, 1958).

In addition, the goodwill accumulated during this time led directly to NZAS’ consent to my initiating this research. It also contributed to the open and candid observations and opinions offered by the participants in the qualitative research. For my part, I have valued the resulting knowledge and experience gained by my association with the aluminium smelter. In particular, I have become drawn to understanding workplace injury prevention. This has led to my undertaking a large number of similar video productions across Australasia, all influenced by NZAS safety practice, and ultimately, to the initiation of this research. Both my chosen profession and the smelter’s drive to eliminate workplace injury has given me a pragmatic worldview (Cherryholmes, 1994).

There are similarities between research and making a video: the camera is objective, but the director chooses his/her point of view and influences the message accordingly; the researcher strives for objectivity, but should also be aware of his/her heuristic viewpoint and its impact on the outcome (Patton, 2002). As a participatory observer, my familiarity with the subject matter has contributed to my contextualisation of the research and my understanding of the resulting data.

3.3 Ethics approval and research agreements

Ethical approval was granted by the University of Otago Human Ethics Committee and the Ngai Tahu Research Committee (Appendix A). A Tripartite Postgraduate Research
Project Agreement was also negotiated between the researcher, the University of Otago, and New Zealand Aluminium Smelters Ltd (Appendix B).

### 3.4 Quantitative methods

#### 3.4.1 Quantitative data sources

Section 2.3.4 of the literature review highlighted issues of definition, measurement and reporting of LTI's. In particular, it identified that LTI totals must include: all people legally on site at NZAS, including contractors, students, and visitors; all injuries where the person injured could not work in his/her shift following, or could not perform his/her normal duties as a result of the injury (restricted work duties); and must be recorded and reported in a timely manner. The period of study was defined as the 40 full years of NZAS operation: from January 1, 1972 to December 31st 2011. The smelter operated for only part of 1971, and 2012 measurements are incomplete, so these part-years were omitted from consideration.

From the field documents described in section 3.5.1, all empirical data relating to 40 years of NZAS LTI’s, personnel numbers, and tonnage produced, was collated on an Excel spreadsheet, across columns for each of the 40 years of the research period. For each file included in the Excel spreadsheet, separate rows were allocated for distinct classifications of personnel such as contractors and students\(^9\), since the exclusion of some categories of onsite personnel could have led to under-reporting of LTI’s. Some files such as EMPLHIST.xls tabulated precise employee details for the 40 years of study. Other spreadsheets such as NZAS Injury Stats.xls gave a detailed breakdown of monthly injuries by category and MRU\(^{10}\) for the year 1990, giving a comprehensive insight into how injuries were categorised at that time. Each spreadsheet examined gave either specific data to be tabulated on separate rows for comparison, or more detailed data on

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\(^9\) NZAS has often employed students over university summer holidays.

\(^{10}\) MRU stands for Mutual Recognition Units – essentially NZAS departments with equal status.
specific periods, MRU’s or injury type. The latter data were used for interpolation or further confirmation of other data. The NZAS files used are listed in Table 4.
<table>
<thead>
<tr>
<th>NZAS Name</th>
<th>Title or description</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book1.xls</td>
<td>NZAS saleable metal from 1971 to present</td>
<td>Production totals over 40 years 1971-2011</td>
</tr>
<tr>
<td>EMPLHIST.xls</td>
<td>Employees by MRU 1971-2001</td>
<td>Employee details to 2001</td>
</tr>
<tr>
<td>LTIFR &amp; LTISR.xls</td>
<td>1998 year-to-date lost-time injury frequency and lost-time injury severity rate</td>
<td>Comprehensive breakdown of injury statistics 1998</td>
</tr>
<tr>
<td>NZAS Injury Stats.xls</td>
<td>Injury/illness statistics by monthly range</td>
<td>Comprehensive breakdown of injury statistics 1990</td>
</tr>
<tr>
<td>Reporting &amp; Analytics Injury 3 Year Statistics - 12 Month Moving (Avg) - Table 1.htm</td>
<td>Statistics – counts, rates &amp; graphs by 3-year, monthly trend</td>
<td>Comprehensive breakdown of injury statistics by month March 2003 – January 2006</td>
</tr>
</tbody>
</table>
3.4.2 Quantitative data analysis

The data were compared to establish a consistency of definition and recording across the full 40-year period of study. Wherever differing definitions of who should be included in LTI totals were noted (below), the most recent and most rigorous definition, as specified in the Rio Tinto health and safety definitions 2012\textsuperscript{11}, was used as the consistent standard. Therefore, where earlier totals of personnel on site did not include contractors or students, total hours worked had to be reconciled with the 2012 definition\textsuperscript{12}. Contractor and student hours were therefore added to the total hours worked in years where they had previously been omitted. All offsite work by contractors was excluded since meaningful data about their work safety record were impossible to obtain. Once such reconciliations had been performed, accuracy was assumed where specific data from multiple NZAS files matched exactly over two or more rows. Where inconsistencies could not be reconciled, the researcher corresponded with NZAS to resolve the issue.

Some data required for the inclusion of all contractors were missing. General contractors on site have been nominally included in the LTI measurement for all of the 40 years in consideration, although it is likely that the early figures from the 1970s and the early 1980s were not robust, and subcontractors were omitted. Importantly, there were three large construction projects undertaken on site, all involving large numbers of construction workers, and their status was initially unclear. Stage III of the smelter was built from early 1974 to mid 1977. Very little information on this expansion was available, but in discussing the expansion, Lind (1996) wrote, “They would add another 102 cells and, by late 1975, total jobs would exceed 1000”. This implied that the total employees for those years included the construction workers i.e. not an outside contracting company. Therefore no adjustments were made for the number of contractors for the period of Stage III construction.

\textsuperscript{11} These definitions were consistent with the Health and Safety in Employment Act (1992) and Amendment (2000) i.e. all people who are legitimately on site, including all employees, contractors, visitors, casual staff, and students working over their summer breaks.

\textsuperscript{12} The 2012 definition was the same as that for 2011 – the final year of the study period.
However, regarding the third potline (Stage IV), built between 1981-1983, Lind (1996) wrote in June, 1981, “770 directly engaged on project”; and in 1982, “830 people were working on site”. Since NZAS employee numbers for the years 1981 and 1982 were recorded as 1,189 and 1,327 respectively, and Lind (1996) noted that the contractors Bechtel and McConnell Dowell Construction were established on site, it is assumed that these contractors worked on site in addition to the employee numbers recorded by NZAS. Similarly, in late 1994, a major upgrade of the smelter commenced and was ultimately commissioned in 1996. Lind (1996) lists the contractors who were to perform this upgrade and notes that 800 people were expected to be involved in the project. Again, it is assumed that these 800 people were indeed contractors.\(^\text{13}\)

Between the years 1990-1993, NZAS operated its own stevedoring company on Tiwai wharf. At the conclusion of 1993, the company was discontinued and casual stevedores were employed. The casual stevedore data was thereafter included in contractor numbers from 1994-2011. Prior to 1990, stevedore numbers were estimated at 75 per annum\(^\text{14}\) for the years 1972-1989.

There were no contractor data for the years 1972-1986\(^\text{15}\), but data of general contractor numbers on site were available for the years 1987-2011. Therefore, a factor proportionate to NZAS employee data was calculated using the known contractor data from 1987-1993, to estimate the contractor totals for 1972-1973, 1978-1980, and 1984-1986. Lind’s (1996) reported contractor numbers were added for the years of the major contracting construction projects (above) and ‘shoulder means’\(^\text{16}\) added for the adjacent years. For instance, a ‘shoulder mean’ was calculated for 1996 as set out in Table 5. Total recorded and interpolated contractor numbers are appended as Appendix E.

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\(^{13}\) The researcher’s participation in and recollection of this project also substantiates this assumption.

\(^{14}\) One of the NZAS spreadsheets specified a 1990 total of 75 employees of the NZAS stevedoring company.

\(^{15}\) Until 1987, the number of contractor employees and subcontractors was of limited interest to NZAS i.e. as long as the contract was fulfilled satisfactorily, the actual number of contractors involved was not important.

\(^{16}\) A ‘shoulder mean’ is the mean of Lind’s (1996) reported numbers and the total for the nearest non-construction year, to provide ramping-up or ramping-down contractor numbers for the years when the construction project was still in progress, but no data were available.
Table 5. Calculation of a ‘shoulder mean’ for NZAS contractor numbers interpolation.

<table>
<thead>
<tr>
<th>Year</th>
<th>From Lind (1996)</th>
<th>From NZAS spreadsheet data</th>
<th>‘Shoulder mean’</th>
<th>Data used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>800</td>
<td>no data</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>no data</td>
<td>no data</td>
<td>(800+130)/2 = 465</td>
<td>465</td>
</tr>
<tr>
<td>1997</td>
<td>no data</td>
<td>130</td>
<td>130</td>
<td></td>
</tr>
</tbody>
</table>

When the total number of people legitimately on site at NZAS for each of the 40 years had been determined, either by reconciliation or interpolation of all staff, contractors, and students, a calculation of lost-time injury frequency rates (LTIFR) was performed. LTIFR is a measure of how many LTI’s occur in relation to the number of hours worked per annum on a given worksite, thereby indicating the worksite’s safety improvement or deterioration from year to year. It is normally calculated as (LTI’s/total hours worked) x 1,000,000 in order to report the number of LTI’s per one million hours worked (Massey, 2007). However, in this study, the annual LTIFR was calculated as per the 2011 Rio Tinto directive, using a multiplier\(^\text{17}\) of 200,000, thereby representing the number of LTI’s per 200,000 hours worked:

\[
\frac{(\text{LTI} \times 200,000)}{\text{Total hours worked}}
\]

Total work hours for each of the 40 years studied were therefore required before LTIFR could be calculated. Work hours for all NZAS staff for all 40 years were available from NZAS records. However, total work hours included contractors’ hours for the years 1987-2011 only. For the years 1972-1986, the contractor numbers interpolated as described above and represented in Appendix E were multiplied by a factor of 2,016 to estimate contractor hours. The factor 2,016 was supplied by NZAS, as an estimate of annual hours worked per contractor. These estimated hours were therefore added to staff hours to give total work hours for the years 1972-1986. Using the LTI’s from the Excel

\(^{17}\) The LTIFR multiplier (200,000) is utilised to produce an easily understandable number for comparison with other years. For example, \((4 \text{LTI's}\times 200,000)/500,000 \text{hours} = \text{an LTIFR of 1.6. Without the multiplier, the LTIFR would equal 0.000008, a difficult number for lay people to comprehend and compare.}
spreadsheet compiled from NZAS sources, an LTIFR calculation could then be performed for each of the 40 years of study. When estimated or interpolative data were used in this calculation, sensitivity tests were performed to gauge what effect a 50% overestimation or underestimation of the relevant data would have on the resulting LTIFR.

As an additional measure of safety improvement, an LTI productivity indicator was calculated. While the LTIFR is the primary formula for comparing industrial plants, an LTIFR to productivity ratio will provide further indication of a safety improvement. For instance, say company ‘X’ produces aluminium over a 40-year period and in the final year, it produces four times as much aluminium as it did in the first year, with half the workforce. Deductively, without any hazard mitigation, the LTIFR at the end of that period should be eight times as high. A significant reduction in this ratio would represent further evidence of a safety improvement. The annual tonnes of aluminium produced was also available from NZAS spreadsheets provided, and from NZAS annual reports. The LTIFR was therefore divided by the annual tonnes of metal produced to calculate the safety/productivity indicator using the following formula:

\[
\frac{\text{LTIFR}}{\text{Annual saleable tonnes produced}}
\]

Finally, graphic representations and trend analyses of the LTIFR and the LTIFR/tonne calculations were prepared. These graphs plotted the reduction of both indicators to determine objective one of the research project. Regression coefficients and p-values were calculated using Excel functionality to indicate the significance of the observed trend. Any p-values less than or equal to 0.05 were regarded to be statistically significant.
3.5 Qualitative methods

3.5.1 Qualitative sampling

Prior to the first research visit to Tiwai Point, NZAS health and safety personnel were asked to call for an unspecified number of interview participants, particularly from the ‘25-year club’\(^{18}\), on the smelter intranet. While NZAS facilitated the recruitment of these participants, the respondents were self-selected. The ‘25-year club’ was targeted by the researcher initially because of their long work experience on site and their insight into the changes in health and safety over the life of the smelter. The first request produced 16 participants, all of whom were interviewed during June, 2012. A second sample of interviews was sought from NZAS health and safety personnel during July, 2012, in order to access a broader distribution of smelter employees. Again, an open request for more participants was sent out on the smelter intranet by NZAS health and safety personnel. The second request produced a further 7 participants, all of whom were interviewed during July, 2012. The total sample of 23 NZAS staff was spread across all major operational areas and across all organisational levels.

3.5.2 Interview protocol

All interviews were conducted in an empty office in the NZAS administration block on site at Tiwai Point, with only the interviewer and the participant present. All interviews were recorded. The interviewer confirmed that the participant had read the Information Sheet for Participants, and written consent was obtained from each participant prior to initiation of the interview. Participants were free to end the interview at any time and their confidentiality was assured. The interviewer recorded the date, time, media tape number, and number of the interview. As a final confidentiality measure, the participant was advised that forthwith they would be identified only as the relative interview number.

\(^{18}\) The ‘25-year club’ is an informal reference to NZAS employees who have worked on site for at least 25 years.
The participants’ names and their number were recorded on a single page which was placed in an envelope marked ‘confidential’ and retained by the researcher.

To build a workplace profile of each participant, the interviews commenced with enquiries about their work history, both before NZAS and during their period of employment at NZAS. They were asked in which area(s) of NZAS they had worked, and what level(s) of position they had held in the past; and in which area they worked and in which position at the time of the interview. The semi-structured nature of the interview was based on the schedule of questions appended as Appendix C. As soon as the participant was clearly comfortable with the interview situation, the researcher introduced the concept of safety at the smelter asking the participant to comment on their impressions of general safety standards and safety interventions over the years. The interviews varied in duration between 20 and 40 minutes, depending on the depth of discussion. No participants requested premature termination of their respective interviews. The quality and openness of participants’ responses to the researcher’s questions suggested that participant bias was minimal.

3.5.3 Data collection and administration

The field research during these visits also included taking notes from responses to informal questions posed to smelter personnel and reviewing the archives of the plant fortnightly newsletter, the ‘Tiwai Pointer’ 1971-2011, noting all articles relating to safety. A number of documents were also requested by and supplied to the researcher by smelter personnel:

- Rio Tinto Alcan (RTA) safety policy
- TaprooT® accident investigation supporting documentation
- Rio Tinto health and safety definitions 2012
- Rio Tinto risk assessment matrix
- NZAS Health, Safety, Environment and Quality (HSEQ) Management System documentation
- ‘Journey to Zero Sept 2010’ Powerpoint presentation
A history of the Tiwai Point smelter *The Power and the People* also provided background to the plant from its conception as a project until 1996 (Lind, 1996). In addition, the NZAS accountant was consulted on statistics covering the years 1971–2011. After searching the computer archives with the accountant, the researcher accessed 13 spreadsheet files covering personnel, injury, and productivity.

All data, both qualitative and quantitative, were stored securely during the period of analysis. All recordings and confidential documentation will ultimately be destroyed in accordance with University of Otago policy and with clause 9.1(c) of the Tripartite Research Agreement.

### 3.5.4 Qualitative data analysis

The goal of qualitative data analysis is to uncover emerging themes, patterns, concepts, insights, and understandings (Patton, 2002). Upon completion of the 23 interviews, the dialogue was transcribed and any identifying name or phrase in any of the interviews was deleted from the transcript. The transcript was then coded by the researcher according to themes emerging from the participants’ responses. Quotes identified as being rich in detail and contextual meaning were highlighted (Patton, 2002). The copy of the original transcript was then manually reorganised by the researcher according to the emerging themes, with the selected quotes retaining their anonymous source identification. An inductive analysis was developed interpreting the participants’ statements insofar as they related to the research project’s two objectives.
A timeline was constructed from the qualitative documents obtained from NZAS. This was used to contextualise the quantitative data and the results of the qualitative interviews. The qualitative data set was then triangulated with the quantitative data in a process of ‘between methods triangulation’ (Johnson, Onwuegbuzie, & Turner, 2007) in order to meet the study’s first objective. Qualitative data relating to lost-time injuries measurement and reporting (see thematic analysis method below) was considered in order to provide an insight into the robustness of the quantitative results.

The themes identified were categorised initially as interventions or outcome according to their role in safety at NZAS. However, it was recognised that not all themes classified as interventions could be considered as direct safety interventions. The themes initially identified as ‘interventions’ were therefore further classified into 3 categories: ‘enablers’, ‘moderators’, and ‘interventions’. An ‘enabler’ was defined as a critical element required for the identified interventions to be established; a ‘moderator’ was defined as a contextual condition which may influence the success or failure of the intervention process; an ‘intervention’ was defined as a specific programme introduced with the intention of effecting change and contributing significantly to the achievement of the goal.

The qualitative data was also used to provide robustness to the quantitative data. Empirical data drawn from document analysis was cross-referenced with the quantitative data drawn from NZAS spreadsheets (section 3.5.1); definitions of LTI’s and inclusion of contractors were considered in the analysis of the quantitative data; and participants’ responses were analysed to substantiate the quantitative results.

The qualitative data set was then used to meet the study’s second objective. Exploring the relationship between the enablers, moderators, interventions, and goal, identified how the key thematic components interacted at NZAS in the smelter’s progress towards its goal. The direct safety interventions were then identified and described. As part of the description of the identified interventions, the hierarchy of control effectiveness vector (Figure 3, Section 2.4.4) and the ergonomic/egocentric effectiveness vector (Figure 4,
Section 2.4.5) were combined in a hazard intervention effectiveness matrix (Figure 7). The identified interventions were then placed on this matrix to better understand their relative effectiveness.

![Figure 7. Hazard intervention effectiveness matrix.](image)

Once the key safety interventions had been identified, the principles of goal theory identified in section 2.4.6 were used to assess each intervention’s contribution to the NZAS safety programme. Finally, the key safety interventions were also assessed in the light of the evaluation considerations identified in section 2.5.
Chapter Four: Results – the 40-year safety journey

4.1 Introduction

Chapter Four sets out the research results as they relate to the first objective: to determine the safety improvement record at NZAS, 1971-2011. Mixed methods were used to analyse the smelter’s 40 years of operation from 1971-2011. Section 4.2 of this chapter reports the quantitative results from the document analysis as they relate to this objective. To substantiate these results, section 4.3 then draws on the qualitative research for contextual data to further elucidate the first objective. A profile of the participants in the programme of semi-structured interviews is provided. Qualitative data gathered from both NZAS documents and from the programme of interviews reviews participants’ first impressions of the smelter, and their recollections of changes in safety conditions over the 40 years of NZAS operation. A brief safety-related NZAS timeline is tabulated for contextual reference. The recording and reporting of LTI’s at NZAS are also considered through participants’ statements in order to elucidate and strengthen the quantitative results. A summary of the mixed method results relating to the first objective of this case study is presented in section 4.4.

4.2 Quantitative results

Using the methodology set out in section 3.8, the annual LTI data summary was tabulated and LTIFR and LTIFR/tonne calculated. These resulting data and calculations are set out in Table 6. When estimated or interpolative data was used, sensitivity tests were performed to gauge what effect a 50% overestimation or underestimation would have on the resulting LTIFR. No significant distortion of the resulting LTIFR was found with an inherent 50% error in these unsubstantiated inputs.
Table 6. NZAS LTI, LTIFR & LTIFR/tonne figures for the period 1972-2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>LTI</th>
<th>Hours</th>
<th>LTIFR</th>
<th>Tonnes</th>
<th>LTI/Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
<td></td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>Injuries per 200,000 hours worked</td>
<td>LTIFR per tonnes produced</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1972</td>
<td>27</td>
<td>1,858,956</td>
<td>2.90</td>
<td>85,272</td>
<td>63.3</td>
</tr>
<tr>
<td>1973</td>
<td>46</td>
<td>1,989,480</td>
<td>4.62</td>
<td>114,982</td>
<td>80.0</td>
</tr>
<tr>
<td>1974</td>
<td>82</td>
<td>2,318,424</td>
<td>7.07</td>
<td>110,894</td>
<td>147.9</td>
</tr>
<tr>
<td>1975</td>
<td>157</td>
<td>2,551,104</td>
<td>12.31</td>
<td>108,569</td>
<td>289.2</td>
</tr>
<tr>
<td>1976</td>
<td>134</td>
<td>2,571,876</td>
<td>10.42</td>
<td>138,076</td>
<td>194.1</td>
</tr>
<tr>
<td>1977</td>
<td>197</td>
<td>2,689,068</td>
<td>14.65</td>
<td>143,741</td>
<td>274.1</td>
</tr>
<tr>
<td>1978</td>
<td>90</td>
<td>2,717,436</td>
<td>6.62</td>
<td>149,831</td>
<td>120.1</td>
</tr>
<tr>
<td>1979</td>
<td>104</td>
<td>2,774,172</td>
<td>7.50</td>
<td>153,557</td>
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<td>2,819,592</td>
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<td>4,538,400</td>
<td>5.16</td>
<td>153,980</td>
<td>152.0</td>
</tr>
<tr>
<td>1982</td>
<td>132</td>
<td>4,984,584</td>
<td>5.30</td>
<td>163,419</td>
<td>161.5</td>
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<td>1983</td>
<td>189</td>
<td>4,858,380</td>
<td>7.78</td>
<td>218,608</td>
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<td>1984</td>
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<td>3,634,668</td>
<td>7.37</td>
<td>242,850</td>
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<td>1985</td>
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<td>6.27</td>
<td>240,835</td>
<td>85.5</td>
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<td>1986</td>
<td>100</td>
<td>3,258,288</td>
<td>6.14</td>
<td>236,331</td>
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<td>1987</td>
<td>141</td>
<td>2,909,772</td>
<td>9.69</td>
<td>248,365</td>
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<td>1988</td>
<td>64</td>
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<td>257,007</td>
<td>49.8</td>
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<tr>
<td>1989</td>
<td>53</td>
<td>3,249,000</td>
<td>3.26</td>
<td>258,359</td>
<td>41.0</td>
</tr>
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<td>1990</td>
<td>29</td>
<td>3,229,296</td>
<td>1.80</td>
<td>259,408</td>
<td>22.4</td>
</tr>
<tr>
<td>1991</td>
<td>34</td>
<td>2,760,540</td>
<td>2.46</td>
<td>258,790</td>
<td>26.3</td>
</tr>
<tr>
<td>1992</td>
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<td>2,605,800</td>
<td>3.45</td>
<td>241,775</td>
<td>37.2</td>
</tr>
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<td>1993</td>
<td>35</td>
<td>2,609,520</td>
<td>2.68</td>
<td>267,175</td>
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</tr>
<tr>
<td>1994</td>
<td>41</td>
<td>3,172,620</td>
<td>2.58</td>
<td>268,588</td>
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</tr>
<tr>
<td>1995</td>
<td>53</td>
<td>3,723,900</td>
<td>2.85</td>
<td>270,400</td>
<td>39.2</td>
</tr>
<tr>
<td>1996</td>
<td>52</td>
<td>2,879,280</td>
<td>3.61</td>
<td>283,329</td>
<td>36.7</td>
</tr>
<tr>
<td>1997</td>
<td>49</td>
<td>2,079,300</td>
<td>4.71</td>
<td>310,324</td>
<td>31.6</td>
</tr>
<tr>
<td>1998</td>
<td>14</td>
<td>1,914,840</td>
<td>1.46</td>
<td>317,599</td>
<td>8.8</td>
</tr>
<tr>
<td>1999</td>
<td>4</td>
<td>1,902,792</td>
<td>0.42</td>
<td>326,805</td>
<td>2.4</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>1,937,237</td>
<td>0.21</td>
<td>328,413</td>
<td>1.2</td>
</tr>
<tr>
<td>2001</td>
<td>4</td>
<td>1,908,460</td>
<td>0.42</td>
<td>322,248</td>
<td>2.5</td>
</tr>
<tr>
<td>2002</td>
<td>3</td>
<td>1,891,557</td>
<td>0.32</td>
<td>333,893</td>
<td>1.8</td>
</tr>
<tr>
<td>2003</td>
<td>4</td>
<td>1,829,344</td>
<td>0.44</td>
<td>334,399</td>
<td>2.4</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
<td>1,728,013</td>
<td>0.35</td>
<td>350,299</td>
<td>1.7</td>
</tr>
<tr>
<td>2005</td>
<td>5</td>
<td>1,853,388</td>
<td>0.54</td>
<td>351,449</td>
<td>2.8</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>1,930,931</td>
<td>0.21</td>
<td>337,264</td>
<td>1.2</td>
</tr>
<tr>
<td>2007</td>
<td>4</td>
<td>1,905,628</td>
<td>0.42</td>
<td>352,976</td>
<td>2.3</td>
</tr>
<tr>
<td>2008</td>
<td>6</td>
<td>1,960,793</td>
<td>0.61</td>
<td>316,931</td>
<td>3.8</td>
</tr>
<tr>
<td>2009</td>
<td>7</td>
<td>1,827,283</td>
<td>0.77</td>
<td>271,902</td>
<td>5.1</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>1,926,048</td>
<td>0.10</td>
<td>343,335</td>
<td>0.6</td>
</tr>
<tr>
<td>2011</td>
<td>7</td>
<td>1,953,966</td>
<td>0.72</td>
<td>354,029</td>
<td>4.0</td>
</tr>
</tbody>
</table>
The LTIFR data set was then represented in graphical form, with an overlaid trend line as shown in Figure 8. The regression coefficient represented by the trend line was found to be statistically significant ($R^2 = 63\%, p<0.001$).

![Figure 8. NZAS lost-time injury frequency rate, for the period 1972-2011.](image)

The LTIFR/tonne was also represented in graphical form, with an overlaid trend line as shown in Figure 9. The regression coefficient represented by the trend line was also found to be statistically significant ($R^2 = 64\%, p<0.001$).
The extremely low p-value in both graphs indicated that the observed decline in LTIFR and LTIFR/tonne is not due to chance. Therefore, the decline in lost-time injuries was confirmed and the trend for this decline was statistically significant.

4.3 Qualitative results

4.3.1 Timeline

From the notes taken from the documents listed in section 3.4.3, an extensive table of milestones was prepared, listing all available information on pertinent events relating to safety initiatives and results, governance and management changes, and major plant developments. An abbreviated timeline is presented as Table 8.
### Table 7. Significant events and milestones at NZAS.

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>- Flame-proofing for work clothing</td>
</tr>
<tr>
<td>1974</td>
<td>- Stage III NZAS plant expansion started</td>
</tr>
<tr>
<td>1976</td>
<td>- Stage III NZAS plant commissioned</td>
</tr>
<tr>
<td></td>
<td>- Major fire</td>
</tr>
<tr>
<td></td>
<td>- 2nd &amp; 3rd General Managers (GM) appointed</td>
</tr>
<tr>
<td>1977</td>
<td>- All-wool clothing on trial</td>
</tr>
<tr>
<td></td>
<td>- Safety glasses and hard hat compulsory in Rodding</td>
</tr>
<tr>
<td></td>
<td>- Sign at gate to measure LTI’s for 12 week competition</td>
</tr>
<tr>
<td>1978</td>
<td>- Comalco New Zealand took ownership (from Comalco Australia)</td>
</tr>
<tr>
<td></td>
<td>- Worker lost leg</td>
</tr>
<tr>
<td></td>
<td>- 4th GM appointed</td>
</tr>
<tr>
<td>1979</td>
<td>- Computer-controlled cell automation system commissioned</td>
</tr>
<tr>
<td>1980</td>
<td>- 5th GM appointed</td>
</tr>
<tr>
<td>1981</td>
<td>- Stage IV, 3rd potline begins</td>
</tr>
<tr>
<td>1982</td>
<td>- 2 fatalities during construction of 3rd potline</td>
</tr>
<tr>
<td></td>
<td>- Comalco becomes subsidiary of Conzinc Rio Tinto Alcan (CRA), itself a subsidiary of Rio Tinto Zinc (RTZ)</td>
</tr>
<tr>
<td>1983</td>
<td>- 6th GM appointed</td>
</tr>
<tr>
<td>1984</td>
<td>- Automatic friction welder commissioned</td>
</tr>
<tr>
<td>1985</td>
<td>- CRA now stand-alone company</td>
</tr>
<tr>
<td></td>
<td>- MRU’s established – management levels reduced from 7 to 4</td>
</tr>
<tr>
<td></td>
<td>- Carbon Rodding has 365 days free of injury</td>
</tr>
<tr>
<td>1986</td>
<td>- 7th GM appointed</td>
</tr>
<tr>
<td>1987</td>
<td>- 1659 man-days lost through accidents</td>
</tr>
<tr>
<td>1989</td>
<td>- GM writes dedicated safety article in the <em>Tiwai Pointer</em></td>
</tr>
<tr>
<td></td>
<td>- Rehabilitation workshop established in Invercargill</td>
</tr>
<tr>
<td></td>
<td>- ‘Essential factors’ incident investigation introduced</td>
</tr>
<tr>
<td>1990</td>
<td>- TQM introduced</td>
</tr>
<tr>
<td></td>
<td>- Occupational Health MRU established</td>
</tr>
<tr>
<td></td>
<td>- New safety board at front gate</td>
</tr>
<tr>
<td></td>
<td>- 8th GM appointed</td>
</tr>
<tr>
<td>1992</td>
<td>- Metal Products achieves ISO 9002 accreditation</td>
</tr>
<tr>
<td>1993</td>
<td>- 12-hour shifts adopted across site</td>
</tr>
<tr>
<td>1994</td>
<td>- Major upgrade started</td>
</tr>
<tr>
<td></td>
<td>- NZAS safety videos adopted by International Labour Organisation (ILO)</td>
</tr>
<tr>
<td>1995</td>
<td>- CRA merge with RTZ to become Rio Tinto</td>
</tr>
<tr>
<td>1996</td>
<td>- Major upgrade commissioned</td>
</tr>
<tr>
<td>1997</td>
<td>- Robot welding introduced into Rodding</td>
</tr>
<tr>
<td></td>
<td>- 9th GM appointed</td>
</tr>
<tr>
<td>Year</td>
<td>Events</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| 1998 | - ACC accreditation achieved  
- Du Pont Safety Training Observation Programme (STOP) introduced |
| 2000 | - National Occupational Safety Association’s (NOSA) rating improved from 2 stars to 4 stars  
- Lean auditor noted excellence performance  
- Alcohol and drug policy introduced  
- 10th GM appointed |
| 2001 | - New safety value statement: ‘If it’s not safe, don’t do it that way’. |
| 2002 | - Electrical safety team initiative; residual current devices across site  
- ‘Our Goal is Zero’ slogan introduced |
| 2003 | - NZAS named safest smelter in the world by the International Aluminium Institute |
| 2004 | - 11th GM appointed |
| 2005 | - NZAS first Australasian business to receive 5 NOSA stars |
| 2007 | - 12th GM appointed |
| 2009 | - 13th GM appointed |
| 2011 | - As at 7/1/11, 365 days without any LTI's |

### 4.3.2 Profile of interview participants

In total, 23 interviews were conducted. The research sample distribution, represented in Table 7, was 78% male and 22% female; compared to a current NZAS sex ratio of 93% male and 7% female.
Table 8. Distribution of sample NZAS participants by sex and age.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Number n =23</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18</td>
<td>78</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-35 years old</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>35-50 years old</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>50+ years old</td>
<td>16</td>
<td>70</td>
</tr>
</tbody>
</table>

The age distribution is represented in Table 7: 70% were aged 50 years or more, 13% were aged between 35-50 years, and 17% were aged between 20-35 years. The current average age of NZAS employees is 47 years. This partly explains the predominance of participants over 50 years of age. However, there was a deliberate bias chosen towards selection of this group since they were able to compare changes in conditions and to qualitatively describe interventions they could recall over their long period of employment.

The sample was spread across all organisational levels, with a predominance of 13 operators/trades people, 2 crew leaders, 4 superintendents, 3 specialists, and 1 manager. This is represented in Figure 10.
However, the predominance of older, experienced employees is again noted, and when their employment history was explained, many had risen (and in one case, fallen) through the organisational ranks, holding a variety of positions. For instance, the manager had held positions in all of the 5 categories. The aggregated positions illustrating participants’ experience is represented in Figure 11.

![Figure 10. Distribution of present positions held at NZAS.](image)

![Figure 11. Distribution of aggregate positions held at NZAS.](image)
A cross-site sample is also important since each area of operation has its own hazards and preventive procedures. The 3 key areas (MRU’s) of the process, Carbon, Reduction, and Metal Products, employ most of the operations staff. However, many of the ancillary staff – engineers, specialist trades people, maintenance technicians, laboratory technicians etc. – work across all the operation areas and therefore have a familiarity with the entire plant. The present work areas of the sample population are represented in Figure 12.

![Figure 12. Distribution of participants’ operating areas at NZAS.](image)

As with the spread of positions held, when the participants were asked about the breadth of their experience on site, the aggregate representation of areas in which they had worked, revealed a much more even and representative spread. This is represented in Figure 13.
The initial response to the researcher-prompted NZAS request for long-term employees to participate in the interview programme resulted in 16 participants. Of these 16 participants, 14 had worked at the smelter for more than 25 years. In transcribing verbatim the interviews from this first participant sample, 12 themes emerged relating to NZAS safety. To provide a wider perspective on these emerging themes, a second group of participants was sought, comprising mostly younger, less experienced employees. Seven further participants were interviewed. On completion of the second set of interviews and a consideration of the subsequent verbatim transcription, no further themes had become apparent, so the programme of interviews was considered complete. The data set was considered to have reached ‘saturation’, since nothing new was emerging from the second stage of interviews, and replication and redundancy of dialogue were strengthening, but not expanding the identified themes (Bowen, 2008).

### 4.3.3 First impressions and safety changes

Section 1.1 outlined some of the obvious hazards such as molten metal and large machinery at NZAS. A brief description of the aluminium smelting process, and potential hazards presented in an aluminium smelter, is appended as Appendix D. The description
of the hazards is not exhaustive but is clearly formidable, and the scale of the smelter environment is daunting to any initiate.

...quite intimidating to see the production process, particularly around the metal passage – centre passage in the pot – centre of the potlines – it just seemed to be to me, quite chaotic... [6]

First-time visitors and new employees are not only overawed by the scale of the work environment, but also intimidated by the obvious and constant hazards.

...for the first few months I was terrified and that was actually an interesting fact – they instill it into you right from the outset so it becomes quite terrifying. [22]

This deliberate drawing of attention to the hazardous nature of the workplace has always been a sobering introduction to employment at Tiwai Point.

...if I walk from here to Metal Products, I've got four sets of eyes bloody rotating, you know – it’s an unfamiliar area, and I'm pretty aware of what can go wrong and you know, what has gone wrong. Ah yeah, so it is a pretty daunting place. [3]

...and Potrooms is not a place that you can be complacent – because you can electrocute yourself – you can get burnt – you can get squashed – and you got to be aware of yourself all the time... [15]

The participants who had worked at the smelter for more than 25 years were particularly forthcoming in describing the very different early workplace conditions compared to the workplace environment in recent years. In the beginning, safety standards and practices were virtually non-existent.

...we had a lot of hard people here in those days, and they were still learning the technology – it had only started in '71 and I think I started in February '72 so it was dirty, it was dusty, it was smoky, there was sick cells, there was riding on jacking cranes, there was people sitting in cruces – and all those funny things used to go around. [15]
There was also a constant “churn” in workers (Lind, 1996). The pay was worse than competing workplaces in the region, so, in an era of full employment, workers drifted between the many employment opportunities available.

...back in those days there was a lot more employment opportunities so – like the freezing works paid more money that we did. So by 10.30 – 10.30 break, one guy had left – by lunchtime another guy had left – because they couldn’t be bothered with the so-called ‘bullshit’ that they would have to go through for an induction because, you go to another business and they don’t do inductions. [17]

However, in the early days, the ‘induction’ programme at Tiwai Point was rudimentary; training consisted primarily of learning on-the-job, and safety was a side-issue.

The procedures and that were there but not really adhered to. The guys just showed you the way to do it, and that’s the way you done it, whether it was right or wrong, you know? [10]

The consequence of establishing a new, hazardous worksite employing workers unfamiliar with any of the unique difficulties of an aluminium smelter, and unaware of even the basics of safety prevention, was a high casualty rate.

...lighting standards and all that type of stuff just didn’t really apply – I mean they probably existed but nobody ever applied them. But you know, we had for example, we’ve got moving conveyors, we have vehicles running around the place and back in those days they, you know, I’ll be honest with you, people didn’t wear seatbelts, the vehicles weren’t probably that well maintained, they went flat out like you wouldn’t believe – you could drive in through the conveyors as the anodes were moving and the rods[19] were moving around, you know, you could play dodgem cars in them – it was OK, you know? No barriers, then we had molten cast-iron at 1500 degrees Celsius which we all cast manual and we loaded the furnaces manually by hand, all right? – with a shovel like – fed them with a shovel – burns were unbelievable – we had a huge number of burns... [17]

[19] Steel rods are used to suspend the 1 tonne carbon anodes into the reduction cells, and the assembled components are transported around the Rodding room hanging from overhead railways, comprising long rows of large, moving, dangling anodes.
Management were not unmoved by the high number of casualties on site, and various financial incentives were offered to reduce lost-time injuries. The Tiwai Pointer published on 14 January, 1977, noted that 1976 was their “best ever safety performance”, recording the lowest all-injury “frequency rate” of 289 compared to the previous low of 361.3 in 1973. The editorial commented, “…improvements can be made and there is no future in the belief that ‘fate’ will have its way, regardless”. Later in 1976, the Tiwai Pointer published on 6 October, 1976, advertised a monetary prize to be offered to the safest department and introduced a sign at the front gate which urged the workforce to record no more than 40 lost-time injuries over 12 weeks.

However adding to the hazardous nature of smelting aluminium, two very large construction projects were undertaken during the 1970s and early 1980s. ‘Stage III’ construction, between 1974 and 1976, significantly expanded the existing operation; and ‘Stage IV’, between 1981 and 1983, added a third potline. Two fatalities occurred during the third potline build, and seven people, not employed by NZAS, were drowned in 1980 when a car in which they were travelling drove off the Tiwai wharf into Bluff harbour. In addition, a worker had his leg amputated in a production area in 1978 (Lind, 1996).

*Coming here in ‘84 it was like the wild west I guess – the number [of] people who were getting injured on a daily basis was horrendous – there was actually no safety focus at all – it was all process driven so, it was, “Get the tons out the gate as fast as you can”... [6]*

And yet, members of the ‘25-year club’ stayed with NZAS, their careers progressed, and they are intensely proud of their company and the relative safety of their workplace in the 21st century. They valued the size and complexity of the plant, and the range of opportunities it offered, both in job variety and in promotion opportunities.

*...that’s the beauty of this place. You come in the gate and you change your job every five years. [1]*
Moreover, they contest that their worksite is now considerably safer than it was when they started working onsite, and they take pride in their belief that it is safer than other worksites, and in particular, safer than the work environments of their ‘sister’ smelters in Australia.

*I’ve been in Australia and worked when that smelter broke down and people were walking under cruces*, and they’re big, big cruces – and you say to – “You want to go home in a matchbox?” And they just look at you and say, “What are you talking about you square bastard?” “No, we’re from New Zealand: we don’t walk under those places…” [15]

All staff, even those who have worked onsite for fewer than five years, are especially proud of NZAS’ reputation for a notably low injury rate.

*I always wanted to work at Tiwai with the health and safety because I knew here that Dad used to say, “They’re so anal-retentive that you will never have an accident there because they’re so on to it”*. [22]

### 4.3.4 Lost-time injury at NZAS

#### 4.3.4.1 Lost-time injury measurement

From research field-notes and an examination of NZAS spreadsheets, it was ascertained that the definition of an LTI at NZAS has changed over the period researched. However, the LTI definition has become more inclusive and comprehensive as time progressed. The most rigorous NZAS definition appears to be manifest in the present Rio Tinto health and safety definitions 2012, with the pertinent items being:

- A lost-day injury (LDI) ‘is an injury or occupational illness that results in one or more days/shifts away from work, excluding the day of the incident’.

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20 ‘Cruce’ is an abbreviation of ‘crucible’ – a very large steel vat in which more than a tonne of molten metal is rapidly transported by large specialist vehicles from the Reduction lines to Metal Products where it is cast into saleable product.
- A lost-time injury (LTI) ‘is the sum of fatal, lost day and restricted work day injuries (RWDI)’.

- A restricted work day (RWD) injury is an ‘Occupational injury or illness where, as a result, a) the employee was assigned to another job on a temporary basis; or b) the employee worked at a permanent job less than full time; or c) the employee worked at his or her permanently assigned job but could not perform all the duties normally connected with it.’

Analysis of Rio Tinto Alcan’s 2012 safety definitions, additional documents gathered in field research, and NZAS spreadsheets confirmed the following increasing rigour in defining the LTI’s:

- The LTI was retrospectively changed back to January 1994 to include Restricted Work Days (RWD) to bring NZAS reporting into line with Rio Tinto’s reporting requirements.

- The GM in 1998 required that students’ work hours be included in safety measurement from November 1998.

- From June 1999 contractors include casual and temporary staff, and exclude students who are thereafter reported in the employees category.

It is impossible to apply these more comprehensive categorisations retrospectively back to 1972 since accurate records and earlier definitions of casual workers and restricted work days do not now exist\(^{21}\), but since the first objective of this research is to substantiate a decreasing trend in acute injury on site, it is apposite that the definition of LTI has become progressively more inclusive over the period of research, rather than less so.

\(^{21}\) They may never have existed – see the following section 4.3.4.2, Absenteeism.
Nevertheless, there are other acknowledged and potential difficulties associated with the accuracy of this calculation, particularly for the early years of the smelter operation. To understand how these issues have influenced these results, the investigation must draw on the qualitative research component of this project:

- Absenteeism in the early years is considered in section 4.3.4.2;
- The issues associated with the reliability of LTI data are investigated in section 4.3.43.

4.3.4.2 Absenteeism

The older interview participants pointed out that in the past, absenteeism was rife, and contributed significantly to LTI measurements. Absenteeism therefore inflated absolute LTI numbers without involving any workplace injury.

…it had nothing to do with work, but it was recorded as an LTI. [21]

In the 1970s and early 1980s, NZAS had a vibrant social life centred on the Tiwai Social Club and the Tiwai Rugby Club. The older interviewees who began their career at the smelter during this period spoke fondly about the easy-going work environment and social life of the early days, but admitted that the injuries often had nothing to do with their work.

If people played rugby in their days off, and got hurt, they just wouldn't come to work, and they would record it as an LTI. [21]

There was even an altruistic motive employed in favour of their workmates.

...people would play rugby and they would be hurt – not be able to come to work – and that would generate overtime for their mates at work, so that drove a lot of the absenteeism... [2]
New Zealand’s Accident Compensation Corporation was established shortly after the smelter was built, and the new idea of external compensation for not being able to work further exacerbated the problem.

In the early days here, and even at the [meat processing] works, people [would say], “Oh yeah it’s great – bloody cut my hand” or “Squashed it – I’m off for 3 weeks on ACC now” – or even people that would have injured themselves at home and struggled to work – they’d say, “I did it at work”… [8]

It has been noted above that the GM in the mid 1980s had come from a background of dealing with highly unionised American workforces, and he set out to reform the work practices of the time.

...he tightened the whole operation like – because it was pretty loose back in those days – still under the union but it was very, very loose, so he decided to come with a fairly big stick... [6]

The management practices were tightened, the medical centre at the smelter became more pro-active in managing the return to work of absent workers, and a rehabilitation unit was opened in 1989 (Lind, 1996) for those who were unable to work.

I think a significantly large improvement in safety and reducing loss on injuries at the smelter was addressing the issues that were associated with people coming to work with injuries and saying they were injured at work or going off work for injuries that weren’t really lost time injuries but taking time off anyway and managing those people – individual people a lot closer. So leadership, managing those people closer and making sure that we were aware very much what the condition was by having them go to our own doctor – even their doctor and our own doctor working together to understand exactly what wrong with them, and then making sure that we bought them back to work on some full restricted duties, and – they could see that the tide was turning with regards to not having an ACC contribution holiday sitting at home. [2]
The extent to which absenteeism contributed to an inflated LTI measurement over the first 10–15 years of smelter operation cannot be determined. No investigations into early absenteeism at the smelter have been recorded. However, one interviewee estimated that the effect of absenteeism on LTI numbers to be as high as 40%.

When I first started here we were injuring people to the extent of something like a 175-odd a year – to the point where they couldn’t come back to work the next day. Yes, some of that you could probably say 75 of those probably could have come back to work the next day, but the way the regime went in those days, it wasn’t such a critical issue. [3]

4.3.4.3 Lost time injuries reporting

No evidence of current under-reporting or concealment of LTI’s was revealed in the course of the qualitative research. However, during the 1970s and early 1980s, there were very low expectations that injuries could be prevented and injuries were often regarded as an integral part of the work at NZAS. Long-term employees drew a bleak picture of the early days of smelter operation.

...back in the ‘70s – there was no real focus on safety – I don’t think anybody looked at the cost of safety and the cost of people off injured all the time so – we had hundreds of people in a year injured – myself included – I got a couple of severe injuries back in the early days... [6]

Some participants admitted that, as an awareness of the need for safety improvement began in the 1980s, ‘rehabilitation’ became a means of bringing injured workers back onto site in a timely manner, and thereby decreasing the LTI figures.

[It was] a natural reaction of both a department manager and a superintendent in particular – “Right, I’ll bring her in and she can clean the floors or something – or type up some CBP’s” – training was a bit like that – “Shit, who are we going to get to train this guy? I know, Bert’s got a twisted ankle – well he can do it.” Or, “He’s recovering from a burn, he can do it.” [9]
However, many of the interviewees were quick to discuss the migration to a more enlightened attitude to rehabilitation.

...we’ve certainly reduced greatly the “I’m hurt.” “So bring him back – stick him in an office – cleaning the windows or whatever so it’s not a lost-time injury” now. The desire’s not there to get that done – to get people back in just for the statistics – which is good. [9]

...as far as the company goes, they were bloody good about it – didn’t push me back into the workplace before I needed to or anything like that – so – that way they’re very good. [10]

And one person pointed out that, particularly for musculo-skeletal injuries, a managed return to work is often the best solution for both the company and the employee.

...it depends on the injury – and the person too, because sometimes bringing them back to work is the best thing for them. You know, like a back injury, lying on the – sitting on the couch at home is the worst thing you can do – so you may as well come back do a wee bit if you can – and it depends on the individual of course, and the injury, but – no – I think it’s good to bring them back, as soon as we can... [10]

Many of the interviewees appeared to be very aware of the propensity for some companies to under-report or hide LTI’s in order to improve their safety reputation or to achieve ACC employer accreditation22, and most were quite dismissive about the possibility that NZAS may be manipulating the LTI numbers.

...they couldn’t hide something that needs hospital [22]

Yes, there’s different reporting – people say “Oh, it’s only the reporting that’s making the difference”, but it’s not – you’re either injuring people or you’re not, and we’re not. Investigations into near hits, you know, rather than injuring

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22 NZAS achieved ACC accreditation in June 1998.
someone – “Shit, that was close but we got away with it that time – what do we need to do to stop it happening again?” – that sort of stuff. [2]

But the whole reporting thing – a very, very small percentage of stuff isn’t reported [2]

The debate over whether or not LTI’s were hidden on site was especially animated when the published LTI’s started to decrease significantly in the late 1990s.

A prevalent myth at the time was that well, actually we’re not really improving safety, you buggers are hiding them – you know, “They are hiding them” and of course they’d lay this on [General Manager], and he would respond in a way that said, “Well”, he said “I don’t see that”. He said “I don’t see people with broken arms, broken legs, badly burned, eyes out”. He said, “You can’t hide that – I’m not seeing that – you can’t hide that stuff”. He said, “You guys might be hiding the nick and the cut of the finger the first aid type of thing,” but he said, “No-one’s hiding medical treatment or lost time injuries because you can’t”. [19]

And the interpretation of incidents, LTI’s and near misses, continues to be debated on site.

We do talk about this quite a bit, you know – at meetings – especially after we’ve had an incident and we say “Well, have we heard about this happening before?” “Mmm, not really” or, “Shit, yes we have because guys have actually…” – you know? So – and it might be some dark little corner of the bloody plant at two o’clock in the morning – there’s not a lot of people round, so – there will still be a percentage of stuff is unreported – probably more the near-misses than the incidents. With the checks and so forth that go on now it’s going to be figured out – that there’s a new scratch on that – a dint in this – that’s been hit – that is not where it should – that’s going to be noticed reasonably quickly in most cases. [2]

Another interviewee agreed that a lot of minor damage may be under-reported.

I think the stuff that gets reported falls into two categories – one of which is: the person who did it is one of that the true gems in the company, and there are a
minority who will report everything – or it’s so bloody obvious, you’re never gonna get away with it; (but) if you’re one of these people that, “Oh shit, my job’s on the line and nobody saw me”, I reckon a lot of stuff doesn’t get reported. [8]

Most people were very doubtful that any significant LTI would have been hidden in recent times.

I don’t know if an LTI would go unreported – basically – there’s a few reasons – we do have a – it is part of your employment here, so if you are caught not reporting something that’s reasonably serious – it probably would cost you your job, and a lot of people – I would hope that everybody here knows that. Second of all, I guess the nature of an LTI – you know if you’ve got a broken leg, it’s bloody hard to hide the fact that you’ve got a broken leg. [21]

Nevertheless, many were equally sure that the perceived or real sanctions placed on those who reported damage was too punitive and acted as a deterrent to reporting near misses.

Some of them hide it – we see unreported damage quite a lot with production cranes and that type of thing we maintain… [7]

I nearly crashed a work van last year but because there was someone behind me I reported it, and that sounds terrible, but if there wasn’t I wouldn’t have – and that’s really bad – but it’s honest. [23]
There is a culture out there that “If no-one’s seen me, I wouldn’t actually report it” [23]

…the way we are now, if you go anywhere and damage something or do anything, you’re going to try and hide it – and that’s not a good thing. I’m not saying we’re going in the wrong direct… – we’re going in the right direction, but I think it could be improved if there is more encouragement, to be honest – and tell the truth like – I’d certainly hide it. [5]

So while minor injuries and property damage appear to be under-reported, one comment clearly indicated that significant non-injurious incidents (serious near misses) were reported on a large scale.
…we still have a lot of incidents – don’t get me wrong – we still have hundreds and hundreds of incidents a year, but from an injury perspective, we will have typically maybe 40 first aid injuries and they tend to be very low level. [17]

Generally, most people appeared to believe that all LTI’s and most serious near misses were well reported, but they also acknowledged that there was a tension between open and honest reporting, and an organisational drive to eliminate LTI’s. The LTI measurement displayed prominently at the front gate had a particular resonance with people who felt the organisational pressure associated with the experience of a rare LTI.

*I get pissed off with leaders who – the only thing they say is, “Oh, is it a first aid or is it an LTI?” And you know that they’re only asking “Is it an LTI?” because it means that the [‘days without LTIs’] number out the front is going to go back to zero,* [21]

One person also felt that the organisational pressure sometimes also resulted in a reluctance to report near misses, and therefore was seen as ultimately bad for the worksite.

*There’s probably near misses that go on in this plant where people go, “Oh, that was close”, that don’t get reported, and therefore we don’t have that opportunity to learn from those close calls and that’s where a lot of companies will never get zero because they are not learning from the close calls that they have* [8]

However, in the case of NZAS and the reporting of LTI’s, the same staff member also pointed out that,

*…clearly we’re not having people going home with broken arms and they’re trying to cover it up as they go out the gate or anything. So when we do investigate, we do it well, but there’s a lot of stuff that goes on that we don’t know about.* [8]

Despite these reservations about organisational pressure to reduce LTI’s most employees praised NZAS’ general treatment of employees with respect to sickness and injury leave.
…what I appreciate is they just really look after people – like if you’re sick, you know, it’s a constant stream of support – their sick days are enormous comparable to the sick day legislation – it’s just excessive compared to other places – so they always – if you’ve got cancer or an injury or anything, you’re well looked after…. [22]

Other aspects of LTI measurement irked many of the interviewees. In particular, several people were outspoken about the fact that the staff bonus system was linked not only to productivity and profitability, but also to the number of LTI’s recorded in any one year.

…and he felt terrible that he was going have to face his crew to say, “I’m sorry I cost you money” – it was bullshit – and back then too, they would – it was almost like a bit of name and shame – so he would have had to have stood up in front of everyone and went, “Oh this is what I’ve done – I’ve done wrong” and I just think that’s shit myself. [23]

…the other thing that I’m really passionate about is that safety bonus – you’d know about that – and I’m really anti that – you should never get a bonus for safety – you should get a bonus for performance – only. [22]

I don’t think that safety should be tied up with money and right when I first started actually, I was a little bit outspoken I guess, because I kind of just didn’t think that it was right. You know – I think you’re encouraging people to hide things. And I don’t think that does happen now but it certainly would’ve at the start – absolutely. [23]

…although another person felt that blaming individuals for the loss of a bonus, either by the company or staff, had not happened.

I remember saying, “Well, how’s somebody going to feel when we’ve lost the bonus because that was the last accident that actually broke the camel’s back?” but I think people are actually reacting quite well with it, and used it quite well – they haven’t actually come back in to say “You bastard, you lost us the bonus” like, you know? [5]
Despite their misgivings about aspects of LTI and near miss reporting such as its effect on bonuses and organisational pressure, in general the interviewees were clearly proud of the drop in LTI’s and all appeared to have a high level of faith in the integrity of the numbers.

_If you’d have talked to me in 1986 and said we could have no accidents on this site in a 12 month period, you couldn’t have convinced me no matter what you said. It was impossible to have convinced me of that. And I know, because we had these discussions, and it was, “Accidents happen - we work in a tough environment…” every, every possible excuse you had for an accident or an incident you could roll out – well guess what? We’ve gone – and some of my team – over 13 years without a lost-time accident or a first aid injury – and that is not just through good luck, that’s good management._ [7]

_…in the [ ] plant where I’ve been, we haven’t had an accident in probably 20 years… [12]

_…we’ve probably gone past that phase at NZAS now – we don’t have big serious injuries – we don’t have big explosions and big fires and anything like that any more. What we do do is have people almost being run over by forklift trucks and stuff like that which from a personal individual point of view is quite serious – you know if you get run over by a forklift truck it’s really gonna hurt… [8]

### 4.4 Summary

Comparison of the NZAS LTIFR and LTIFR/tonne rates over the period 1972-2011 indicates a continuing safety improvement at NZAS over its 40 years of operation. However, for the safety improvement to be confirmed, some confidence is required in the LTI input. Some early data was missing, and these data were estimated through interpolation. Other data was altered to reconcile historic data with 2011 definitions. Nevertheless, sensitivity tests confirmed that even a considerable error in any one set of interpolated or reconciled data would not alter the resulting LTI significantly. It has been noted above that, with additional shifts and overtime prior to the 1991 Employment Contracts Act (1991), nominal (and not actual) total hours worked could be substantial.
On the other hand, absenteeism was rife, and the origin of LTI’s was sometimes unclear. The issues of absenteeism and other counterproductive work practices would have had some effect on the accuracy of estimated total work hours. However, these irregularities were not able to be reconciled and were therefore not taken into account.

Nevertheless, the resulting LTI totals can be treated with increasing confidence as the smelter moved into the 1980’s. More importantly, the qualitative research provided strong data about the reliability of LTI measurement and recording at NZAS. In particular, the clear absence of serious injuries and hospitalisation in recent years was cited by many study participants as evidence that LTI’s had indeed decreased substantially. Triangulated with the quantitative results showing a significant decrease in LTIFR and LTIFR/tonne tabulated in section 4.2, the improvement of the safety record at NZAS 1971-2011 can be confirmed.
Chapter Five: The key drivers for safety

5.1 Introduction

In this mixed method case study, both qualitative and quantitative research methods were used to determine the first objective, with the results reported in Chapter Four. The qualitative data were then employed to meet the second objective of the research, to describe interventions associated with the reduction in lost-time injury rates at NZAS, 1971-2011. The themes identified from the programme of interviews as they relate to objective 2 are set out in this chapter. The qualitative discourse analysis divided the 12 identified themes into 11 interventions and 1 outcome as set out in Table 9. Participant discussion on the outcome, LTI, was a key qualitative contributor to the determination of the first objective, and was considered in detail in section 4.3.4. The remaining themes are considered in depth in the following sections 5.2 to 5.13.

Table 9. Division of qualitative themes into interventions and outcome.

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5.2 Automation

All the staff who had worked at the smelter for many years were unequivocal when asked what they considered to be a key driver for the improved safety record.
The use of mechanisation. We had some very hard tasks out there that we were required to do and they were very physical – you were really exposed to some pretty unpleasant conditions out there. [14]

Much of the work in the early days was very physical. The use of sledgehammers, pikes, crowbars, manual lifting, along with proximal exposure to molten iron and aluminium, molten bath23, and exposed machinery, was common. Many of these tasks and exposures have been eliminated progressively over the smelter’s 40 years of existence.

The big difference is, personally, I think is equipment changes, all right? Automation – let’s face it – if you’re not doing stuff with your hands – because the hands are the things we injure, and it’s not surprising is it? [17]

In the earlier period of the smelter’s operation, there were two extremely hazardous manual processes in Rodding: attaching the anodes to steel rods using a cast iron foundry for the purpose of suspending them into the reduction cells; and spraying the anodes with molten aluminium to increase their conductivity within the electrochemical process.

Before the process was automated, the use of the molten iron foundry presented an ongoing threat of large explosions and catastrophic injury, but also a constant hazard of molten iron splatter. The resulting burns were so frequent; they became a source of macho pride.

...if you flinched, you were thought to be a cissy – and it was the cast iron – the stuff would bite you... [17]

While personal protective equipment had always been provided for the manual foundry workers, the foundry was eventually automated and is now controlled by an operator who is isolated from any possibility of splatter burn.

23 ‘Bath’ is cryolite – used to dissolve the alumina in the reduction cells.
The casting station, right? – the guy’s now sitting in an air-controlled cabin, operating a couple of joysticks that have two 1,500 kg ladles with 1,500 degree Celsius cast-iron in it – whereas before, we used to stand beside them with a wheel and pour it – kitted up – so you’ve got your leather jacket on, we used to have to wear skullcaps, visors, gloves, bloody leggings in some situations – and we still got burnt. Christ knows the last time they had a burn over there – I can’t remember it, you know? The furnaces – nowadays, instead of shoveling it, the operator [of the] vibrating feeder, you push the button – you’re in a booth, protected, you know? [17]

Similarly, the spraying of anodes was once regarded as one of the most hazardous jobs on site.

We had the spray station that was a very manual system – that’s spraying molten aluminium at 800 – 820 degrees Celsius, it was then – and man, that was the worst job on site, whereas today, the way they’ve got it set up, it’s a push button thing. It’s the best job on site. [17]

Many of the automation projects delivered considerable productivity gains, but either deliberately or coincidentally, they also effectively removed or isolated previously significant hazards. One participant, who had worked in Carbon24 for many years, explained that automation had not only brought a huge increase in production of anodes per employee, but had also reduced worker exposure to hazards.

...we used to work our absolute bollocks off in those days – to do 150 anodes over 30-something people – these days, they’re doing 500 anodes, all right? Think of the productivity gain – with less people, with a way less risk exposure. [17]

Furthermore, the earlier lack of automation i.e. manual control, meant that operators could speed up or slow down elements of some of the processes such as speeding up

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24 ‘Carbon’ refers to three factories on site: Green Carbon where the anodes are formed, Carbon Bake where the anodes are baked in huge gas-fired ovens, and Rodding where the baked anodes are attached to steel rods before being sent to the reduction cells.
casting production, but the hit-or-miss control frequently resulted in explosions of molten metal splattering over workers.

*Back then you had a lot of manual control over these things so, safety-wise, some of the things didn’t turn out too good sometimes, you know, we had a few eruptions back in those days and like, I don’t know, every couple of months we were running out of the casting pit – when we shouldn’t have been – the metal chasing you...* [10]

At other times, operators would manipulate the process to give themselves or their mates, more overtime.

*When I first started the job, we had to manually control a lot of set points – things like that, so you could speed things up to finish on time or before the end of the shift, type of thing, or slow it down if you didn’t want to do it, and things like that. Now it’s just – technology took over, you can’t do that sort of thing – it’s all in the system – so you push the start button and away it all goes...* [10]

The automation of previously strenuous manual work has also been progressively introduced, thereby reducing the incidence of musculo-skeletal injury. For example, the spent anode butts were withdrawn from the reduction cells and cleaned by workers wielding crowbars and sledgehammers.

*We used to stand there with a crowbar and beat the shit out of them and clean ‘em up – and that was your job. And now that job’s removed you know, you just go, “Well, everything’s a bit easier – mechanised.”* [14]

*...one day I went down there and tried to clean one for them – with a crowbar – fucking great – the crowbar must have weighed 20 kilos – it was a big bastard – knocking the bath off by hand – the fumes – I was spewing out the louvres – and these guys were doing it all the time – unbelievable, you know? No wonder they got potroom asthma and stuff – no wonder. And nowadays, you know, they’re cooled before they clean them – the guy’s sitting there in an air-conditioned cabin with huge jackhammers and just operating off of joysticks, you know? His biggest risk is putting his back out with his feet up on the window...* [17]
Between 1994-1996 another major upgrade was undertaken which added another half-potline, increased productivity, met higher environmental standards, and added yet more automation which, as well as removing the hazard from people, also removed the need for so much manual labour. A senior staff member explained that the 1996 upgrade removed many more of the manual tasks.

*There was an exercise to downsize and the enablers there were mainly the introduction of new technology through the upgrade which did take out a lot of manual intervention tasks – so a lot of that, you know, musculo-skeletal stuff and so on, was removed and tasks that had formally been quite physical, were turned into control-room type tasks as the anode-handling project delivered.* [19]

However, one interviewee cautioned that the automation had to be carefully specified and designed lest it created its own hazards.

*…we’ve had that a number of times, where we’ve had equipment that has not been built to spec and for whatever reason we’ve still accepted it, and we’ve brought it into site and then we’ve had to do a lot of retrofitting and all that other stuff, to get it safe for operation basically…* [21]

But the same participant also supported the significant effect that high levels of capital investment and mechanical innovation had played in NZAS safety.

*…from a NZAS specific point of view, I do think that automation has played a huge role in reducing injuries. I also think that because – I don’t know if it’s because NZAS belongs to an overseas company which probably has access to more resources than what a strictly New Zealand-owned company does, but they’ve always been really keen to try something new and so I think that helped them stay ahead of the game with safety.* [21]

As well as contributing to the control aspects of mechanical automation, computerisation also led to more effective information sharing and management control. NZAS’ first
computer was introduced in 1973 and SAP software\textsuperscript{25} was introduced in 1990 (Lind, 1996). Compilation of taxonomies of hazards and injuries, and accident investigation and reporting became more precise and more available.

\textit{When I raise an incident, it’s electronic – and that electronic process forces you to – it escalates to your boss, automatically, and then he sees that incident and makes certain that the actions you have put in are appropriate. You can’t – he won’t allow me to put in something like, “Talked to team member, we’re aligned.” He doesn’t let me do that and that’s as it should be – there’s gotta be some action...} \textsuperscript{[7]}

5.3 Ownership and governance

NZAS has always been remotely owned and therefore governed from overseas. This appears to have had both a beneficial and a detrimental effect on NZAS staff. Staff appreciate the substantial amounts of capital invested into not only the increased productivity at Tiwai Point, but also the enhanced workplace conditions. They enjoy a certain amount of autonomy, being the biggest industrial plant in New Zealand, yet they are separate from other New Zealand companies. However, they also periodically resent directives from overseas that they may not agree with, and they tire of the differing governance regimes as ownership of the smelter passes between large international company structures. However, they do credit much of the improvement in safety on site to the adoption of international best safety practice emanating from the large overseas companies.

\textit{I was a crew leader back in those days – in the ’90s and there started to be more of a structured approach to looking after safety and site-wide approach; and then of course a Comalco approach; and then obviously when we got taken back into Rio Tinto, then the Rio Tinto approach – so there was a lot more external audits started to be done and just a sharper focus on accidents.} \textsuperscript{[6]}

Some staff felt that their remoteness added to the potential for injury at Tiwai Point.

\textsuperscript{25} A German software system frequently used by large industrial companies. Systemanalyse und Programmentwicklung (System Analysis and Programme Development)
...the policies are being driven top-down and a lot of the people who are up there, don’t really know what the people on the floor are actually doing... [20]

As an example, NZAS supervisory staff now receive all incident reports from all the companies within the RioTinto Alcan group, including those from mining and other only partially related industries; whereas previously, incident reports from other aluminium smelters were received with interest.

...overload with them coming through – and also we’re not only getting them from there now – we’re getting them from all the other Rio sites... [11]

5.4 Employment Contracts Act (1991)

The participants who had worked at the smelter for more than 20 years repeatedly referred to the Employment Contracts Act (1991) and its downstream effects as a major driver for the way work was organised onsite. All contrasted the work environment before and after the introduction of the Act. The heavily unionised work environment prior to 1991 focused primarily on pay rates and concessions for those on the shop floor.

That’s all the arguments were ever about. It was always over this allowance for that, this allowance for that – we need to have overtime, we need to have minimum manning levels. [17]

Work practices were geared towards maximum shift opportunities, and therefore maximum remuneration, for workers. A worker could nominally work over 100 hours per week, particularly if he was able to sleep on the job.

We were able to do the seven doubles a week which was 16 hours a day which is roughly 20 [by] the time you got home. So in those days we could work those hours and yes, a few of us got the head down now and then which was pretty well accepted by the company. [1]
These extended work hours often led to work practices which were less about productivity and more about creating work opportunities.

*...the reality was that the union made significant advances dictating how the place was managed, to a point where there was clearly counterproductive stuff.* [19]

*...there would always be ways of breaking some equipment, or breaking something, or making sure that they couldn’t finish their job so they’d need to stay back for a double or create a double for somebody else – and someone would create it for them – and there was a massive amount of that sort of stuff going on...* [11]

The introduction of the Employment Contracts Act 1991 coincided with the tenure of a GM who had come to Tiwai Point from a tough background in USA industrial plant management.

*...he had come from a very, very harsh union environment where plants get shut down for from months or years until such times as an agreement is reached – you know, one party or the other caves in – so he actually put backbone into the management in a way that hadn’t been around before so – and there were a number of things probably changed so one was overtime, which was being rorted – stopped – or the rorting stopped...* [19]

However, as well as having a tough GM to confront the union-controlled workplace, the management team took the opportunity presented by the introduction of individual employment contracts to restructure the hours of work and traditional allowances.

*...people didn’t have to work as long hours, right? There was no overtime – it just died overnight – people got remunerated a lot better than what they used to...* [17]

Many of the interviewees identified this period as a major driver towards lowering the incidence of workplace injuries at Tiwai Point, both in terms of the hours worked, and of job demarcation.
...it was a step change then – and the fact that there wasn't the exposure to the long hours of work – which I consider to be a contributor to some of the accidents and incidents we were having. [1]

...it released people from what had been previous areas of demarcation, I think. And people were actually allowed to use their brains and think about what they were doing – and people that wanted to take pride in their work and wanted to go that extra step could do so, and were recognised for doing so [19]

One older participant was generally very supportive of the company’s management and safety initiatives, and admitted that he had, “…done well out of it”, yet still yearned for the time when unions were a source of strength and brotherhood.

I don’t think it helps the way we’re going today where everybody’s an individual looking after himself – you’ve lost the team thing because you’ve got people just looking after their career path, if you like. [5]

...although he did not miss the hourly allowances paid for doing a dangerous job.

...so you were buying safety, you know? You wouldn’t do that today. So that’s a big, significant change – in them days: “Give me more money and I’ll do it”, whereas now, you wouldn’t do it – yeah – that’s a plus. [5]

Two of the interviewees were union delegates prior to 1991, and while they spoke fondly of the days of the union, they admitted that previously the drive for safety took second place to the drive for allowances and benefits.

...one of the concerns [was] the fact that people were working too many long hours – so there was a programme introduced to reduce people’s ability to do overtime within one shift in three days which I think helped that – which frustrated people as well – there was concerns of what impact that would have on people’s income but you know, [it] was a driver of mine at the time certainly that the income thing didn’t come into it. It was the fact that we were continually having – injuring people. [1]
None of the interview participants, even the erstwhile union delegates, wanted to return to the days before 1991.

*I’m not against union principles but the company did treat us really fairly…* [7]

*…have we lost anything? I think we’ve gained a lot more than what we ever lost with regards to that and the concern of maybe in a few years time the company would come back and take and take and take – I don’t think has ever eventuated. I’ve seen it as quite a positive move.* [1]

### 5.5 Leadership

There have been 13 GMs of the Tiwai Point smelter over its 40+ years of operation. The GM position is accountable to the smelter owners for everything that happens on site, including productivity and profitability, product quality and environmental and safety outcomes. Each GM has, by role definition, been autocratic in management style, and each has had a unique agenda, accompanied by differing levels of popularity and support on site.

Many interviewees referred to a sea-change in the mid-1980s when the then GM took a very different tack to that that had been taken in the first decade and a half of the smelter’s operation.

*…a general manager at that time – whoever it is – it gets hard to remember now – put his flag in the ground and said, “No, this is not acceptable anymore, we’re not going to be hurting people” – so, he had a different viewpoint and he was more, “We can’t keep working like this – where we are just living off the fat of the company – we’ve got to start becoming more accountable”. [12]*

Before the stewardship of this GM, the Tiwai Pointer only rarely mentioned safety features or safety statistics; but almost every magazine published during his stewardship had some reference to a safety highlight, a new safety video or safety initiative. In the Tiwai Pointer published on 28 July, 1989, he wrote “It is my desire to have every man
and woman employed at Tiwai return home at the end of each work period, safe and healthy, albeit a little more tired than when they arrived.” However, his approach was confrontational, punitive, and widely unpopular.

...he started to tighten it up; and then we went – under his stewardship – we went to – if you had an accident, it was written warning time – and you know, the axe really fell quite heavily... [6]

Succeeding GMs continued with an increased focus on safety and introduced more sophisticated concepts of injury prevention.

And [name] brought a school of thought that was around – well actually – it’s all interwoven, so he would say, “You haven’t got a successful business if you haven’t got a safe business because if you haven’t got a safe business, you’ll go out of business”, you know? Eventually, he made the link between people working safely and people doing quality work so if people are working safe, not taking shortcuts and you’re getting the job done right first time. You know, that manifests itself in our ability to produce purity metal for instance – it’s that precision of tasks – execution – so [ ] rolled these things all together and pushed them as a combined initiative and it was very, very powerful. [19]

These new approaches to safety continued to be driven by the GMs well into the 1990s. Another GM initiated the slogan ‘If it’s not safe, don’t do it that way’ which was more than an exhortation to work safely – it was effectively a license for staff to cease work when they felt unsure about the measures taken to protect them from injury.

[In] [ ‘s time as General Manager where people were explicitly given the authority to not go and do the work if they believed it wasn’t safe. And I think that was – that was another significant period where people actually felt empowered to say, “Look, actually – I think this is not the best way of doing it – we need to go and stop and look at doing it a better way.” [16]

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26 Researcher’s recollection
The combined effect of these successive management styles eventually led to the normalisation of safety as a central management theme.

[In] the mid-1990s when the focus started to come on accident rates and we started to really take a look at it and then there was some real action started to get taken – there was a lot more training started to go into the leadership teams – you know at crew leader level – I was a crew leader back in those days – in the ‘90s and there started to be more of a structured approach to looking after safety and site-wide approach... [6]

As well as a management focus on safety, a devolution of safety accountability was promulgated through a revised organisational and management structure which coincided with the introduction of the Employment Contracts Act 1991. A deliberate programme of increasing leadership skill throughout the smelter was undertaken.

…it wasn’t until we focused on leadership out on the floor actually monitoring the policeman type stuff – monitoring people for compliance to the safety systems or wearing personal protective equipment that we actually started to see some changes. [2]

Despite the differing attitudes to leadership style and effectiveness, the interviewees strongly acknowledged the importance of leadership vision, encouragement and enforcement on improved safety outcomes at the smelter, even when they initially disagreed with the interventions.

Well I suppose to a large extent you’re dragged kicking and screaming into the safety thing... moaning about it and all that, but – you gradually accept the fact that, I suppose when your activities or the way you did things first started to getting curtailed a bit you thought, “How bloody stupid’s this” and all this sort of thing, but nowadays you kind of accept that this is not the way it is and that’s the safe way of doing it – to the point where you go to other places now and you see things happening and you [laugh] – you know, other companies and you think, “Man, how the hell do they get away with that? They’re sort like where we were 20 years ago...” Yeah. [4]
In the early 2000’s, the tenth GM introduced a further slogan which was embroidered on every staff uniform: ‘Our Goal is Zero’. This amounted to a unilateral declaration of eliminating lost-time injuries on site. The interview responses on whether this ambitious goal was achievable were mixed, but all acknowledged the appropriateness of its focus and intent.

20 years ago, I wouldn’t have said it was achievable but I think it is achievable. [7]

Well I’ve been at zero for an awful long time – I can’t remember how long ago I did something – hurt myself. [14]

…but if you don’t have that goal, well you’re never going to progress. [9]

Some people were concerned that the existence of the goal might paradoxically generate punitive measures or negative connotations when an injury did occur.

We are very close – we are close but I just yeah – it’s a double edged sword that one – because it is an achievable goal, but it’s also a goal that implies that because it’s achievable, if you stuff up, you know… [21]

But in general, staff were again proud of their company, proud of its safety achievements, and openly acknowledged their own personal safety metamorphosis.

I’ve seen it works – I’ve seen it – I know where I was and I know where I am now and I can see the results; and the results are that we have – we still – we haven’t quite cracked it – there’s still the odd lost time injury and odd – a few first aiders across site – that type of thing – but we’re close… [7]
5.6 Ergonomic focus

Many of the long-term employees spoke about changes in the 1990s, including a period of considerable capital investment into the smelter, and a change of emphasis on injury prevention by improving the physical work environment.

...there was a whole lot of work probably between the mid-90s through to early 2000 maybe, which was all those physical conditions – and I certainly believe that a lot of that work contributed to people not having accidents... [16]

Not only did the emphasis swing towards engineering solutions as a defensive mechanism against hazardous conditions, but the company actively discouraged blaming human behaviour for any injury suffered by an employee.

...when the company became – started to get more accountable, it went into the culture of ‘we will engineer the issue out of it – we will redesign this – we will change that, so that it can’t happen again – and there’s no fault attributed to a person; it will just change the equipment’... [11]

Participants reported that, particularly for the period between the mid-1990s and the early 2000s, funds for ergonomic intervention in hazard mitigation were readily available and the workplace conditions were acknowledged as improving significantly.

I think they spent quite a bit of money over that period of time but it certainly did raise the standard of the whole place... [12]

...it would have cost us hundreds of thousands if not millions of dollars – with items that were put in the skip and replaced because they weren’t in a fit condition. [16]

One of the long-term employees had been involved in two serious incidents in the 1990s – both potentially fatal. In one incident, he slipped on top of a crane and cracked his tailbone; in the other, he received a 1000 volt direct current electrocution, but after being
hospitalised briefly, was discharged unharmed. Both incidents were thoroughly investigated, and substantial engineering alterations and administrative actions were implemented to prevent a recurrence.

...it was not a cheap exercise - we’re talking hundreds of thousands of dollars – but it was done – and when you look at it from that perspective, you know, the company does do their utmost to actually prevent – detect and provide reassurance to their employees that they’re doing the right thing. You know it’s not a case of saying, “You didn’t test properly” or, “You didn’t do this...” you know? There’s never been any blame like that. [13]

And yet, later in the interview, the same employee also commented on another person’s injury involving a trip on an uneven stairway. The company investigated and concluded that the stairway had to be replaced with optimally spaced steps.

...it was just overboard rhetoric – you know? Whereas we all knew that the steps that were in there were actually quite adequate. They might not have the quite correct spacings, but I mean – a sign at the bottom of the stairs saying this step has short steps – when you’re going up – a visual sign – you’re going to take notice of that – you know – everybody else knew them, because we knew “Oh, they’re short steps” – You could ask someone, “Where’s all the short steps around here? Oh yeah, this one there – I know another one...” [13]

But a staff member in a more senior operations position addressed a similar recent incident that had resulted in an employee suffering a broken hip. The injured person had stumbled on two 30 mm steps, which were regarded as impossible to guard using handrails. This consensus was challenged in the incident investigation.

It was glaringly obvious to us after we’d gone through that process that we needed to put handrails in place – when people said it was impossible to have handrails in place; and we’ve been able to do that, using the current method – understanding accident methodology that we use. [2]
When discussing injuries and incidents involving the interviewees, the researcher probed for further information regarding the aftermath and consequences of the injury. Several staff members mentioned the increased focus in the early 1990s on the company understanding exactly what had happened in each significant event.

…when we had lost time injuries, right – we didn't just discard them as being, “Oh well, it’s one of the business risks – shit happens” type of stuff. We spent a lot of time and effort into undertaking incident investigations. [17]

…the communication to people is important as well so they understand both the event, the circumstances around the event – what we call ‘essential factors’ and what we’re doing going forward to prevent recurrence [2]

Australian safety consultant, Roger Kahler, had a significant influence on incident analysis at NZAS in the late 1980s and early 1990s by using model known as ‘essential factors’. The consultant taught that for a damaging, and therefore unintentional energy exchange to occur, there are ‘essential factors’ in the sequence of events preceding the exchange of energy. If any one of the typically 30–40 essential factors is removed, then the exchange of energy cannot occur and the damage is averted. Since all essential factors are of equal importance, no one essential factor is more relevant than any other and therefore cannot be termed a ‘cause’. For the purpose of injury prediction and prevention therefore, it is up to the interventionist to decide which essential factor or factors should be extracted from the predicted sequence of event.

…you go back through and you can see, “If this didn’t happen, it wouldn’t have happened”. There’s a few critical decision making points there or events that happened that you know, at some point if you had have recognised it then – so they’re the ones you concentrate on. [3]

This repudiation of the ‘egocentric approach’ to incident investigation even required cross-department investigations.

[27] The researcher observed the techniques being taught to NZAS staff at that time, and made videos explaining the technique.
...there was a group of people who were trained and they went across and did the investigation for the department – and they were typically from outside the department. Now there was a good reason for that – because sometimes, people being people, if you’re doing an investigation in the area, you have I guess, a certain amount of self-interest maybe – in the outcome of that – and nobody wants to be made to look like – they haven’t done their work or their role … [17]

Following the implementation of the ‘essential factors’ approach, the NZAS GM in the early to mid-1990s introduced the proprietary ‘Safe Work’ system. This system was developed by the South African National Occupational Safety Association (NOSA), and its implementation continued the association of safety with the physical work environment.

...making sure that the plant was in a good operational and safe condition – and auditing it to keep it there. So we’re looking at stairways: handrails, designs of stairways, looking at areas that we’ve had accidents and incidents structurally to try and improve it. [1]

...a lot of painted lines and placement of where you could put things and general upgrades with the painting and getting more light into the buildings and things like that. [12]

...it’s all standards like standards for building inspections – it’s almost like a building warrant of fitness – pipe-work and all those sort of things had to be colour-coded; cords on an electrical heater were inspected; lighting conditions; lifting standards... [17]

This system involved NOSA performing periodic audits to award the smelter a star rating for standards compliance – from one to five stars.

... and they would come in and audit you every year, and it took us a number of years to get from one star – sort of the fundamentals – up to five-star... [17]
The 2003 NZAS Sustainable Development Report included a table which showed safety results for the preceding five years. This is repeated here as Table 10.

Table 10. NOSA star rating and LTIFR for NZAS, 1999-2003.  
[Reproduced from 2003 NZAS Sustainable Development Report]

<table>
<thead>
<tr>
<th>Year</th>
<th>LTIFR per 200,000 hours</th>
<th>NOSA Star rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1.5</td>
<td>**** (4*)</td>
</tr>
<tr>
<td>2000</td>
<td>0.3</td>
<td>***** (5*)</td>
</tr>
<tr>
<td>2001</td>
<td>0.5</td>
<td>***** (5*)</td>
</tr>
<tr>
<td>2002</td>
<td>0.5</td>
<td>***** (5*)</td>
</tr>
<tr>
<td>2003</td>
<td>0.4</td>
<td>***** (5*)</td>
</tr>
</tbody>
</table>

During this period, a drop in LTI numbers was noted; but over the past seven to eight years, some interviewees commented that, with the lapsing of the external NOSA audits some time after the smelter achieved its five-star rating, the standards started to slip a little.

...the environment’s starting to drop again in terms of cleanliness, structure, and that sort of stuff – because I don’t think they – there’s no real accountability for it. [12]

...(the audits) were done religiously – it was a leader expectation that they were done – they were checked, and I think it really did help. But as the years have gone by, that’s kind of slipped a little bit, and we’ve had a few incidents where we’ve got nothing to blame it on apart from the fact that someone did not do an audit or a check. [21]

When ownership of the smelter shifted into the Rio Tinto Alcan group, the proprietary TaprooT® investigation methodology became mandatory. TaprooT® has some similarities to the ‘essential factors’ approach in its logical, impassive approach, and in particular, the identification of causal factors which if eliminated, could have eliminated or reduced the severity of the incident, and SnapCharts® which establish a detailed timeline of events and actions leading up to the incident.
The thorough nature of this process both impressed and frustrated those who have been involved in the investigations. Some appreciate the methodological advantage in the detailed sequential nature of the investigations.

*Every time you were asked to go back and have a look at it and look at it and: “Oh no, actually – before that, this happened,” and we were away the hell around the corner and you know, just about on the third wall... [3]*

However, some also felt that there was a lot of routine ‘ticking the boxes’.

*...some of us feel that it may be that where there is a known outcome you’re probably wasting a lot of resource in going through it.* [3]

One person felt that the understanding of the process was not as good as it should be...

*...there’s still this old-school belief that if people just think about what they’re doing they won’t have an incident – and that’s still here.* [21]

…and another felt that many of the investigations did not focus enough on the classical hierarchy of controls.

*...we don’t focus high enough you know, say, “So why can’t we eliminate the task or the activity with a process?”*[17]

**5.7 Personal protective equipment (PPE)**

In the 1970s and even into the early 1980s, the availability and use of PPE was rudimentary at best and discouraged at worst.

*...could get a white paper mask if you went and asked for it and to get a blue mask with a bit of charcoal in it – to try and block out some of the smell or whatever, was pretty near impossible – you had to beg your superintendent sort of thing – so – and nowadays if you get caught without a proper mask or filter out of date, and things like that, it’s a big deal. Back in those days it was, “Just get on with it – don’t worry about putting a mask on”.* [3]
Coincident with the plant upgrades and the advances in safety leadership in the 1980s and 1990s noted above, the same participant commented on NZAS’ PPE standards at the time he arrived when compared to his previous employment.

...they were probably two steps ahead of the Government labs that I was working with around safety – and that's, for example, mandatory use of safety glasses in labs and having protective clothing and having got operational fume hoods etc...

[16]

By the 1990s, NZAS regarded PPE as a critical step in the ‘sequence of events’ leading to an injury. PPE with correct specifications for the relevant hazard became mandatory across site.

...if you need something to protect yourself, you get something to protect yourself.

[16]

The researcher experienced the introduction of PPE first-hand during the late 1980s and throughout the 1990s. The NZAS Occupational Health Specialist at the time directed that isolation from a hazard could be achieved by any one intervention or by multiple interventions along the potential path of the unwanted energy exchange, from the hazard to the worker. In the view of NZAS thereafter, all isolating interventions were regarded as being of equal value in their protection of the worker from the progression of the hazard energy path. Therefore, guards on a hazard, a barrier between the hazard and the worker, or PPE specific to the hazard were all held by NZAS to have identical efficacy and value. When achieving isolation from a particular hazard, no isolating hierarchy is presumed or inferred by NZAS; any one or any combination of effective isolating techniques is regarded as appropriate. In accordance with NZAS treatment of energy isolation, the PPE specified for any particular hazard is therefore styled ‘isolating PPE’ and is represented in Figure 14. For instance, in the NZAS Metal Products MRU (the casthouse), a full-face polycarbonate shield is used to isolate molten metal splash from an operator’s face. At NZAS, this full-face shield is regarded as equivalent to all other isolation measures employed to isolate the molten metal hazard such as a guard on the
source of the molten metal, a barrier between the metal and the operator, or sufficient
distance between the metal and the operator. At NZAS, all such ‘isolating PPE’ is
considered to achieve isolation from the hazard. Other general purpose PPE used to
protect from multiple hazards such as gloves to protect from sparks, molten metal splash,
cuts and abrasions may be styled ‘risk mitigation PPE’.

Figure 14. ‘Isolating PPE’ as a means of hazard isolation

5.8 Total quality management (TQM)

One line of questioning in the qualitative research stage probed for indications of this
insofar as ‘total quality management’ (TQM) was used at the smelter – particularly in
relation to safety.

The concept of lean management and the 5 S’s had contributed to production gains, and
some interviewees had also seen gains for safety best practice around site.

…it changes the way people think and I think it changes the way that you operate
because you know that you are in a cleaner area everything is tidy, and I think you
have more pride in the workplace and more pride in yourself too I think – to make
sure that things are maintained that way and that I think actually creates a safer
environment to start with. [23]
…one of the lean tools is planning the job out – and it covers all the safety steps that have to be involved, and there is a lot more photos and that sort of thing… [6]

However, while these TQM techniques and other methodology such as ‘six sigma’ have been used extensively in production areas with considerable success, their impact on safety appears to have been muted. One interviewee reported an initiative called ‘In control and capable’ which was based on six sigma calculations.

…you have to have your processes which includes safety in control before you can put more current into your potline, before you can, do stuff and move forward… [19]

However, he was confident that TQM generally had not had any significant effect on NZAS safety performance.

I think lean six sigma is a tool when applied in the workplace – if safety is part that process – it can make a significant contribution. But at the moment it’s not a systematised input and neither is a measurable output… [8]

While both the success of NZAS’ production techniques and the apparent thoroughness of their safety procedures inherently indicate evidence of TQM principles being employed, it appears that TQM methodology is seldom applied overtly to safety management. However, one of the most fundamental TQM tools, Deming’s ‘cycle of improvement’, is evident in much of NZAS’ auditing and accident investigation techniques.

They’re pushing us all the time to try and think of better ways of doing things – you know – I mean it’s a good company, they’ve been doing that for quite a while. [5]

5.9 Proprietary interventions
After the period between the mid-1980s and the mid-1990s, when there had been a major focus on automation and ergonomic management of hazards, NZAS introduced a series of proprietary interventions intended to monitor and improve staff safety behaviour.

## 5.9.1 DuPont’s STOP programme

The first of these was the DuPont Chemical Company’s ‘STOP’ programme. This involved leaders carrying out observations on their staff to monitor their safety-related behaviour, and to effect changes where necessary.

...learning the principles of STOP, we could actually go out and observe people’s work and look at how they were going about certain tasks, and probably the work method of it. [1]

Several interviewees reported excellent initial results and an increased drive to improve each other’s work behaviour insofar as it related to injury prevention.

...you have that corrective discussion – and it is also the opportunity to provide them with positive feedback on the good things they were doing so they become ingrained habits, you know? Keep on encouraging that positive stuff so it’s – they think, “Oh shit, he values what I’m doing here” type of thing, you know? [17]

However, others reported less favourable impressions of the suitability of ‘STOP’ within NZAS.

...we then got involved with the STOP programme and actually had a lot of internal debate around the cultural fit of that because a lot of the supporting movies that came out of America we felt didn’t necessarily reflect our culture – they were quite sort of command control focused... [19]

In particular, the word ‘gotcha’ was frequently used to describe observations where the perceived unsatisfactory behaviour of the subject of the observation was recorded.
...there were a whole lot things that went on with STOP that made it very unpalatable to people and the fact it had become like a ‘gotcha’ type thing... [5]

...we came to understand that the quality of a lot of the interactions were quite variable so there was an element of ‘gotcha’ – “I’m gonna write you a ticket”... [19]

...it’s not the way to treat people – and they were both the whole, “Yeah, got you” kind of thing – it doesn’t work – people need to be treated with dignity and respect. [23]

The negativity surrounding ‘STOP’ appeared to grow to the extent where the observations sometimes became perfunctory formalities.

...it comes down to having to go out and do STOP observations and – go out there – do them as quick as they can – they don’t do them properly – they come back in and, “Here’s my ticket, I’ve done that, I’m back to what I’ve gotta do”. [10]

One person even reported falsification of the STOP reports.

...towards the end it got to the point of “I’m not even going to tell Joe Bloggs that I’m looking at him – I’m just going to fill in this card and I’m going to hand it in” – and then it got even worse – then they were just filling them out in the cribroom. [21]

Eventually, ‘STOP’ appears effectively to have been discontinued.

The behavioural – the observation process itself has – I’ll be honest with you – has died in most areas because a few years ago it was decided by the General Manager that we will not make it mandatory for operators and trades-people to undertake observations of their peers or other people, right? [17]

5.9.2 Take 5 cards

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28 Morning tea/lunchroom
‘Take 5’ is a Rio Tinto initiative that involves everyone doing a job taking 5 minutes at the start of each shift, assessing the hazards that they will be facing in performing their allotted tasks, noting these down in a little ‘Take 5’ booklet, and conferring with their teammates. This process was also received well initially and regarded as a successful intervention.

They do things like Take 5’s for example – which makes you stop and pick things you know, before you do the job; and that helps, it makes you actually look around for what’s dangerous. [5]

...when we introduced Take 5, we saw the accident rate just drop immeasurably… [6]

However, as with the ‘STOP’ intervention, the interviewees noted reservations with ‘Take 5’.

Take 5 is an interesting tool… I don’t get too carried away with it myself because I tried to do a Take 5 every day before I drove home for a month – couldn’t. It becomes meaningless. [19]

Again, one person noted a cynical misuse of the initiative.

...a lot of guys around this site, I know – and they go and fill out Take 5 – they go and hide – and they’ll fill out ten Take 5’s – they’ll hide – because they’re, how would you say – they’re sort of – objecting to the system that – but trying to play the game, because at the end of the day it has an impact on, on their financial gain – so a lot of people – yeah, they say they’re doing the right thing – they say they’re doing – but in fact they don’t. [13]

However, others recognised that, when adapted to their particular workplace, ‘Take 5’ can be a valuable tool.

...we’re upgrading our current Take 5 books so that they are easier to operate for the guys on the floor doing the bizzo – they’re the ones that use it – people in
offices don’t – generally systems are created by people that sit in offices and don’t actually do the work. (1)

Others saw the need to apply the ‘Take 5’ process whenever there is a change in the course of their work through a shift.

…the guys utilise those Take 5 books for jobs that aren’t frequently done… [1]

5.9.3 Zero Incident Process (ZIP)

‘ZIP’ was another proprietary intervention that focused on individuals’ personal motivation for work and life in general, and encouraged staff to become more pro-active in their safety behaviour. Several of the operator-level staff were very enthusiastic in their personal observations of ‘ZIP’.

…the biggest influence on my life would be – and my work environment was the – zero incident process. [9]

…I’m staying safe because I want to – and that was a real fundamental mind shift compared to what I’m used to. [8]

…went down the road of that ZIP training recently and that sort of highlighted a few things to me, in how your mind works and things like that, so that was a good series – that ZIP [10]

But again, other interviewees did not withhold their reservations.

…someone out there making a hell of a lot of money. That’s where it’s coming from. And that is one of the issues that we saw as well here. [3]

I think that’s where ZIP fell apart – it wasn’t that the material in ZIP was incorrect or silly or anything like that, it was just the material that was in there was not the right stuff to [be] building a safety programme in keeping people safe. [21]
The ‘Safe Days’ system – from the same company that delivered ZIP - was also less than well received by one participant.

…the Safe Days system – to me that was one of the biggest wanks that we – I believe it was sold to us – it was a slick marketing ploy which we picked up on – it was sold to the corporate, and then we had to implement it and even as we were implementing it you can see the holes that were in it; and it was unsupported – and it would basically give you some results for about 12 months and after that there was nothing you – you were basically inventing it as you went after that…. [6]

5.9.4 Constant change

A very common theme across most of the interviewees was a fatigue with the succession of interventions and the seemingly constant change.

...they hit you too hard – you got one thing going, then another thing comes in, then another thing comes in – so you’ve got all these things going, and people just turn off, to tell you the honest truth… [15]

...a lot of people out there have just got to the point, ‘Well it’s just a new fad – we’ll just go with it’ and, “Yep – whatever.” [20]

Nevertheless, even if they were often frustrated with the constant change, some people acknowledged the benefits of an ongoing programme of interventions.

I see some systems that I think don’t have that much value, but I’m loathe to champion and get those systems out because I’m not convinced that there is not parts of those systems that don’t end up with the total result of fewer accidents. [7]
I think it is good to have a change every now and again – it refocuses everyone on what we’re doing and how we’re going to do it – and everything else – and I don’t know whether it is because of the systems we’re doing that has brought the numbers down on-site or whether it is the fact we’ve kept changing it a few times and kept people thinking more and more about the safety… [11]

5.10 Work organisation

It has been noted above, that the interviewees frequently referred to the Employment Contracts Act, 1991 and its worksite consequences as the paramount change in NZAS work organisation over the life of the smelter. Other general comments and observations also provide further insight into how work organisation has influenced Tiwai Point safety practice.

5.10.1 Organisational hierarchy

In the early 1990s the management of the production process was reorganised into ‘Mutual Recognition Units’ (MRU’s). Despite the production process being split into these separate operations areas, a conscious effort was made to minimise barriers across site, and effect some vertical and horizontal integration in staff levels.

...we just, started to get more HSE teams together – like, we used to have things called participation teams – and it would actually be made up of people on the floor as well as a few bosses and stuff – and so that got us around the table talking more and I think that also from the organisational development side, we started sharing the same crib rooms – and a lot of barriers got broken down between the groups: the maintenance group, production group, and other groups – it sort of became more intermingled which is always better – if everyone's talking to one another you can't help but improve the safety and stuff like that [12]
5.10.2 Alcohol and drug policy

Several people mentioned the introduction of alcohol and drug testing in a very positive way. The older operators talked about the lax attitude to alcohol in the early days.

*It wasn’t uncommon to – come to work upon an afternoon shift and you’d be at the pub for 2 or 3 hours before you came to work – and have a few beers. In fact, alcohol used to end up on-site – and blind eyes got turned to it for Christmas Day and New Year’s…*[14]

NZAS introduced their alcohol and drug policy before it became the norm throughout New Zealand process industries. The *Tiwai Pointer* of March 2000 announced its introduction to site. Even those who were not using alcohol and drugs soon saw its relevance to safety on such a hazardous site.

*… I had no idea before I went in because it wasn’t my scene – and it was really interesting and I completely changed my view on that and I think back then I think people thought, “NZAS – how weird that they’re doing it” whereas now it is just like everybody is expected to do…*[23]

*…for us it was a good thing – there wasn’t a bad culture of it, but it was something there that just needed fixed up – those that didn’t want to change their lifestyles – some left – some stayed and took the risk – paid the price – and for some people it’s probably been the best thing for them.* [14]

5.10.3 Procedures and rules

Some of the older interviewees spoke of the virtual lack of any training when they first arrived at the smelter in the 1970s or early 1980s.

*…when I started here you were just sort of shown the job and safety wasn’t really – there were a few rules like you weren’t supposed to go down pits but people did – to clean them and things like that…*[4]
Over time, a number of training methods have been progressively introduced, including standard operating procedures (SOP’s) and current best practice (CBP).

*I think CBP’s have come into play – current best practice – so you have a list of the hazards involved in the task that you’re doing – which is a big improvement, especially the safety side of it.* [15]

However, some interviewees stressed that SOP’s and CBP’s were not always exhaustive, and did not necessarily cover safety aspects of a task.

*…a lot of our rules here are verbal or cultural, historical, you know – and it’s great for the old-timers who you’ve been interviewing who’ve been here 25 years – but speaking as a relative newcomer you rock up on the gate and is no training package given to, there’s no instructions on how to do this particular task or anything – you basically, “What the fuck do I do now?” you know? – and that’s too flexible in my opinion; you need a happy medium between the two…* [8]

This observation is perhaps supported by the following comment.

*…we’ve introduced this job instruction training and that’s pretty good, but it’s trying to teach the old dogs how to suck eggs really – they’ve been doing it for 20, 30 years, and we’re trying to tell them a way of doing it and it’s not really any different from what they’ve been doing – it’s just more structured.* [10]

But one operator, having previously condemned CBP’s being written in offices and then issued to crews to follow, highlighted a change where authority for fine-tuning the CBP’s was devolved to the crews accountable for the particular process.

*…then we became accountable for looking after those current best practice, so we could – we had the authority to change them – rewrite them – get them up to standard and then everyone would follow those standards better. So that was an improvement as well.* [12]
5.10.4 Audits

Descriptions of the upgrading of standards and the auditing thereof during the late 1980s and 1990s were presented in section 5.6 above, including the proprietary NOSA system. A perception was also revealed that auditing of systems had subsequently slipped. Discussions of safety auditing generally on site confirmed this.

...something we’re not good at – is auditing the effectiveness of actions and making sure that they’re as high up the hierarchy of controls as what we can make them. [17]

One interviewee was critical of NZAS’ propensity to ‘blitz’ a safety issue to resolve it, and pointed out that this was often only a temporary fix.

...we need a more structured approach that makes sure that thing happens every five years, not just this year when I’ve raised it to you – so to my mind there needs to be more systems in place. [8]

Other people highlighted the need for auditing to reveal the true conditions on the shop floor.

You can have the best systems in the best bits of paper works in a filing cabinet in a computer that you can display to an auditor – but that doesn’t mean to say you’re doing the bizzo... [1]

... so we check to make sure they’re trained in how to drive a forklift and Metal Products rules – that type of stuff – you talk to people about the training process – how they’re assessed as being competent – check their training documents because sometimes you will find that they’re – have lapsed... [17]

However, incident reporting and pro-active auditing processes do appear to be emerging once more as a key safety initiative.
That’s one thing I’ve learnt over the last year or so, is you really have to audit to make sure people are doing what they’re supposed to be doing – or say they’re doing – you know? [17]

5.10.5 Induction

A general induction is compulsory for every person visiting site for the first time. Departmental induction programmes are undertaken for every new staff member before they commence work on site. However, some people felt that the induction process was too concentrated and too intense for a new staff member to absorb, especially if they were expected to work across the different processes.

When I first started here my whole first week was induction, web-based trainings – like first day was Reduction induction – then Metal Products, then Carbon – it’s the only time I’ve been through those places and I couldn’t – no idea what was even in those inductions any more… [18]

5.10.6 Brother’s Keeper

Many interviewees mentioned a relatively new safety innovation being introduced to site called ‘Brother’s Keeper’ which is a team-based approach to managing safety behaviour.

…for argument’s sake, we’re tapping metal – so it looks at all incidents around the tapping of metal and then puts them [into] different categories and then we go out and we observe people against those categories and say, “Well OK, that’s a high incident rate area – there’s the procedure”. A little bit of that procedure’s in it but it’s all done by the guys on the floor as to how the task should be done… [6]

This latest initiative to devolve accountability for safety appears to have been enthusiastically received.

The Brother’s Keeper initiative is a good one – it sits well with Kiwis too I think – you know, that sort of team atmosphere? [9]
“...It’s looking really, really positive at this stage and – it’s taken a wee while to gain momentum and sort of get the trust back, but it’s starting to gain momentum...” [6]

5.11 Culture

The word ‘culture’ was used freely by many of the interviewees. The usage of the word varied widely, but in general, people used it to describe the way they generally performed tasks and interacted with each other, and usually, to contrast ‘then’ and ‘now’. Several of the long-term employees spoke of the culture of the early days of the smelter operation...

I know that they’ve always known that having accidents isn’t a good thing for people, but – it was almost accepted – that it’s going to happen – and then somewhere along the line, it became not accepted that it should happen. [4]

...and talked about the tightening of control at the smelter.

We then started to see an improvement in the culture at the smelter whereby people were more aware that the days of being able to do that were very, very quickly diminishing and that we were managing that process a lot closer; they had a lot less opportunity to take advantage of that. [2]

5.11.1 Safety versus productivity

The researcher probed for any opinions on the potentially contradictory aims of safety and productivity. No-one thought that productivity ever took precedence over safety at the smelter.

Some people may believe that production becomes before everything else – I’ve never seen that, personally. [1]

...at times, safety will always take priority – so, do I ask people or do I expect people to continue casting when there is potential safety issues? The answer to that is, ‘Definitely not’. [2]
However, two people mentioned the highly publicised 2012 redundancies at NZAS and the adverse effect they were having on morale. These workers felt that the low morale brought about by job uncertainty was damaging the safety culture at the smelter.

*I do think the culture’s changed here, and at the moment we’re just spiraling down I think, because morale – I’ve never seen morale as bad as what it is now.* [23]

*You’ve got a lot of people very stressed, very pissed off – it’s very dangerous out there now...* [11]

### 5.11.2 The ‘Kiwi way’

Generally, people expressed pride in being New Zealanders, and some mentioned the special qualities of Southlanders; but in relation to production and safety, several people raised the ‘Kiwi way’ of not wanting to leave work undone, or to leave a mess for your mates, and how this may have occasionally led to production short-cuts and hazardous practices.

*...the group of guys sort of pride themselves on being able to do anything – and getting everything done and getting it done in the timeframe you know, within the schedule, sort of thing...* [3]

*The Kiwi way – we don’t like leaving work – no one likes leaving work – they like to get the job done – but you don’t think about sometimes what you’re doing, you can have an accident...* [15]

Conscientiousness and camaraderie also often stood in the way of a thorough adherence to appropriate procedure.

*...it’s sometimes a bit hard to convince people of that – they – “I just want to get it done mate – why do you keep bloody annoying me?” you know?* [7]
One interviewee who had only been in New Zealand a few years, contrasted New Zealanders’ staunchness when it came to injury and self-reliance with what he had been used to.

*I think that’s a Kiwi cultural thing – it’s just like “I’m harder than that”...* [8]

As well as pride in their community and in their workplace, many people were also adamant that the stability and even the advancing average age of the workforce at Tiwai Point, were significant drivers for the improving safety record at NZAS.

*I think the strength of a lot of where we've been and where we are today; it's the strength of that locked into a group of people that have been here for a long period of time and those people are still charged with handing that over to the new people that come from building that, that culture into them, and that building it in is just continual reinforcement and changing of behaviours – to get those people*
believing in those systems and, and then once and they believe in it they will hand it on to the next generation of people coming in. [2]

But irrespective of age or ability, the increase in safety performance, and the pride it generates, appears to be a safety driver in itself.

I think that we’ve created a culture where we’ve put ourselves on a pedestal and when you start putting yourself on a pedestal, the last thing you want to do is knock yourself off the pedestal so we’ve actually put ourselves there, so we’ve got to keep going. [16]

5.11.3 Contractors, the community, and families

The smelter is a major user of contractors in Invercargill and beyond. Under the Health and Safety in Employment Act, 1992, NZAS is accountable for the safety of contractors while on site at Tiwai Point, and NZAS appears to have always included contractors in its LTI records. Therefore, NZAS has had a major influence on its subcontractors’ safety culture. This was not universally welcomed initially, especially in the 1980s and 1990s when NZAS’ safety standards were rising far above the accepted norm of New Zealand industry, but commercial expedience meant that contractors either reluctantly or enthusiastically complied with the smelter’s requirements.

...the local contracting firms in town would have been the first to agree that we were going [out] there and imposing our safety systems on them – and they used to get quite snarly about that... [6]

Eventually, contractors raised their own standards to a level on a par with NZAS.

It’s probably also a sign of the times that you see that happening with other industries in town as well and they’re really starting to push a lot of safety stuff as well. [20]

...whereas a few years ago, you walk in there and there’d be people working under overhead loads and all this sort of stuff – but you just don’t see that stuff now... [6]
Many people commented on how the safety standards and general culture had had a significant impact on their community and personal lives outside the workplace. For instance, seatbelt use in all vehicles is compulsory on site at Tiwai Point without exception, and one person related an anecdote about attending a conference at a North Island industrial complex…

...they shuttled us around on buses – so first thing you do, you climb on the bus and you just went automatically ‘seatbelt on’ and it’s like – nobody else had their seatbelt on – it was just an automatic reaction. Yeah, so it’s just something that I guess in a sense, seeps in… [20]

Others – even those who had been critical of the smelter operation through much of the interview – revealed a pride in what the smelter had achieved, and what it meant to them personally.

...when I look at myself and the changes that I’ve made personally from when I first started to now, it’s like chalk and cheese you know, and now everything that I do I think, “Shit, am I going to get hurt if I do it this way?” [23]

5.12 Individual behaviour

The 1990s focus on ergonomic factors as the basis for injury prevention frustrated some people. Many thought that the behaviour of individuals was at least as important as ergonomic factors in injury causation and they welcomed the more recent emphasis on human behaviour.

...If it’s something where we say, “Well shit, that might actually be behavioural – more behavioural than anything”, then we’ve gotta be big enough to deal with that too which again – in the last couple years started dealing with that rather than putting another handrail up or another bloody sign up or another whatever – it’s your responsibility… [3]
Some thought that no system would be effective unless individuals took ownership of the system and integrated it into their personal behaviour.

\[\text{So it's people related, so once you've got the people with the belief – everyone believes that it is achievable; and people are following systems are in place to protect them and it'll work – definitely. And we know it will work because we're very close.} \text{[7]}\]

\[\text{...it's the behaviour that you worry about. You know, certainly you worry about the costs as well, but you've got to worry about the behaviour.} \text{[16]}\]

Some participants referred to the assertion that 95% of accidents are caused by human behaviour. This percentage\(^{29}\) appears to have originated in the ‘Safe Work’ data derived from the DuPont safety management material.

\[\text{95% of your accidents or incidents are generally caused by behaviour, and that can be how it's been presented by the management team i.e. the crew leader that controls the team or the superintendent of that particular department or general behaviour.} \text{[1]}\]

However, one interviewee thought that the idea that 95% of injuries result from human behaviour, was not correct.

\[\text{...in the mid-2000s there was, there was a huge focus on that – that 96% of incidents are caused by humans, and I think that has been – around the world – that has been blown out of its original context and completely misunderstood by a lot of people who actually use it...} \text{[21]}\]

\[\text{...they thought 96% of the time if [ ] crashes her car it's because she's done something wrong, and that is not what it means. It means that 96% of all incidents have some kind of human factor in them...} \text{[21]}\]

\(^{29}\) The actual percentage stated in the ‘Safe Work’ data is 96%.
5.13 Enablers, moderators, and interventions – a summary

Further analysis resolved the 11 themes into ‘enablers’, ‘moderators’, and ‘interventions’ as defined in section 3.7. This further division was required to identify the effect that each theme had on the ultimate interventions. For instance, total quality management could not be regarded as a safety intervention, yet it enabled other direct interventions to be introduced. Similarly, ‘ergonomic focus’ could not be regarded as a direct intervention, yet it moderated the effect of the ultimate safety interventions. The identified enablers, moderators, interventions, and outcome are set out in Table 11.

Using these distinctions and carefully considering their relationship, resulted in the identification of one more intervention. The TQM cycle of improvement model was found to be influential in the prevalent NZAS practice of incident investigation and analysis. The qualitative research also revealed that at NZAS, incident investigation has had a distinct ergonomic focus. ‘Incident analysis’ was therefore added as a further direct safety intervention.

<table>
<thead>
<tr>
<th>Enablers</th>
<th>Leadership</th>
<th>Total quality management</th>
<th>Ownership and governance</th>
<th>Employment Contracts Act (1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderators</td>
<td>Ergonomic focus</td>
<td>Work organisation</td>
<td>Culture</td>
<td>Individual behaviour</td>
</tr>
<tr>
<td>Interventions</td>
<td>Automation</td>
<td>Proprietary interventions</td>
<td>PPE</td>
<td>Incident analysis</td>
</tr>
<tr>
<td>Outcome</td>
<td>Lost-time Injuries</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In summary, the research identified four enablers:
Leadership – as well as the initial impetus to begin the quest for reduced injuries on site, leadership at all levels set directions such as the ergonomic focus, changes in work organisation and individual behaviour; and also had a high level of input into automation decisions and incident investigation accountability.

TQM - the cycle of improvement methodology underpinned the relentless incident investigation methodology, which was also identified as a key intervention.

Ownership and governance – commissioning and enabling automation required significant capital and will to initiate and perpetuate.

The Employment Contracts Act (1991) – the act enabled the reorganisation of work practices and allowed leaders more flexibility to introduce goal-oriented interventions.

Four moderators were also identified:

- Ergonomic focus – a directive that appeared to have had a major effect on choice of interventions: automation, PPE, and an emphasis on plant and work conditions in the incident investigation methodology.
- Work organisation – a flexibility that facilitated the incident investigation process in particular.
- Culture – the pervading attitude to safety by NZAS staff as it related to individual behaviour and proprietary interventions.
- Individual behaviour – also a significant consideration in self-efficacy and its effect on proprietary interventions.

Four interventions were identified:

- Automation – the process of eliminating or isolating hazards.
- Proprietary behavioural interventions – programmes intended to alter behaviour in the workplace.
- PPE – used to isolate the hazard.
- Cycle of improvement incident investigation – the cyclical process of constant improvement based on analysis of historical incidents.

Figure 15 highlights the relationship between the enablers, moderators, enablers and the ultimate goal.

![Figure 15. NZAS enablers, moderators, interventions and goal.](image)

The primary focus of Figure 15 is to illustrate the direct effect of the interventions on the goal (dark arrows), and the contributory effect of the enablers and moderators on those interventions (white arrows). A simple figure showing the four interventions affecting the goal would not explain their efficacy. For example, in examining the automation intervention, plant upgrades were directly enabled by NZAS owners and its leadership; however, this leadership was also moderated by an ergonomic focus, prioritising eliminating or isolating hazards through automation.
Some relationships work in both directions. For example, the ‘cycle of improvement’ incident investigation process, while moderated by an ergonomic focus, also recommends specifications for PPE and automation, and ‘cycles upwards’ to make recommendations for work organisation, individual behaviour, and leadership.

Despite the complexity of these relationships, it is important to distinguish the interventions from the enablers and the moderators. It is the interventions that have the direct effect on the ultimate goal. Enablers and moderators on the other hand, do not have a direct effect on the goal, but do influence the success (or otherwise) of the interventions through facilitation (enablers), or influencing their efficacy (moderators).

5.14 NZAS interventions and goal theory

Section 2.4.6 reviewed goal theory and identified the established drivers for a goal to be successful. Since the central theme to NZAS’ safety success has been their slogan ‘Our Goal is Zero’, an important component in the description of NZAS safety success must be an analysis of their interventions in relation to the pursuit of their goal. An analysis of the qualitative evidence in comparison to the established principles of successful goal-related activity is set out in Table 12.
Table 12. Goal theory characteristics and NZAS evidence.

<table>
<thead>
<tr>
<th>Characteristics of successful goals:</th>
<th>NZAS evidence:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A goal may serve as a benchmark against which performance feedback can be evaluated.</td>
<td>NZAS asserted that the only absolute definition of a ‘safe’ worksite was one that had zero injuries on site – and having a goal of zero injuries is the ultimate benchmark. The potential difficulties with using LTI’s as a performance measure have been noted and discussed, but as a benchmark, consistently recording zero carefully specified LTI’s would indeed represent the benchmark for an achieved goal.</td>
</tr>
<tr>
<td>Conscious goals can constitute an intervention on a measureable outcome and the power of the ‘self-fulfilling prophecy’ has been well established.</td>
<td>While variation in the way NZAS staff viewed the efficacy of interventions was noted, all staff were conscious of the goal and enthusiastically supportive of its pursuit.</td>
</tr>
<tr>
<td>Specific, difficult goals consistently lead to higher performance than urging people to do their best.</td>
<td>Exhortations to ‘be safe’ were not acceptable at NZAS. Absence of LTI’s represented a pragmatic and unambiguous target.</td>
</tr>
</tbody>
</table>

**Effectiveness indicators:**

| Goals serve a directive function, avoiding distraction from goal-irrelevant activities | It has been noted above that Deming’s cycle of improvement was used in incident analysis pervasively. The goal of recording zero LTI’s was a compelling directive – with little room for distraction. |
| Goals have an energising function, leading to greater effort than low goals. | Every level of management, from GM to crew leaders, was accountable for injuries suffered by subordinates – and all understood the difficulty of preventing injury in such a hazardous environment. Their motivation for success has been kept at a high level. |
| Goals affect persistence, with difficult goals often inducing prolonged effort. | The effort applied to injury prevention has been unrelenting – the plant operates without pause, and successive leaders have sought to improve interventions to approach the unilateral goal in a more effective manner. |
| Goals affect action indirectly by leading to the use of task-relevant knowledge or strategies. | NZAS personnel sought solutions to hazards from a wide range of TQM and engineering sources, with a pragmatic attitude to applying the hierarchy of controls. |

**Goal moderators:**

| Commitment | Since the ‘pivot point’ moment in the 1980s of the GM ‘putting his flag in the sand’ over |
workplace injuries, all GMs and owners have shown their commitment to injury reduction through both declaration and resource allocation.

**Feedback**

A large board at the front gate has displayed the yearly tally of LTI’s. The negative connotations of this tally have been noted above, but staff were never unaware of the current status.

**Task complexity**

While they may have differing views on the interventions used, all staff understood the complexity and the aspirational nature of the goal.

The characteristics identified in the literature for the achievement of a chosen goal all appear to be also be present as characteristics of the NZAS worksite.

### 5.15 Evaluative summary

The qualitative results above described the four key NZAS interventions identified:

1. Automation
2. PPE
3. Incident investigation and analysis
4. Proprietary behavioural interventions

These interventions were plotted on the hazard intervention effectiveness matrix in Figure 15.
The automation intervention is exclusively ergonomic and primarily eliminating and is therefore largely plotted in quadrant 1. Quadrant 1 is the most effective quadrant since it describes interventions that are both eliminating and ergonomic. Automation may also be isolating only, so it is also plotted into quadrant 2.

Section 5.7 Personal protective equipment (PPE) described the NZAS distinction between ‘isolating PPE’ and ‘risk mitigation PPE’. At NZAS, intervention using isolating PPE is regarded as ergonomic and has efficacy across the isolation hierarchical control, so isolating PPE is plotted across quadrants 1 & 2. The placement of the isolating PPE intervention here is regarded as ergonomic in accordance with NZAS’ practice portrayed in Figure 14 above.
NZAS incident investigation is plotted across quadrants 1 & 2, and also has an acknowledged behavioural input. However, it has been established above that NZAS incident investigations preferentially focus on ergonomic solutions wherever possible, and while behaviour may be important to understanding the incident, it is generally regarded as a lesser consideration. This intervention is nevertheless closest to the egocentric quadrants.

It has also been demonstrated above that behavioural intervention can never eliminate a hazard. The proprietary behavioural interventions are therefore primarily plotted in the 4th quadrant. Because companies often attempt to use human behaviour to isolate a hazard, e.g., a sign stating “Do not go near this machine”, this intervention is also plotted into the 3rd quadrant.

In 2001, NIOSH initiated a programme to redress the lack of safety intervention models (Goldenhar, et al., 2001). In this initiative, Goldenhar, et al., (2001) specified that an intervention must meet three criteria to be evaluative: 1) the intervention should be operating or have been implemented as intended; 2) the intervention should be relatively stable; 3) the intervention should seem to be achieving positive results.

Therefore, as a final observation on NZAS safety, the identified interventions are tabulated against these criteria in Table 13.
Table 13. NZAS interventions and evaluative criteria.

<table>
<thead>
<tr>
<th>Implemented as intended</th>
<th>Automation</th>
<th>PPE</th>
<th>Incident investigation</th>
<th>Proprietary behavioural interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>Yes – since the 1980s</td>
<td>Yes – since the 1980s</td>
<td>Inconsistent</td>
</tr>
<tr>
<td>Relatively stable</td>
<td>Yes</td>
<td>Yes – since the 1980s</td>
<td>Mostly</td>
<td>No</td>
</tr>
<tr>
<td>Seem to be achieving positive results</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Using these criteria, the rating of the interventions remained the same as plotted on the hazard intervention effectiveness matrix:

1. Automation – criteria all positive
2. Isolating PPE – criteria all positive since the 1980s
3. Incident investigation – criteria mostly positive since the 1980s
4. Proprietary behavioural interventions – criteria inconsistent

The LTIFR graph from the quantitative results was then overlaid with three sets of qualitative data relating to 1) major capital projects, 2) ownership and GMs, and 3) TQM, legislation, and safety interventions. These are represented in Figures 16, 17, and 18 respectively.
Figure 17. NZAS LTIFR overlaid with major capital projects.
Figure 18. NZAS LTIFR overlaid with ownership and General Manager tenure.
Figure 19. NZAS LTIFR overlaid with TQM, legislation and safety interventions.
The association between the LTIFR and the criteria represented by the overlays was impossible to establish definitively, even with more precise reference to the background data. There were several reasons for this. Firstly, the beginning and end of the overlaid criteria were usually impossible to determine with any absolute certainty. A major upgrade necessarily involved a significant period of progressively increasing staff and contractors before the project commencement and graduated commissioning to completion. Similarly, changes of ownership often involved several years of transition. GMs typically took some time to initiate their new styles of management or unique interventions. The initiation of TQM methods and safety interventions were also usually introduced inconsistently across the many production areas on site. The interview responses above also described how when one safety intervention was officially superseded by another, elements of the original intervention often continued in a modified form in some areas of the plant, or were subsumed into the succeeding intervention. Other possible effects such as changes in political or industrial influences, if they had featured in the qualitative research, would have had similar analytical constraints. Secondly, section 2.5, (Evaluation of interventions), emphasised the need for caution in assessing causal phenomena, pointing out that many interventions are multi-factorial (Zwerling, et al., 1997), complex (Goldenhar & Schulte 1994), and that the cyclical design and management of ongoing intervention programmes should be an important part of any research outcomes (Goldenhar et al., 2001).

Notwithstanding these reservations, the following observations could be made about Figures 16-18. In Figure 16, the first major upgrade coincided with the highest rates of injury in the smelter’s history, as measured by NZAS LTIFR. This suggests that the ‘peaks’ represent LTI’s arising from the construction process rather than the smelting process. The third highest LTIFR ‘peak’ also coincided with the second major upgrade, although the fourth ‘peak’ does not, and is unexplained by any of the factors examined in Figures 16-18. The poorest safety performance of the past two decades also coincided with the third major NZAS plant upgrade.
In Figure 17, the most dramatic sustained decrease in the LTIFR coincided with the ownership of Conzinc Rio Tinto Aluminium (CRA), and the tenure of the 7th GM – the same GM who was quoted by a participant in Section 5.5 below:

“No, this is not acceptable anymore; we’re not going to be hurting people” [12]

Figure 18 illustrates that introduction of the majority of the interventions identified in Table 9, section 5.1, were introduced from 1990-2011. As a general observation, the introduction of TQM, the Employment Contracts Act, and the ergonomic approach appear to relate to a relative increase in LTIFR. Although low in comparison to earlier periods in NZAS history, this rise culminates in the third major NZAS plant upgrade noted above. The continuation of incident investigation from the ergonomic approach into the Taproot® methodology, the introduction of the ergonomically-based NOSA certification, and the proprietary interventions, all appear to coincide with the consistently low period of LTIFR from 1998-2011.
Chapter Six: Discussion

6.1 Key results

This case study demonstrated that NZAS has achieved a significant reduction of lost-time injuries over its 40-year history of operating a complex and hazardous worksite. The inductive triangulation process using quantitative and qualitative data in this case study confirmed the significantly decreasing trend of LTI as demonstrated by the LTIFR over the 40-year operation of NZAS. In particular, the use of a mixed methods study was able to corroborate the quantitative evidence of a current low LTIFR, using qualitative data. This qualitative data confirmed that serious lost-time injuries were very rare in recent years in a hazardous worksite where once they had been frequent. Any skepticism that serious lost-time injuries were being concealed or under-reported to artificially improve the safety statistics was dispelled by the information from staff interviews. Even long-serving staff who were disaffected by contemporary problems at the smelter and had many criticisms of NZAS operation, were unequivocal when discussing the inability of the company to hide lost-time injury. There was confirmation that minor near misses often went unreported, but research participants all believed that lost-time injuries and serious potential incidents were typically recorded and addressed.

The qualitative research also contributed rich data to an understanding of how this dramatic drop in LTIFR had eventuated. The discourse analysis revealed a three-tier process of continuing intervention that appeared to constitute the ongoing process of cumulative intervention called for by Goldenhar, et al., (2001). Four identified interventions were described. For each intervention, events or conditions that enabled their introduction and conditions that modified their positive efficacy were also identified. The relationships between the enablers, modifiers, interventions, and the ultimate goal, were further explored using goal theory and evaluated using this study’s hazard intervention effectiveness matrix.
6.2 Strengths and limitations

The researcher’s access to NZAS’ complex workplace was a notable strength of this research project. The confidence of NZAS management that this study would be conducted in good faith was founded in the researcher’s long, mutually beneficial association with the smelter. The study was therefore a unique opportunity to affirm and describe NZAS’ remarkable safety achievement. However, as outlined in section 3.2, the researcher’s association with NZAS was also a possible source of bias. The participants in the qualitative research were self-selected, and the codification of the interview transcript was performed solely by the researcher. In addition, the historical LTI data cannot be validated. These may be seen as a limitation of the study.

The selection of an historical intrinsic case study as the research mode also presented an inherent limitation since it relies on retrospective data, rather than more robust strong prospective data. Further, data from other, similar companies were not available for comparison. However, the real-world evidence presented herein may contribute to a better understanding of industrial safety in general, and initiate opportunities for further enquiry. In particular, the descriptive distinction between enablers, moderators, and interventions has been shown to be a useful construct for the analysis of safety interventions. The development of a hazard intervention effectiveness matrix may also provide opportunities for further research into assessment of safety intervention efficacy.

6.3 Relationship of key interventions to the literature

6.3.1 Automation

Interview participants overwhelmingly identified automation of the smelter over its 40 years of operation as the most important reason for the decrease in acute injuries. Logically, it follows that if a hazard is removed through automation, then it ceases to be a hazard. This is entirely consistent with the requirement of New Zealand’s HSE Act (Health and Safety in Employment Act, 1992) and other OECD countries’ safety legislation. They all proscribe the elimination of hazards in the first instance. The
overarching legislation and the ongoing programme of automation at NZAS are clear applications of the hierarchy of control framework outlined in section 2.4.4. It is important that automation is regarded as an intervention, for while some may see a worksite as a static model and interventions as mere manipulations of the existing plant and workforce, elimination of the actual source of the hazard must always be the first consideration. Ellenbecker, (1996) points out that considering a hazard as a product of a static worksite and therefore difficult to alter, is a mistake. Productivity, return on investment, feasibility, pragmatism, and social outcomes may all feature in any decision to automate, but when safety is prioritised, hazard elimination by replacing people’s exposure to that hazard through automation is the ultimate intervention.

Flin & Yule’s (2004) review of industrial safety literature for leadership research summarises two leadership models: transformational and transactional leadership. Both models appear to be highly characteristic of NZAS leadership. Transformational leaders provide inspiration, question assumptions and encourage others to approach problems from many different angles (Flin & Yule, 2004). The initial drive for safety at NZAS originated from a 1980s GM who demonstrated transformational leadership by refusing to accept the inevitability of injuries on site. Successive GMs have continued the transformational style, introducing the ambitious goal of zero injuries on site, and initiating interventions to achieve that goal. Once the goal had been established, NZAS leadership appears to have delegated a requirement for strong transactional leadership to its superintendents and crew leaders. Transactional leadership requires vigilance and monitors performance to gain compliance from subordinates. Together, transformational and transactional leadership can produce an augmentation effect which both articulates shared goals and ensures compliance with set performance standards (Flin & Yule, 2004).

The enablers necessary to initiate automation at NZAS were identified as ownership/governance, and leadership. Successive owners have provided the resources necessary to enable significant plant upgrades; while leaders from the 1980’s until the present have provided transformational leadership, enabling the application of resources towards goal-oriented interventions. Ongoing GMs have also been the conduit between
worksite identification of the need for automation and the investment of resources from the owners. The key moderator for this leadership conduit was seen as the ergonomic focus on safety that pervaded the smelter throughout the late 1980s and the 1990s. This ergonomic focus may have originated in the transformational leadership characteristic of approaching problems from many different angles (Flin, et al., 2004). This characteristic also echoes the need to consider the multifactorial nature of a complex industrial site from all perspectives when assessing the efficacy of interventions (Zwerling, et al., 1997; Goldenhar & Schulte, 1994).

In preference to the former blaming of individuals’ actions for safety breaches, management moved to address the plant and environmental conditions perceived to have made the injury possible. Haddon’s (1980) concept of linking of epidemiology, energy exchange, and injury was introduced to NZAS by Australian consultants. It was followed by the introduction of the South African NOSA equipment rating system in the 2000’s. Acceptance of the ergonomic rather than the egocentric focus for injury etiology by a succession of GMs from the late 1980’s onwards appears to have intensified the automation intervention as a means of eliminating hazards.

6.3.2 Personal protective equipment (PPE)

Similarly, the NZAS identification of isolating PPE as equivalent to any other means of hazard isolation manifests the ergonomic rather than egocentric focus of NZAS leadership. The high levels of isolating PPE specification and compliance requirements reflect a transformational leadership (enabler) moderated by an ergonomic rather than egocentric outlook. While PPE is generally regarded as a means for hazard minimisation or attenuation in occupational health and safety (Aw, Gardiner & Harrington, 2008), at NZAS, isolating PPE is considered simply as a means of isolating the worker from the respective energy forms distinguished by Robertson (1992). The ergonomic approach is particularly evident in the downstream effect of NZAS incident investigation, where the use of isolating PPE is regarded as a means of isolation of the worker from an energy source equivalent to any other guard or barrier. For example, in the view of NZAS the hazard presented by the dropping of a heavy tool may most simply be isolated by the
compulsory wearing of steel-capped safety boots. This is another manifestation of the hierarchy of control methodology (Health and Safety in Employment Act, 1992), with elements of the Haddon matrix also evident (Haddon, 1980; Runyan, 1998, 2003).

The NZAS interpretation of the isolating PPE intervention is nevertheless indicative of the literature dichotomy between the ergonomic and egocentric approaches, identified in section 2.2. Many valuable papers have been published on overcoming workers’ reticence to wear PPE, or the inappropriate use of PPE (Feeney, 1986; Holmes, Triggs, Gifford, & Dawkins, 1997; Lombardi, Verma, Brennan, & Perry, 2009; Sorock, Lombardi, Hauser, Eisen, Herrick, & Mittleman, 2004). These papers are primarily egocentric in focus, for they are essentially advising on means to alter human behaviour to promote PPE usage. However, the transformational leadership at NZAS, moderated by an ergonomic focus, initiated research into the exact energy characteristics of each hazard on site. Where the hazard could not be eliminated, precise specifications for isolating PPE were established in order to isolate the NZAS worker from the hazard. For example, aluminium smelting presents potential for both acute and chronic respiratory injury and disease through the presence of dust and fumes (International Primary Aluminium Institute and The Aluminium Association, 1997; O'Donnell, et al., 1989; O'Donnell, 1995). Previous use of paper masks offering limited respiratory protection was replaced by filtered and positive-pressure masks specified for exposures higher than those on site at NZAS. These are ergonomically-based interventions initiated by NZAS to prevent worker exposure to unintended energy exchange. It was noted in section 6.3.1 that, once the goal of zero incidents had been established by NZAS transformational leaders, the role of monitoring performance and achieving compliance was delegated to superintendents and crew leaders, using transactional leadership styles. Incorrect wearing of PPE has been a cautionary and ultimately dismissible offence at NZAS.

In general industry, appropriate wearing of PPE or otherwise is usually regarded as a function of human behaviour. However, Locke & Latham (2002) identified that goal specificity decreases variation in performance by reducing the ambiguity about what is to be attained. Moreover, due to the high specifications of NZAS isolating PPE within their
hazard isolation programme, variation of PPE usage, or ‘human error’, is a minor consideration in hazard isolation. The transactional leadership in place relies very little on motivating workers to wear PPE, since no alternative is possible to ensure the specified protection.

The egocentric versus ergonomic foci will continue to characterise differing perspectives of safety professionals. In a consideration of the plotting of isolating PPE within the hazard intervention effectiveness matrix, section 5.15 pointed out that in the context of the transformational leadership initiation, the precise empirical identification of hazards, and the highly specified PPE response, NZAS use of isolating PPE can primarily be characterised as ergonomic.

6.3.3 Incident investigation

Comprehensive incident investigation has been undertaken for every significant injury or near miss since the late 1980s. These investigations use the Haddon matrix (Haddon, 1980; Runyan, 1998, 2003) as a framework for analysis of each incident. However, tools introduced by the total quality management methodology also became important in incident investigation from the late 1980s. In particular, the TQM methodology’s cycle of improvement (Evans, 2008; Foster, 2007) became an enabler for effective incident investigation across site. The cycle of improvement ethos took incident investigation beyond a simple analysis of the incident. Using the cycle of improvement model in incident analysis led to recommendations which were duly implemented, monitored, and institutionalised when found to be effective. Leadership also became an enabler for this process to succeed, for without leadership commitment across site, recommendations from investigation recommendations would not have been as effective (Flin & Yule, 2004). Another unanticipated enabler, the Employment Contracts Act, (1991), also emerged from the qualitative research. This Act enabled reconstituted hierarchical and interdepartmental relationships on site, allowing significant changes in work organisation.
Work organisation therefore became a moderator of incident investigation. The effect of causal attribution (DeJoy, 1994; Gray, 2009; Gyekye, 2010) identified in Section 2.3.3 has been minimised by a policy of frequently using horizontally and vertically integrated incident investigation teams. Team members are often drawn from across different departments and from differing organisational levels. For instance, a relatively low-skilled operator from a totally unrelated department, albeit with some training in investigative methodology, may investigate an incident from an unfamiliar department alongside the manager of that area. Other elements of work organisation such as safety audits, safety-oriented policies and alternate procedures became unencumbered by conflicts over worker allowances, thereby moderating the cycle of improvement in a positive manner.

The transformational leadership change from an egocentric to an ergonomic focus at NZAS has also been a moderator on incident investigation. In particular, in the late 1980s, Australian consultants introduced the ‘essential factors’ model of incident analysis which treats human behavior as but one element of any injurious event. Heinrich’s (1931,) focus on human error as the most likely ‘cause of the accident’ was given little weight in NZAS incident investigations after the late 1980s. Similarly, Reason’s (1990, 1997, 1998, 2000; Reason, et al., 2006) ‘Swiss cheese’ model of incident investigation appears not to have been used at NZAS. This may be due to the egocentric focus of much of Reason’s work when compared to NZAS’ ergonomic paradigm. It is more likely however, that the ‘Swiss cheese’ model’s reliance on a chance alignment of opportunities for the incident to progress is inconsistent with the ‘essential factors’ model of a predictive sequence of critical events.

### 6.3.4 Proprietary behavioural interventions

Section 5.9 described a number of proprietary interventions introduced from the late 1990s. These were primarily based around the intended modification of individual and team behaviour. In common with the other interventions, transformational leadership was a clear enabler for these proprietary behavioural interventions. Without leaders selecting
these interventions and facilitating their introduction, they simply would not have been launched.

Culture and human behaviour were identified as moderators of these behavioural interventions. Many writers have pointed to the difficulties in defining ‘culture’ in an organisation (Cooper, 2000; Flin, et al., 2000; González-Romá, Lloret, Peiro, & Zornoza, 1999; Zohar, 1980, 2000). The qualitative research also revealed the many different uses of the term by NZAS staff, with participants often not distinguishing between organisational, local or national culture. The New Zealand, Southland, or NZAS ‘culture’ was generally felt to have either a positive or negative moderating effect over safety interventions. For instance, some of the training media accompanying the STOP programme was regarded as inappropriate to the local ‘culture’ and disparaged accordingly. However, one participant who had doubts about the cultural fit and efficacy of several programmes, also said that he was unwilling to reject them because he considered that some parts of each of the programmes might contribute to fewer accidents. This is suggestive of Cooper’s (2000) work which asserts that a focus on the ‘product’ of safety culture was the most important aspect of a study ‘culture’. The decreasing injuries result is the ‘product’ regardless of the perceived or actual efficacy of any one proprietary intervention (Cooper, 2000).

As a moderator of these proprietary behavioural interventions, the effect of (individual) human behaviour is even more difficult to determine. Reason (1990, 1997, 1998, 2000; Reason, et al., 2006) and Rasmussen (1982, 2003) have added much to the understanding of how people interact with their workplace, but some writers argue that the means by which behaviour can be changed within a workforce have not been demonstrated (Robertson, 1992; Wagenaar, 1998). Furthermore, Gray (2009) identifies the DuPont ‘STOP’ programme discussed in section 5.9.1 as an example of the ‘responsibilisation’ of safety, attributing individual’s ‘human error’ as the frequent cause of incidents. It is perhaps indicative of NZAS’ ergonomic focus that participants have generally rejected or adapted many of these proprietary behavioural interventions that do not fit the overall pursuit of their goal.
6.4 Pursuit of the goal

Ultimately, the only absolute definition of a ‘safe’ worksite is one that has zero injuries on site: the very goal set by NZAS more than twenty years ago. Indeed, in 2010, NZAS celebrated having operated for twelve months without a single LTI\textsuperscript{30}. However, the following year seven LTI’s were recorded, and annual LTI’s have varied between one and seven for the twelve years to the end of 2011: the goal has not been reached. Nevertheless, the examination of LTIFR over NZAS’ 40 years of operation reveals an extraordinary reduction and represents an outstanding achievement.

Locke and Latham’s (2002) four characteristics of goal effectiveness all appear to have been met at NZAS, either consciously or intuitively. NZAS’ use of their slogan ‘Our Goal is Zero’ provides an unequivocal direction for safety on site (Rothkopf & Billington, 1979, cited in Locke and Latham, 2002). Failure to consistently achieve the aspirational goal of zero injuries frustrates NZAS staff, but also energises them to pursue the goal more assiduously (Bandura & Cervone, 1986, cited in Locke and Latham, 2002). The pursuit of a difficult goal often induces prolonged effort (LaPorte & Nath, 1976, cited in Locke and Latham, 2002). The NZAS goal was introduced more than 20 years ago and has yet to be consistently achieved, but the persistence of successive GMs and other NZAS leaders has brought LTI numbers tantalisingly close to zero. Health and safety professionals at NZAS have repeatedly sought task-relevant knowledge from around the world to confront persistent safety issues on site, in pursuit of their goal\textsuperscript{31} (Wood, et al., 1987, cited in Locke and Latham, 2002). Other indicators of successful goal pursuit such as public commitment to the goal (Hollenbeck et al., 1989), a belief that the goal can be attained (White & Locke, 2000), and feedback on progress to all personnel (Bandura & Cervone, 1986), were all represented in this study’s qualitative research of NZAS safety.

\textsuperscript{30} The zero LTI was not for the calendar year 2010 – one LTI was recorded late that year – but for a full 12 months from late 2009 until late 2010, there were no LTI’s.

\textsuperscript{31} For instance, working at heights equipment and methodology was first introduced to New Zealand by NZAS, and is now commonplace throughout the country.
6.5 Final observations

This research project has highlighted the dichotomy in the literature between those who advocate ergonomic means of injury prevention through the control of energy inherent in the industrial process, and those who advocate egocentric means through human behaviour change. It also described four interventions that appear to be the key drivers for NZAS’ success, describing the three ergonomic interventions as being the most efficacious. The study identified the NZAS safety transformational shift from the egocentric ‘blame the worker’ style of management, to the ergonomic ‘change the work environment’ as the prime reason for NZAS’ success.

The notion of ‘human error’ as a driver for (the lack of) industrial safety is intuitively attractive, but not immediately useful in the hierarchy of control preventive methodology. Human behaviour may, further down the hierarchy, contribute to isolating or minimising a hazard through proscribed or voluntary avoidance, but it is axiomatic that a significant hazard can never be eliminated through a programme of behavioural change: if a person and a significant hazard are present in a workplace, no human behaviour can eliminate that hazard. Furthermore, the theory of attribution has been demonstrated as a powerful motivator for employers to attribute blame to workers for worksite injury (DeJoy, 1994; Gray, 2009; Gyekye, 2010).

This research project has found few case studies or randomised trials in the literature on reduction of acute injury in a large industrial plant. Discussions on the polarisation between the ergonomic and the egocentric approaches to injury prevention are also few and far between in peer-reviewed literature. This study may provoke some further discussion on this issue, particularly in the light of contemporary safety concerns by employers and employees alike. For instance, section 2.3.2.1 quoted the HSE Act (Health and Safety in Employment Act, 1992) which requires employers to take “all practicable steps to ensure the safety of employees while at work”. During the course of conducting this case study, the Royal Commission on the Pike River Coal Mining Tragedy
considered one of New Zealand’s greatest industrial tragedies of recent times\textsuperscript{32}. The New Zealand Council of Trade Union’s (CTU) submission to the Royal Commission addressed the implications of the term ‘all practicable steps’ inasmuch as it relates to the discretionary expenditure of significant capital on eliminating hazards in the workplace, noting:

“The CTU’s concern is that an operator, such as Pike River Coal Limited, is currently able to embark on a high risk coal mining operation without any prior consent process to determine whether it has the financial capacity and expertise to put in place the necessary protections for the health and safety of its workers and other persons, and then may have the benefit of having the cost of undertaking a “practicable step” as a balancing factor” (Wilson, 2012).

While the CTU’s submission (Wilson, 2012) also refers to the case law underpinning the term ‘all practicable steps’, it must be acknowledged that the process of weighing the potential risk of occupational injury against the often significant capital required to eliminate or isolate the risk, is ill-defined and imprecise, allowing differing interpretations of risk versus cost to be applied. In contrast to the Pike River Mining Company Limited, NZAS’ practice of virtually continuous upgrading of plant in response to incident investigation appears to have leant heavily towards the amelioration of the risk of injury, virtually regardless of the capital expense. Further, hazard elimination appears to have been incorporated into any capital redevelopment aimed at productivity and profitability gains.

However, while diminishing the role of human behaviour change in injury prevention, by definition, the ergonomic paradigm will still consider the role of people in the workplace. Barling et al., (2003) demonstrated that high-quality jobs affect occupational injuries directly through the mediating effects of job satisfaction. This may be relevant at NZAS through the self-efficacy of the ‘If it’s not safe, don’t do it that way’ motto, which gave

\textsuperscript{32} The Pike River coal mine on west coast of New Zealand’s South Island exploded on 19 November 2010, killing 29 miners.
workers increased ergonomic control over their allotted tasks. Similarly, a flatter organisational structure appears to have given individuals more access to decision making processes relating to their own safety. Moreover, the effects of the theory of attribution appear to have been diluted in individuals at NZAS through the emphasis on ergonomic rather than egocentric factors in the process of incident investigation. The stigma of blame and culpability is avoided. This is turn, appears to influence the efficacy of the proprietary interventions and effective incident investigation.

Chapter Seven: Conclusion

7.1 Research conclusion

The aluminium smelter at Tiwai Point in New Zealand is an industrial site where potentially catastrophic hazards are confronted 24 hours a day, 365 days a year; and yet, its safety record has improved significantly over its 40 years of operation. From the early years of the smelter’s operation, when workplace injuries were frequent and tacitly accepted, NZAS has worked assiduously to reduce the incidence of injuries on site. Lost-time injuries have reduced from 682 for the five years 1975-1980, to 24 for the five years 2005-2010. This has been investigated within this research project by analysis of composited NZAS records and field data, and a programme of semi-structured interviews with NZAS staff. The research confirmed the trend of declining LTIFR over the 40-year period examined, and has established that under-reporting of LTI was not likely to be an explanatory factor for this decline.

The qualitative research component also identified and described the key enablers, moderators, and interventions at NZAS through which the safety improvement was engineered. These components were positioned within the context of the available literature, and the relationship between each component was described. Four interventions were identified and ranked in order of their perceived efficacy:

1. Automation
2. Personal protective equipment
3. Incident investigation – cycle of improvement

4. Proprietary behavioural interventions

The ranking of these interventions was achieved by deductive analysis, and by devising a hazard intervention effectiveness matrix using a hierarchy of control vector and an ergonomic/egocentric vector. The progress of NZAS towards their goal of having zero injuries on site was also assessed and found to be consistent with the established principles of goal theory. In addition, the identified interventions were evaluated against the NIOSH evaluation criteria which provided further confirmation of their efficacy ranking.

Frameworks and strategies for intervention in industrial safety were identified. Theoretical frameworks for assessing the efficacy of safety interventions are limited, and existing intervention research is often based on individual researchers’ intuition and experience rather than on theory and evidence (Goldenhar, 1994; Shannon, 1999). However, this research project has demonstrated that a mixed method case study can identify the efficacious safety interventions in a major industrial plant, and deductively explain the factors that enable and moderate those safety interventions. A deductive hazard intervention effectiveness matrix has also been demonstrated to rate the relative effectiveness of identified interventions within a literature-based theoretical context.

7.2 Recommendations

7.2.1 Recommendations specific to NZAS

NZAS’ recent record of injury reduction is exemplary. This research project recommends continuation of NZAS’ combined safety interventions as described, with an expectation that NZAS’ goal of having zero injuries on site will ultimately be met. However, leadership must continue its progressive attitude of introducing whatever new interventions are regarded as necessary for the achievement of that goal. NZAS’ present ergonomically-focused, hierarchy of controls methodology exemplifies a successful model for injury reduction in a large industrial plant.
However, it is important to note that some misgivings were recorded about the perceived ‘gotcha’ aspect of some of the proprietary behavioural interventions. Staff sometimes felt that they were being watched for unsatisfactory behaviours and blamed accordingly. In addition, while staff were proud of the smelter’s safety improvement, some felt that the emphasis on LTI as a measure of safety was a negative factor in the workplace, particularly when it was linked to a staff bonus system. Inclusion of lead-time indicators such as a positive performance indicator (PPI) (Massey, 2007), in addition to the LTI measurement, could provide a clearer picture of safety performance on site. For instance, the results of a formalised audit schedule, shown to the researcher by the Safety and Loss Superintendent, could be published internally to show the progressive improvement in safety compliance.

7.2.2 Recommendations specific to other large industrial plants

Other companies can learn from NZAS’ success. In general, the smelter’s unrelenting focus on an unequivocal goal of having zero injuries on site, while not yet fulfilled, has demonstrated that a significant reduction in lost-time injuries is possible. Specific, difficult goals consistently lead to higher performance than urging people to do their best (Locke & Latham, 2002). Exhortations to ‘be safe’ are not acceptable at NZAS: a genuine absence of lost-time injuries is the non-negotiable, unambiguously defined target.

Specifically, other industrial plants must acknowledge that hazards are more readily ameliorated by long-term persistence with hierarchy of control methodology for injury prevention. In particular, the control of unintended energy exchange through ergonomic rather than egocentric measures has been shown by the NZAS experience to be the most effective intervention. Automation and the use of PPE are clear manifestations of the hierarchy of control methodology. Cycle of improvement TQM methodology, using non-blame incident investigations can result in meaningful worksite changes. Over time, these changes are able to produce a significant decrease in LTI’s.
Further, other worksites should not be regarded as a static environment where automation and ergonomic intervention are regarded as impracticable. Effective feedback from incident investigation can result in the elimination or isolation of hazards. Automation may have major financial implications for the elimination of major hazards, but these must be considered against the ongoing costs of a high injury rate, the company’s reputation, and its duties under the Health and Safety in Employment Act, (1992). Notwithstanding the process of major plant upgrading, avoidance of perfunctory judgements of ‘human error’ in incident investigations often identifies simple, low-cost engineering solutions for worksite hazard elimination or isolation.

7.2.3 Recommendations for Policy

This case study supports the effectiveness of hierarchy of control methodology as the basis for legislation governing workplace injury prevention. In New Zealand, the Health and Safety in Employment Act, (1992) prioritises hazard elimination as the most effective safety intervention, followed by hazard isolation, and then hazard minimisation. However, the use of the term ‘as far as practicable’ in the Act (Health and Safety in Employment Act, 1992) offers tacit support for those who may regard any significant intervention as ‘impracticable’. Consideration should be given to the capacity of companies to deal with major hazards at all. The success of NZAS in its mitigation of potentially catastrophic hazards can be contrasted with the disastrous Pike River coal mine failure. Furthermore, in ongoing hazard mitigation, the term ‘as far as practicable’ requires reconsideration. To continue to leave the definition of what is ‘practicable’ to those who are convinced that ‘human error’ underlies the majority of worksite injury, is to expose workers to injury indefinitely.

This case study of industrial safety places New Zealand Aluminium Smelters Limited at the forefront of hazard amelioration both within New Zealand and internationally. Their relative success should be recognised and emulated wherever possible.
References


Appendix A – Ethics approval

Dr R Lilley
Department of Preventive and Social Medicine
Dunedin School of Medicine

23 April 2012

Dear Dr Lilley,

I am writing to let you know that, at its recent meeting, the Ethics Committee considered your proposal entitled “A Case Study of Industrial Safety: New Zealand Aluminium Smelters Ltd”.

As a result of that consideration, the current status of your proposal is: Conditional Approval.

For your future reference, the Ethics Committee’s reference code for this project is: 12/099.

The comments and views expressed by the Ethics Committee concerning your proposal are as follows:

Please address the following comments before proceeding with the research:

The Committee notes that Item 17 (page 9 of application) states that a “formal research agreement” is to be signed by both the University of Otago and NZAS clarifying the management of any potential problems. Please supply the Committee with a copy of this.

Before approval of the research to proceed can be granted, a response must be received addressing the issues raised above. The Committee expects that these comments will be addressed before recruitment of participants begins. Please note that the Committee is always willing to enter into dialogue with applicants over the points made. There may be information that has not been made available to the Committee, or aspects of the research may not have been fully understood. Please provide the Committee with copies of the updated Information Sheet and Consent Form, if changes have been necessary.
Yours sincerely,

[Signature]

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor J L Connor Head Department of Preventive and Social Medicine
Dr R Lilley
Department of Preventive and Social Medicine
Dunedin School of Medicine

14 June 2012

Dear Dr Lilley,

I am again writing to you concerning your proposal entitled ‘A Case Study of Industrial Safety: New Zealand Aluminium Smelters Ltd’, Ethics Committee reference number 12/099.

Thank you for providing the signed copy of the Postgraduate Research Project Agreement, which was completed on 5 June 2012.

On the basis of this response, I am pleased to confirm that the proposal now has full ethical approval to proceed. We wish you well with this project.

Yours sincerely,

[Signature]

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Professor J L Connor  Head Department of Preventive and Social Medicine

University of Otago Ethics Committee Reference Number 12/099 – 14 June 2012.
Ngāi Tahu Research Consultation Committee

Te Komiti Rakahau ki Kai Tahu

17/04/2012 - 39
Wednesday, 18 April 2012

Dr Lilley
Preventive & Social Medicine
Dunedin

Tēnā koe Dr Lilley

Title: A Case Study of Industrial Safety: New Zealand Aluminium Smelters Ltd.

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 17 April 2012 to discuss your research proposition.

By way of introduction, this response from the Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum, it states “Ngāi Tahu acknowledges that the consultation process outlined in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago”. As such, this response is not an “approval” or “mandate” for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology; they are separate requirements with other committees, for example the Human Ethics Committee, etc.

Within the context of the Policy for Research Consultation with Māori, the Committee based consultation on that defined by Justice McGeohan:

"Consultation does not mean negotiation or agreement. It means: setting out a proposal not fully decided upon; adequately informing a party about relevant information upon which the proposal is based; listening to what the others have to say with an open mind (in that there is room to be persuaded against the proposal); undertaking that task in a genuine and not cosmetic manner. Reaching a decision that may or may not alter the original proposal."

The Committee considers the research to be of interest and importance.

As this study involves human participants, the Committee strongly encourage that ethnicity data be collected as part of the research project. That is the questions on self-identified ethnicity and descent, these questions are contained in the 2006 census.

The Committee encourages contact with Southland Rūnanga, namely Hokonui Rūnanga, Waihopai Rūnaka, Awarua Rūnanga, Ōrākei Aparima Rūnaka and Awarua Social and Health Services in Invercargill regarding this study.

The Committee suggests dissemination of the research findings to Waihopai Rūnanga regarding this study.

The Ngāi Tahu Research Consultation Committee has membership from:

Te Rūnanga o Ōiākou Incorporated
Kāti Huirapa Rūnaka ki Paketeru
Te Rūnanga o Moeraki
We wish you every success in your research and the Committee also requests a copy of the research findings.

This letter of suggestion, recommendation and advice is current for an 18 month period from Tuesday, 17 April 2012 to 17 October 2013.

The recommendations and suggestions above are provided on your proposal submitted through the consultation website process. These recommendations and suggestions do not necessarily relate to ethical issues with the research, including methodology. Other committees may also provide feedback in these areas.

Nāhaku noa, nā

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The Ngāi Tahu Research Consultation Committee has membership from:

Te Rūmanga o Orākau Incorporated
Kāti Huirapa Rūnaka ki Pukerewa
Te Rūmanga o Moeraki
INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

This research project is being undertaken by Steve Young for his University of Otago Master’s thesis. It is part of the requirements for Steve to attain a Master of Heath Science (Endorsed in Occupational Health).

What Type of Participants are being sought?

The project will be seeking to verify and explain NZAS’ safety improvement over recent decades. It will do this by looking at the smelter’s own statistics, doing general research on the academic literature available, but also – and this is where you come in – talking to staff who have been involved with the smelter.

You have been selected as a participant for this study on suggestion of NZAS Health and Safety staff. In total, Steve will conduct approximately 20 interviews with NZAS staff.

Unfortunately, no compensation or reward is being offered for participating in this research.
If you wish, a copy of the audiotape of this interview, or a transcript, will be provided to you, on request.

**What will Participants be Asked to Do?**

Should you agree to take part in this project, you will be asked to participate in an interview with Steve Young.

This interview will last between 15 and 30 minutes, and will consist of an open discussion with Steve regarding your experience and opinions on NZAS safety interventions and performance during the course of your employment on site.

No-one else will be present during the interview (unless you wish it so).

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind; and if you proceed, you may terminate the interview at any point without explanation.

The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops. Consequently, although the University of Otago Human Ethics Committee is aware of the general areas to be explored in the interview, the Committee has not been able to review the precise questions to be used.

In the event that the line of questioning does develop in such a way that you feel hesitant or uncomfortable you are reminded of your right to decline to answer any particular question(s) and also that you may withdraw from the project at any stage without any disadvantage to yourself of any kind.
What Data or Information will be Collected, and What Use will be Made of it?
The interview will be recorded on audiotape, and the text subsequently transcribed onto a computer file. Steve Young will be the only person who will be involved in the taping or transcribing process. No-one else will hear the audiotapes, and they will be destroyed at the conclusion of the research. The transcripts of the interviews may be viewed by the supervisors of the research project, and these transcripts will be stored on the University of Otago’s computer system for at least five years.
Selected extracts from your interview may or may not be included in Steve’s final thesis. This thesis will ultimately be available for public viewing in the University of Otago library. Neither NZAS nor any other party is funding the research, and no commercial use will be made of the thesis or contributing data.
No personal information will be gathered about you, and it is anticipated that you will not be able to be identified by any interview extracts that may be used in the resulting thesis.
It is intended that NZAS will be given a copy of the thesis when completed. The researcher has indicated to NZAS his wish that this be made available to those who contributed to the interviews.

What if Participants have any Questions?
If you have any questions about our project, either now or in the future, please feel free to contact either:-

Stephen Young, Student
Dept. of Preventive & Social Medicine
Email: steve@vidmark.co.nz

Dr Rebbecca Lilley, Supervisor
Dept. of Preventive & Social Medicine
University Telephone: 479 7196
Email: rebecca.lilley@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.
University of Otago Ethics Committee Reference Number 12/099 – 14 June 2012

A Case Study of Industrial Safety:
New Zealand Aluminium Smelters Ltd.

A Research Project undertaken by Steve Young for his University of Otago Master’s thesis.

CONSENT FORM FOR PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-
1. My participation in the project is entirely voluntary;

2. I am free to withdraw from the project at any time without any disadvantage;

3. Personal identifying information in the form of speech recorded on audiotape – will be destroyed at the conclusion of the project but transcripts of the interview on which the results of the project depend will be retained in secure storage for at least five years;

4. This project involves an open-questioning technique. The general line of questioning includes the changing nature of safety initiatives at New Zealand Aluminium Smelters Limited and the apparent improvement in its safety record. The precise nature of the questions which will be asked have not been determined in advance, but will depend on the way in which the interview develops and that in the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable I may decline to answer any particular question(s) and/or may withdraw from the project without any disadvantage of any kind.

5. No interviewee will be subjected to any form of risk or discomfort.
6. No remuneration or compensation is offered or requested as a result of participating in this interview.

7. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity should I choose to remain anonymous.

I agree to take part in this project.

..........................................................................................  ....................... ........
(Signature of participant)     (Date)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.
Appendix B – Tripartite research agreement

Postgraduate Research Project Agreement

BETWEEN: NEW ZEALAND ALLUMINIUM SMELTERS, Level 6, 109 Featherston Street, Wellington Central, Wellington, 6011, New Zealand (“Company”)

AND: THE UNIVERSITY OF OTAGO a body corporate established under the University of Otago Ordinance 1869, the University of Otago Amendment Act 1961 and the Education Act 1989, of Dunedin, New Zealand (“University”).

AND: STEPHEN ALAN YOUNG, a student of the University, residing at 44 Franklin St, Dunedin, New Zealand

(individually known as “Party” and together known as “the Parties”)

1. BACKGROUND
1.1 The University wishes to undertake a scientific research project in conjunction with the Company and Student and as described in Schedule 2 (“Research Project”).

1.2 The Company is the owner of the Materials. The University and Student wish to acquire samples of the Materials for the Research Project.

1.3 The Company and the University hereby agree that this Research Project will be carried out by the Student, under the supervision of Dr Rebbecca Lilley and Dr Kate Morgaine (“the Supervisors), and all parties shall be bound by the terms and conditions of this Agreement.

2. INTERPRETATION
2.1 In this Agreement unless the context otherwise requires:

“Background Intellectual Property” means pre-existing or independently developed Intellectual Property made available by a Party for the purpose of the Project; Background IP is listed at Schedule 2.

"Confidential Information" means proprietary information or know-how and data, technical or non technical, owned by a party to this Agreement, with the exception of the following information:

• information or materials that are in the public domain or subsequently enter the public domain in a manner not in breach of any obligation or confidentiality clause under this Agreement
• information or materials that are released under the terms of this Agreement
• information or material that is known or acquired by one of the other parties separately from this Agreement
• information which is obtained lawfully from a third party without any breach of confidentiality

"Company Supervisor" means the person named as such in Schedule 2.

"Intellectual Property Rights" includes but is not limited to all inventions, discoveries, innovations, technical information and data, prototypes, processes, improvements, patent rights, circuitry, computer programmemes, drawings, plans, specifications, copyright, trade mark rights, design rights, plant variety rights and Confidential Information.

“Materials” means the materials as more particularly described in Schedule 1. For the purposes of this Agreement, the term Materials shall also mean any and all derivatives, portions, divisions, metabolites, improvements and components (as the case may be) obtained from or as a result of the use of the Materials described in Schedule 1;

“New Intellectual Property” means all Intellectual Property Rights in and to the Project Results;

“Project Results” mean the Results that were specifically anticipated in terms of the Research Project, as more particularly described in Schedule 2;

“Protective Application” means any application for patents, designs or other form of intellectual property protection concerning the Results;

"Research Project" means the research project set out in Schedule 2;

“Results” means all results, outcomes, conclusions, products, discoveries, inventions, reports, records, data (in whatever form or format including all supporting data), materials (including substances, compounds and biological and genetic materials), research processes, research protocols, lab books, associated documents and research notes, memoranda and other writings and drawings (whether or not patentable or otherwise capable of intellectual property protection), created, discovered, invented, reduced to practice or developed during or as a result of performance of the Research Project.

2.2 In this Agreement:
• Words importing the singular include the plural and vice versa.
• References to one gender include the other.
• References to clauses and schedules are references to clauses and schedules to this Agreement.

3. THE PARTIES AGREE
3.1 That this Agreement commences on the Commencement Date and shall continue until Completion Date unless terminated:
(a) by earlier written agreement of the parties, or
(b) in accordance with the termination provisions of this Agreement

4. THE PARTIES' OBLIGATIONS
4.1 In consideration of this Agreement, the Company agrees to provide the resources and facilities as set out in Schedule 1.

4.2 In consideration of this Agreement the Student agrees to:
(a) conduct the Research Project in accordance with Schedule 2 and Schedule 3.
(b) use best scientific practices in undertaking the Research Project.

4.3 The University shall obtain all necessary consents for the Research Project.

5. STATUS OF STUDENT
5.1 The parties agree that the Student is not an employee of the Company or the University and that nothing stated or implied in this Agreement shall create an employment relationship between the Student, Company or University.

5.2 The Student shall comply with all standard practices, including Health and Safety requirements, of the party at whose premises the Research Project will be undertaken.

6. FUNDING
6.1 The University will pay pre-approved project consumables and operating expenses while the Student is on site at the University.

6.2 In addition, the University will also separately pay for pre-approved project operating costs incurred while conducting research at the Company's premises.

7. INTELLECTUAL PROPERTY AND OWNERSHIP
7.1 The Company, University and Student shall continue to own all rights to their respective Background Intellectual Property which they contribute to the Research Project, including Background Intellectual Property as more specifically described in Schedule 2. The University will own improvements to its Background Intellectual Property made through the course of the Research Project.

7.2 The Company hereby grants to the Student and University a non-exclusive royalty-free perpetual licence to use the Company's Background Intellectual Property for the purpose of the Research Project and for academic and research purposes.

7.3 Copyright to any thesis, dissertation or research report created by the Student during the course of this Research Project shall at all times remain the property of the Student.

7.4 The Student agrees to allow the Company a copy of any thesis, dissertation or research report and will not unreasonably withhold consent from the Company to refer to or publish part of the thesis, dissertation or research project.

8. REPORTING
8.1 The Student shall provide progress reports on the Research Project to the Company and the University in the manner and on the dates specified in Schedule 2.

8.2 Upon completion of the Research Project and no later than 31 December 2012, the Student shall deliver to the Company and the University a final written report on the Research Project.

9. MATERIALS
9.1 Return or Destruction of Materials: The University and Student shall return to Company or destroy (at Company’s request and in concordance with Clause 10.8) the Materials upon the earlier of:
   (a) demand by Company;
   (b) termination of this Agreement; and
   (c) the date on which the Materials are no longer required for the Research Project.
   Upon any destruction of the Materials under this clause 9, the University and Student shall provide Company with a certificate confirming that the Materials destroyed comprised all the Materials in the possession or under the control of the University and Student.

10. PRIVACY and CONFIDENTIALITY
10.1 A party shall be free to use and disclose to any third party its own information and Background Intellectual Property.

10.2 All information directly related to the Research Project or New Intellectual Property whether produced as a result of the Research Project, shall be treated as confidential information and shall not be published, disclosed or used by the University, Supervisors or Student except as expressly provided within this Agreement.

10.3 These confidentiality obligations do not apply to information that:
   (a) was legally in the possession of the party before it was disclosed to it by one of the other parties,
   (b) was, or becomes legally available to the public,
   (c) was received in good faith from a third party provided that information is not subject to an obligation of confidentiality to that third party, is not information relating to or about the Company, and does not breach privacy legislation,
   (d) was independently developed by the party without reference to the project information or the Company,
   (e) is required to be disclosed by law

10.4 Upon submission of the Results by the Student, the Student and the University shall treat such material as confidential information, except that the Results may be submitted to appropriate third parties, in confidence, as required by the thesis examination process.

10.5 The Sponsor may request that arrangements be made for examiners to enter into an agreement to protect the Sponsor’s Confidential Information which is contained in the thesis.
10.6 The Parties agree that publication of thesis and research papers is a desired outcome of the Research Project. Company approval, which shall not be unreasonably withheld, must be obtained in writing before any printing or publication of thesis/research papers. The Company may reasonably decline approval if there has been a breach of this Agreement, or printing or publication causes or may cause the Company or its staff any business or privacy concerns. Such business and privacy concerns may include, but are not limited to, breaches of privacy legislation, defamatory or untrue statements, or information that could detrimentally affect the Company's business reputation. The Company must, within 30 days of receipt of the copy of the thesis or research papers, advise the University whether it requests revision of any content in the publication. Such revision is not limited to matters affecting its reputation, or the sensitivity or confidentiality of the content. The Student must respond to all of the Company's requests for revision, and reasonably consider making such revisions.

10.7 The obligation of confidentiality between the Parties shall survive:
(a) the completion of the Research Project by the Student, and
(b) termination of this Agreement.

10.8 The Student and University shall ensure that they collect, use, retain, disclose and store information in accordance with their obligations as agencies under the Privacy Act 1993 and any other statutes in law.
The Student shall only use the Company’s employees’ personal information in a form that does not identify the individuals, and shall only publish information in a form that could not reasonably expect to identify the individuals concerned. The only exception to this is where the Student/University publishes information about an employee of NZAS with that employee’s written consent.
The Student shall only collect information necessary for its lawful purpose, being the completion of its Research Project.
The Student shall collect information from the Company only in a lawful way that is fair and does not intrude unreasonably upon the extent of the personal affairs of the individuals involved.
In accordance with their obligations under the Privacy Act 1993, the Student shall seek the signed consent of the employees of the Company prior to interviewing the employees, and shall inform them in writing of the following:
That information is being collected, its purpose, the intended recipients of the information, the name and address of the agencies collecting and holding the information, if the collection of the information is required by law, the consequences for the individual if they do not provide requested information and the rights of access to, and correction of, personal information provided by these principles.
The interviewees shall have the opportunity to access and correct their own transcripts before their information is used in the research project or is published.
The Company will have the opportunity to review the interview quotes that are considered for use and have, within 30 days after receiving these quotes, the right of reply to this information before the information is used in the research project or is published.
Subject to Clause 10.3, the Student and University are not permitted to use any information received, disclosed or acquired during the course of the Research Project or in relation to NZAS for any purpose other than producing the thesis/research papers as described in Schedule 2 of this Agreement.

The Student will securely store all information collected from the Company or in relation to the Company and prevent unauthorised use or unauthorised disclosure of the information. The University will securely store all information received from the Company or from the Student in relation to the Company and prevent unauthorised use or unauthorised disclosure of the information.

The Student and University shall only retain information relating to NZAS for as long as required to complete the Research Project or as required for thesis and research paper purposes, and shall then immediately return all relevant documentation and information to NZAS. Documentation and information that cannot be disclosed to Company will be destroyed when no longer required for thesis and research paper purposes.

11. LIABILITY OF THE PARTIES

11.1 All Parties will exercise all reasonable skill, care and diligence in carrying out the research, and any other services to be performed in connection with this project, in accordance with recognised professional standards.

11.2 The Student shall only be liable for any loss, damage, expense, loss of profit, loss of business or consequential loss of the other Party/s, if the Student breaches provisions under clause 11.1, any part of this Agreement, or any law or regulation.

The University shall only be liable for any loss, damage, expense, loss of profit, loss of business or consequential loss of the other Party/s, if the University breaches provisions under clause 11.1, any part of this Agreement, or any law or regulation.

The University indemnifies the Company against all liability, loss, damages, expenses, or action that the Company may suffer or incur due to the University’s failure to fulfil its obligations under clause 11.1.

The Student indemnifies the Company against all liability, loss, damages, expenses, or action that the Company may suffer or incur due to the Student’s failure to fulfil its obligations under clause 11.1.

12. TERMINATION

12.1 This Agreement may be terminated by any Party giving 14 days’ notice in writing to the Party or Parties considered to be committing a breach, or reasonably anticipating a breach, of any term of this Agreement and, where the breach or anticipated breach, is capable of being remedied it has not been remedied within 14 days after receipt of such request.

12.2 If for any reason any Party is unable to commence or continue to discharge its obligations in respect of the Research Project or forms the opinion that success of the Research Project is improbable, then it shall consult with the other Parties to determine
the appropriate action to be taken. The Parties agree that the Student’s ability to complete their thesis is an important outcome of this Research Project and they will work in good faith together to support this occurring, including the use of the Results.

13. **DISPUTE RESOLUTION**
13.1 If any of the parties believes that there is a dispute in respect of this Agreement, it will first notify the other Parties in writing giving details of the nature of the dispute. If the Parties cannot resolve the dispute within 14 working days, they will first use the services of a mediator (supported by the Parties). The costs of mediation will be borne equally between the Parties.

13.2 If mediation is unsuccessful the dispute will be submitted to the President of the New Zealand Law Society, who will appoint a single arbitrator. The Parties agree that any decision by the arbitrator shall be fully and finally binding, and that all costs and expenses of the arbitration proceeding shall be borne in accordance with the decision of the arbitrator.

14. **PUBLICITY**
14.1 No Party will use the name of any other Party or other Party’s employees or logo in relation to this Agreement without the prior written permission of that Party.

15. **MISCELLANEOUS**
15.1 Each Party acknowledges that it is relying solely upon its own judgement in entering into this Agreement and is not relying on any representations, warranties or statements made by either of the other parties, except as provided in this Agreement.

16. **VARIATION**
The Agreement and conditions may be varied by mutual, written agreement between the Parties and signed by the authorised representatives of the Parties.

17. **JURISDICTION**
This Agreement is governed by New Zealand law and the New Zealand courts have jurisdiction in respect of this Agreement.

18. **REPRESENTATION**
The undersigned represent that they are duly authorised to execute the Agreement on behalf of the respective Parties and to bind the respective parties to the terms and conditions of this Agreement.
Executed as an Agreement

NEW ZEALAND ALUMINIUM SMELTERS
by: Tiwai Road, Southland, Via Invercargill, New Zealand

Signature of Authorised Signatory

Name of Authorised Signatory
Date:

UNIVERSITY OF OTAGO by:

Signature of Authorised Signatory

Name of Authorised Signatory
Date:

STEPHEN YOUNG:

Signature of Authorised Signatory

Name of Authorised Signatory
Date:
SCHEDULE 1

Company agrees to:

1. Provide the Student such resources as are necessary such as office space, consumables and associated facilities and equipment, to allow the Student to meet his or her obligations in respect of the agreed research project.
2. Allow access to the Student of consenting key staff members, so that the Student can collect qualitative research data.
3. Provide the Student with information on the Company’s health and safety and employment requirements and require the Student to comply with these requirements.
4. Allow the Student’s Supervisors named in Schedule 2 to supervise jointly the Student in accordance with the University’s course regulations, provided that the Supervisors agree to maintain all privacy and confidentiality in accordance with this Agreement.
5. Provide the Student with the following Materials: NZAS Injury and near-miss records and NZAS Occupational Health and safety information as allowed under the Privacy Act 1993, provided that these records and information will not identify the employees, is used for research purposes and will not be published in a form that could reasonably be expected to identify the individuals concerned"."
Research Proposal – Stephen Young – 2012

Title
Name of Research Project:
A Case Study of Industrial Safety: New Zealand Aluminium Smelters Ltd.

Name and academic qualifications of candidate: Stephen Alan Young. B.Com (Management) University of Otago, 1975; Post Graduate Diploma in Health Science (endorsed in Occupational Health) awarded with Distinction, University of Otago, 2011.

Degree Sought: Master of Health Science (endorsed in Occupational Health)

Proposed Supervisors: Dr Rebbecca Lilley, Lecturer, Department of Social and Preventive Medicine, University of Otago; Dr Kate Morgaine, Department of Dentistry, University of Otago.

Date of Submission: December, 2012

Abstract
This proposal proposes a case study investigating the injury prevention record of New Zealand Aluminium Smelters Ltd (NZAS) since beginning operations in 1971. A mixed method research approach will be undertaken. Quantitative research using existing NZAS data, qualitative research (interviews with key participants), and a literature review of relevant safety theory, will be triangulated to establish a structured narrative of the NZAS safety success.

Background
New Zealand Aluminium Smelters Ltd (NZAS), at Tiwai Point in Southland, is an extremely hazardous worksite, ((Abramson, 1989; Akbar-Khanzadeh, 1995; Benke, 1998; Borrje, 1975; Kjellén, 1997; O'Donnell, 1989, 1995) yet the company claims that its injury rate is (now) very low – approaching their motto of “Our Goal is Zero” (NZAS, 2004). In 2004, the International Aluminium Institute named NZAS as the safest smelter in the world from 60 in its class, and in the same year, NZAS won the Auckland University of Technology (AUT) Business Ethics Award for its “Our Goal is Zero” safety programme at the Deloitte Management Top 200 Awards (NZAS, 2004).

The smelter appears to have become a “high reliability organisation” (Reason, 2000; K. Weick, Sutcliffe, & Obstfield, 2008; K. E. Weick, 1987) insofar as its safety record is significantly better than its peers. The organisation has adopted a number of safety research interventions during the period 1971 – 2012.33 These interventions include:

1. Abandonment of the word “accident”; focusing instead on exchanges of energy resulting in injury (Doege, 1978, 1999; Haddon, 1973; W. Haddon, Jr, 1968; R. Kahler, 2007; R. J. Kahler & Ellis, 2002; Langley, 1988; Loimer, 1996; McDonald, 2003)).

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33 The researcher has worked with the smelter from 1985 - 2011 as producer of their safety audio-visual media, and is familiar with most of their interventions.
2. Decreased reliance on human behaviour as a safety strategy (Feyer, 1991; W. Haddon, Jr, 1968; R. J. Kahler & Ellis, 2002; Reason, 2000; Shepherd, Kahler, & Cross, 2006).
3. A focus on “Sequence of Events” analysis (as it relates to historical and potential injury) (Feyer, 1991; R. J. Kahler & Ellis, 2002; McDonald, 2003).

The literature on these interventions provides a structure that may point to an explanation for the smelter’s success.

Public Health Significance
In 2007, there were 231,300 work-related claims on the Accident Compensation Corporation (ACC) – 67 for work-related fatalities – costing $227 million. Manufacturing comprised 17% of these claims (the highest industry segment) (ACC, 2009). The aluminium smelter has long been regarded as superior in industrial health and safety compared to other New Zealand companies. A research-based narrative of NZAS’ success may significantly contribute to decreasing injury in large manufacturing organisations – both within New Zealand and beyond.

Objectives
The thesis will therefore pursue the following research objectives:

1. To quantify the safety improvement record at NZAS 1971-2011.
2. To describe safety interventions that led to the improvement in safety at NZAS 1971-2011.

Methods
This case study will describe NZAS’ safety record, using a mixed methods approach. Firstly, existing NZAS records will be interrogated to establish the NZAS injury experience over its 40 years of operation. The study will focus on acute trauma – excluding chronic conditions such as noise-induced hearing loss and occupational asthma. Acute trauma can be defined as injury “coming sharply to a point or crisis of severity” (Oxford English Dictionary, 1989). Once the quality of the NZAS data can be ascertained, the data will be stratified by injury severity thresholds such as deaths, serious injuries, lost-time injuries and near misses (incidents).

Secondly, using a series of interviews with 20 key participants, the study will seek information on the nature and progression of safety interventions at NZAS. In parallel with the gathering of this information, a literature review will explain the background of the safety interventions more fully, and provide a structural framework for further analysis.

Finally, the study will produce a structured narrative (Cunliffe, 2004; S. B. Johnson, 2008) to attempt to explain the smelter’s safety record. This structured narrative of the mixed method findings will “turn the pattern into a dialogue” (Hoey, 2001) by

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34 When the researcher was producing videos for OSH to introduce the Health and Safety in Employment Act in 1994, OSH representatives asked that NZAS not be included in the production because they “are so far ahead of other New Zealand businesses” and therefore “not representative”.

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triangulating the findings from the quantitative and qualitative research and literature review.
Evaluation of evidence within a structured narrative has been used in many studies to produce a meaningful and pragmatic discourse for dissemination to interested parties (Escalas, 2004; Greenhalgh, 2005; Hänninen, 2004; Hsu, 2012; Jackson, 2005; Jones & Lyons, 2003; Killick, 2009; Lincoln et al., 2004; Williamson, Feyer, Stout, Driscoll, & Usher, 2001).

**Expected Outcome**
It is expected that the research will develop a narrative to describe and attempt to explain the NZAS safety record within a structure of relevant injury-reduction theory. This may contribute to safety interventions in other large Australian and New Zealand industrial plants.

**Resources**
It is anticipated that very few resources will be required to complete this project. NZAS has informally indicated their support, and the researcher is a frequent visitor to the smelter. Some road travel expenses may be incurred for purely research-based visits. The researcher also intends to apply for a University of Otago Master’s scholarship.

**Organisation of the Project**
Some interviews may be conducted concerning sensitive injury and privacy issues, and a full proposal on interview etiquette will be submitted to the University of Otago’s ethics committee for their approval. A formal agreement between NZAS and the University of Otago will be established early in the project – covering ownership of the research and copyright of the resulting thesis.

- **Background Intellectual Property (for both Company & University)**
  Company: Occupational Health & Safety protocols, know-how and records
  University: Qualitative and quantitative injury prevention research methods, know-how and expertise

- **Course**
  Master of Health Science (endorsed in Occupational Health)

- **Names of supervisors:**
  - University Supervisor: Dr Rebbecca Lilley, Dr Kate Morgaine

- **Research time frame:**
  February 2012 – December 2012 (data collection June – August 2012)

- **Commencement Date and Completion Date**
  1 February 2012 and 31 December 2012

- **Total funding:**
  As per University of Otago stipend and MSc project arrangement

- **Funding sources:**
  University Stipend and University of Otago injury Prevention Research unit (as applicable)
Project results:
It is expected that the research will develop a narrative to describe and attempt to explain the NZAS safety success within a structure of relevant injury-reduction theory. This may provide significant health and safety injury-reduction opportunities for other New Zealand businesses to emulate.
Research milestones (at least three for a PhD and at least two for a Masters):

<table>
<thead>
<tr>
<th>Month</th>
<th>Activities</th>
</tr>
</thead>
</table>
| February 2012 | - Project definition and proposal  
                    - Conduct preliminary literature review |
| March 2012  | - Design structure of thesis  
                    - University approval (including ethics approval)  
                    - Initiate approval from NZAS |
| April 2012  | - Begin writing thesis  
                    - Begin literature review |
| May 2012    | - Complete first draft of literature review  
                    - Final approval from NZAS sought |
| June 2012   | - Conduct interviews (up to 20)  
                    - Interpret quantitative data |
| July 2012   | - Transcribe interviews  
                    - Collate notes and code |
| August 2012 | - Interpret qualitative data  
                    - Visit NZAS for quantitative data  
                    - Interpret quantitative data  
                    - Write thesis |
| September & October 2012 | - Write thesis  
                    - Submit draft to supervisors  
                    - Submit draft to NZAS |
| November 2012 | - Revise thesis |
| December 2012 | - Submit thesis |

- Reporting dates  
  31 December 2012

- Research project location/research location:  
  **New Zealand Aluminium Smelters**, Tiawai Road, Southland, Via Invercargill  
  **University of Otago**, Dunedin
Schedule 3

The Student agrees to

1. Use best endeavours to ensure that the Research Project is completed in a timely manner and in accordance with milestones specified in Schedule 2.

2. Conduct the Research Project within proper and recognised scientific and research standards.

3. To meet or contact the Company monthly to discuss progress, and to provide a final report by 31-12-2012.

4. Notify the supervisors in respect of any changes which prevent him or her from working on and/or completing the research project.

5. Comply with all relevant health and safety in employment and other site requirements when at Company or University premises.

6. Operate Company/CRI's equipment, made available for the project, in accordance with operating procedures and instructions given by Company personnel and only with the prior approval of the Company.

7. Comply with all privacy and confidentiality obligations under the Privacy Act 1993 and as required by the Company in accordance with this Agreement.

8. Provide the Company with interview quotes from the interviews with staff members that are considered for use in the thesis and research papers, and the opportunity to reply to any of this information.

9. Provide the Company with a copy of the thesis, and allow the Company a reasonable opportunity to suggest revised changes before any printing or publication.

10. Consider all NZAS’ revised changes to his thesis, and apply such revised changes or give reasoned consideration for not applying such changes.

11. Not provide any information in the thesis disproving the improvement in NZAS’ safety record over the past 25 years without first consulting with the Manager of Technology and Sustainability at NZAS.
Schedule 4
The University agrees to:

1. Comply with all privacy and confidentiality obligations under the Privacy Act 1993 and as required by the Company in accordance with this Agreement.

2. Provide the Company with a copy of the thesis, and allow the Company a reasonable opportunity to suggest revised changes before any printing or publication.

3. Not provide any information in the Student’s thesis disproving the improvement in NZAS’ safety record over the past 25 years without first consulting with the Manager of Technology and Sustainability at NZAS.

4. Ensure supervisors oversee the Research Project and that all supervision is within proper and recognised research standards.

5. Oversee all health and safety in employment and other site requirements at university.
Appendix C – Semi-structured interview questions

A Case Study of Industrial Safety: New Zealand - Aluminium Smelters Ltd.
Semi-structured Interview Questions

Questions proposed as basis for semi-structured interviews with NZAS staff

- When did you start working at NZAS?
- What jobs have you had outside of NZAS? For how long?
- In what area of NZAS do you now work?
- In which other areas have you worked?
- Can you recall your first impressions of the safety procedures at NZAS when you started?
- How did these compare to those of other employers you have worked for? [If applicable]
- What safety interventions or changes can you recall being introduced during your time at NZAS?
  - 1
  - 2
  - 3
  - Etc
[For each of these interventions…]

- Where did this intervention or change come from, and who introduced it? [OSH, NZAS management, union, self, workmates, supervisor etc]

- What, if any, difference do you think it made? Over what time period?

- Please tell me more about that intervention [perceived efficacy, personal viewpoint, participants, authority structure, persistence with intervention, variation or corruption of intervention, retrospective judgement etc]

- What is your perception of NZAS’ safety record compared to other large New Zealand companies? Compared to other aluminium smelters internationally?

- What, in your view, are the most significant safety initiatives introduced to NZAS during the time you have worked here? [anecdotes welcomed]

- Please describe one or two significant accidents or incidents at NZAS that involved you or your workmates.

- In your opinion, did any of the safety interventions you have mentioned have an effect on those accidents or incidents? Prevention, cause, or no effect?

- What are your thoughts on the present safety procedures at NZAS? Do you feel “safer” than in previous years?

- Where do you see NZAS going in the next few years with regard to improving safety?
Appendix D – New Zealand Aluminium Smelters Limited

A brief history of New Zealand Aluminium Smelters Limited

NZAS commenced the production of aluminium in July 1971 at Tiwai Point at the southern tip of the South Island of New Zealand. It was owned by the Commonwealth Aluminium Company of Australia (Comalco), 79.36%; and Sumitomo Chemical Company of Japan, 20.64%. Comalco also owned two other smelters in Australia. Since then, the ownership of the majority shareholding has changed to Conzinc Rio Tinto Aluminium (CRA), and then to Rio Tinto Alcan. Currently, Rio Tinto is seeking to divest itself of its aluminium producing plants, and the three smelters are presently majority owned by a holding company, Pacific Aluminium Limited.

The process of aluminium smelting

The aluminium smelter at Tiwai Point, Southland, New Zealand is expansive work precinct of one square kilometre.

![Figure 20. The NZAS work precinct.](image)

Specifically, the chemical equation completed at the aluminium smelter is $2\text{Al}_2\text{O}_3 + 3\text{C} \leftrightarrow 4\text{Al} + 3\text{CO}_2$. Molecules of aluminium oxide (alumina) are ripped apart by enormous amperages of electricity to produce pure aluminium, and, as part of the chemical reaction, the oxygen molecules from the alumina bond with the carbon to form carbon dioxide which is released into the atmosphere. This is known as the Hall-Heroult process (New Zealand Aluminium Smelters Limited, 2007).
Figure 21. The Hall Heroult aluminium smelting process.
[reproduced from *How aluminium is made* NZAS.]

The other key inputs are imported through a purpose-built 1.2-kilometre-long wharf extending into Bluff Harbour. Alumina arrives from the Gladstone, Queensland, refinery; it is vacuumed out of the ship’s hold, and transported via conveyor to a huge alumina store building. The carbon arrives in two forms: petroleum coke from California, and liquid pitch from Korea which is piped to large tanks, alongside imported heavy fuel oil (HFO), and Cryolite (used to dissolve the alumina). The coke is crushed on site and mixed with the liquid pitch in the Green Carbon plant; the mixture is then formed into large blocks weighing more than one tonne each – these constitute the anodes for the electro-chemical process.

The ‘green’ anodes are transported to Carbon Bake – where they are baked in huge gas-fired ovens at temperatures of up to 1,100 degrees centigrade, to improve their strength and conductivity. The baked anodes are transported to the Rodding Room where they are attached to steel rods by casting iron (using an iron foundry), ready for suspension into the reduction cells.

The electro-chemical reaction takes place in a series of individual reduction cells in four buildings called reduction lines or ‘potlines’ – three are more than half a kilometer in length. Production of aluminium is continuous – the key activities of the smelter continue 24 hours a day, 365 days a year. The aluminium accumulates in the cells and is vacuumed out into large crucibles which are transported to Metal Products, where it is cast into ingots, billet, rolling block, and T-bar forms. Most of the aluminium is exported via the Tiwai wharf. In addition to the line functions outlined above, the Tiwai Point worksite includes large maintenance workshops, a participant fire brigade, administration offices, occupational health services, laboratories, metal storage yard, and a wide range of other contributing plants and facilities.

**Potential for injury**

To underestimate the hazards of an aluminium smelter is to expose its entire workforce, contractors, and visitors to serious injury. Any aluminium smelter has the potential to explode catastrophically at any time. If say, a simple can or bottle of soft drink was thrown into an aluminium holding furnace or crucible, the superheated steam expanding beneath the molten aluminium could create an explosion powerful enough to destroy the huge Metal Products building and fatally injure its operators. The massive electrical
current (610 megawatts) is converted from alternating current (AC) to direct current (DC) and feeds the reduction lines at 920 volts. The potlines are ‘live’ but operators are insulated from electrocution by a wooden floor. However, if an earthing circuit was formed from a reduction cell to the ground outside – by, for instance, an aluminium ladder, a cable, or water course – an operator could receive a lethal electrocution.

The potential for crushing or cutting injury from mechanical equipment is ever-present. Forklifts, trucks, huge specialist vehicles, cranes, automatic and manually operated conveyors, crushing machines, pneumatic and mechanical tools, etc., operate across the Tiwai Point worksite. Burns and heat stress are a constant hazard. The anodes are baked at up to 1,100°C; molten aluminium is vacuumed, poured, stored and cast at 730°C; heavy fuel oil (HFO) is used to fuel a large number of heating devices and mechanisms. Much of the plant is housed in buildings as high as an eight-storey office block. Falls from ladders, vehicles, cranes, roofs and stairways, along with slips and trips, are a constant hazard. The physical nature of some tasks may also generate sprains and strains. Asphyxiation from working in confined spaces or from drowning, and acute poisoning from chemical hazards are very real possibilities.

And then there are the chronic exposures such as noise-induced hearing loss (NIHL), occupational asthma, musculoskeletal injury, long-term effects from exposure to chemicals, psychosocial factors from shift work etc – these all present real threats to the ongoing health of smelter personnel.
### Appendix E – Interpolated contractor numbers

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<tr>
<th>Year</th>
<th>Known contractors numbers</th>
<th>Known NZAS staff numbers</th>
<th>Contractor /staff ratio</th>
<th>Mean(^{35}) contractor /staff ratio</th>
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\(^{35}\) Mean percentage of contractors to NZAS employees for the years 1987-1993.

\(^{36}\) NZAS employees multiplied by mean contractor/employees percentage.

\(^{37}\) Mean of 1982 reported major project contractor numbers and 1984 interpolated estimate.