Framework for review and prioritisation of rail safety risks in New Zealand

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Project scope and background

The NZ Transport Agency commissioned Navigatus Consulting to undertake this research project to identify and provide evidence-based recommendations for managing priority safety risks for New Zealand rail operations.

The report is split into four parts:

1 Risk management context

2 Current New Zealand practice

3 Risk assessment

4 Conclusions and recommendations.

Risk management context

The new ‘so far as is reasonably practicable’ (SFAIRP) requirement in health and safety legislation is considered to be the same, for the most part, as the ‘as low as reasonably practicable’ (ALARP) concept already used by many operators.

However, information on ALARP (as presented in current rail risk assessment guidelines in New Zealand, such as National Rail System Standard/4 (NRSS4)), would not be sufficient as standalone resources for rail operators to meet the SFAIRP requirement. The Health and Safety at Work Act 2015 and amendments to the Railways Act 2005 clearly signal to duty holders there are different expectations required of them, and they will need support and guidelines to help them with their interpretation of the law (and implementation of appropriate practices).

The researchers were asked to suggest enhancements to NRSS4 (risk management). The researchers found NRSS4 to be no longer fit for purpose as it does not represent good practice. The researchers recommend the NRSS2 (safety management) be expanded to cover risk management. The principal reason for recommending this option is to recognise more explicitly the integral role of risk management in the wider risk management framework (the safety management system).

In terms of acceptable risk levels (as presented in current rail risk assessment guidelines in New Zealand), the researchers suggest the boundary between tolerable and intolerable risk for rail workers may be lenient. A bound of a 1 in 10,000 annual fatality risk may be more appropriate for rail workers than the current 1 in 1,000, given rail’s improved safety performance over the last 15 years. The purpose of the bound would be for the regulator to track safety performance for the industry as a whole (rather than for operators or individual risks). If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry.

Current New Zealand practice

The researchers benchmarked rates of New Zealand incident occurrences against Australian and UK data. Generally the New Zealand rail industry performed more poorly than rail operations in these other jurisdictions. Although the benchmarking shows New Zealand has room for improvement, there are some differences between the rail systems between the countries that mean it may not be practicable for New Zealand to reach the same level of safety. For instance, while New Zealand rail is dominated by freight, UK rail is dominated by passenger services. This means UK rail infrastructure is maintained to a higher standard (because of the passenger services), which also benefits the safety performance of freight services on those lines.

The researchers found metro and long-distance rail operators appeared to have relatively good risk management capability (at least centrally), as well as having access to greater resources (eg industry bodies and other organisations). Tourist and heritage operators tended to have lower risk management capability and might struggle to meet rising health and safety expectations despite good intentions.

Risk assessment

A risk assessment was carried out to identify priority risks for the rail industry as a whole. The rankings were based primarily on societal risk (using average estimated fatalities per year) and weightings (to reflect the degree of control the rail system has over outcomes and broad societal values on acceptable risks). The risks identified as being the highest are a priority for assessing whether they have been reduced SFAIRP. If the cost to reduce these risks further is grossly disproportionate to the benefits, then although the risk is higher than others, it may be tolerable.

An unexpected outcome of the risk assessment was tsunami appearing at the top of the list. While the likelihood of the event was low, the potential fatalities occurring in any one event were higher than any other risk assessed. Recognising that tsunami are natural events and are a wider issue than just for rail, there is value in considering whether there are additional controls that could be reasonably implemented (either by operators, regulators, or other organisations as part of a wider societal response to tsunami risk). While a tsunami cannot be prevented, there may be societal actions that the rail industry can influence and others that the industry can take directly to reduce risk.

Other priority risks include collisions with unauthorised members of public, level crossing collisions with light vehicles and pedestrians, civil works failure leading to collision or derailment, and passenger train derailment (mainline operations, tourist and heritage). While acknowledging rail participants have shared responsibility for some of these risks, there may be further opportunities to reduce risks or formally consider whether they have been reduced SFAIRP.

The priority risks are intended to inform discussion of priorities. The railway industry has many different stakeholders, each will have different viewpoints, and no single list of prioritised risks addresses the needs of all stakeholders.

Conclusion and recommendations

Looking at the rail sector as a whole, care must be taken to direct efforts where they will achieve the greatest benefit. There is a need for balance, viewing safety not as an absolute to be pursued at all costs, but as a relative good, pursued to the extent that is reasonably practical, consistent with New Zealand law and with societal expectations.

Some suggestions from the researchers included whether competency requirements should be established for defined safety roles within the rail sector (eg recognised qualifications and experience). The researchers also commented that the benchmarking initiative that is planned (populate the metrics with data and publish the results) is an important piece of work and should be advanced.

In terms of the regulator's role, the researchers suggest that as part of the current improvement project for ordinary safety assessments, a 'deep slice' and human factors approach could be introduced, and a more overt, systematic and persistent follow-up of investigations and recommendations made by the transport sector.

Abstract

The Transport Agency commissioned Navigatus Consulting to undertake this research project to identify and provide evidence-based recommendations for managing priority safety risks for New Zealand rail operations. The project was carried out in 2015/16 in New Zealand. The primary purpose of the project was to provide a reliable foundation for future risk reduction activities by carrying out research on best and current risk practice, undertaking a risk assessment to identify priority safety risks, and identifying potential mitigation options to reduce these priority risks to an acceptable level. A number of recommendations have been made relating to the research undertaken.

1 Research overview and findings

This chapter provides a comprehensive summary of the research and its findings, including the recommendations made. It also provides an overview of the structure of the report.

The NZ Transport Agency (the Transport Agency) commissioned Navigatus Consulting to undertake this research project to identify and provide evidence-based recommendations for managing priority safety risks for New Zealand rail operations. The project was carried out in 2015/16 in New Zealand.

While the research was conducted for rail, there are aspects of the research that may be applicable in other transport sectors and other industries.

1.1 Research objectives

The primary purpose of this research was to provide a reliable foundation for future risk reduction activities by:

- identifying a best practice risk assessment methodology for the New Zealand rail industry
- identifying any alterations that should be made to the National Rail System Standard/4 risk management (NRSS4)
- carrying out a risk assessment to identify the priority safety risks to rail operations in New Zealand
- identifying potential mitigation options to reduce these priority risks to an acceptable level.

The brief asked for comment on the 'so far as is reasonably practicable (SFAIRP)' principle that has been introduced in the Health and Safety at Work Act 2015 (HSWA). The researchers were also asked to quantify an acceptable risk level for rail in New Zealand. The research addressed risks directly related to railway activities or ones that could be mitigated via improvement of rail activity risk and safety management[1]. Mining and forestry related rail activities exempted from the Railways Act 2005 were excluded from the scope of the research, as well as ferry operations.

1.2 Background to the New Zealand rail industry

The New Zealand rail industry needs to manage a number of hazards, but there are challenges in developing a common view of risks across the industry and ensuring there is sufficient capability and evidence to objectively assess the risk from these hazards and how best to address them.

New Zealand rail operations are predominantly freight on the mainline, metro passenger services in Auckland and Wellington, and tourist and heritage (T&H) operations. While freight volumes have been steady in recent years, metro passenger operations have increased markedly. In particular, Auckland metro rail has increased from 2.5 million trips per year in 2003 (when the Britomart station opened) to 16.8 million in July 2016 (Auckland Transport 2016).

The November 2016 Kaikoura earthquake fragmented the National Rail System (NRS) into two operational parts: the North Island with a connection to Marlborough via the Cook Strait ferry and the remainder of the

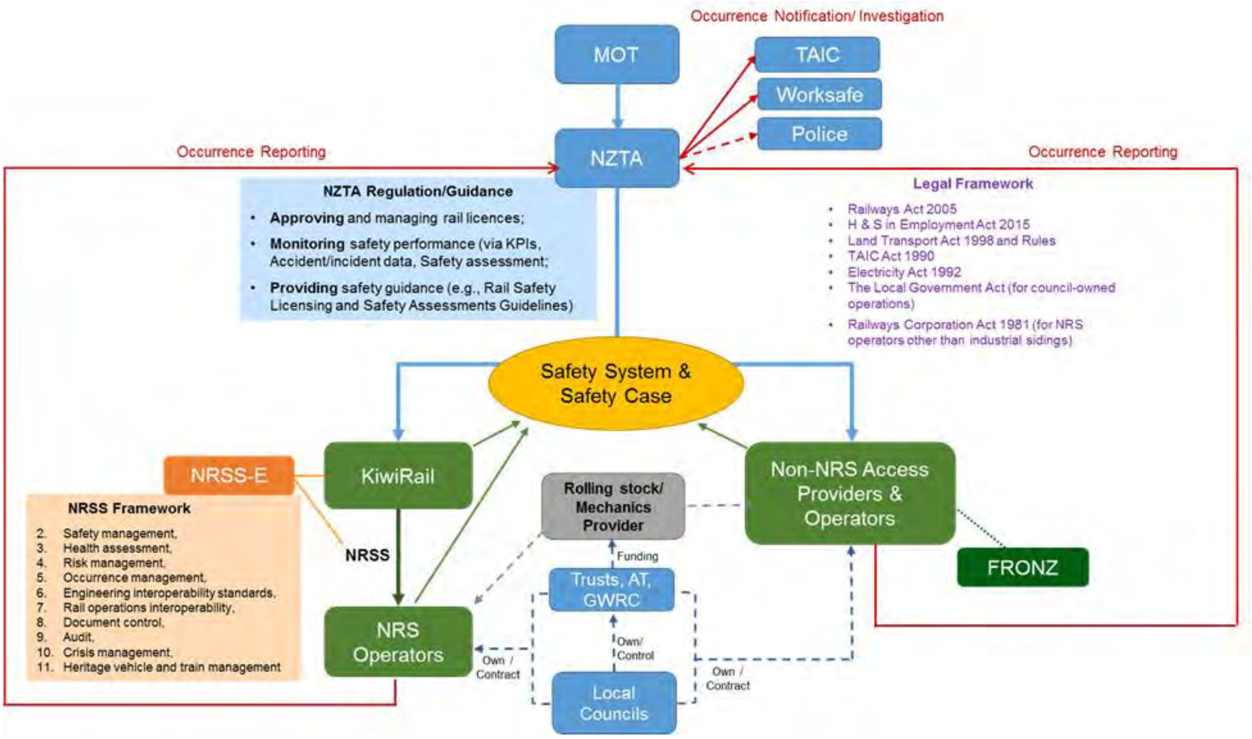
[1] The research excluded suicides and suspected suicides, which the researchers consider to be a wider societal issue. The research also excluded risk from terrorism.

South Island. Repairs to the damaged rail line are underway alongside restoration of State Highway 1 north of Kaikoura.

Figure 1.1 shows a simplified relationship map for the main parties in the New Zealand rail industry (appendix B has a more comprehensive table showing rail operators' roles).

All rail operators must have rail licences issued by the Transport Agency, which undertakes annual assessments of licensed operators.

Figure 1.1 New Zealand rail safety system overview



The main legislation for the railway sector is the Railways Act 2005, Railways Regulations 2008 and the HSWA. The Ministry of Transport (MoT) is the government's principal transport advisor for rail. When the Railways Act was introduced in 2005 to implement recommendations of the Ministerial Inquiry into Tranz Rail (2000), deaths and serious injuries were declining (NZ Transport Agency 2013a. Following the Pike River coal mine disaster in 2010, the HSWA came into force and a new agency, WorkSafe New Zealand, was formed. Both were key initiatives towards reducing serious work-related injuries and deaths in New Zealand. Rail workers are represented by the Rail and Maritime Transport Union (RMTU).

The New Zealand Transport Accident Investigation Commission (TAIC) is an independent Crown entity that holds inquiries into rail accidents. TAIC is an important independent party in rail safety and while it only has recommendatory powers, many of its recommendations are put into practice. Industry organisations include the Federation of Rail Organisations of New Zealand (FRONZ), which represents the T&H rail industry. FRONZ members include operators that use their own track (as shown in the relationship map) and also operators who use the NRS. Of rail operators in New Zealand, KiwiRail has the most roles (not all of which are shown in the relationship map). These roles include access provider, rolling stock owner, mechanics provider, operator and track maintainer.

The simplified relationship map does not show all the complex interactions and interfaces within the rail industry, for instance, while the relationship map shows the rolling stock and mechanics provider together, ownership of rolling stock is often separate from the maintenance undertaken on that stock. An example of this is the Auckland metro fleet, which is owned, operated and maintained separately.

1.3 Findings – risk management context

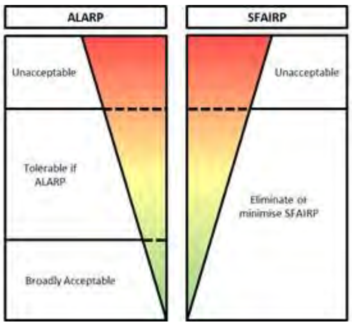
1.3.1 Understanding 'so far as is reasonably practicable' (SFAIRP)

The researchers examined existing literature, guidance and case law, and used their expertise in risk management to interpret the meaning of SFAIRP, compared with the ALARP 'as low as reasonably practicable' principle, and considered what this might mean for the railway industry.

The new SFAIRP requirement in the HSWA is considered to have the same meaning, for the most part, as the 'as low as reasonably practicable' (ALARP) concept already used by many operators.

However, information on ALARP (as presented in current rail risk assessment guidelines in New Zealand, such as NRSS4) would probably be insufficient standalone resources for rail operators to meet the SFAIRP requirement. As can be seen in figure 1.2, there is no 'broadly acceptable' area in SFAIRP, whereas this is communicated as part of ALARP in NRSS4. Under SFAIRP, risks must always be reduced wherever it is reasonably practicable.

Figure 1.2 ALARP vs SFAIRP conceptual model



The changes to the HSWA and the Railways Act clearly signal to duty holders there are higher expectations required of them. They will need support and guidelines to help them with their interpretation of the law and appropriate practices. Without these, duty holders may risk developing an approach to risk management that is either too lax or overly restrictive due to excessive caution.

The Health and Safety at Work (General Risk and Workplace Management) Regulations 2016 provide useful information to support the application of SFAIRP. In particular, the regulations set out a hierarchy of control measures and when to review and revise these measures.

Some useful resources to help rail operators understand what SFAIRP means for their organisations include the Australian guideline *Meaning of duty to ensure safety so far as is reasonably practicable* (ONRSR 2014) and the Safe Work Australia (2013) guideline *How to determine what is reasonably practicable to meet a health and safety duty*. The UK Health and Safety Executive (2001) document *Reducing risks, protecting people* provides a fundamental understanding of risk management expectations under a 'Robens'[2] approach to managing occupational risks. This resource would provide a good basis within New Zealand, which uses the Robens approach for health and safety legislation.

1.3.2 NRSS4

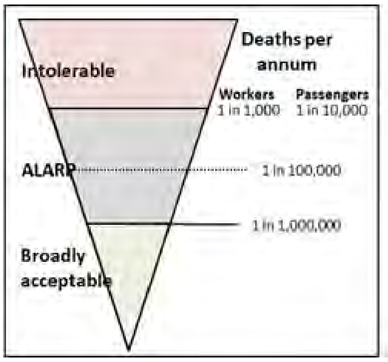
The researchers were asked to suggest enhancements to the NRSS4, which they found was no longer fit for purpose as it did not represent good risk management practice. The researchers recommend revoking NRSS4 and expanding the NRSS2 standard (safety management) to include risk management (updated to reflect best practice). The principal reason for recommending this option is to more explicitly recognise the integral role of risk management in the wider risk management framework (the safety management system). Some examples of issues in the NRSS4 are presented in appendix D. These issues may also be more widely applicable to other industry standards, particularly issues around a lack of alignment with the new health and safety legislation and modern risk management principles.

1.3.3 Quantifying 'acceptable' risk level

The researchers approached the question of quantifying acceptable risk level for rail operations in a number of ways: by applying their risk expertise and knowledge of the New Zealand rail industry; and by undertaking a review of relevant case law, guidance documents and other literature. Quantifying acceptable risk levels is difficult because the 'risk-landscape' is complex and public risk appetite can change quickly over time.

The NRSS4 (risk management) and the *Rail safety licensing and safety assessment guidelines* (Land Transport NZ 2006) both use the same proportion of deaths per annum to indicate boundaries in the ALARP triangle (see figure 1.3).

Figure 1.3 Current acceptable risk levels for New Zealand rail



For workers, an 'intolerable' bound of a 1 in 10,000 annual fatality risk may be more appropriate for rail workers than the current 1 in 1,000. Rail has improved its safety performance over the last 15 years; since 2010, the average annual fatality rate has been below 1 in 10,000 (based on a five-year rate) and sits at a similar level to construction (refer to figure 1.4). The purpose of the stricter 'intolerable' bound would be for the regulator to track safety performance for the industry as a whole rather than for operators or individual risks.

If this bound was used, a 5- or 10-year moving average rate would be best for monitoring safety performance given the small size of the industry.

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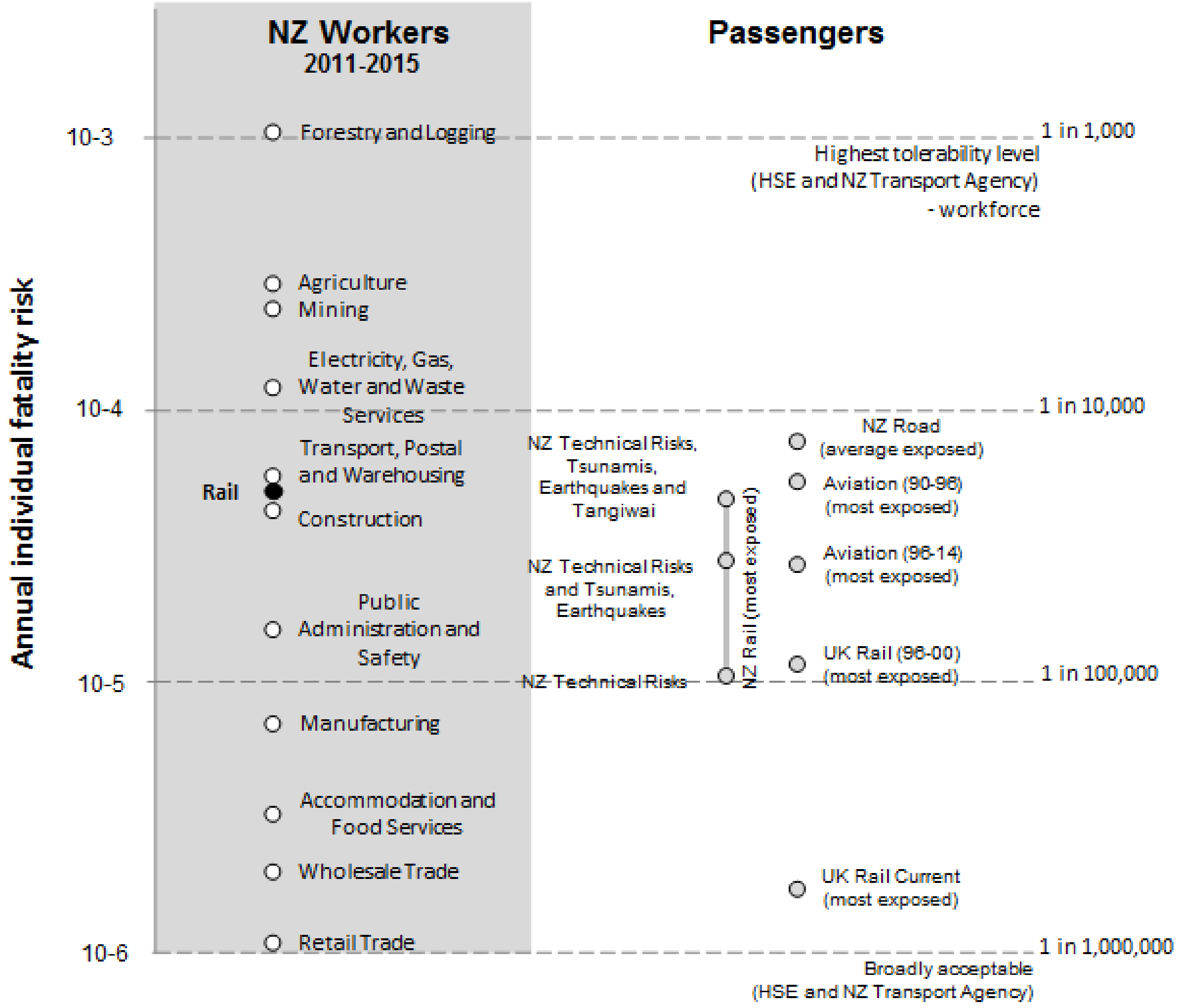
[2] The Robens approach is named for the Safety and Health at Work report written by Lord Alfred Robens in 1972, which made recommendations that were adopted across the world as a best practice approach to health and safety at work.

However, changing the tolerability limit for rail may have wider impacts for other industries, particularly in the transport sector, so these should be carefully considered before implementation.

The researchers suggest that while the 1 in 10,000 passenger tolerability limit is appropriate, the rail industry should be working towards 1 in 100,000 as a likely future upper bound for individual fatality risks.

Figure 1.4 Annual individual fatality risk comparison[3][4]



As explored in chapter 2 on understanding SFAIRP, risks in the 'tolerable' region need to be reduced so far as reasonably practicable. This is linked to the concept of gross disproportion.

A risk mitigation or control is clearly reasonably practicable if the cost of avoiding a fatality is the same as the statistical value of life.[5] For workers, the UK Health and Safety Executive (HSE) gives a rule of thumb ratio of 3 for workers. This means if the cost of avoiding a fatality is three times the value of a statistical

[3] Refer appendix C for derivation of comparison.

[4] The rail estimate in figure 3.3 includes a worker using hi-rail vehicle, recorded as construction fatality by WorkSafe NZ.

[5] The current value of a statistical life (VSL) set by the New Zealand Ministry of Transport is $4.06 million per fatality.

life then that control is reasonably practicable. For the public, the UK HSE gives a ratio that varies between 10 (higher risks) and 2 (lower risks) for the public (Health and Safety Executive 2016). However, the HSE states each decision needs to be taken individually and should take account of the level of individual risk and the extent and severity of the consequences of major incidents. What society considers grossly disproportionate may change swiftly and vary greatly depending on the circumstances involved. There are also increasing public expectations that old systems will be replaced by new and better systems that will not fail. They will be free of the potential for catastrophic outcomes and in particular single point failures will not occur.

The researchers suggest, while the HSE ratios are useful as a rule of thumb, their application requires a thorough understanding of context and good judgement including of prevailing societal attitudes.

1.3.4 Best practice in risk management

The researchers looked at what is best practice in risk management – as in other industries, best practice continues to evolve in the international rail industry. Key themes include:

- moving from blaming the individual to seeing failure as a symptom or outcome of a systemic issue or weakness
- recognising that organisational culture lies at the heart of, and is the foundation of achieving, high levels of safety performance
- placing less emphasis on rules as a safety intervention and more focus on hazard elimination and/or engineering controls
- moving from viewing safety as isolated processes and activities to thinking of it as an integrated system
- monitoring precursors (buckled rails, level crossing failures etc) to low probability, high consequence events, even if they did not result in any actual harm, as they give more insight than monitoring the levels of unrelated minor injuries.

1.4 Findings – current New Zealand practice

The researchers benchmarked rates of New Zealand rail occurrences against Australian and UK data and found the New Zealand rail industry performed poorly compared with these jurisdictions.

Although the benchmarking shows New Zealand has room for improvement, operational differences may render it impracticable for New Zealand to reach the same level of safety. For instance, New Zealand's rail is dominated by freight while UK rail is dominated by passenger services. This means UK rail infrastructure is maintained to a higher standard which happens to benefit the safety performance of freight services on its lines.

The researchers found metro and long-distance rail operators appeared to have relatively good risk management capability as well as having good access to resources (eg industry bodies, other organisations). The researchers also found examples of operators following international best practice like moving from blaming the individual to seeing failure as a symptom or outcome of a systemic issue or weakness, and recognising that organisational culture lies at the heart of achieving high levels of safety performance.

T&H operators tend to have lower risk management capability and may struggle to meet rising health and safety expectations despite good intentions. In terms of best practice, some of the more traditional safety control methods used by T&H operators possibly no longer represent modern best practice standards.

Safety challenges for T&H operations include using older heritage equipment that often has lower levels of in-built safety, and the difficulty of maintaining competencies in a volunteer labour force. Reducing speed is a common response and partially addresses some, but not all, of these challenges.

T&H operators may also struggle with the move from viewing risk management as an isolated process to thinking of it as an integral part of a joined up system.

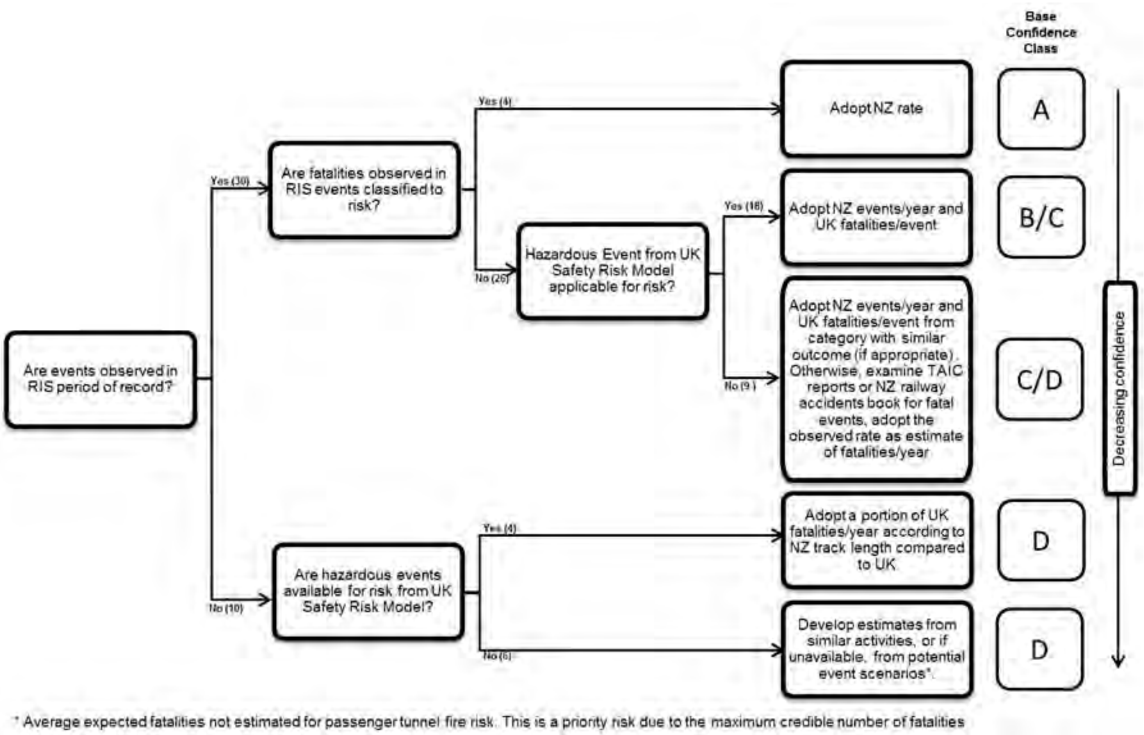
The researchers only visited a single industrial operator so they cannot draw strong conclusions but expect risk management capability of industrial operators in managing their rail operation safety risks will vary considerably depending on the wider business type (eg logistics, forestry, agriculture) and its safety culture.

In general, best practice internationally is to move away from an emphasis on rules as a safety intervention and to instead focus on hazard elimination and engineering controls (eg move up the control hierarchy). As a whole, the New Zealand rail industry is beginning down this path with some examples of advanced and innovative controls being tested and implemented.

1.5 Findings – risk assessment

A risk assessment was carried out to identify priority risks for the rail industry as a whole. The method used in the risk model is shown in figure 1.5. Historic New Zealand data (RIS 2010–2015) was examined for each risk, providing a count of the number of instances and number of fatalities observed. Given New Zealand's limited industry size, the data on incidents and accidents was also limited, particularly for rarer, higher consequence events. In this case, international data was drawn on to provide estimates.

Figure 1.5 Navigatus Safety Performance and Casualty Estimates (SPACE) risk model



The final risk rankings were based primarily on societal risk (using average estimated fatalities per year as shown in figure 1.5) and weightings (to reflect the degree of control that the rail system has over outcomes and broad societal values on acceptable risks). The highest risks identified by the assessment are a priority for assessing whether they have been reduced SFAIRP. If they have been and if the cost to reduce these risks further is grossly disproportionate to the benefits the risk may be tolerable.

One of the risks considered was fire in tunnels – while fires in tunnels can be catastrophic, this risk presented the greatest area of uncertainty for this research in terms of average expected fatalities due to the paucity of data. This risk is already a focus of WorkSafe New Zealand and the Transport Agency and is one of the national rail operator's critical risks. Assessment of this risk would require detailed evaluation and assessment of each higher risk tunnel which is beyond the scope of this assessment. Given that evaluation and treatment of this risk appears to be well in hand this risk is not evaluated further in this analysis.

Table 1.1 Ranked highest risks

Top risks in party and outcome control weighted order	
Tsunami	Priority risks
Collision with unauthorised member of public	Priority risks
Level crossing collision with light vehicle	Priority risks
Level crossing collision with pedestrian	Priority risks
Passenger train collision with civil works failure	Priority risks
Mainline passenger derailment	Priority risks
Tourist and heritage derailment	Priority risks
Collision with infrastructure maintenance worker	
Shunting incident	
Fire at station	
Freight derailment	
Mainline passenger level crossing collision with heavy vehicle	
Collision between trains involving at least one passenger train	
Level crossing collision with bus	
Tourist and heritage level crossing collision with heavy vehicle	
UMOP electric shock	

An unexpected outcome of the risk assessment was tsunami events appearing at the top of the list. While the likelihood of the event was low, the potential fatalities occurring in any one event were higher than any other risk assessed. Recognising that tsunami are natural events and are a wider issue than just for rail, there is value in considering whether there are additional controls that could be reasonably implemented (either by operators, regulators, or other organisations as part of a wider societal response to tsunami risk). While a tsunami cannot be prevented, there may be broader actions that the rail industry can influence or actions they can take directly to reduce risk.

Collision with unauthorised members of the public (ie members of the public walking along or crossing the railway tracks outside of level crossings) are by far the most common fatality type after suicides, which are not evaluated in the study. If this risk is higher than it could practicably be, it should be of concern to rail and wider society. Fatal events also have a significant impact on drivers' wellbeing and disrupt services across the network, which can create additional risks.

Of the assessed level crossing risks, light vehicles and pedestrians were identified as priority risks. While bus and heavy vehicle collisions are potentially more catastrophic, their much lower likelihood meant they did not rate as highly. While there are differences between the types of collision, in general, controls that reduce light vehicle risks will also reduce bus and heavy vehicle risks.

Civil works failures rated as a priority risk. They can be caused by many different factors and the consequences can range from minor to major. Derailment of passenger trains is also rated as a priority risk (with higher confidence in the estimates of mainline passenger derailment risk and lower confidence for estimates for tourist and heritage risk).

The priority risks are intended to inform discussion of priorities. The railway industry has many different stakeholders, each will have different viewpoints, and no single list of prioritised risks addresses the needs of all stakeholders.

1.6 Findings – research discussion and conclusions

Looking at the rail sector as a whole, care must be taken to direct efforts where they will achieve the greatest benefit. Parliament has set the legal test for safety, which is the gross disproportionality test contained in the SFAIRP principle. While the courts will be the ultimate arbiter for what is grossly disproportionate, we observe the greater good of society is not served by excessively stringent railway safety standards that drive up fares to such an extent many people move to less safe forms of transport. There is therefore a need for balance, viewing safety not as an absolute to be pursued at all costs, but as a relative good, pursued to the extent that is reasonably practical, consistent with New Zealand law and with societal expectations.

The researchers have made a number of recommendations which are given below. These are recommendations based on the research as a whole, as well as recommendations that relate specifically to the priority risks identified in the risk assessment.

1.6.1 Recommendations

Recommendation 1: Consider whether competency requirements should be established for defined safety roles within the rail sector (eg recognised qualifications and experience).

Recommendation 2: Continue benchmarking initiative that is planned (populate the metrics with data and publish the results).

Recommendation 3: Update guidance available to operators on licencing and safety case requirements (currently set out in the 2006 *Rail safety licensing and safety assessment guidelines* (Land Transport NZ 2006).

Recommendation 4: As part of the improvement project for ordinary safety presently being carried out, consider introducing ‘deep slice’ human factors approaches.

Recommendation 5: Ensure safety cases remain valid through increased emphasis in ordinary safety assessments on continuous improvement of safety cases by operators in accordance with section 30(1)1 of the Railways Act.

Recommendation 6: More overt, systematic and persistent follow-up of investigations and recommendations made by the transport sector.

Recommendation 7: All parties should support FRONZ, as appropriate, to enable the organisation to strengthen resourcing of Heritage Committees.

1.6.1.1 Priority risk recommendations

Priority risk recommendation 1: The national network access provider should consider whether imminent tsunami risk could be considered in the rules and procedures for earthquakes.

Priority risk recommendation 2: The national network access provider and the metro rail operator should work with central government, regional authorities and road transport funders to investigate, especially for the Wellington region:

1 Likelihood and consequences of tsunami risk on rail operations (as part of a wider assessment of risk to all transport modes)

2 Feasibility of civil defence warning and protection systems such as automated early warning buoy systems, tsunami defences and refuges

3 Feasibility of including elements of tsunami protection into projects currently under design such as the Wellington to Hutt cycleway and foreshore protection.

4 How such systems should integrate with wider civil defence protection and response responsibilities.

Priority risk recommendation 3: Rail operators might use introduction of SFAIRP as an opportunity to formally assess whether any further controls regarding unauthorised members of the public might be reasonably practicable. [6]

Priority risk recommendation 4: The transport sector to consider whether there would be value in establishing a formal policy regarding new level crossings and/or closure of current level crossings.

Priority risk recommendation 5: The transport sector to consider actions to strengthen pedestrian-related data inputs into ALCAM.

Priority risk recommendation 6: Rail operators might use introduction of SFAIRP as an opportunity to formally assess whether any further controls regarding potential civil works failures might be reasonably practicable.

Priority risk recommendation 7: Operators that have had derailments since 1 January 2010 due to passenger loading irregularities to undertake SFAIRP assessment of risks and options for additional controls.

Priority risk recommendation 8: Track inspection and maintenance to be added as a focus area for ordinary safety assessments for T&H rail operators.

Priority risk recommendation 9: A standard for track maintenance and inspection to be prepared or adopted for use by T&H rail operators on non-NRS tracks.

1.7 Method overview

The method for this research project had four main steps:

1 Literature review

2 Site visits and meetings

[6] This recommendation is not related to a legal requirement. HSWA requires that SFAIRP, the safety of 'other persons' is not put at risk from operations, but this requirement likely does not apply to trespassers. However, WorkSafe New Zealand states (in relation to other industries) that if trespass is reasonably foreseeable, then 'barriers' may be appropriate.

3 Data analysis

4 Risk assessment.

The method was based on the general risk assessment process outlined in AS/NZS ISO 31000:2009. The primary purpose of the literature review, site visits and meetings was to establish the context for the risk assessment.

The focus on building the context enabled the researchers to identify, analyse and evaluate risks appropriately at the risk assessment stage. Throughout the risk assessment process the researchers communicated and consulted with the Steering Group, other rail industry members and rail specialist advisor Greg Hight.

1.8 Report structure

The report structure is outlined below:

PART A: Risk management context

Chapter 2 provides comment on the SFAIRP requirement in the HSWA 2015.

Chapter 3 discusses what is an acceptable risk level for rail operations, based on modern industrial safety expectations and the 'risk appetite' of the public to travel by rail.

Chapter 4 explores existing best practice for risk assessment in rail in New Zealand, as well as in Australia and the UK. Although the focus is on rail, reference is made to practice in other industries.

PART B: Current New Zealand practice

Chapters 5 and 6 outline current New Zealand practice in railway risk management. This section is based on the researchers' visits to operators, a literature review, reports and data analysis.

PART C: Risk assessment

Chapter 7 provides the results of the risk assessment and outlines causes and impacts, protections in place, and possible additional protections. The assessment was undertaken in three stages, with the final stage being identification of priority safety risks.

PART D: Research discussion and conclusions

Chapter 8 suggests ways the underlying system of safety management in rail could continue to improve over the long term through addressing the question *what can be done to make it more likely that the priority issues will continue to be identified and well managed in the future?*

Chapter 9 gives the conclusions and recommendations of the report.

Chapter 10 references the works consulted during the research.

PART A: RISK MANAGEMENT CONTEXT

2 Understanding 'so far as is reasonably practicable' (SFAIRP)

2.1 Introduction

The researchers were asked to:

> *Consider the implications of the 'so far as is reasonably practicable' (SFAIRP) requirement in the new Health and Safety at Work Act and the amended Railways Act on management expectations (particularly for high consequence, low frequency events) and comment on the relationship of SFAIRP compared to the similar 'as low as reasonably practicable' (ALARP) principle.*

The researchers referred to existing literature, guidance and case law, and used their expertise in risk management to interpret the meaning of SFAIRP, compare SFAIRP with ALARP ('as low as reasonably practicable') and consider what this may mean for the railway industry. The opinions in this chapter are those of the researchers and do not constitute legal advice.

The HSWA, which came into force on 4 April 2016, is a key initiative the government has taken towards reducing serious work-related injuries and deaths in New Zealand. The HSWA is focused on enabling businesses to manage their specific risks, and introduces to New Zealand the key concept of SFAIRP. The HSWA requires that SFAIRP, and the health and safety of workers and other people, are not put at risk by the undertaking of a business. The Railways Act 2005 was also amended at the same time to adopt the SFAIRP approach.

The adoption of SFAIRP is not intended to be a significant departure from the previous Health and Safety in Employment Act 1992, but is intended to communicate to New Zealand businesses that new behaviours are required of them (MBIE 2013b).

New Zealand's HSWA is based on the Australian model Work Health and Safety Act, which uses the SFAIRP concept that originated in the UK. The Australian model Work Health and Safety Act, which was finalised in 2011, has so far been implemented by four of Australia's six federated states. The SFAIRP requirements are also found in the Australian Rail Safety National Law. As the SFAIRP concept has been in use for some time in Australia, the guides published for interpreting the requirements in Australia are referred to in this research to give an understanding of how SFAIRP is likely to be interpreted in the New Zealand rail sector.

While the interpretation of the requirements by New Zealand regulators and by New Zealand courts may differ from Australia in practice, there is no case law to draw on in New Zealand. A search of Australian case law found there was little of direct relevance to the SFAIRP concept.

2.2 Meaning of reasonably practicable

The HSWA requires risks to be first of all eliminated (and if this is not reasonably practicable), then minimised (so far as is reasonably practicable). The meaning of 'reasonably practicable' in the Railways Act is given in figure 2.1:

Figure 2.1 Meaning of 'reasonably practicable' in the Railways Act 2005

5 Meaning of reasonably practicable

In this Act, unless the context otherwise requires, **reasonably practicable**, in relation to a duty to ensure health and safety or to protect property, means that which is, or was, at a particular time, reasonably able to be done in relation to ensuring health and safety or the protection of property, taking into account and weighing up all relevant matters, including—

(a) the likelihood of the hazard or the risk concerned occurring; and

(b) the degree of harm or damage that might result from the hazard or risk; and

(c) what the person concerned knows, or ought reasonably to know, about—

(i) the hazard or risk; and

(ii) ways of eliminating or minimising the risk; and

(d) the availability and suitability of ways to eliminate or minimise the risk; and

(e) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

Section 5: replaced, on 4 April 2016, by section 232 of the Health and Safety at Work Act 2015 (2015 No 70).

Essentially, the requirements mean risk assessments should be undertaken for risks and hazards[7] and that ways of eliminating or minimising these risks should be identified and considered, based on what the organisation or persons know, or what a person in that position should reasonably be expected to know. Once the assessment has been carried out, then everything that can be done to eliminate, and if not eliminate then minimise, the risk should be done, unless it is reasonable that less is done (for instance, if the cost of the control is grossly disproportionate to the risk). Safety should always be considered ahead of cost.

While the Australian model Work Health and Safety Act is fairly recent, the concept of reasonably practicable has been in use much longer; most modern guidelines still refer to the 1949 Edwards vs National Coal Board case under English case law. The case established the need to undertake risk assessments that considered cost and time, balanced against the severity of harm that may result. On 'reasonably practicable', Lord Justice Asquith stated:

> *Reasonably practicable is a narrower term than 'Physically possible' and implies that a computation must be made... in which the quantum of risk is placed in one scale and the sacrifice involved in the measures necessary for averting the risk (whether in time, trouble or money) is placed in the other and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the person upon whom the obligation is imposed discharges the onus which is upon him.*

In a more recent case, the Australian High Court stated (Slivak v Lurgi [2001]):

- *The words 'reasonably practicable' have, somewhat surprisingly, been the subject of much judicial consideration. It is surprising because the words 'reasonably practicable' are ordinary words bearing their ordinary meaning. And the question whether a measure is or is not reasonably practicable is one which requires no more than the making of a value judgment in the light of all the facts. Nevertheless, three general propositions are to be discerned from the decided cases*
- *the phrase 'reasonably practicable' means something narrower than 'physically possible' or 'feasible'*

[7] The HSWA does not define risk and refers to both risks and hazards.

- *what is ‘reasonably practicable’ is to be judged on the basis of what was known at the relevant time*
- *to determine what is ‘reasonably practicable’ it is necessary to balance the likelihood of the risk occurring against the cost, time and trouble necessary to avert that risk.*

While this interpretation is illuminating, its applicability must be modified in light of the recent amendments to the Railways Act (and HSWA), in particular the term ‘grossly disproportionate’ in the definition of ‘reasonably practicable’. In regards to the final bullet point of the Court’s comment, for something to not be reasonably practicable, it is no longer a matter of costs just being unbalanced with the risk, but that they are not grossly disproportionate to the risk. Refer to the section “Reasonably Practicable and Grossly Disproportionate” later in this report for further discussion.

There are well known cases in the UK[8] that have also added to the understanding although New Zealand will have its own interpretation of requirements. Practical implications of those cases include that risk must be real to be of concern (not fanciful/farfetched) and that foreseeability of a risk is a relevant factor when deciding if all reasonably practicable steps have been taken. Risk foreseeability includes considering whether an employee might do something contrary to their training (for instance, to save time or effort).

The 1993 New Zealand case of Department of Labour v de Spa and Co Ltd considered under the Health and Safety in Employment Act 1992 commented on this matter, including concluding that the defendant:

> *… ought reasonably to have anticipated that an employee standing on the walkway might decide, on the spur of the moment and without thinking about the potential danger of a descending bar, to look down the shaft. There was nothing in place to prevent or discourage an employee from doing so and no warning about the risk involved.*

The Australian Office of the National Rail Safety Regulator (ONRSR) points out that while the concept of reasonably practicable can be objectively tested, it is not always straight forward, and ‘the “comfort” of the individual duty holder is borne from adhering to the decision-making process and taking into account all relevant matters in an appropriate way’ (ONRSR 2014b). As an operator, this should be a prompt – if something did go wrong – where is the evidence that we thought about this risk and have done something about it? This does not mean that rail operations have to be (or could ever be) completely risk free.

An example of how SFAIRP applies might be a risk assessment undertaken by an operator of older rail carriages. The assessment might find the carriages pose a higher risk to passengers because of the potentially greater consequences, should a collision occur, due to the lesser structural protection offered. A reasonable person might consider introducing a strengthening or replacement schedule for the carriages that spans multiple years, or use other controls, such as using those carriages less or at reduced speeds compared with other carriages. The operator could demonstrate they understand the risks and that these controls either reduce the consequence or the likelihood of an incident sufficiently to lower the overall risk. If overall the risk is fairly low, a reasonable person would not be expected to immediately decommission or replace the carriages because the cost of this would be grossly disproportionate to the risk. It is important the risk assessment shows what all the options are before they are assessed on a cost basis.

An example of an operator using a risk assessment on older rolling stock can be taken from the UK (the MK1 carriages). The UK Health and Safety Executive (HSE) directed the carriages to be withdrawn by the end of 2002 unless they were modified to reduce the potential for overriding in the event of a collision.

[8] For example, R v Hatton Traffic Management (2006) EWCA Crim 1156; R v Porter [2008] WLR (D) 167; Baker v Quantum Clothing Group [2011] UKSC 17; R v Veolia and R v Tangerine Confectionary Ltd [2011] EWCA Crim 2015.

However, the life of the carriages was later extended by the UK HSE with the introduction of the UK Train Protection & Warning System, because this reduced the likelihood of a head-on collision. This is an example where a risk assessment led to the withdrawal of a regulatory directive.

The Australian ONRSR specifically states in its guidelines that it recognises older rolling stock may still be able to meet SFAIRP requirements despite offering less structural protection than newer carriages. However, this is within the context of continuous improvement. The ONRSR advises existing assets should continually be compared against more modern standards so that retrofit might be considered, or specific monitoring and review of the asset's condition should be undertaken.

The rolling stock example described here applies in the heritage sector and was included as it was used as an example in the ONRSR guidelines – these principles apply equally when assessing other rail activities, for instance, operating and signalling systems.

Capacity to pay should not factor as to whether a control would be reasonable to implement – essentially, if reasonable protections cannot be afforded, then that activity should not be undertaken. A lower cost option can still be chosen if there will be the same level of reduction in risk, but cost should not be a deciding factor alone (Safe Work Australia 2011). In fact, the Safe Work Australia (2013) guidelines go so far as to state where the potential degree of harm is significant (eg death or serious injury is at least moderately likely) then the cost of implementing available and suitable safety measures is unlikely to ever be disproportionate enough not to put the measures in place.

The availability and suitability of ways to eliminate or minimise risk are also considered in the definition of reasonably practicable under the Railways Act. Safe Work Australia (2013) states a piece of equipment is regarded as being available if it is provided on the open market or if it is possible to manufacture it. While a piece of equipment's presence or absence on the open market is straightforward, there can be more interpretation around custom manufacture. Introducing a customised element into a complex system requires a high level of design and engineering skill as changes can introduce new human factors, complexity and reliability risks. Because of these potential risks, the availability of an item also relates to its suitability.

Safe Work Australia considers a control to be suitable if it is effective in eliminating or minimising risk, it does not introduce new or higher risks and is practical to implement (Safe Work Australia 2013). This judgement requires consideration of a control within the wider context.

Availability and suitability, as discussed here, are very different considerations to cost. This is an area where there is a potential for divergent views between operators and regulators. In general, rail operators will have greater technical and working knowledge of their operations and may be able to more accurately assess the availability and suitability of proposed additional safety controls for their operation. A challenge for operators is effectively communicating the outcomes of such assessments (and demonstrating the evidence base) to regulators when it is systemic safety considerations rather than cost that has led to rejection of proposed individual safety improvements.

2.3 SFAIRP vs ALARP

The ALARP principle is referred to in both the NRSS4 (NRSS-E 2007) and the *Rail safety licensing and safety assessment guidelines* (Land Transport NZ 2006) as, up until 2016, this was the terminology in the Railways Act. The HSE (2015) considers ALARP to be equivalent to SFAIRP and continues to use ALARP in its guidance documentation despite using the SFAIRP phrasing in its Health and Safety at Work Act. However, it is not clear this equivalence has been demonstrated in law (Hughes 2005).

A key difference between the terms is that while ALARP has a 'broadly acceptable' region of risk (as presented in NRSS4), there is no corresponding concept in SFAIRP. This is one of the reasons that reference to the ALARP information presented in NRSS4 or the rail safety licensing and safety assessment guidelines alone would unlikely be sufficient for operators to meet the SFAIRP requirement. These documents simplify the ALARP concept described by HSE (2015) (which is necessary for brevity's sake) but in doing so leave out context important for meeting SFAIRP by using ALARP.

For instance, in the NRSS4, the ALARP diagram presented shows a 'broadly acceptable' region of risk and indicates maintaining this level of risk is sufficient with the implication that no further risk reduction is necessary (see figure 2.1). ALARP, as described by the HSE (2001), still requires duty holders to reduce risks wherever reasonably practicable, even for those risks in the broadly acceptable region. While in practice the cost of reducing risks in the 'broadly acceptable' region may often end up being grossly disproportionate, operators should still be aware that SFAIRP applies. This issue is particularly relevant if the risk assessment tool used inappropriately categorises a risk as broadly acceptable (eg a risk matrix or calculation is used that does not reflect society's current tolerance for a risk – what is acceptable can change rapidly).

While SFAIRP and ALARP (in its non-simplified form) can be considered identical in theory (see HSE 2015), there may be practical differences between how such tests play out in practice and are interpreted by the courts in the future. Based on our experience, operators applying ALARP in New Zealand have tended to focus on reducing risk by following current known practice and therefore progressively reduce system-wide risk, whereas a focus on continual reduction of risk for each individual aspect is required for SFAIRP. The lack of a 'broadly acceptable' area in SFAIRP makes this concept clearer for operators (see figure 2.2).[9]

Figure 2.2 From NRSS4 (NRSS- E 2007)

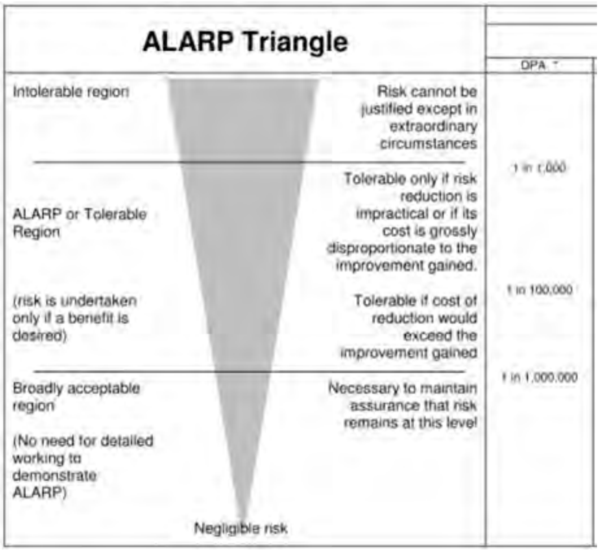
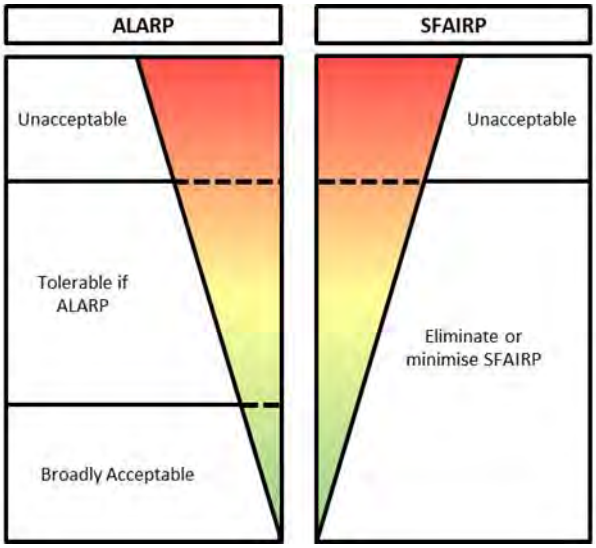


Figure 2.3 ALARP vs SFAIRP conceptual model



A paper by Robinson and Francis (2014) on the Australian model Work Health and Safety Act requirements and the move from ALARP to SFAIRP, argues that the move from ALARP to SFAIRP makes the rareness of an event largely irrelevant in building a defence should a high-consequence event occur. While a judicious

[9] Europe uses the common safety method (discussed further in section 4.4.2) targets for system failures that lead to a single or multiple fatalities. This effectively determines what is reasonably practicable or broadly acceptable for railway systems (for instance, the European Train Control System).

verdict would look at what someone ought reasonably to have known and ought reasonably to have done pre-incident, it is difficult to discount the impact that hindsight could have when ruling on a high-consequence incident. In terms of high-consequence events, the remote possibility of the event occurring making the risk 'acceptable' is unlikely to be a good defence should such an incident occur, if all reasonable measures have not been taken to reduce the risk.

The previous Health and Safety in Employment 1992 Act in New Zealand also had 'all practicable steps' and 'reasonably practicable' components to hazard management, but the Royal Commission on the Pike River Coal Mine Tragedy found this approach had not been effective as the necessary detailed regulations and codes of practice were not there to support the Act (Royal Commission on the Pike River Coal Mine Tragedy 2012).

2.4 Conclusion

The changes to the HSWA and the Railways Act, particularly relating to SFAIRP, are a clear signal to duty holders that there are different expectations required of them. Duty holders will also need codes of practice and guidelines to help them with their interpretation of the law. Without these, duty holders may struggle to attain an approach to risk management that is neither too lax, nor overly restrictive due to excessive caution.

The Health and Safety at Work (General Risk and Workplace Management) Regulations 2016 provide useful information to support the application of SFAIRP. In particular, the regulations set out a hierarchy of control measures and when to review and revise these measures.

The requirements of SFAIRP should not be unreasonable; the real test will be how the requirements are interpreted and applied in New Zealand courts. If the enactment of the HSWA is discomforting to organisations, this is a critical indication the organisation might not be managing risks as well as it should be, or the systems in place are not adequate or are not being followed. As WorkSafe New Zealand (2017) states, it is 'not just about compliance; it's about getting people home healthy and safe. It's not just good for your business, it's the right thing to do'.

The following resources may also be useful to duty holders to understand what SFAIRP means for their organisations.

2.4.1 Useful resources

- HSE (2001) *Reducing risks, protecting people* (2001) provides a fundamental understanding of risk management expectations under a 'Robens' approach to managing occupational risks
- *Meaning of duty to ensure safety so far as is reasonably practicable guideline* by the Australian Office of the National Rail Safety Regulator (2014) is a useful resource and can be found on the website www.onrsr.com.au
- The Safe Work Australia (2013) guideline *How to determine what is reasonably practicable to meet a health and safety duty* is also a useful resource.

3 Quantifying ‘acceptable’ risk level

3.1 Research question and approach

The researchers were asked to:

> *Quantify what is an acceptable risk level for rail operations, based on modern industrial safety expectations and the ‘risk appetite’ of the public in regards to rail travel as compared to other modes of transport.*

The researchers approached this research question by applying their risk expertise, knowledge of the New Zealand rail industry, and by undertaking a review of relevant case law, guidance documents and other literature.

The research undertaken and literature studied on this issue are more fully described in appendix C. The main context and findings have been summarised here to give readers a concise answer to the research question.

The researchers have applied their risk expertise and knowledge of the New Zealand rail industry to suggest changes that might be appropriate to rail risk levels (quantified as annual fatality risk). The comments here are given within the context of the New Zealand rail industry and do not consider whether tolerable or acceptable risk levels should be aligned across other types of transportation or industries.

3.2 Introduction

Quantifying acceptable risk levels is difficult because the ‘risk-landscape’ is complex and public risk appetite can change quickly over time.

The level of acceptable risk also depends on the circumstances. For instance, a railway-related death may be viewed quite differently depending on whether it is a suicide (deliberate), a trespasser (voluntary and unauthorised), at a level crossing (voluntary and in control), a railway worker (voluntary, control varies), a passenger (voluntary, no control), or a bystander (involuntary imposed risk).[10] Acceptance of a risk imposed upon us is much less than one we voluntarily take. Other factors include dread, where unfamiliar and unseen risks such as nuclear radiation are feared more than familiar risks such as vehicle crashes.

Although the researchers quantify risk levels here, this needs to be considered within both the quickly changing societal risk appetite and the context of SFAIRP.

A risk is not acceptable if it is reasonably practicable to reduce it further. Individual operators might also have goals such as ‘zero harm’, which show a commitment to continual reduction of risk regardless of what is considered ‘acceptable’.

Further information on quantifying acceptable risk is available in appendix C.

[10] See appendix C, section C2.5 for more discussion of risk acceptance criterion.

3.3 Current acceptable risk levels

NRSS4 and the NZ Transport Agency (Land Transport NZ, 2006) both use the same number of deaths per annum to indicate boundaries in the ALARP triangle (shown in figure 3.1).

Tolerable risk for workers is higher than for passengers. This difference between tolerable worker and passenger/public risk is common practice and reflects both the higher exposure a worker has and the perceived volition over this exposure. Figure 3.2 demonstrates the volition concept for different persons, where tolerance of a risk is proportionate to the level of control the person has over the risk.

Some operators have visions, such as ZeroHarm, which help capture the idea that no injury or fatality is ‘tolerable’ if avoidable.

Figure 3.1 Current acceptable risk levels for New Zealand rail

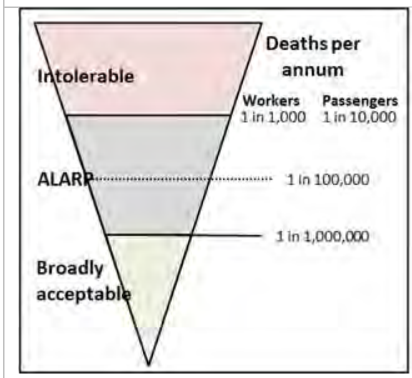
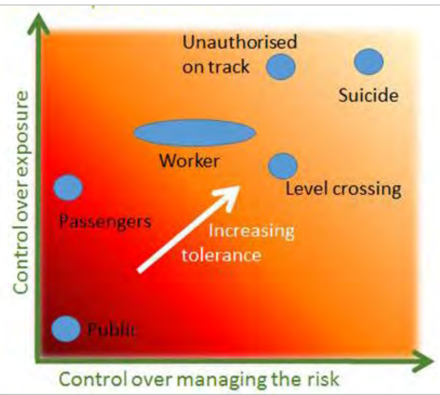


Figure 3.2 Risk tolerance for persons based on level of control over risk (C Ballantyne, NZ Transport Agency)



3.4 New Zealand safety performance

Measuring New Zealand’s safety performance gives an opportunity to compare it against the currently stated tolerable and acceptable risk levels. Figure 3.3 shows New Zealand’s safety performance for different industries and transport modes, including rail. This is presented as annual individual fatality risk for New Zealand workers (left side, 2011–2015) and passengers (right side). UK safety performance (current and historic) for passengers is also shown for comparison. Passenger estimates must be regarded as indicative estimates of the underlying level of risk; no passengers were killed on either the New Zealand or UK rail systems in the latest periods of analysis.

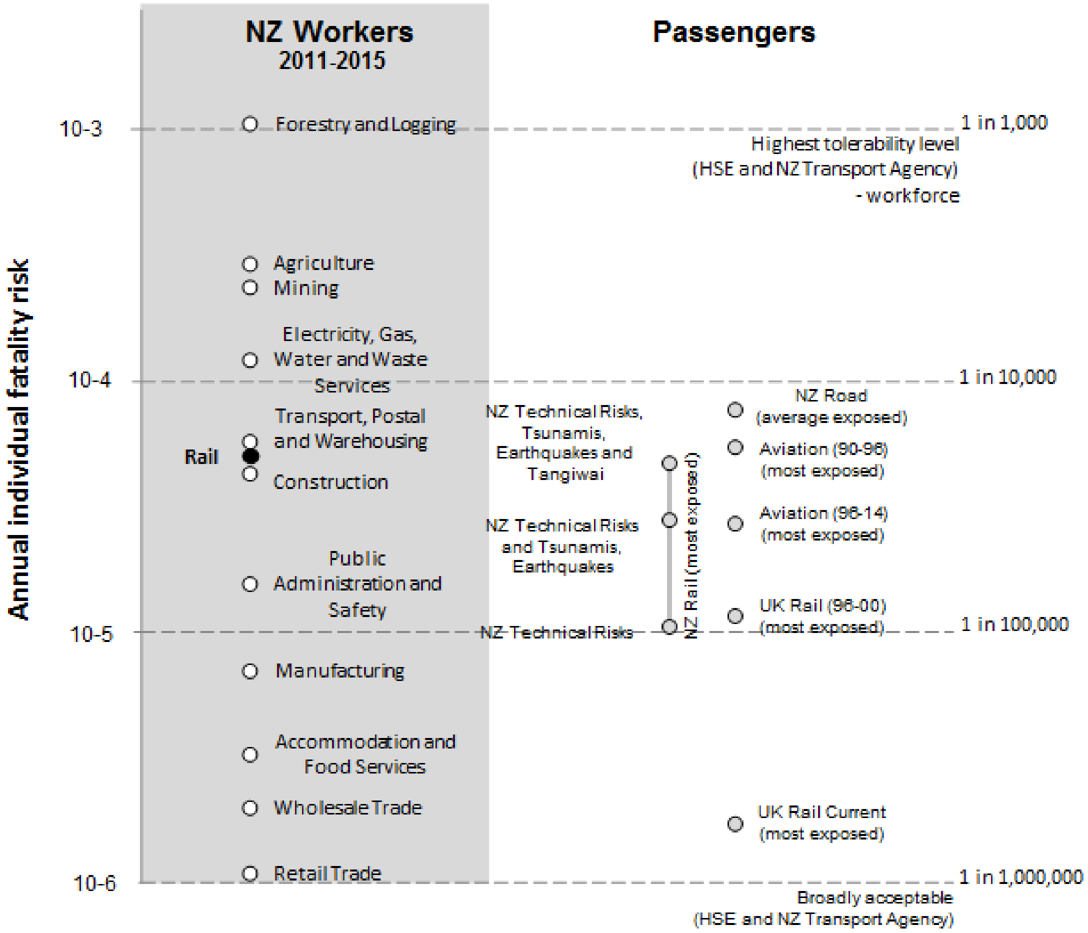
The estimated individual fatality risk to rail workers is higher than industries such as construction and manufacturing and lower than mining, agriculture and forestry. For this period, the annual fatality risk for rail workers sits within the ALARP region as specified by current standards and guidelines.

The figure also shows a range of rail passenger fatality risk estimates derived from the Navigatus SPACE risk model for the most exposed individual. The risk is lower than that for travel by road and is similar to the most exposed aviation passenger (on a per passenger km travelled basis). As with workers, the risk for this period sits within the ALARP region.

The New Zealand passenger risk is similar to UK rail industry safety performance in the 1990s; current UK safety performance is much better.

The UK rail data shows safety performance is improving internationally. This mirrors societal expectations of improved safety across all transport modes. We expect the pressure for improved safety performance will only increase. For instance, some cars already have autonomous braking systems to avoid collisions. Once such systems become commonplace in private cars, the public may come to expect the rail system is equipped with at least equivalent levels of safety technology.

Figure 3.3 Annual individual fatality risk comparison[11 12]



3.4.1 Worker risk

The Land Transport NZ (2006) guidelines define the upper bound of tolerable risk as an individual worker annual fatality risk of 1 in 1,000. This is said to be tolerable only if the cost of risk reduction is grossly disproportionate to the improvement gained. We would suggest that regardless of gross disproportion, this level of risk for rail workers is likely intolerable to New Zealand society and could only be justified in extraordinary circumstances.

An analysis of forestry fatalities in New Zealand showed between 2011 and 2015 inclusive, annual worker fatality risk was approximately 1 in 1,000. Societal concern and the regulator reaction showed a fatality rate this high was not tolerable, even for such a high-risk industry. During this period, as many as 15 forestry operations were shut down until acceptable safety improvements had been made.

[11] Refer appendix C for derivation of comparison.

[12] The rail estimate in figure 3.3 includes a worker using hi-rail vehicle, recorded as a construction fatality by WorkSafe NZ.

Over this same period (2011–2015) there were no recorded fatalities to rail workers. There has since been one serious incident involving a worker using a hi-rail vehicle (HRV) who subsequently died. However, this was recorded as a construction worker fatality by WorkSafe New Zealand. If we assume one fatality in five years for rail workers is the current state, this would represent a 5 in 100,000 individual annual fatality risk.

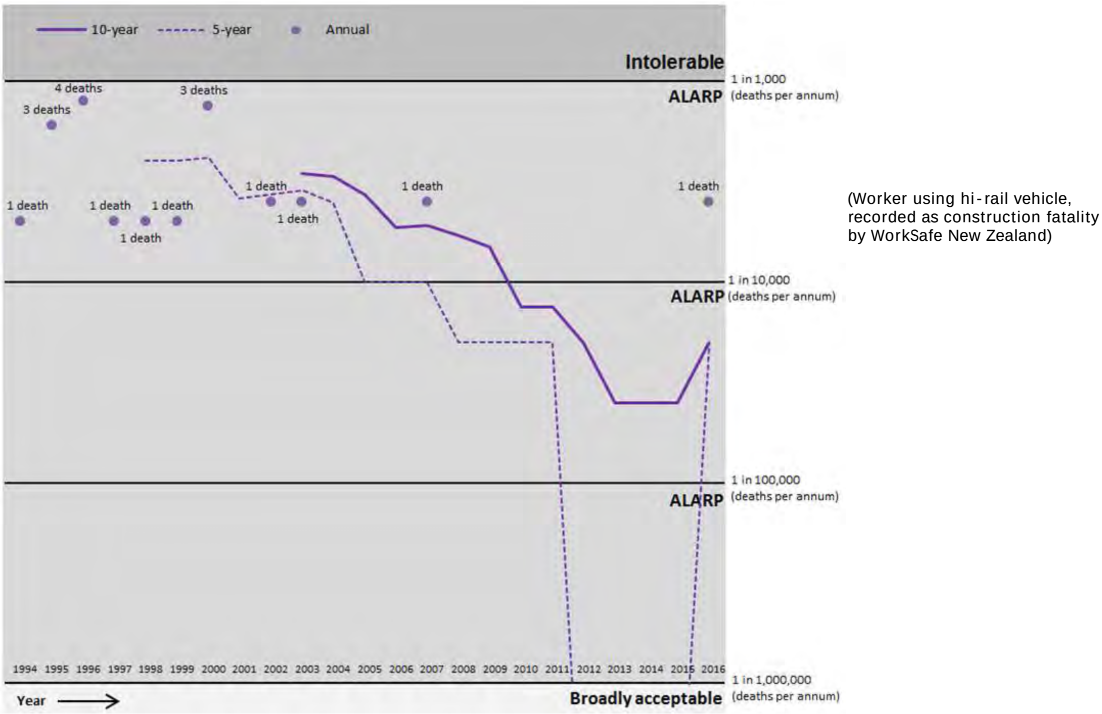
Figure 3.4 shows a longer data series for annual fatality risk (represented as an annual data point and moving average annual rates (5- and 10-year)). Measured on a single year basis, a single fatality in any year puts the rate into the highest tolerable risk band. This is due to the small size of the rail industry and likely does not represent an actual change in the industry's risk profile.

Since 2010, both the 5- and 10-year moving average annual rates have been below 1 in 10,000. To stay within this band in the future, there could be no more than two worker fatalities within five years, or no more than four worker fatalities within 10 years (assuming that employment numbers remain constant).

Given the improvement in safety performance over the last 15 years, and assuming the rail risk profile remains similar, we would suggest the bound between tolerable and intolerable risk for workers is too lenient. An upper bound of tolerability of a 1 in 10,000 annual fatality risk may be more appropriate to the risk profile the rail industry has achieved. This bound would relate to the rail system, but might not be appropriate for abnormal activities (such as debris excavation following a landslip or tunnelling). If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry.

The current 'broadly acceptable region' of risk has an upper bound of one in one million fatality risk for workers. We consider this appropriate, so long as risk is still reduced so far as is reasonably practicable.

Figure 3.4 Annual individual fatality risk to New Zealand rail workers. 10- and 5- year rates are a moving average.[13]



[13] The figure includes one serious incident involving a worker using a hi-rail vehicle who subsequently died and which was recorded as a construction worker fatality by WorkSafe New Zealand. There may have been other incidents related to rail activities that have been recorded as construction fatalities and have not been captured in the figure (eg construction of a train station).

3.5 Passenger risk

Society clearly has a higher expectation of public safety when using rail transport compared with road. Most likely this is largely based on the actual fatality rates of each transport type; fatalities to rail passengers are rare in New Zealand and are consequently not expected or accepted by the public.

The current upper bound of tolerability for rail passengers is a fatality risk of 1 in 10,000 (Land Transport NZ 2006). Should a significant incident occur, we would expect public tolerance for passenger safety risk to be low, and possibly much lower than current safety performance levels, given that high levels of passenger safety performance have been attained in countries we traditionally compare to, such as the UK.

We suggest while the 1 in 10,000 tolerability limit may still be appropriate at this time, the industry should be working towards 1 in 100,000 as a likely future upper bound for passenger individual fatality risks for all rail-specific hazards. The 1 in 100,000 target would be more stringent than for workers – this is common practice and reflects both the higher exposure a worker has and the perceived volition over this exposure.

The current 'broadly acceptable region' of risk of one in one million, as with workers, is likely to be appropriate, so long as risk is still reduced so far as is reasonably practicable.

3.6 Reasonably practicable and grossly disproportionate

SFAIRP is linked to the concept of gross disproportion. Work in the UK shows a control is clearly reasonably practicable if the 'implied cost of an avoided fatality' (ICAF) is the same as the statistical value of life (Franks 2006). The current value of a statistical life (VSL) set by the New Zealand Ministry of Transport is $4.06 million per fatality.[14] Allowing for the other social cost components (such as loss of productive output and medical costs) gives an updated average social cost per fatality of $4,094,500 at June 2015 prices (Ministry of Transport 2016c).

While it is clear a control is reasonably practicable if the VSL is the same as ICAF, it is not as clear when a control becomes grossly disproportionate in cost. The HSE (2016) gives, as a rule of thumb, a ratio of 3 for workers and a ratio that varied between 10 (higher risks) and 2 (lower risks) for the public. However, the HSE states each decision needs to be taken individually and take account of the level of individual risk and the extent and severity of the consequences of major incidents. Other factors, such as whether the risk is under the person's control, might also be taken into account.

Evans (2013) has criticised the validity of the 'grossly disproportionate' argument, pointing out the introduction of the terminology in Edwards v National Coal Board was when human life was valued much lower than presently. In 1949, the compensation paid to the widower in the case was £984, and in this sense the intangible costs of a lost life were grossly disproportionate to this amount.

However, the term 'grossly disproportionate' was introduced into New Zealand through the enactment of the Health and Safety at Work Act and amendments to the Railways Act by Parliament in 2016. The VSL had been in use for 25 years at that point, and so the terminology 'grossly disproportionate' in New Zealand was introduced in the context that a 'proportionate' amount would be the VSL. Therefore the

[14] The VSL is derived from a 1991 study (Miller and Guria 1991), which asked approximately 600 people what they would be willing to pay for various improvements in road safety.

law should be interpreted that an acceptable level of risk, under the Railways Act, must reflect more than just the VSL. More detailed case studies are presented in appendix C, section C2.5, of this report.

What society considers grossly disproportionate may change swiftly and vary greatly depending on the circumstances involved (Evans 2013). The researchers suggest, while the VSL and HSE ratios are useful as a rule of thumb, application of the concept requires a thorough understanding of context and good judgement (including of prevailing societal attitudes).

3.7 Conclusion

The researchers suggest the broadly acceptable risk level for rail passengers and workers of a 1 in 1,000,000 fatality risk in the Land Transport NZ (2006) guidelines is likely to be in line with modern industrial safety expectations and the risk appetite of the public. The SFAIRP test governs, so this risk level remains acceptable only if it is reduced SFAIRP.

For rail workers, the researchers suggest an upper tolerability bound of a 1 in 10,000 annual fatality risk may be more appropriate than the current 1 in 1,000, given rail's improved safety performance over the last 15 years. This bound would relate to the rail system, but might not be appropriate for abnormal activities (such as debris excavation following a landslip or tunnelling). If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry. However, changing the tolerability limit for rail may have wider impacts for other industries, and these should be considered before any changes are made.

For passengers, the researchers suggest that while the 1 in 10,000 tolerability limit is appropriate, the rail industry should be working towards 1 in 100,000 as a likely future upper bound for individual fatality risks for rail-specific hazards.

In general, a more stringent tolerability limit should be applied to new systems and system-related risks.

Society's perception of what is and is not reasonably practicable is likely to vary greatly depending on the circumstances. Accordingly, we do not suggest a set ratio for determining what is grossly disproportionate.

Quantified risk levels are more useful for assessing industry performance as a whole than for an operator to use in risk assessments for individual activities. Working out whether a specific risk is acceptable or tolerable introduces an apportionment issue, so is less useful at an operator level in the absence of accurate system-wide modelling of risk. This gap between system-wide performance expectations and operator decision making on individual system components is addressed by approaches such as the common safety method, which is one of the techniques outlined in the next chapter.

4 Best practice in risk management

4.1 Research question and approach

The researchers were asked to:

> *Look at what is best practice in risk management (specifically in the rail industry), both in New Zealand and internationally.*

The researchers approached this research question by applying their risk expertise, knowledge of the New Zealand rail industry, and by undertaking a review of relevant literature.

The initial literature review was targeted towards international best practice in risk management, specifically as applicable to rail. Given the large scope of the review, only the most applicable findings from the literature search are reported on.

The views on risk management in this section are guided by the researchers' own professional knowledge, specific research, and risk management practices, rail advisor Greg Hight, insights from the Steering Group Committee and input from our peer reviewers.

4.2 Introduction

Any industrial type activity that involves the movement of heavy equipment, the management of energy and, in particular where human control is exercised, inherently creates the chance of harm and hence risk. The purpose of risk management in a rail safety context is to protect the public and workers from harm.

The research brief called for a review of *best practice in risk management*, which we have interpreted to include the wider risk management principles, framework and processes where appropriate. While the risk management principles discussed are sometimes generic and can be applied to a range of both safety and non-safety outcomes, such non-safety applications are not explored in this research. The purpose of the summaries in this chapter is to provide a brief overview of the current state of best practice in risk management.

There is a considerable body of work on the management of safety risk spanning sector-specific material, broad popular-style books and a range of expert papers, as well as highly regarded academic-based theses and publications. However, the commentary in this chapter references only those sources that are most pertinent to our research. To avoid duplication, other references have been cited only in the relevant findings and discussion sections of this report.

The more complex, involved or multi-faceted a system is, the more necessary it is to gain an insightful understanding of the inherent risks and a continuing view of any changing circumstances and other factors. This is now done by applying risk management principles and in particular by means of formal risk assessments (using whichever method best suits the context, organisation or issue in question). It is now recognised that to understand and manage risk in complex system circumstances, it is necessary to first understand and describe the context, identify the sources of risk (hazards) and then analyse the risks and the effect of current as well as proposed controls. To be complete, this must be done at both a strategic and operational level.

Some view the process of 'risk assessment' as a somewhat academic exercise; however, in sectors where the understanding and management of risk is mature and usually highly effective, the view is that no 'change' or 'non-routine' undertaking should be commenced without first completing a full formal risk assessment and design and implementation of risk controls. These risk management processes can sometimes support or conversely challenge established professional views.

The recognition of the value and importance of formalised risk management within New Zealand society is developing, and to some extent the recent changes to health and safety legislation and accompanying regulations are a reflection of this. If organisations want to meet their legislative requirements, and, in the event of incidents, protect themselves from subsequent social scrutiny, they need to ensure they are aligned with these expectations and can demonstrate genuine efforts to formally consider and manage risk.

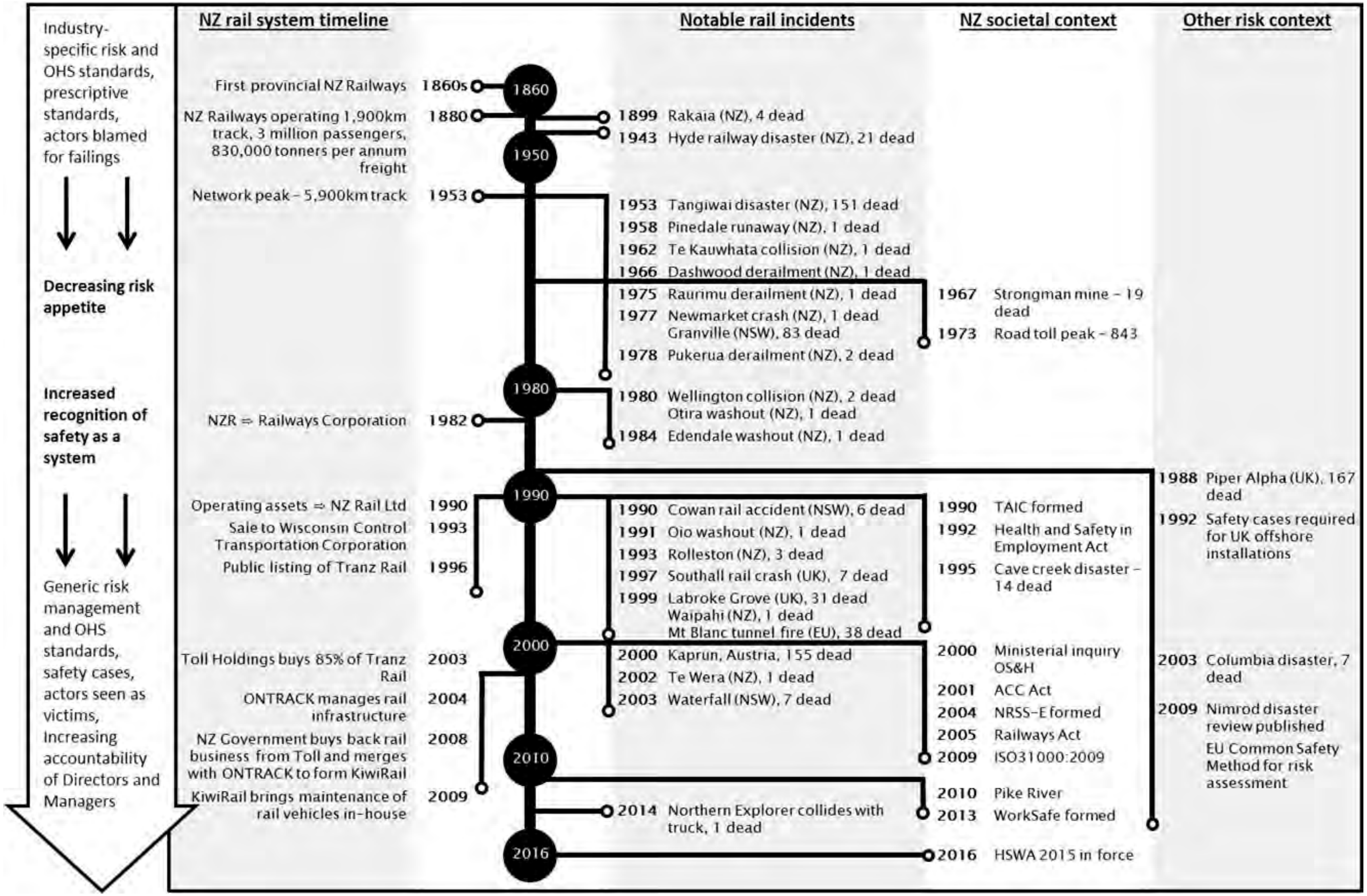
Best practice in rail safety management has evolved over many years, and in some ways it can be argued that the earliest formalisation of safety management was initiated by the development of the steam engine. Rail safety management evolution has typically been sporadic and in response to major disasters, initially boiler explosions, but also, those resulting from increased speed and activity. Originally, incidents were probably seen as the inevitable and unavoidable outcome of industrial activities, but in time major incidents have been recognised as a failure of controls and are now often recognised as systems failures, with the system being seen to include the regulatory framework. They can become known as *regulatory disasters* (Black 2014). This is where the regulatory framework and oversight has failed to ensure the required management of risk.

Applying this thinking to recent events, the following can be considered to be 'regulatory disasters':

- the explosion at the Pike River coal mine in New Zealand that killed 29 workers, and which directly led to the restructuring of New Zealand's health and safety legislation and regulatory oversight of workplace health and safety
- the Montara well blowout in the Australian-controlled Timor Sea, and the Deepwater Horizon blow-out in the Gulf of Mexico, which led to reformation of the licensing and control systems for offshore exploration in their respective countries.

Figure 4.1 presents a condensed overview of the evolution of the management of safety within a rail context. As touched on above, the original approach was to respond to major incidents by requiring – by means of specific regulation – engineering or procedural controls. The term 'risk management' (as distinct from accident prevention or loss control) only started to be used in the context of safety management in the latter half of the twentieth century. Broad trends over many years have moved from blaming the individual (whether that is the driver, fireman, engineer or craftsman) towards treating the assurance of safety as the management of the 'system', with the system comprising both the engineering and human dimensions. This has both driven and reflected the increasing societal expectations of the assurance of safety while new methods have had to be developed to assess and demonstrate safe operation.

Figure 4.1 Evolution of New Zealand rail and risk management



The ‘notable rail incidents’ column of figure 4.1 only shows major train incidents on the mainline recorded in railway history publications. Similar trends occurred in shunting and track maintenance activities, but have not been published. An example of this was the cluster of shunting fatalities that sparked the inquiry into Tranz Rail in 2000 (Ministerial Inquiry into Tranz Rail Occupational Health and Safety 2000) and led to the introduction of the Railways Act 2005. The Railways Act also included protection of property from damage.

Best practice in the management of safety (and more broadly, for risk within all endeavours that expose people to potential harm) has developed considerably since the New Zealand rail network was constructed in the 1800s.

4.3 Risk and safety theory

4.3.1 Normal accident theory

Normal accidents: living with high-risk technologies (Perrow 1984) was for some time an influential text in modern risk management, as it relates to industrial undertakings. Normal accident theory holds that accidents are inevitable (or ‘normal’) when technologies are complex and tightly coupled.

Perrow was inspired by the 1979 Three Mile Island nuclear accident and defines a normal accident as occurring when an unexpected interaction of two or more failures (because of interactive complexity) causes a cascade of failures (because of tight coupling). Perrow’s theory is somewhat pessimistic as it anticipates such failures are inevitable, and hence should be considered as ‘normal’. However, this is now a somewhat dated text and although still valuable, arguably does not reflect more recent work and understanding of the management of safety within complex organisational environments.

4.3.2 Swiss cheese model

James Reason has published a body of work on the management of safety risk, developed primarily in the aviation and healthcare (surgical) fields (see Reason 1991; 1997; 2000). Certainly within these fields, and arguably more broadly, his work is held in high esteem and has strongly influenced the thinking on and management of safety in the aviation sector.

Most famously, Reason developed the concept of ‘multiple layers of defence’ and applied the ‘Swiss cheese’ model of organisational safety management (figure 4.2). This intuitive model has helped to simplify thinking about both safety management as well as more generally risk management – even within the banking sector.

Figure 4.2 Swiss cheese model from Reason (2000)

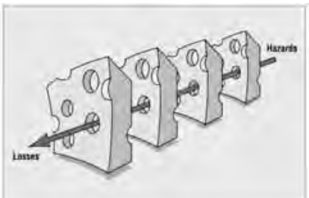


Figure 4.3 Health Quality and Safety Commission logo

The model develops a concept that the sequence or chain of events from an initiating event to an accident outcome is prevented by layers of defence. These layers (or barriers) can be conceived as slices of Swiss cheese, complete with holes which represent weaknesses or shortcomings in each layer of defence.

This enables the process of reducing risk to be thought of as making the holes in the barriers smaller or fewer or adding more barriers.

While the model is not so self-evidently applicable in every situation (eg in complex systems with interdependence between controls), this mental model has made risk management more accessible to many. There can be little doubt much of the credit for the continued improvement in safety, despite rapid growth in some sectors, must go to this model. In New Zealand, a representation of the Swiss cheese model can be seen in the logo of the Health Quality and Safety Commission (figure 4.3), while the national airline and the Civil Aviation Authority (CAA) view the Reason model as an important conceptual tool for improving the management of safety risk.

4.3.3 High reliability organisations

Considering successes rather than failures can mean asking the question, what enables some organisations to consistently succeed when the potential for disaster seems to always be near? High reliability theory considers organisations can successfully compensate inevitable human shortcomings with high-risk technologies by proper design, management and training.

The concept was initially developed in the late 1980s from considering operations on aircraft carriers and other high-risk enterprises. More recent research on high reliability organisations (HROs) suggests they share a preoccupation with failure, a reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise (Weick et al 1999).

There is an argument that railway organisations cannot be HROs because the technology used is reasonably simple and prioritising reliability (eg insisting trains run on schedule) can sometimes be in direct conflict of safety (Hopkins 2007). However, many of the principles of HROs are still applicable to rail (eg a preoccupation with failure could benefit rail if it leads to proactive risk assessment and testing of assumptions). Additionally, a feature of HROs is that while operations are centralised much of the time, decentralised decision-making is emergent in crises or abnormal operations (Jeffcott et al 2006). The relevance of this to rail is that there are risks associated with being overly reliant on rules and centralised control, if it is to the extent that it compromises the ability to decentralise decision making and flexibility in non-routine situations. Hence, while railways do not fit traditional definitions of HROs, many of the learnings in literature may nevertheless be helpful.

4.3.4 ‘No blame’ and ‘just culture’

Organisational culture is a key determinant of safety performance (Smith and Wadsworth 2009). Railways, as a mass transportation technology, have potentially catastrophic consequences should accidents occur, although the technology used is relatively simple and straightforward rather than tightly coupled (Hopkins 2007).

In an assessment of two UK incidents, each resulting in the death of between 30 and 40 people in 1988 (Clapham Junction) and 1999 (Ladbroke Grove), Busby (2006) draws attention to the contribution of a *no blame* culture, which was promoted by the UK regulator at the time. In the Ladbroke Grove Rail Inquiry, Lord Cullen determined ‘the ready acceptance of “blame” by drivers, encouraged by the “no blame” culture, may have contributed to this poor analysis of root causes’ in the case of signal passed at danger (SPAD) investigation (Cullen 2001).

A similar approach has previously been taken in New Zealand. Around 1998, New Zealand rail organisations, with support from the RMTU, implemented a no blame culture. This was the accepted approach at the time but has since been understood by the railway industry to remove individual and management accountability.

Over time the concept of a *just culture* model has been developed (originating in the global aviation sector). The exceptional level of safety now evident in the aviation sector is in part a result of the determined efforts to benefit from just culture. Although still being continually developed, an illustration of a current definition of the concept is given by the European air traffic co-ordination organisation (Eurocontrol):

> *A culture in which front-line operators and others are not punished for actions, omissions or decisions taken by them which are commensurate with their experience and training, but where gross negligence, wilful violations and destructive acts are not tolerated.* (Eurocontrol 2014)

The New Zealand railway industry has also been moving towards a just rather than no blame culture in some areas. An example of this is how the national rail operator has identified human factors and the need for a culture shift to help underpin ongoing improvements. Recently, the national rail operator has worked closely with the RMTU to implement a 'just and fair culture'.

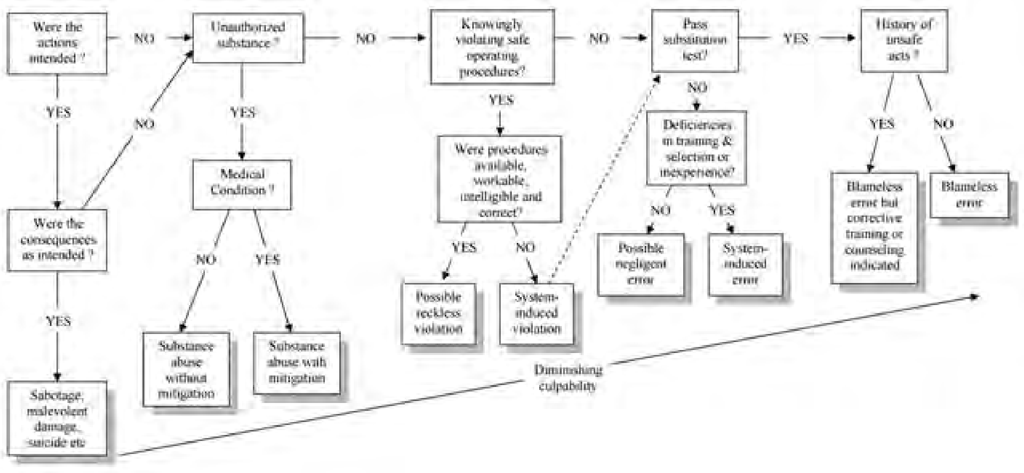
The researchers have witnessed just culture working effectively in aviation and consider a just culture model could be effective in the New Zealand railway industry. The work the national rail operator has undertaken in this area may be an example that could be useful to other railway participants.

4.3.5 Human factors

Human cognition is imperfect. This should be understood and incorporated into systems – 'though we cannot change the human condition, we can change the conditions under which humans work' (Reason 2000). There needs to be strong linkages established between systems and behaviours. This can be incorporated into the design of systems and the culture of an organisation, and includes providing the right information in the right format to the right people at the right time.

While having reporting systems and strategies in place might satisfy auditors and regulators, putting them into operation and making them work is a different challenge (Hudson 2014). Part of this challenge is having an organisational culture that supports the systems and strategies (refer back to section 4.3.4). Workers need to be able to report incidents they were involved in and know they will be treated fairly (eg work in a just and fair culture) (see figure 4.4). It is not until good habits are ingrained that the culture has changed.

Figure 4.4 Reason (1997) – a decision tree for determining the culpability of unsafe acts[15]



[15] Figure 4.4 shows a decision tree published in 1997 – many companies have taken this concept and developed their own version. While this decision tree begins at the greatest culpability (sabotage, malevolent damage etc), more advanced versions may invert the tree to begin with diminished culpability.

An example in New Zealand of a human factors approach is the national rail operator's approach to SPAD risk reduction, based on designing systems and procedures to minimise risk through error-tolerant design and effective driver practices (O'Connell and Mills 2016). Research by the national rail operator into the causes of SPADs on the NRS has established that a key factor in SPADs is driver memory. A warning signal is either not recognised or not imprinted into memory. National rail operator initiatives include:

- requiring drivers to call out caution signals ('risk commentary driving') even when alone in the cab, so as to imprint it into their memory
- the implementation of a fourth aspect[16] (eg flashing amber) enables the driver to more clearly identify available braking distances to the next 'stop' signal.

Figure 4.5 The safe system from Safer Journeys (2013)

Calling signals used to be standard practice when locomotives were dual crewed, but was no longer required when operations moved to single drivers. A robust approach to change management needs to be followed to ensure emergent risks, including those related to human factors, can be identified and mitigated.

Another example of a human factors approach is the metro operator driver selection process, which includes psychomotor and psychometric testing. These help to identify people with the right competencies for the role (eg aptitude, compatibility).

The Transport Agency also reflects a similar approach, in terms of understanding and designing around human factors in its 2015–2019 statement of intent. One of the Transport Agency's medium-term objectives is to 'Implement the Safe System approach to create a forgiving land transport system that accommodates human error and vulnerability' (NZ Transport Agency 2015a). The Safe System approach accepts mistakes are inevitable but deaths and serious injuries can be minimised by strengthening the performance of roads, vehicles and speeds etc, which visualises this safe system approach.

4.3.6 High potential incidents

Low probability, high consequence events (LPHC) can be difficult for any single organisation to fully understand and manage because they happen so rarely there are not enough learning opportunities to draw from (Threadgold 2011). While incidents like slips and trips are frequent they are rarely fatal. In comparison, transport accidents are often fatal.

[16] An 'aspect' is a distinguishable signal mode (eg red, amber, green lights would be three aspects).

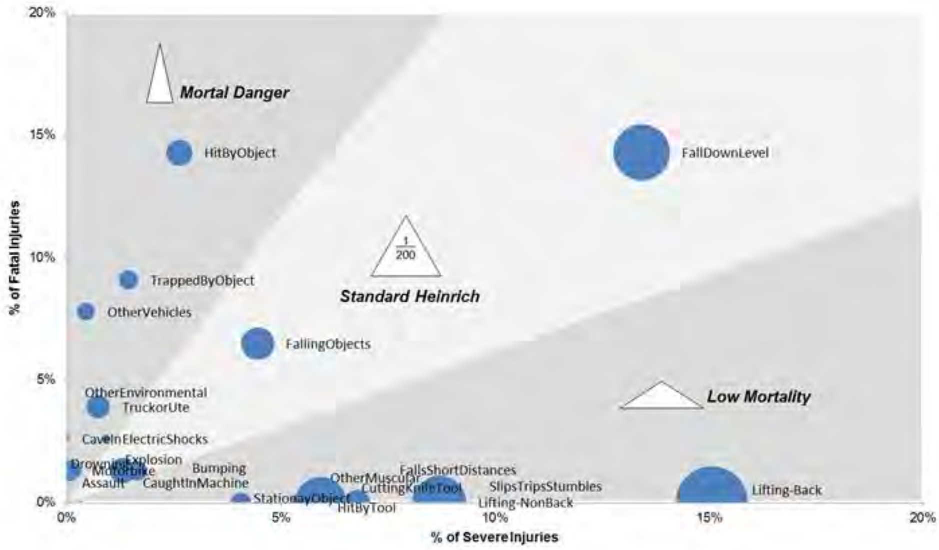
Figure 4.6 Heinrich's triangle

There is a theory of accident prevention (see figure 4.6) that focuses on addressing root causes of low consequence incidents (eg those that do not result in injuries) in the belief that it will in turn reduce fatalities. The theory is illustrated as a triangle with a large number of incidents at the bottom of the triangle to one fatality at the top. In its simplest form the theory assumes a fixed ratio between incidents and injuries, and between injuries and fatalities. The theory rests on an implicit assumption that causal factors are the same at all levels of the triangle.

However, analysis by Navigatus of fatality and injury rates by proximate cause for work-related injuries in the New Zealand construction industry showed that incidents can be classified into three groups (see figure 4.7).

- standard Heinrich: proximate injury causes where the Heinrich triangle broadly applies
- low mortality: proximate injury causes which seldom result in fatalities
- mortal danger: proximate injury causes which have high fatality rates.

Figure 4.7 Comparison of injury mechanisms contribution to severe and fatal injuries in construction, 1 April 2008 to 31 March 2013



As figure 4.7 indicates, Heinrich triangles can be conceptualised for each proximate cause, but each triangle has a different shape. Addressing proximate causes such as muscular strains due to lifting does not address LPHC events such as explosion resulting from a process failure.

The narrow shape of the mortal danger events shows that learning opportunities will be few, ie most of these events result in fatalities.

A feature of the mortal danger events is they generally involve the release of large amounts of energy (eg kinetic energy from moving heavy objects and electrical energy in electrocutions).

It follows that a focus on low consequence incidents alone will not prevent fatalities. Locally and internationally there are examples where fatalities have remained constant or risen even as injury frequency rates have fallen (Fulton 2013; Teakle et al 2012).

LPHC events are also more difficult to address because they are rarer (and a higher proportion are fatal) and often involve multiple barrier failures. Consequently there are fewer learning opportunities (Denkl et al 2010). Threadgold (2011) suggests the best way to reduce the risks is by working on issues at a global or industry level, even including regulators.

Within an organisation, one way to address this issue is to measure the potential harm of an incident rather than actual harm alone. There are many incidents where workers are completely unscathed, but it is only good luck that prevented harm, and had that harm occurred it could have been fatal. For instance, a SPAD is a high potential event. Most of the time a SPAD will result in no harm, and has an additional built-in control of an 'overrun' allowance. However, each incident still has a high potential for a fatality (or multiple fatalities).

The national rail operator already undertakes an approach that includes consideration of high potential events – these are events where a serious injury or fatality could have occurred if one further control had failed. Reported incidents are triaged and assessed for potential harm, with a daily and weekly summary of the triage process reported within the organisation. The high potential events are discussed at executive level and reported to the board.

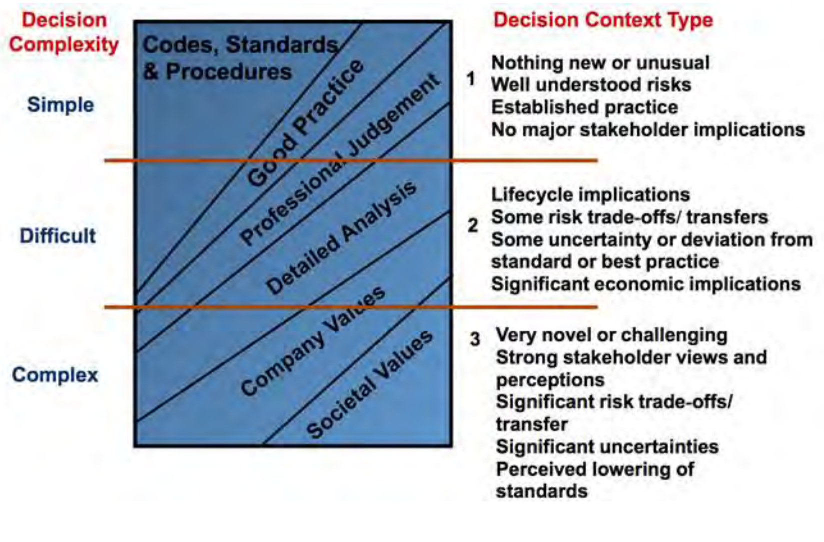
While organisations should still aim to reduce and minimise lost time injuries, metrics like this should not be used alone with the expectation that all fatality risks will be reduced. An approach like this could be used in conjunction with a parallel focus on high potential incidents.

4.4 Standards, tools and guidelines

This section includes many of the standards, tools and guidelines available. However, depending on how complex a risk management decision is, influences how far these tools can guide decision-making.

Figure 4.8 shows how codes and standards can guide simpler decisions, but that societal values become more important when there are significant risk trade-offs.

Figure 4.8 Decision- making framework (HSE 2006)



4.4.1 New Zealand

4.4.1.1 AS/NZS ISO 31000:2009 and accompanying guidelines

The most developed foundation for risk management is the ISO 31000:2009 standard that has been adopted locally as AS/NZ ISO 31000:2009.

The standard sets out principles, and a framework and process for the management of risk of any type in any organisational situation – the standard is designed as guidance rather than a basis for certification. The standard was designed to set a top-level framework from which more detailed and specific risk standards could be developed. As such it is written in generic terms – a feature that can result in some difficulty in immediately recognising its application to specific contexts.

ISO 31000 is appropriate as a general framework under which rail specific standards would apply, such as controls associated with rolling stock, infrastructure (including signalling), safety, interoperability and train control systems (Rail Industry Safety and Standards Board 2013; CRC for Rail Innovation 2014).

As ISO 31000 provides only high-level guidelines, it can only form a foundation for more detailed application of the associated principles, framework and process (ie it is not intended to be used alone) to meet legislative risk management requirements (ONRSR 2014b).

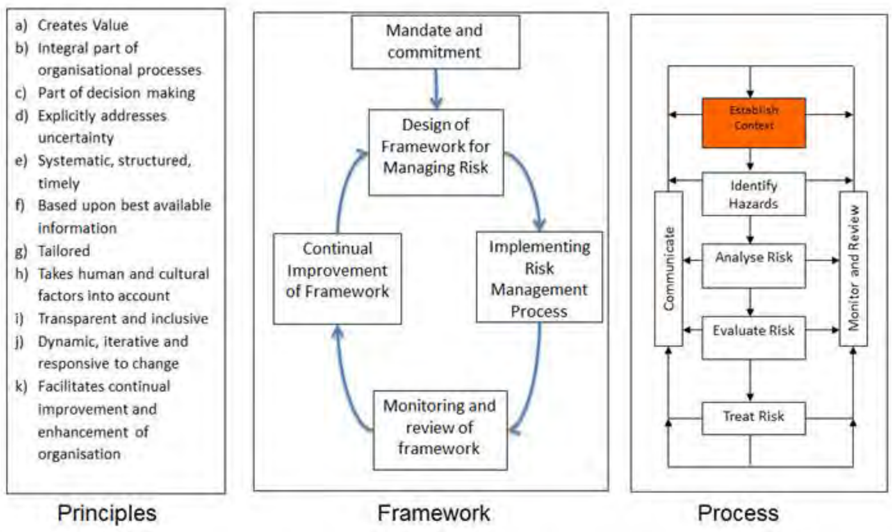
In the standard, the definition of risk given is:

> *The effect of uncertainty on objectives.*

The definition highlights that risk is not just about negative outcomes, but also positive outcomes and hence about opportunities.

The standard is summarised in figure 4.9:

Figure 4.9 Overview of ISO 31000:2009 risk management principles, framework and process



SA/SNZ HB 436:2013 Risk management guidelines – companion to AS/NZS ISO 31000:2009) (SA/SNZ (2013b)) gives guidance on how to implement ISO 31000:2009, and includes numerous examples and illustrative templates. This handbook does not have the status of a standard. It is also of note that it was not unanimously accepted by the committee members responsible for its publication, with the Institution of Professional Engineers New Zealand representative arguing it did not represent contemporary best practice and that some of the examples were flawed.

SA/SNZ HB 89:2013 Risk management – guidelines on risk assessment techniques[17] (SA/SNZ (2013a)) is aligned with AS/NZS ISO 31000:2009 and provides an overview of the suitability of various developed risk assessment techniques for differing applications.

Together the standard and guidelines give a good basis for any approach to the management of risk within an organisational context.

AS/NZ ISO 31000:2009 is an excellent starting point for risk management; however, its requirements are often misrepresented. In particular, there appears to be a general understanding that it sets out and requires the application of a probability-consequence matrix for the assessment of risk. Within New Zealand this view may be the result of an earlier standard (AS/NZS4360:1999) including such a matrix as an example. The current handbook (HB 436:2013) also includes various similar examples. In the opinion of the researchers, some of the examples in the handbook do not represent current best practice in the way risk matrices are presented and used (noting AS/NZS ISO 31000 does not set out or require the use of matrices). The use of such risk matrices has been criticised on theoretical grounds, showing that the answers depend almost entirely on how the matrix is framed (Cox 2008). In the view of the Navigatus research team this criticism does not invalidate this much-used tool but suggests it should be used with care, as one of a suite of analytical tools.

However, the researchers have a concern about the way the risk matrix tool is commonly used. In our view, assigning just one probability and one consequence to an event or incident type is over-simplified to the point of being misleading in many cases. The reality is that future incidents have a range of potential consequences and associated probabilities, which, if risk is to be properly considered, leads to the need to describe a zone of risk. This more nuanced view is critical to developing the insights that allow risk to be effectively understood and managed.

The Standards Australia handbook *AS HB 205-2004 OHS risk management handbook* is currently being drafted and is intended to be a joint Australia/New Zealand handbook to provide guidance in applying AS/NZS ISO 310000 to manage safety-related risk. Based on the draft version sighted by the researchers, when published it will provide guidance on key concepts (eg SFAIRP) and methods which may help rail operators meet new legislative requirements.

4.4.1.2 National Rail System Standard 4 – Risk management

The NRSS4 was first issued in 2004 and was last updated in 2007. The standard is produced by the NRSS executive (NRSS-E), a body of representatives currently from KiwiRail, Transdev, Spanish railway company CAF, the Transport Agency and FRONZ.

NRSS4 is intended to provide a general framework for risk management within the rail safety system, and is mainly used by heritage operators. Larger organisations generally have their own risk management requirements (eg KiwiRail). The standard is intended to meet the requirements of legislation and Land Transport NZ (2006).

Having last been updated in 2007, the standard is out of date with ISO 31000:2009 and other developments. The NRSS-E is currently in the process of updating the standard (and is waiting for the outcomes of this research). The research team's recommendations regarding this standard are outlined in appendix D. While the researchers do not consider the standard to now represent best practice, it is included here to acknowledge its current role in the heritage sector.

[17] This standard is based on the international standard ISO/IEC 31010:2009, *Risk management – risk assessment techniques*.

4.4.1.3 Rail safety licensing and safety assessment guidelines (Land Transport NZ 2006)

Appendix 1 of Land Transport NZ (2006) covers risk management. The guidelines give advice on risk matrices and how resulting ratings align with the ALARP principle. An explanation is also given of how to calculate fatality rates, fatal accident rates and equivalent fatal accident rates. As the guidelines were last updated in 2006, they do not represent best practice and are out of date with respect to the rail industry structure, but are included here to acknowledge their current role in the rail sector.

4.4.1.4 Risk management competency

Workers at all levels of an organisation need to have a good understanding of risk management principals and how risk management is integrated on a day-to-day operational basis. Best practice is to establish competency standards for managing risks in a given industry. For example, in extractive mining, workers in safety critical roles are required to achieve unit standard 26856 (Carry out the risk management processes at an extractive site), while site senior executives are required to achieve unit standard 23547 (Establish the risk management system at an extractive site).

In many cases, workers are most exposed to safety risks so it is important their views are taken into account in determining risk criteria. People at different levels of an organisation and with different exposures to risk (eg frontline workers compared with CEO or board members) may have differing perceptions on what defines the level of risk.

4.4.1.5 Office of the National Rail Safety Regulator

The ONRSR (2013) guideline for safety management systems refers to the steps for risk management that are described in ISO 31000:2009. The guideline also refers back to the older version of HB 89:2013 for selecting the appropriate methodology for assessing different hazards and risks.

4.4.1.6 Standards Australia AS 4292 series on railway safety management

Standards Australia produced a series of six standards on railway safety management in 2006. The first standard (4292.1) covers general requirements and has a short section on risk management, which includes identification and assessment of risks, and control measures.

The standard recommends a treatment plan in accordance with AS/NZS 4360 (which has now been replaced by ISO 31000:2009). Given the age of the standards, the terminology used and principles referenced do not necessarily align with best practice.

4.4.1.7 Rail Industry Safety and Standards Board Australia (RISSB)

At a lower level, the RISSB has produced risk management guidelines for fatigue (2012) and SPADs (2014). The guidelines share good practice and solutions and are intended to improve understanding of these specific risks. The SPAD guidelines were also designed to allow rail operators to benchmark against good practice.

The guidelines are available to RISSB members (who are predominantly Australian rail transport operators, network owners and manager, and rail contractors). New Zealand's national rail operator is also a member of RISSB. The guidelines were designed to be in line with the Australian Rail Safety National Law Regulations requirements.

RISSB is currently developing an Australian safety risk model based on the UK Rail Safety and Standards Board (RSSB) safety risk model. The model will support mainline rail operators in making risk-based decisions and enable national prioritisation.

4.4.1.8 Australian Level Crossings Assessment Model (ALCAM)

ALCAM is a system for assessing and modelling level crossing safety risks to assist with the prioritisation of upgrades. An underlying premise of ALCAM is that, because level crossing accidents are rare, the recent history of incidents is by itself not necessarily an accurate measure of risk. The method is backed by a substantial body of research and represents an attempt to develop a rational, evidence-based prioritisation model.

Users are warned that although the tool is comprehensive, it does not preclude the need for sound judgement. In other words, it is only an aid to decision making (ALCAM 2010).

ALCAM was adopted for implementation in New Zealand by KiwiRail and the Transport Agency in 2014, and has been populated with data on all New Zealand public road level crossings.

4.4.2 United Kingdom

4.4.2.1 Yellow book/International handbook on engineering safety management

A handbook known as the Yellow Book previously provided guidance to the UK rail industry on the safe management of engineering change. The handbook has since been withdrawn in the UK as it was no longer up-to-date and has been replaced by guidance for the application of the common safety method for risk evaluation and assessment (CSM RA).

While the guidance for applying the CSM RA is designed for mainline UK operations (and is discussed below), the withdrawal of the *Yellow book* left a gap for international railways that had used the handbook, as well as non-mainline railways in the UK. To fill this gap, the *International Rail Industry's engineering safety management handbook* (iESM) was developed and is used internationally (eg in Hong Kong, China). The iESM is freely available and, in Australia, ONRSR encourages the rail industry to review the iESM and consider how it might be applied.

Parts III and IV of iESM (volume 2) (TPD 2013) cover risk analysis and control. Part V provides technical support. Application note 5 shows a worked example to illustrate the application of these methods.

4.4.2.2 Common safety method for risk evaluation and assessment

The CSM RA has been partly in force from 2010 and fully in force since 2012. The CSM RA applies to any technical, operational or organisation change if there will be an impact on safety, and the risk management process must be applied if the change is significant. One of the objectives of the CSM RA is to ensure cross-country acceptance of risk assessments within Europe.

The CSM RA has been most recently amended by EU regulation 2015/1136, which allows safety targets for systematic failures and faults of 10^{-9} per hr[18] (highly improbable) for catastrophic accidents (multiple fatalities affecting a large number of people) and 10^{-7} per hour (improbable) for critical incidents (single fatality/affecting small number of people).

In effect, below these values no further action is required to mitigate the risk. While this contradicts SFAIRP/ALARP, it has been introduced to enable common standards to be applied across all EU countries (ie to allow mutual recognition of risk evaluation, assessment and documentation across member states).

The UK has adopted the CSM RA and has provided its own guidance documents on meeting the requirements along with other UK requirements (ORR 2015). While the CSM RA only has to be applied if the change is significant, the Office of Rail Regulation (ORR) suggests it be applied in other situations to

[18] This can also be expressed as an event occurring once in approximately 10,000 operating years.

avoid the need to have duplicate risk assessment processes (ie to meet domestic requirements) (ORR 2015). If the CSM RA is applied in this manner, in practice it should meet UK health and safety risk assessment requirements (including SFAIRP) (Railway Safety Directorate 2013; RSSB 2014e).

The European regulation sets out that risk acceptability of a significant change must be evaluated using one of the following methods:

- the application of codes of practice
- a comparison with similar parts of the railway system
- an explicit risk estimation (particularly for complex or innovative changes).

The regulation does not give an agreed principle for the explicit risk estimation, which could be quantitative or qualitative.

The ORR (2015) guidance suggests:

- To apply codes of practice, they must be widely accepted in the railway sector, be relevant for control of the specific hazard and be available to an assessment body.
- A comparison with similar parts of the railway system can be used if it has been proven and has an acceptable safety level, is accepted in the member state where the change is to be introduced, and the system being assessed is used under similar functional, operational and environmental conditions and has similar interfaces as the reference system.
- An explicit risk estimation (particularly for complex or innovative changes) is used when hazards cannot be addressed in the hazard identification stage of the risk management process via a code of practice or comparison with a reference system, deviations are necessary from codes of practice or reference systems; or a proposer needs to analyse the hazards and evaluate design principles or safety measures. No specific tools or techniques are specified, but industry documents and standards are listed.

Annex I of the regulation sets out general principles applicable to the risk management process, Figure 4.9 shows the risk management process and independent assessment method (The European Commission 2013).

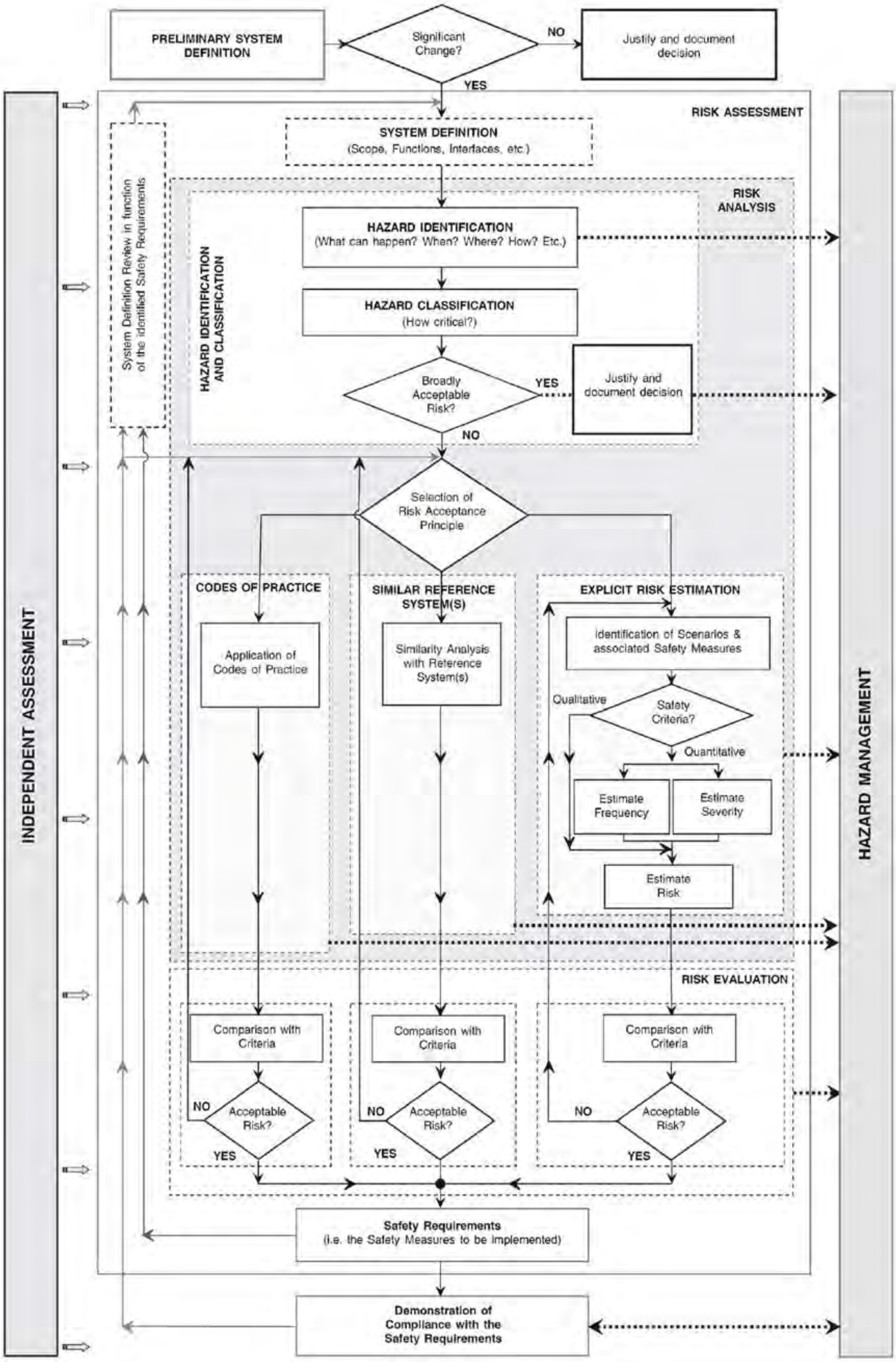
GE/GN 8642 'Guidance on hazard identification and classification' (RSSB 2014c) gives guidance on how to apply hazard identification and classification steps of the risk assessment process set out in the CSM RA.

Hazard identification is one step in the risk assessment process, and is a way of identifying all hazards (and the risks they create). A risk matrix is one suggested technique (see figure 4.10), and can allow the hazards with broadly acceptable risk levels to avoid further risk analysis.

Figure 4.10 An example of a quantified and calibrated risk matrix from RSSB (2014a) using fatalities and weighted injuries as the consequence.

			Consequence (FWI)				
			Class 1 Minor injury / multiple Class 2 injuries	Multiple Class 1 minor injuries / more severe injury	1-2 Major injuries	Multiple major / single fatality	Multiple fatalities
Frequency			1	2	3	4	5
	Once in	No/year	0.008	0.04	0.2	1	5
5	12 days	31.25	6	7	8	9	10
4	2 months	6.25	5	6	7	8	9
3	9 months	1.25	4	5	6	7	8
2	4 years	0.25	3	4	5	6	7
1	20 years	0.05	2	3	4	5	6

Figure 4.11 Diagram showing the risk management process and independent assessment (The European Commission 2013)



The document *GE/GN8643* 'Rail industry guidance note on risk evaluation and risk acceptance' (RSSB 2014a) continues on from hazard identification. It is intended to help with selecting a risk acceptance principle and applying each of the principles (codes of practice, comparison and explicit risk estimation). Where explicit risk estimation is necessary, the Taking Safe Decisions framework (see figure 4.12) is referenced.

A qualitative method is summarised as:

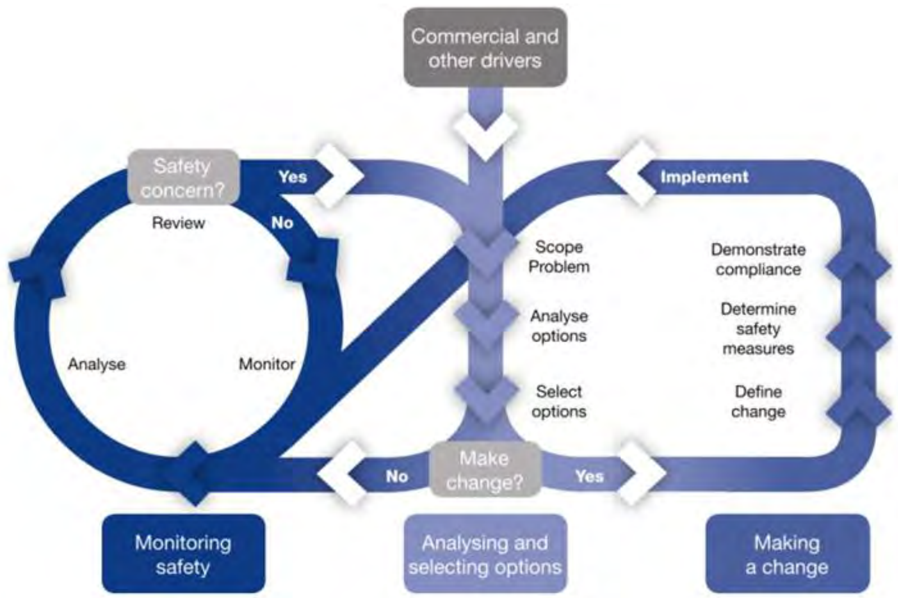
> *a) Identify the causes of the hazard, and document as a table or short explanation.*
>
> *b) Identify the possible consequences of the hazard and the factors that affect those consequences, and document as a table or short explanation.*
>
> *c) Identify the existing safety measures which control the hazard.*
>
> *d) Identify the practical additional safety measures which might be implemented to control the hazard further.*
>
> *e) Review the additional safety measures, discard those that are judged not to be reasonably practicable and set safety requirements to implement those that are judged to be reasonably practicable.*

For the quantitative method, fatalities and weighted injuries (FWI) is one convention (see Taking Safe Decisions framework below).

4.4.2.3 Taking Safe Decisions Risk Management Framework

RSSB (2014e) sets out an industry view of how safety is taken into account in decision making in UK rail. Figure 4.12 shows the three basic parts of the risk management framework: monitoring safety, analysing and selecting options, and making a change.

Figure 4.12 Diagram from RSSB (2014e) showing the Taking Safe Decisions Risk Management Framework



In the UK rail industry, consequences are generally quantified using the measure of FWI (RSSB 2014c). However, the guidelines state that when explicit risk estimation is undertaken, quantification is not always needed. Expert judgement can be used in conjunction with techniques including structured workshops. A cost–benefit analysis can be useful when good practice and qualitative reasoning are not sufficient for a decision to be made (see below for more on cost–benefit analysis).

4.4.2.4 RSSB: Guidance on the use of cost- benefit analysis when determining whether a measure is necessary to ensure safety so far as is reasonably practicable

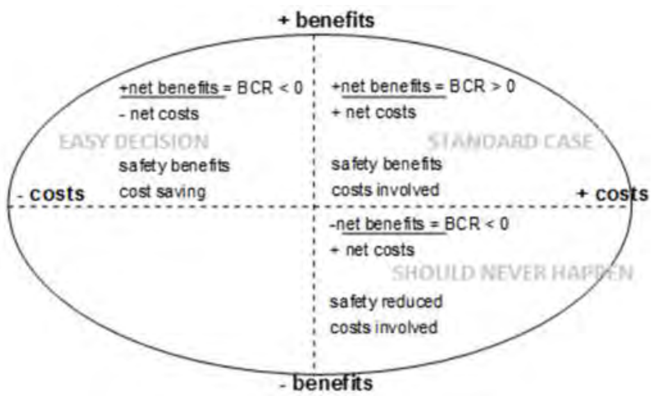
This document provides guidance on undertaking a cost–benefit analysis in the context of meeting the requirements of SFAIRP in the UK (RSSB 2014d). These requirements are set out in the ORR (2017) rail guidance document 'assessing whether risks on Britain's railways have been reduced SFAIRP'.

The guidelines reinforce that cost–benefit analysis should only be used where a decision cannot be made by using good practice or competence-based judgement, and is only an input into decision making. It highlights the places to use it are in 'analysing and selecting options' and 'making a change' (see figure 4.10).

The only benefits included in the analysis should be in terms of improved safety (to passengers, workers and the public). Risk needs to be translated into a financial value using 'value of preventing a fatality'. The figure is 1,899,000 British pounds (as at September 2015) (RSSB 2015).

Figure 4.13 shows three potential outcomes of a cost–benefit analysis: 'easy decision', 'standard case', and 'should never happen'. The 'easy decision' and 'standard case' both show where measures should generally be implemented.

Figure 4.13 Diagram from RSSB (2014d) showing the SFAIRP cost–benefit analysis quadrants



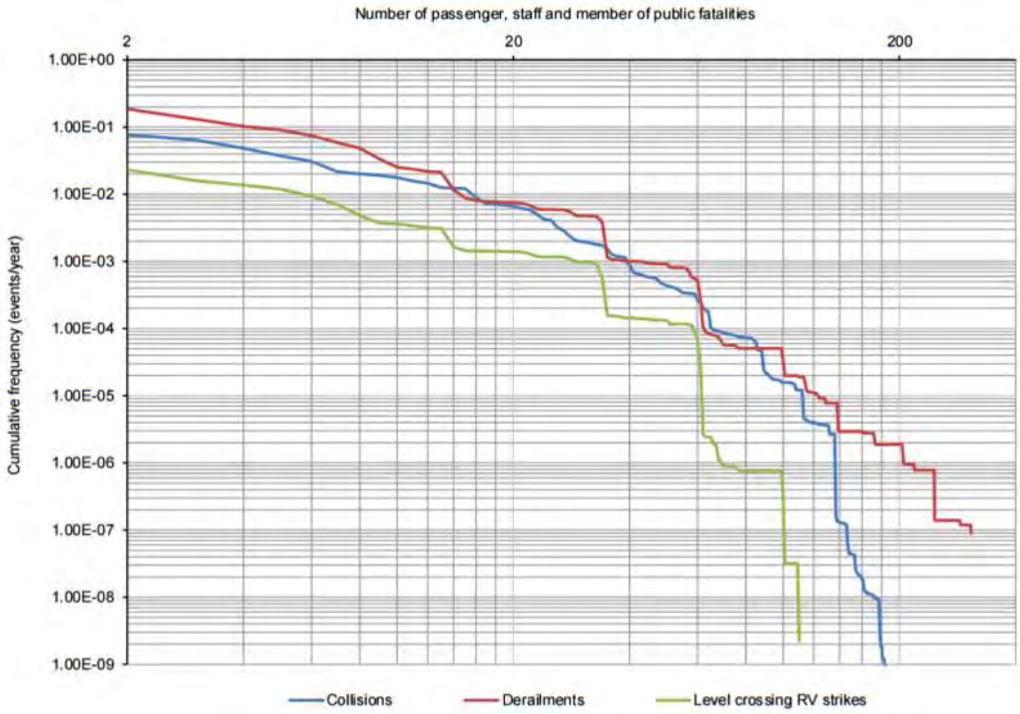
4.4.2.5 RSSB: safety risk model (SRM) and precursor indicator model (PIM)

The RSSB SRM helps users to understand the overall risk level and risk profile of their railway operations. The current version of the SRM assesses 131 hazardous events, using research data to estimate the likely probabilities and consequences of these events occurring.

The model is designed to take into account both high-frequency, low-consequence events and low-frequency, high-consequence events. This model enables a much higher level of understanding of where risks arise in the rail system, and to whom, drawing on the best available information.

An example output is the F-N curves in figure 4.14, which show the relative likelihoods of various types of incidents. From this diagram it can be immediately seen, in the UK rail system, the likelihood and consequences of derailments (upper line), consistently exceed collisions and level crossing incidents. This insight immediately suggests any programme to further reduce overall mainline running risk on the UK rail network would need to consider derailments.

Figure 4.14 Example of an F- N curve



The RSSB has also developed a PIM that measures the underlying risk from train accidents by tracking changes in accident precursors. The model is calibrated against the SRM. The model includes risks of collisions, derailments and fires. The precursors used in the model are operational occurrences that have the potential to cause a train incident (such as buckled rails, level crossing failures, animals on the line and so on). The main benefit of the PIM is that it provides a continuous view on changes in overall levels of risk as precursor incident rates change over time.

4.4.2.6 Office of Rail Regulation Railway Management Maturity Model (RM3)

ORR (2011) sets out the criteria used to assess the rail organisation's ability to control health and safety risks. Risk management is one element of railway management maturity.

The level of risk assessment and management according to evidence in RM3 describes excellence in an organisation as:

- risk assessment is used to drive continual improvement in the risk profile of the organisation
- the approach to risk management is embedded and applied consistently throughout the organisation
- removing risk at its source is part of a consistent approach and is reflected in the organisation's policies.

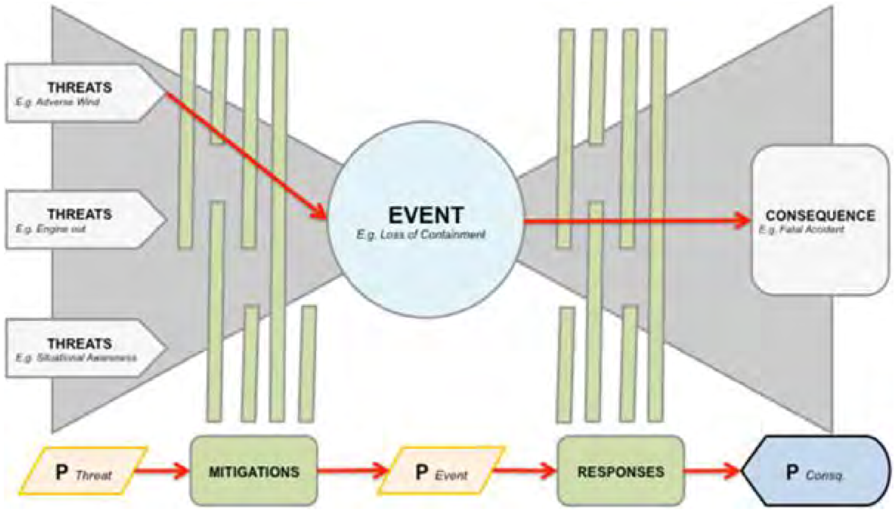
A range of other safety climate and safety culture survey tools are also available to help organisations to assess the maturity of their safety culture (Eeckelaert et al 2011).

4.4.3 Other tools

A tool that has gained acceptance in recent years is the bow tie analysis (see figure 4.2). The bow tie diagram is a useful communication device. It helps clarify and direct thinking towards both reducing the likelihood of occurrence (left-hand side of bow tie), and minimising the consequences (right-hand side of bow tie).

Complex systems can be analysed using bow ties produced from computer-aided analysis (eg European freight train derailment (Det Norske Veritas 2010)). The bow tie is one of a range of risk assessment tools that can be used.

Figure 4.15 Example of a bow tie model



While a bow tie analysis is good for recording operating safety risks and their control, it is less suitable for assessing changes (where other tools, such as risk matrices, are more suited).

4.5 New Zealand health and safety regulation

The HSWA is a key initiative the government has taken towards reducing serious work-related injuries and deaths in New Zealand. The HSWA is discussed in some detail in chapter 2, in the context of the concept of SFAIRP and applies directly to the railway industry.

4.5.1 Control hierarchy

The Health and Safety at Work (General Risk and Workplace Management) Regulations 2016 modifies and makes more explicit the 'control hierarchy' compared with previous legislation. The control hierarchy communicates that although there are several ways an event can be avoided, some controls are much more effective at prevention (ie elimination) while others are less effective and less certain to prevent an incident (eg personal protective equipment) (Hopkins 2005).

The control hierarchy emphasises the importance of not selecting personal protective equipment or administrative controls without first considering controls that are much more effective (ie higher up the hierarchy).

Figure 4.16 Control hierarchy modified from WorkSafe New Zealand (2016a) with reference to the HSWA

Most effective	Elimination	Risks must first be eliminated, if this is reasonably practicable
	Minimisation	If it is not reasonably practicable to eliminate risks, they must be minimised SFAIRP by substituting, isolating or implementing engineering controls
	Substitution (wholly or partly)	
	Isolation/Preventing contact or exposure to risk	
	Engineering controls	
	Administrative controls	If risk then remains, administrative controls must be implemented to reduce risk SFAIRP
Least effective	Personal protective equipment (PPE)	If risk then remains, suitable PPE must be provided and used to reduce risk SFAIRP

Figure 4.17 shows an example of different control types within the control hierarchy for level crossings. An example of elimination (the most effective control) is grade separation (Bentley et al 2009). This removes the risk of level crossings by eliminating the interface between vehicles and trains. In practice, elimination of level crossing risk is very costly, so other controls in the hierarchy (eg barrier arms, lights and bells) would need to be considered after elimination.

Figure 4.17 Level crossing example of control hierarchy

Effectiveness	Control type	Level crossing examples
Most	Elimination	Grade separation / closure of crossings
	Minimisation	Barrier arms / lights and bells
	Administrative controls	Signage / road markings / train driver sounding horn
Least	Personal protective equipment	Airbags in cars

4.5.2 Role of governance in risk

Under the HSWA, persons who have a role where they can significantly influence how an organisation is managed (eg directors, partners, board members) must exercise due diligence to make sure the organisation complies with its health and safety duties. This means those in a governance position must have a good understanding of the organisation's risk profile (Institute of Directors and WorkSafe New Zealand 2016). They are personally liable if they breach their due diligence duty – a failure to manage health and safety risk effectively carries the risk of fines or imprisonment.

4.5.3 Role of engagement in risk

Both the Railways Act and HSWA have a focus on communication with other operators and with staff throughout the risk management process. While there can often be a tendency for risk analysis to be a single-person exercise, the legislation sets clear expectations that this is not sufficient to meet regulatory duties.

This requirement is not particular to legislation – it is a central concept in risk management. It is a key principle of ISO 31000 that risk management is inclusive. This means workers and significant stakeholders need to be involved in processes such as a risk identification and assessment.

4.5.4 Principal hazards (mining example)

The concept of principal hazards is used in mining industry regulation in New Zealand. A principal hazard is a hazard that could cause multiple fatalities (either in a single event or in recurring events). The regulations themselves set out principal hazards (although not exhaustively); they can also be identified through a broad-brush or similar type risk assessment by an operator.

Every principal hazard has to have its own principal hazard management plan, regardless of the level of risk determined by a risk assessment (WorkSafe New Zealand 2013). The principal hazards are singled out for special consideration because of the potential consequences (MBIE 2013a).

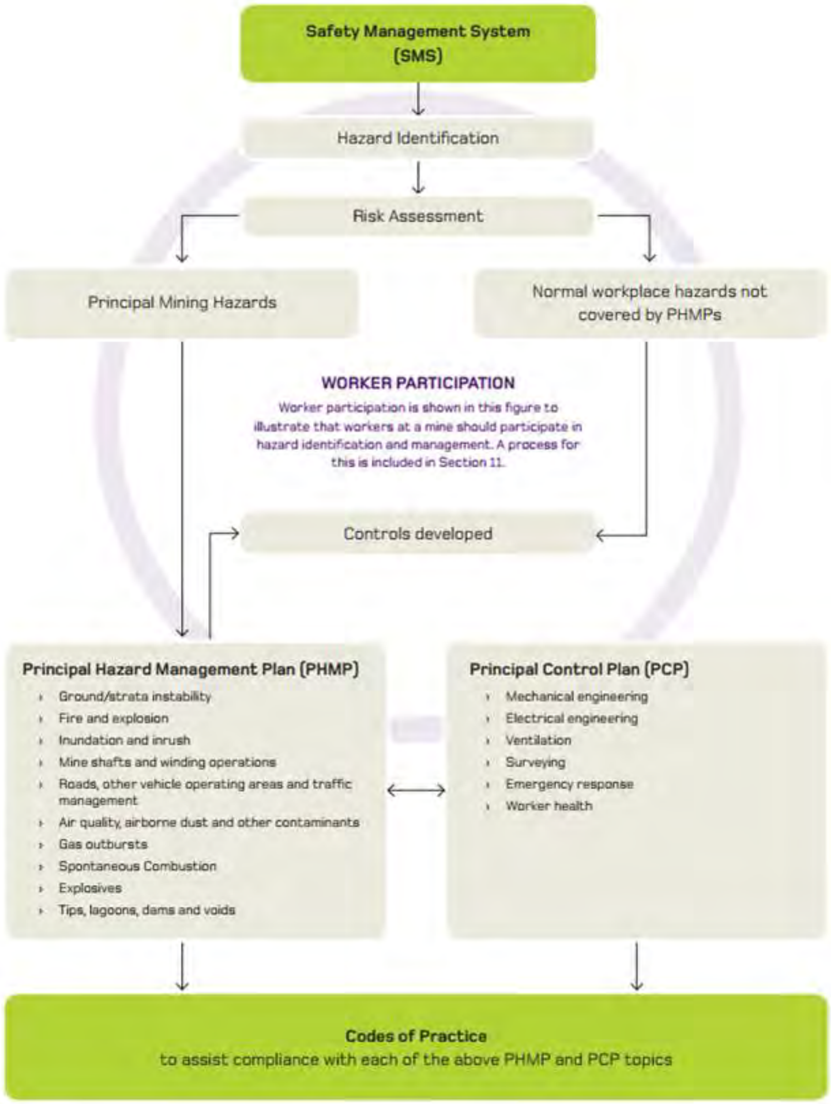
The principal hazard management plan sets out measures to effectively manage the hazard and includes:

- The nature of the principal hazard
- A description of:
  - how risk assessments will be conducted and the results of any risk assessment completed
  - the control measures to be implemented to manage the hazard and the risk of harm it presents
  - how any specific requirements in the regulations (if any) will be complied with
  - emergency preparedness
  - the review and audit processes for the PHMP.
- The roles, responsibilities and competencies required to implement the PHMP
- any other matter required by the regulations in relation to particular principal hazards.

Figure 4.18 shows how the plan fits into the wider hazard management system in mining.

The principal hazards approach seeks to direct safety effort and attention toward controlling risks where many workers can die in a single incident. Equivalent hazards for the rail industry would be high consequence events such as collisions between trains and fires in tunnels. While minor injuries are numerically dominant (and consequently dominate health and safety systems), the principal hazards approach focuses more attention towards the rare catastrophic incidents that are most important from a systems perspective.

Figure 4.18 Elements of a Safety Management System (SMS) from MBIE (2013a)



4.5.5 Proposed safety star rating initiative

WorkSafe New Zealand, the Accident Compensation Corporation (ACC) and MBIE are working together to develop a proposed Safety Star Rating Initiative (SSR) to help reduce the severity and frequency of injuries in the workplace (WorkSafe New Zealand 2016b). It is a voluntary assessment scheme and consists of two parts – online self-assessment and a full onsite assessment. The SSR includes standards on risk awareness and risk management and has indicators to assess organisations against a maturity scale. The SSR is designed with higher than compliance requirements. The onsite assessment will look at how the organisation manages key risks. The SSR is currently being piloted and the final design may differ.

4.6 Conclusion

As in other industries, best practice continues to evolve in the international rail industry. Key themes of that evolution include:

- moving from blaming the individual to seeing failure as a symptom or outcome of a systemic issue or weakness
- recognising that organisational culture lies at the heart of, and is the foundation for achieving high levels of safety performance
- placing less emphasis on rules as a safety intervention and more focus on hazard elimination and/or engineering controls
- moving from viewing safety as isolated processes and activities to thinking of it as an integrated system
- monitoring precursors (buckled rails, level crossing failures etc) to low-probability, high-consequence events, even if they did not result in any actual harm, as they give more insight than monitoring the levels of unrelated minor injuries.

PART B: CURRENT NEW ZEALAND PRACTICE

5 Railway operations

5.1 Research question and approach

The researchers were asked to:

> *Investigate current New Zealand practices in order to gain insights into ways license holders currently identify, assess and manage risk in their operations. Additionally, to gauge how differing capabilities affect operators' ability to robustly address risks.*

As well as providing an opportunity to assess the capabilities of visited operators (and how effectively they identify, assess and manage risk), this research question also allowed the researchers to provide significant context and information for the risk assessment carried out in chapter 7.

A challenge for this research question was that developing a good understanding of risk management practices requires a range of in-depth field assessment tools. However, the research budget was relatively small and the range of activities was broad, so it was not possible to assess risk management practices through field work alone. For this reason, this research relied on incident analysis and benchmarking as primary measures of risk management effectiveness. This was supplemented by contextual observations made by the researchers where practicable.

The three main inputs for the research were data analysis (including comparison with other countries), site visits to a range of operators, and a targeted literature review.

5.2 Method

5.2.1 Methods for data analysis

The purpose of the data analysis was to explore the safety of T&H, mainline passenger, freight and industrial rail operations.

The Transport Agency recently commissioned Interfleet to research international benchmarking for rail safety indicators (Brown 2016). The report proposed initial benchmarking indicators from the United Kingdom and Australia as these countries have rail operations and an environment that is similar to New Zealand, with good available data. Consequently, the data analysis uses UK and Australian statistics as a benchmark of excellence in rail safety.

Australia is similar to New Zealand in terms of operating systems, gauge (in some states), and the mix of freight and passenger on intercity and rural lines. Mining operations dominate freight volumes, including dedicated high-volume railroads operated by individual mining companies.

Like New Zealand, volumes of rail traffic in the UK are not strongly affected by mining. However the UK rail network is dominated by passenger operations, reflecting the higher population density.[19] Due to the dominance of passenger options, it may not be reasonable to expect the same level of safety performance

[19] Passenger operations on a train-km travelled basis comprised over 90% of all UK train operations in 2010–2012 inclusive. Refer European Railway Agency (2014, figure 22).

in New Zealand, although it still provides a useful benchmark. The UK rail network has more double tracking, fewer level crossings, fencing of the rail corridor and separation of track ownership from rail operations. Safety performance of the UK rail system has steadily improved over the years and is now one of the best in Europe.

Available data from Australia is not as readily comparable as that available from the UK, so there is a greater focus on benchmarking with the UK although the Australian operating environment is more similar to New Zealand's. The benchmarks have different normalisations between graphs. This reflects the availability of data. The New Zealand data was formed to match the available statistics in each instance.

5.2.1.1 New Zealand data

The Transport Agency maintains datasets on historic safety incidents as well as rail activity. Incidents are reported by operators as required under The Railways Act 2005, the reports are quality assured by Transport Agency personnel and then incorporated into the Rail Information System (RIS) database. In addition to safety incident reports, each licence holder is also expected to file a safety performance report (SPR). This is done annually and contains a summary of any rail safety issues and also outlines operators' activity for the period, which is collated by the Transport Agency. These datasets were provided to the researchers for the purpose of this study.

5.2.1.2 Occurrences

Unless otherwise specified, the analysis was undertaken on occurrences between 1 January 2010 and 15 October 2015 extracted from the Transport Agency's RIS database. Data prior to 2010 is not regarded by Transport Agency rail staff as suitable for aggregated analysis.

Operation type

The occurrences were classified into mainline passenger, T&H, rail cart, cable car, freight or industrial categories based on the operator involved.[20] To enable a fair comparison where the occurrence code was ambiguous, the description field was reviewed[21] assigning only occurrences identifiable as passenger services[22] to the mainline passenger classification.

Occurrence type

Following the classification of operation type, the occurrences were further classified into the following six occurrence type categories for comparison against UK incident data. This was completed using a combination of the *occurrence code 1* and *occurrence sub code 1* fields as well as a review of the description field in some instances.

- derailment[23]
- collision between trains

[20] The operator involved was assessed as being the first of the *primary participant* or *other participant* fields which was not *KiwiRail Holdings Ltd*. This was done as KiwiRail is often reported as the primary participant while not the operator concerned. If only KiwiRail reported, then KiwiRail was taken as the operator. These were manually reviewed, as for some incidents the other participants were other operators who were delayed due to a KiwiRail incident. These were manually reverted to KiwiRail Holdings Ltd as the operator involved.

[21] This was only completed for occurrences to be included in the analysis.

[22] Passenger services were determined where the train number was either of the following (where _ refers to any number) ____, TM____, TD____, _0_ or where passengers or carriages were specifically mentioned.

[23] Also includes incidents where other occurrence types lead to derailments, for example SPADs.

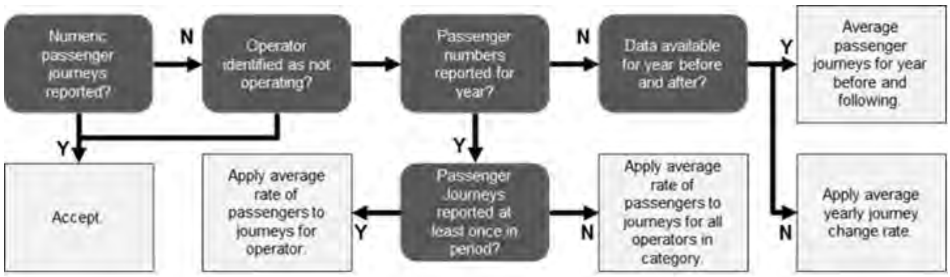
- collision with road vehicles at level crossings
- collision with stock
- train fire
- train parting.

SPADs were also assessed as event precursors.

5.2.1.3 Movements

Movement data was provided from SPRs for the 2011 to 2015 government financial years (01 July – 30 June) for all licence holders. This was in the form of six separate Excel files.

Figure 5.1 Example of method used to estimate missing records



Freight and mainline passenger

For the freight and mainline passenger categories (KiwiRail), one year of records was not completed in the SPR data and so was taken from KiwiRail's SPR for 2012 (KiwiRail 2012).

Tourist and heritage

The tourism records were less complete, with some operators reporting passenger numbers but no journey numbers (or vice versa) for some years and missing usage data for other years of record. Using the SPR files, the passenger numbers and journeys were tabulated. This allowed assessment of missing records and unexplained patterns to be identified.

Where the record was incomplete, passenger journeys and numbers were estimated according to figure 5.1.

5.2.1.4 UK data

Statistics for the number of events per year for the UK mainline were obtained from the Office of Rail and Road data portal (table 5.26). Passenger journeys by year were obtained from the Office of Rail and Road, table 12.5.

The statistics for the heritage sector are not separately published by the Office of Rail and Road data portal. However, we contacted the ORR and requested an output similar to ORR's table 5.26 for heritage operations for the 2010 –2015 financial years combined. Only the incidents involving passenger operations were included. These occurrences were classified into the same six occurrence type categories as the New Zealand data. Incidents involving trains being struck by missiles (eg thrown objects) were excluded as they were viewed by the researchers as being of less relevance to the types of incidents of concern for this study. Incidents involving trains striking level crossing gates/barriers were also excluded due to the different type of barrier arms in use; 'other collisions' were also excluded.

Each year, the UK Heritage Rail Association publishes an annual report containing the number of passengers and the average number of people per train. This data was used to obtain an estimate of the number of journeys, by dividing the number of passengers by the average number of people per train. There was no report available containing 2014 data, so an estimate was made assuming growth for 2014 equal to that of 2013 and an equal number of people per train journey for 2014 as in 2013.

5.2.1.5 Australian data

Australian data was obtained from the national rail safety reports for 2014/2015 and 2013/2014 (ONRSR 2015; ONRSR 2014a). Victoria data was only available for the 2014 and 2015 financial years and Australian Capital Territory for the 2015 financial year. South Australia, New South Wales, Northern Territory and Tasmanian data was available and included for all periods of analysis.

5.2.2 Methods for observations

Given the budget of the research project, the large number of rail licence owners, and the variety of operators, a stratified sampling approach was used for site visits to ensure coverage of all operation types. Ferry operations were outside the scope of the project.

Table 5.1 shows the activity-based classifications that were developed and gives a description of the operators we visited. The operators were selected to provide a cross section of different types and scales of operation. Where possible we have sought to keep the identity of operators confidential to allow operators to be more open with us. However, it was not possible to keep all organisations that participated confidential due to their large or unique operation. In total the researchers undertook site visits to nine rail operators, and had multiple site visits with some operators. We also undertook a site visit to a rolling stock maintenance provider.

While participation in the site visits was voluntary, almost all operators approached were keen to participate, share their thoughts, and were generous with their time and the resource needed to support this research. Table 5.1 also shows organisations we met with who have an important non-operator based role in the rail industry.

Table 5.1 Types of operators visited during research

Type	Role in New Zealand rail	Operator	Track owner	Rolling stock owner	Main maintenance provider	Industry role (eg governance, regulatory)
Access provider	National access provider					
Metro	Auckland metro operator					
	Auckland metro maintenance provider					
	Auckland metro rolling stock owner					
	Wellington metro rolling stock owner					
Freight	National freight operator					
Industrial	Operator with own siding and drivers for shunting, using another operator's locomotive and wagons					
Tourist and heritage	Tourist operator with heritage rail vehicles on NRS/non-NRS track					
	Excursion operator with heritage rail vehicles on NRS track					

Type	Role in New Zealand rail	Operator	Track owner	Rolling stock owner	Main maintenance provider	Industry role (eg governance, regulatory)
	Operator with heritage rail vehicles on non-NRS track					
	Rail cart operator					
	Tram operator					
Special	Funicular railway operator					
Other	Rail regulator					
	Tourist and heritage rail organisation					
	Accident investigator					
	Health and safety regulator					

The site visits provided an opportunity for us to see risk management practices in action, and to have an in-depth discussion with operators around organisation-specific issues, concerns, processes and practices. Where possible, researchers sighted documented processes and records to verify practices (although the visits were not audits).

During the site visits, researchers referred to a list of questions (see appendix E) but were not confined by the questions and followed other lines of inquiry as appropriate. Before the site visits, we also reviewed the reports on annual ordinary safety assessments conducted on behalf of the Transport Agency.

5.2.3 Supplementary surveys

The following two surveys were not a core part of the research but are reported on briefly and are drawn on where applicable.

Following completion of the research, the researchers held a workshop at the 2016 FRONZ conference to get a better understanding of the risk capabilities and attitudes of the T&H rail sector. The results from the workshop are available in appendix F (as circulated to FRONZ members) and are discussed in the T&H rail analysis (5.6).

Separate to this research, an organisational culture, work health and safety survey (OCWHaS) was undertaken for the New Zealand rail industry in late 2016. The survey was funded by the Cooperative Research Centre (CRC) for Rail Innovation, supported by the Australian Centre for Rail Innovation and undertaken by Larissa Clarkson and Verna Blewett (CQUniversity, Appleton Institute) (Clarkson and Blewett (2016). The survey method and results are reported on in appendix G.

5.3 Initial data analysis

We undertook an initial investigation into occurrence reports between 1 January 2010 and 15 October 2015, extracted from the Transport Agency's RIS database. Data before 2010 was not suitable for use in our aggregated analysis. The first step was to examine any overall trends within the dataset.

Figure 5.2 Count of occurrences per year (2015 annualised)

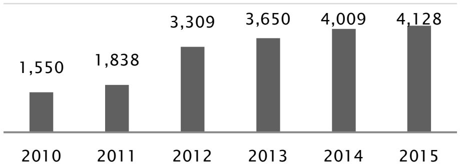


Table 5.2 Count of occurrences per year by severity (2015 annualised)

Type	2010	2011	2012	2013	2014	2015
Fatal	11	13	23	11	8	12
Non-fatal injury	48	235	545	665	671	694
Non-injury	1,491	1,590	2,741	2,974	3,330	3,422

Figure 5.2 shows the annual number of reported occurrences has increased over time, with a marked increase between 2011 and 2012 (80%). This likely reflects an increase in reporting of less serious occurrences, as there has been a sustained increase in the number of non-fatal occurrences over this period while fatalities have remained relatively constant (see table 5.2). We would expect fatalities to be reported more consistently as these are both serious and obvious. The exception to the trend in fatalities was in 2012, when there were a significantly larger number of fatalities. The raw data for 2012 was reviewed and each of the fatalities was from a single event. Of the 23 reported events classified as fatalities, the event descriptions for 20 explicitly referenced fatal injury. It remains unclear why the number of reported fatalities was unusually high in 2012.

The RIS dataset provides for classification of injuries as 'serious'. Although, there were no serious injuries reported in the dataset in 2010 to 2012, this seems unlikely and may reflect non-reporting of this category before 2013. The counts were also low compared with the number of fatalities. This likely reflects continued under-reporting of this category, possibly as a result of unclear definition of what is classed as a serious injury. Investigation of the incident description of the data found several instances where workers required several days off work, crush injuries, and severed fingers and broken bones among others which were not recorded as serious injury.

Due to the serious injury field being incomplete, a broader approach to injury type was undertaken, to identify counts of reported non-fatal injury. This combines the serious injury field with occurrences containing the phrase 'injur' (this accounts for injury, injured, injure and injuries). An additional check was made filtering out any occurrences containing the words 'no', 'nil', 'not', 'nobody', 'or', 'any' or 'uninjur' within the 25 characters prior to and including 'injur'. The counts of occurrences using these criteria are in table 5.2; this shows an increase in the number of non-fatal injury reports over time. We interpreted this difference to be the result of improved reporting rather than an underlying increase in injury rates.

Figure 5.3 Count of reported occurrences per year by reported occurrence code 1 (2015 annualised)

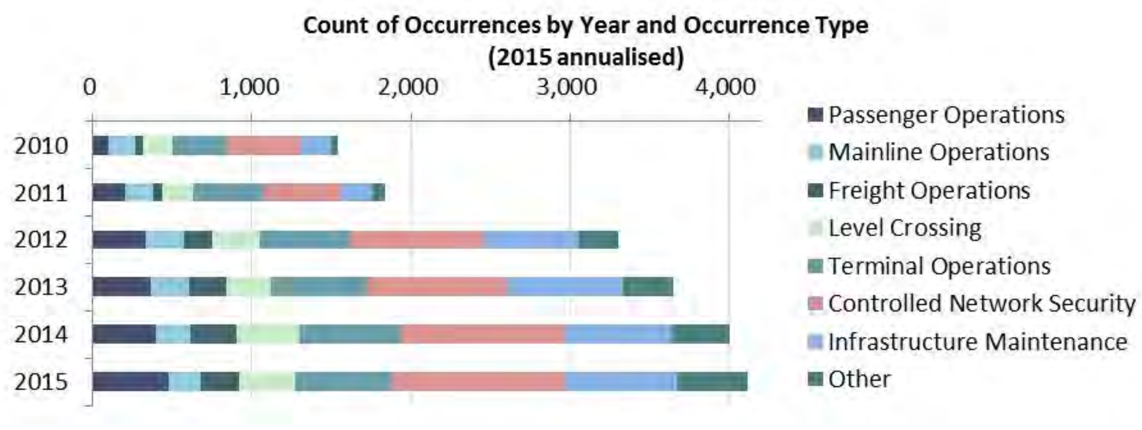


Figure 5.3 shows an increase in the reported number of passenger and freight operations, controlled network security, infrastructure maintenance and other occurrence reports, and a slight increase in level crossing and mainline and terminal operation occurrence reports, particularly between 2011 and 2012. This was interpreted by the research team as indicating the increased frequency of reporting was widespread.

Closer investigation of the occurrences found some inconsistent classification of occurrences between the categories, due to overlap between the categories (eg level crossing incidents classified as 'controlled network security'). Overall, figure 5.2 is considered to provide a suitable general overview of the data.

Figure 5.4 Count of injuries by type (1 Jan 2010–31 Oct 2015) (NF=non- fatal)

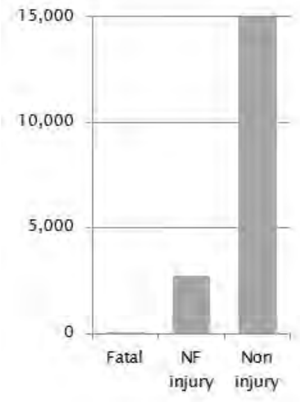


Figure 5.5 Proportion of occurrence sub code for each severity (1 Jan 2010–31 Oct 2015). Classification of occurrences for fatal and serious categories reviewed and reclassified if appropriate. (NF=non- fatal)

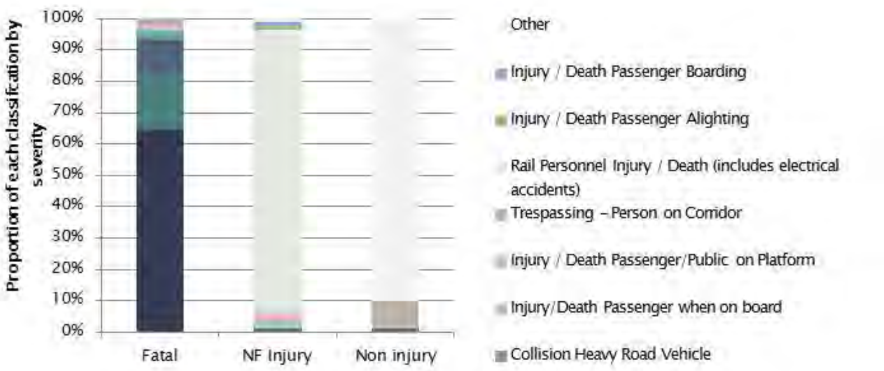


Figure 5.4 shows the overall count of injuries contained in the dataset and the scale of fatal and non-fatal injury compared with non-injury occurrences. Figure 5.5 shows the proportion of each injury type by sub code. The majority of fatal injuries are to members of the public. The non-fatal injuries provide little insight aside from the observation that the majority of these injury events are to rail personnel. This lack of detail is due to the proximate cause of injury not being further coded within the rail personnel injury/death classification. This significantly limits the ability to analyse RIS data.

5.4 National Rail System operations

5.4.1 Introduction and approach

This section of the report covers mainline operations in New Zealand, including national services (freight and passenger) and metro passenger services. Network infrastructure maintenance and network access control are also covered. T&H rail operations have been excluded from this section (except for the purposes of benchmarking with Australia, as the available Australian mainline data includes the T&H sector).

As mainline operations are large, achieving a sufficient sample of personal observations was not possible for the scale of this research study. Also the scale of operation is such that risk management issues can be expected to be evident from the safety performance statistics. For these reasons a data-driven observational approach was proposed for NRS activities for this research. Under this approach incident statistics were used to provide a primary indication of safety performance, particularly for frequent events.

TAIC has thoroughly investigated many of the most noteworthy incidents and their reports and responses provided a further source of literature to draw from. Accordingly, the assessment of mainline operations drew primarily on examination of incident statistics, documented systems and TAIC investigation reports, supplemented by limited observations by the researchers.

The researchers met with or visited the following operations.

Table 5.3 Types of operators visited during research on NRS operations

Type	Role in New Zealand rail	Operator	Track owner	Rolling stock owner	Main maintenance provider	Industry role (eg governance, regulatory)
Access provider	National access provider					
Metro	Auckland metro operator					
	Auckland metro maintenance provider					
	Auckland metro rolling stock owner					
	Wellington metro rolling stock owner					
Freight	National freight operator					

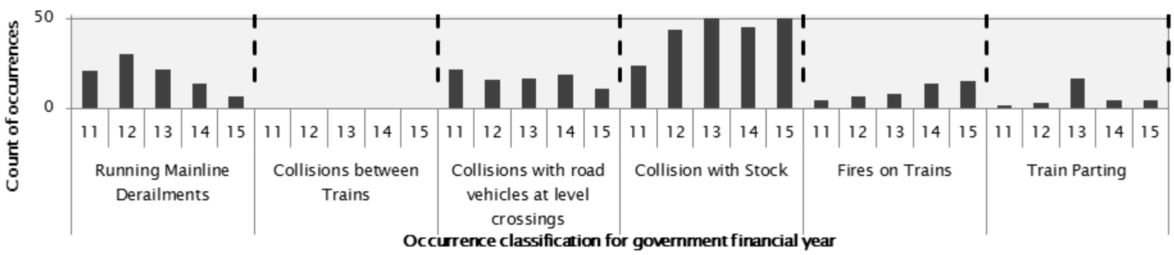
The researchers were able to visit terminal operations, train control, observe track work processes, rolling stock maintenance depots, and undertake a running line freight cab ride. They also interviewed senior executives and other personnel and had access to key documents.

5.4.2 Data analysis of freight operations

5.4.2.1 New Zealand data

Figure 5.6 summarises RIS data for freight operations for the period 1 July 2010 to 30 June 2015. Only running line incidents are included (ie excludes shunting yards, 'lift offs').

Figure 5.6 New Zealand freight occurrences over time



There appears to be a slight decrease in the number of collisions with road vehicles at level crossings and, considering the overall increase in rail traffic over level crossings, this likely reflects an increase in level crossing safety.

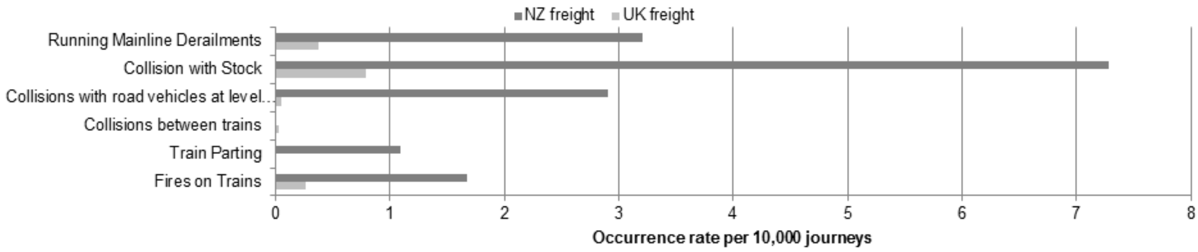
There is a slight increase in collisions with stock. This may be representative of an underlying trend, noting that the number of journeys has increased yearly (with the exception of the 2014 financial year which remained reasonably constant). Alternatively, this may reflect an increase in reporting, although stock trespass reporting is perceived to have been robust over a prolonged period (G Hight, pers comm).

Collisions between trains, train fires and train partings are too infrequent to draw any conclusions on trends. Derailments on the mainline have decreased significantly over the last 10 years.

5.4.2.2 Benchmarking: United Kingdom

The frequency of running mainline freight derailments in the UK is around 10 times lower than in New Zealand when measured on a per journey (ie train movement) basis. New Zealand freight operations have a higher rate of occurrences for every incident type evaluated by the research team. Care should be taken when interpreting figure 5.7 because some of the individual categories counts are low. In the UK there were few collisions between trains and few level crossing collisions leading to a small occurrence rate per journey. The frequency of collision with stock may be more indicative of other practices (eg the UK rail industry has a duty to fence its entire length) so no rail-specific conclusion is drawn.

Figure 5.7 New Zealand and UK freight rail sector occurrence rate per 10,000 journeys[24,25]



Two categories of incident stand out:

- a higher likelihood of a freight train journey resulting in a vehicle collision on a level crossing
- a higher likelihood of a freight train journey resulting in a derailment.

At face value, the difference in derailments suggests ample scope for further improvement, but care should be taken in drawing comparisons. The UK rail system carries proportionately greater volumes of passenger traffic than is the case in New Zealand.[26] Passenger trains usually operate at faster speeds than freight trains and the consequences of a passenger train derailment are likely to be much higher than a freight train derailment. Consequently, UK track may be managed to a higher standard than in New Zealand. If the New Zealand network is viewed primarily as a freight business service, then the optimal quality of track in New Zealand may be lower than in the UK. This observation from freight operations thus has implications for the likelihood of passenger derailments which are considered in a later section.

[24] New Zealand reporting July to June. UK reporting April to March.

[25] There was no record for train parting occurrences in the mainline section of the UK data; however, this was a category in the non-mainline section of the data. This has been interpreted as there being no occurrences in this category for the duration of the UK dataset.

[26] Passenger operations on a train-km travelled basis comprised over 90% of all UK train operations in 2010–2012 inclusive. Refer European Railway Agency (2014, figure 22).

5.4.2.3 Benchmarking: Australia

Figure 5.8 Freight train comparison against Australia[27,28]

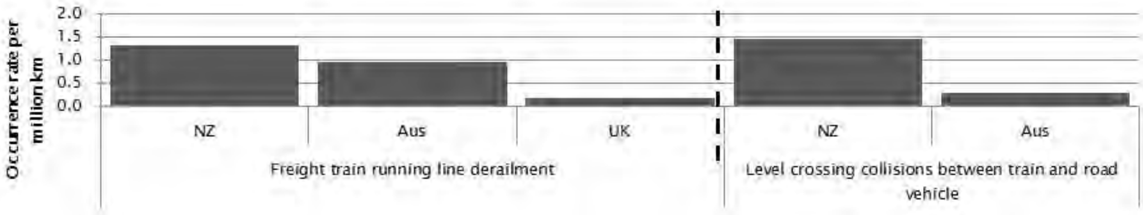


Figure 5.8 shows a comparison between occurrence rates in New Zealand and Australia for the freight sector. The comparison is on a per km basis as that is the basis of the reported Australian data. The figure shows the New Zealand rail system has a higher occurrence rate per km travelled for both derailments and level crossing collisions. The UK rail system has a lower rate of freight derailments than both New Zealand and Australia.

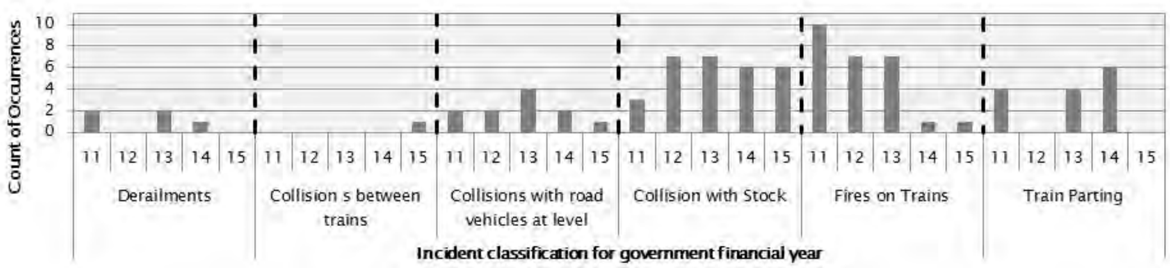
5.4.3 Passenger operations

In this report passenger operations are defined as including metro and national (eg scenic journeys) passenger operations on the mainline, but exclude T&H excursions on the mainline (except where otherwise specified).

5.4.3.1 New Zealand data

Figure 5.9 below identifies incident counts from the RIS system for the financial years ending 31 March 2011 to 2015 inclusive.[29]

Figure 5.9 New Zealand mainline passenger occurrences over time



There are no clear trends in the number of occurrences over time for any of the selected occurrence classifications. The absence of obvious trends may be due to the relatively short period presented.

There may be a slightly decreasing likelihood of fires on trains over this period – some of the passenger train fire incidents were on older electric multiple unit (EMU) and diesel multiple unit (DMU) sets at the end of their service lives which have since been retired from service.

[27] New Zealand and Australia July to June. UK reporting April to March.

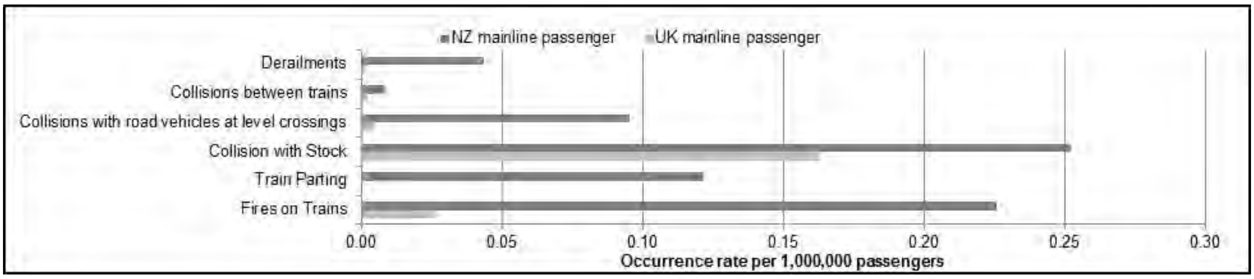
[28] Australian data from ONRSR *Rail safety report 2014–2015* (ONRSR 2015). It includes railways within ONRSR's area of operation in the 2014/2015 financial year — South Australia, New South Wales, Tasmania, Northern Territory, Australian Capital Territory and Victoria.

[29] The data is grouped in March financial years to enable comparison with benchmarking data from the UK.

5.4.3.2 Benchmarking: United Kingdom

A comparison of the rate of occurrences per passenger in the UK is shown in figure 5.10. This graph is presented on a per passenger basis, as journey counts for the UK mainline passenger sector were unavailable.

Figure 5.10 New Zealand and UK mainline passenger sector occurrence rate per million passengers

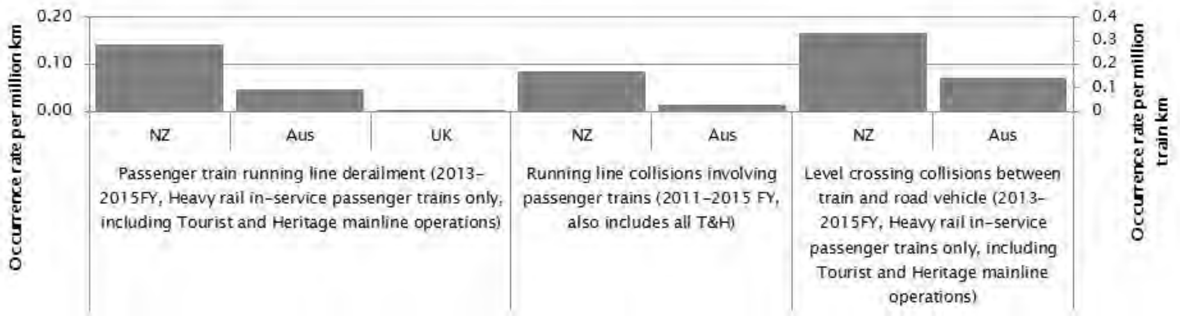


The benchmarking shows elevated rates of occurrences for New Zealand compared with the UK across all occurrence categories. Running mainline collisions and derailments are key incident types of interest due to the potential for catastrophic consequences.

5.4.3.3 Benchmarking: Australia

Australian passenger service incident data is available from ONRSR covering rail activities.[30] Figure 5.11 below presents the benchmarking comparison.[31]

Figure 5.11 Passenger train comparison against Australia



This comparison also shows New Zealand as having higher occurrence rates per km travelled in all examined categories compared with the Australian data.

The biggest difference is for running line collisions involving passenger trains. The New Zealand data includes the T&H sector in this comparison in order to match the Australian data. While two thirds of the New Zealand occurrences were from T&H rail operations, this is unlikely to wholly account for the higher rate; the comparison with the UK in figure 5.10 excludes T&H activities for both datasets and also shows

[30] ONRSR covers the states of South Australia, New South Wales, Tasmania, Northern Territory, Victoria, the Australian Capital Territory and Western Australia. Subject to the passage of applied or mirror legislation, it is expected Queensland will also be regulated by the ONRSR (ONRSR 2016).

[31] The data is grouped on the same basis as the Australian data reported by ONRSR, so it is not directly comparable with the rates shown in figure 5.10.

New Zealand performing more poorly. The counts of collisions are low, so a single event can have a large effect on the rates, especially in New Zealand where the level of activity is relatively low.

5.4.3.4 Benchmarking conclusions

These comparisons indicate the frequency of incidents on New Zealand mainline passenger rail services is significantly higher than in the UK and in Australia. While there are differences between the rail system in New Zealand and in these countries, these are the two countries selected by the industry Steering Committee for the international benchmarking of rail safety indicators in *NZ Transport Agency research report 583* (Brown 2016b). If subsequent stages of the Transport Agency benchmarking research result in the development of reliable comparative benchmarking statistics, then a better understanding of the reasons for these apparent differences may emerge.

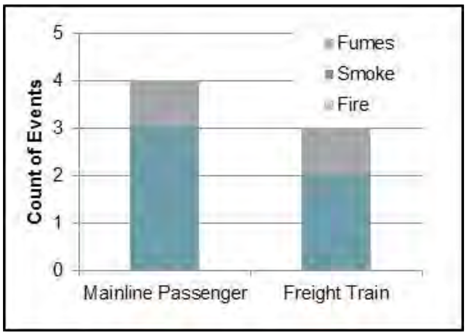
If these comparisons are valid, then passenger rail travel in New Zealand on a per journey basis is significantly more risky than in comparative rail systems. While improved rail safety performance seems self-evidently better, perverse societal outcomes are possible if demands for improved safety result in such increased rail charges that users opt for less safe transport modes.

5.4.4 Other occurrences

5.4.4.1 Fumes, smoke and fire in tunnels

Figure 5.12 shows the count of equipment related occurrences of smoke and fumes in tunnels.

Figure 5.12 Count of equipment related occurrences of smoke and fumes in tunnels



The only reported fire in a tunnel over the data period was an HRV fire forcing three workers to evacuate the vehicle. Near misses in recent years include a fire on a scheduled mainline tourist train in July 2009 and a fire on a T&H train in 2010. There was also a freight locomotive fire in Otira tunnel that occurred outside the data period (September 2015).

5.4.4.2 Signals passed at danger

A SPAD is a signal passed at danger (without authority). A SPAD is potentially catastrophic; it is a precursor to events with significant potential for fatalities, such as train collisions, or collisions with maintenance providers. Refer to appendix F for definitions of the SPAD categories. In general, a SPAD A is the highest risk. A SPAD B is generally not as critical but can still lead to a collision (for example, a runaway train).

Figure 5.13 Rate of SPAD A and SPAD B occurrences per journey by operation type[32]

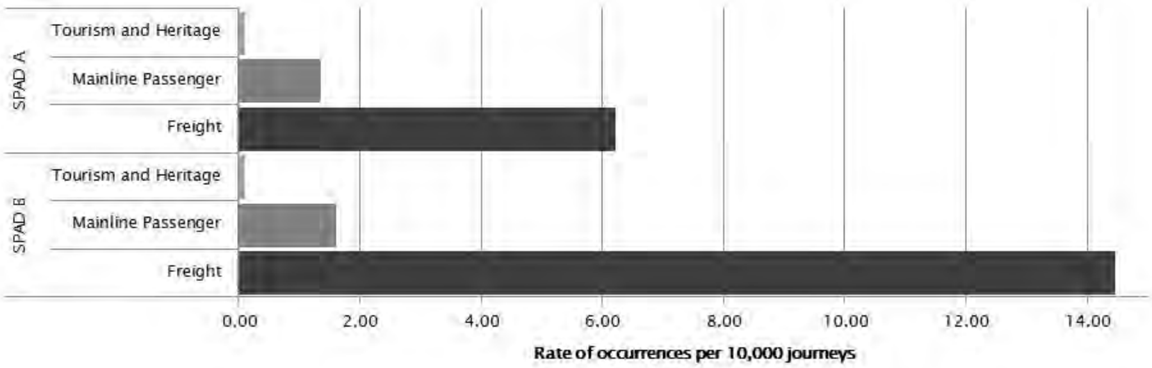


Figure 5.14 Rate of SPAD A and SPAD B occurrences per km by operation type

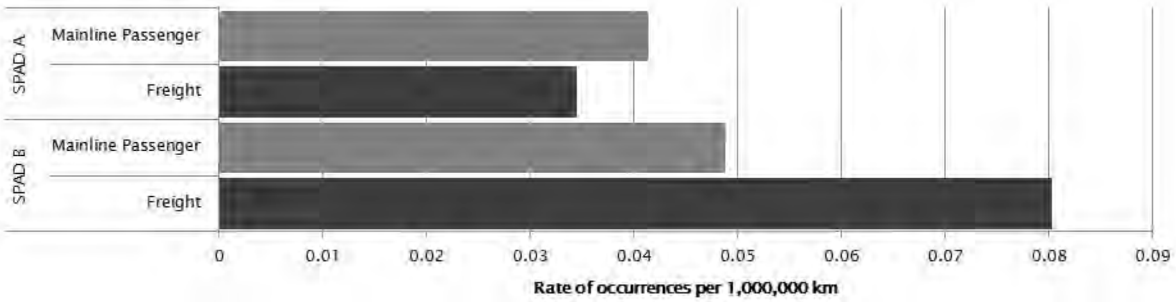
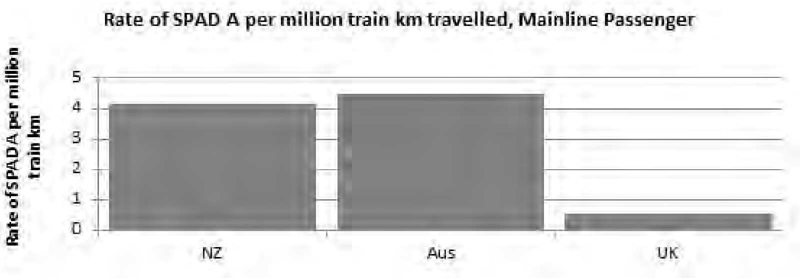


Figure 5.13 shows the rate of both SPAD A and SPAD B occurrences per journey for each operation type. Figure 5.14 shows the rate per km for mainline passenger and freight.[33]

The elevated rate of freight SPAD occurrences per journey reflects the higher number of signals passed due to longer journey lengths. On a per km basis, freight has a lower rate of SPAD A's than mainline passenger trains. Freight trains also have a reduced ability to stop (and so to recover post error). The rate of SPAD B occurrences for freight operations in comparison with the other operation types is much higher than SPAD A. This may indicate that signals in rural areas are more likely to fail or malfunction.

Figure 5.15 Rate of SPAD A per million train km travelled for mainline passenger operations



[32] SPAD B as per 2015 classifications (refer appendix F) (includes occurrences previously categorised as SPAD C or SPAD D under old classification system)

[33] Data for km travelled by T&H operators was incomplete.

Figure 5.15 shows the rate of SPAD A occurrences in New Zealand compared with Australia and also with the UK for the 2011 to 2015 financial years. The figures show a similar rate of SPAD A occurrences between New Zealand and Australia (per km travelled), but a much higher rate by both compared with the UK (per km travelled).

Figure 5.16 Rate of SPAD A occurrences per 10,000 journeys

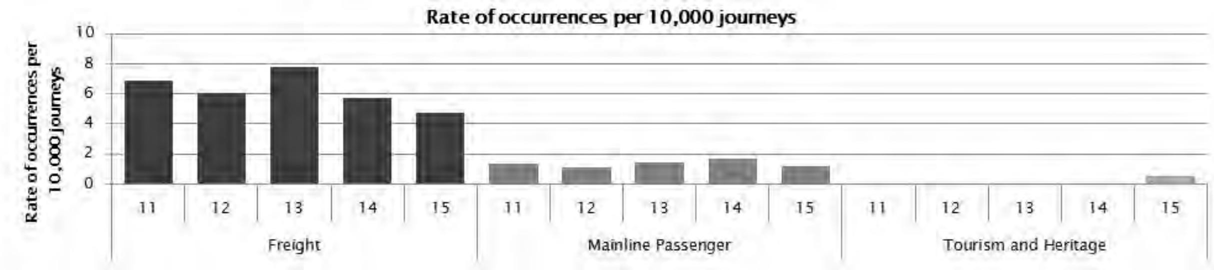
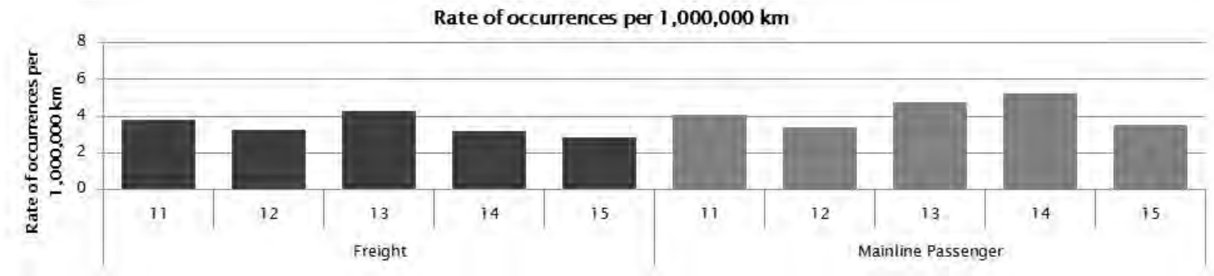


Figure 5.17 Rate of SPAD A occurrences per 1,000,000 km



Figures 5.16 and figure 5.17 show the rate of SPAD A occurrences over time for each operation type. There is no clear trend in the rate of SPAD A occurrences per journey for either freight or mainline passenger. Freight operations may be showing a decreased rate of SPADs over time, but it would require a longer timeline to confirm this.

5.4.5 Observations

5.4.5.1 Freight operations and terminals, shunting and container terminals

Freight

Freight operations occur across the whole network. Freight wagons are often more heavily loaded and can have a more varied vehicle type throughout a train, which stress tests the rail infrastructure as it places more emphasis on vehicle/track dynamics. Proportionately, they are also more exposed to operations in rural territory where stock trespass or unprotected level crossings are more dominant. Derailments are an integrative measure of overall performance in that they involve interactions between track, rail vehicles, loading and operations.

The national rail operator has invested significantly in reducing the frequency of derailments, particularly in the 'golden triangle' (Auckland–Hamilton–Tauranga) where much of the rail freight volume is moved. Analysis found derailments were imposing significant costs. On this basis a business case was developed, approved and implemented for investment to reduce the frequency of derailments (KiwiRail, pers com).

This investment was reflected in the data analysis undertaken by the researchers (which showed derailments have decreased over time). Data in national rail operator reports, and anecdotal comments from current and former New Zealand rail operational staff support the view that frequency of derailments is significantly lower than previously experienced.

The researchers undertook a cab ride on a freight train and were able to observe practices intended to reduce risk (eg calling signals, repeating back track warrant[34], sounding horn approaching level crossings). The researchers observed an error that was identified and corrected during the track warrant process, which demonstrated the system of repeating back worked effectively in this instance.

The researchers did notice driver knowledge of rules and procedures was referenced back to experience rather than to documented systems, which is a potential risk if widespread. If new staff learn mainly from others then there is a likelihood that field practices might not follow the written rules and procedures.

The national rail operator wagon fleet has been changing over to safer Alliance couplers as wagons reach the end of their service lives and are replaced. This process has now been sped up by replacing couplers on existing wagons to reach 75% penetration more quickly. These couplers are inherently safer. During the transition period, transition heads are used for coupling between wagons of differing types. The current fleet mix is a time of peak demand for use of transition heads. Use of transition heads will drop as a greater proportion of the fleet is replaced.

Issues associated with the incorporation of asbestos into the construction of new double-ended DL freight locomotives are being addressed. Removal of asbestos was expected to be completed on all locomotives by the end of 2016.

Fatigue is a recognised risk for freight drivers and tools such as FAID (a fatigue assessment tool) are in use in New Zealand. Of course, to be effective FAID would make up one component within a wider fatigue risk management system. One issue communicated to the researchers (although not explored first-hand) is that FAID may not always accurately measure fatigue risk, as it is used to assess rosters but actual shifts undertaken by drivers may differ (eg swapping shifts, unscheduled work).

Shunting

Shunting was formerly a major hazard, with workers being maimed and killed in shunting operations on an annual basis. The researchers did not directly observe activities in these areas but have provided comment based on literature studied, as explicitly stated in our methodology.

In the year 2000, a ministerial inquiry was held following the deaths of five railway workers, including three shunters, in the space of 12 months. This was equivalent to a fatality rate of 39.3 per 100,000 employees and placed what was then Tranz Rail at eight times the national average fatality rate (Ministerial Inquiry into Tranz Rail Occupational Health and Safety 2000).

At that time shunt locomotive refuges had already been installed, new handgrabs fitted to over 1,000 wagons and loose shunting prohibited due to the dangers. In May 2000 the Ministerial Inquiry was advised boarding and alighting from moving wagons had also been prohibited after a fatal shunting incident. The number of shunters in harm's way was also significantly reduced by restricting the approved riding positions on wagons – shunters could only ride on a trailing footstep behind the last wagon being hauled, in a purpose built locomotive refuge, on the running board of a locomotive or inside a passenger car.

Subsequent to the ban on boarding and alighting from moving wagons and following a review by a newly established Industrial Council, the safe working procedure (code instruction) was changed to allow alighting at walking pace from the shunting locomotive refuge, purpose-built riding wagons, and the trailing footstep of the cowcatcher on mainline locomotives and the trailing shunter's platform when a refuge is not fitted.

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[34] This occurs when the driver responds to track warrant information received from train control by repeating it back (via radio). The train controller confirms whether the information has been correctly received. Track warrants give the driver permission to enter a section of track.

This revision recognised that a shunter alighting from a locomotive, refuge, or purpose-built riding wagon refuge, could safely step off closer to the ground outside the rail vehicle profile, and in the case of a trailing mainline locomotive or wagon avoid the risk of being run over by a following wagon wheel.

During 2001 the Industrial Council reviewed riding positions on wagons resulting in a move away from riding on shunter platforms between wagons and placed further restrictions on riding on bogie wagon decks. This initiative eliminated the risk of falling between wagons and being exposed to trailing wheels which had historically been the leading cause of severe injury and fatalities.

After introduction of the above changes a single shunting fatality at Otaki occurred on 28 November 2005. The turnaround in safety performance demonstrates the elimination of riding where reasonably practical and the introduction of engineering controls supported by lower order procedural controls (where not reasonably practical to eliminate riding) has been effective in reducing fatality risk. This approach is in line with best practice (eg control hierarchy (see section 4.5.1)).

While these changes to shunting practices have been embedded within the national operator, other operators may have different shunting procedures that have greater latent risk.

Terminal operations and container terminals

The researchers visited several freight terminal operations (including a container terminal and a maintenance depot). Particularly in the maintenance depot, the researchers observed evidence of a variety of practical tools used to reduce risk as well as good attitudes towards safety and risk management. The impression received was that risk management was integrated well in practical ways at an operational level. Throughout the freight-related areas the researchers visited, staff appeared to be aware of the significant hazards present in their areas of work.

While a good understanding of risk appeared to be generally evident in workers' behaviour, the researchers did notice some obvious and significant deviations from written procedures (confirmed with the operator). This highlighted the potential of a risk of institutionalised deviations from procedure in NRS operations. This is in part why it is best practice to implement engineering controls over procedural ones (see control hierarchy in section 4.5.1). In practice, controls further up the hierarchy can be very costly to implement but should be considered before procedural controls as they are much less reliant on worker behaviour.

A wider range of safety issues was observed at a container terminal (ie a logistics operation with rail interface). This was interpreted by the researchers as indicating a lower level of capability, at least at that particular site. These observations suggest there may be significant differences in work cultures and risk management capabilities across the same organisation.

5.4.5.2 Passenger operations

The researchers travelled informally on a metro passenger service, met with several parties involved in passenger operations, and visited a maintenance depot. The researchers also had access to safety performance reports. As stated in the methodology, comment on passenger operations was to be primarily informed by the data analysis and literature review.

Long-distance passenger services are run by the national rail operator and are provided using a mix of refurbished British Railways Mark 2 and new AK class passenger carriages built in New Zealand. The Mark 2 carriages are reported to have a semi-integral steel construction improving their crash worthiness over earlier carriage types. We understand the AK carriages are designed to a modern standard, including a significant degree of end protection in the event of collision, and also much better side protection than the previous fleet. Many of the 56-foot wooden-bodied AO passenger carriages, dating from the 1930s, are still owned by the national rail operator but are retired from service. These cars are discussed in section 5.6.

Two examples of the Silver Fern railcars remain in service, one currently operated by the national rail operator for excursion services and one by Dunedin Railways on the coastal route north of Dunedin. The rollover crash worthiness of the Sliver Fern railcar was demonstrated in the rollover accident near Waiouru in 1981 when the railcar overturned and rolled down a 9m bank. While four people died in this incident, principally by being crushed after falling through the windows, the railcar remained intact and was eventually repaired and returned to service.

Metro passenger services operate in only two cities – Wellington and Auckland. Over recent years new rolling stock for Wellington and Auckland metro passenger services has been purchased by the respective local bodies. Both the Auckland and Wellington fleet owners report the EMUs have anti-climb protection. This was observed by the researchers for the Auckland EMU fleet. The main consideration for specification of collision protection on the EMUs appears to have been low-speed collisions between EMUs. Less consideration appears to have been given to the possibility of head-on collisions with freight trains. In Wellington there is a 1,600 volt DC overhead traction supply, while Auckland has a 25 kV AC overhead supply.

The Wellington metro rail system has an older form of partial train protection which relies on mechanical train stops to arrest a train that passes a signal set at danger. In comparison to the European Train Control System (ETCS) installed in the Auckland metro area, this is a simpler and less complete form of protection. In addition the train stop system is only partially implemented: only some signals have train stops, and freight trains do not have the requisite equipment fitted. In Australia, the Melbourne railway system has mechanical stops (rather than ETCS); however, they have the stops at every signal. A review is currently underway of train protection in the Wellington metro area, being undertaken jointly by the national operator, the council and the Transport Agency. Given this review the researchers have made no specific recommendations on train control in the Wellington area.

In Auckland, the researchers found the operator to be concerned about safety performance, able to articulate key issues and committed to attending to those issues. The frequency of SPAD A events has been a significant issue. ETCS Level 1, recently implemented in Auckland, partially mitigates the potential consequences of SPADs. However, the operator has recognised SPADs are a critical risk and has mobilised resources to understand the issue as well as implemented treatments to reduce the frequency. These measures range from high-level reviews by European experts, through to driver training. An interesting human factors initiative is use of the Vienna Testing System, which includes psychomotor and psychometric tests in driver selection and in post-incident investigations in specific circumstances.

Looking beyond SPADs, in the Auckland area the operator has identified two other issues: operation of trains not fitted with any form of automatic train protection (ATP); and level crossings, particularly on the Western Line.

The researchers found the local body in Auckland (and rolling stock owner) takes an active role in managing rail risks, including working closely with the other rail participants in the Auckland metro area. This relationship includes weekly discussions on health and safety, working to improve safety across the network as a team. Discussions showed a high awareness of safety risks of higher importance to the network, and a local body actively involved in safety initiatives such as public education campaigns. Enabling construction work has recently started for the City Rail Link, which will extend the existing passenger rail system (currently terminating in Britomart) through to the rail network at Mt Eden, and will include new stations and tunnels below the city centre. With this project, the local body has used a systematic approach to safety management in the design stage and an independent safety assessment has been mandated for the project by the Transport Agency. Throughout the City Rail Link development there has been close liaison with the national rail access provider.

An issue not discussed in the SPR is vulnerability of the Transdev control room in Britomart to flooding. The control room is located above the station hall, but appears to be below ground level. Evacuation of Britomart station is controlled by Auckland Transport and there is a fully redundant standby control room in the Citigroup building. A more formal assessment would be required to assess if this risk is real, and if so the likelihood of credible threat to the facility. A new purpose-built Station Group Control Centre is to be built as part of the City Rail Link project which will be located above tsunami influence.

An issue for passenger operations is that freight locomotives do not appear to have similar forms of anti-climb protection set at the same heights as the EMU. Collisions with freight trains are a conceivable occurrence. The most recent at the time of writing was in Belgium (June 2016), when a passenger train collided with the rear of a stationary freight train on the same line. Three people were killed in the collision. A near miss occurred in Sydney in January 2016 when a passenger train was driven in the wrong direction by the crew, towards an oncoming freight train. Collisions between freight and passenger trains can result in high death tolls, probably because of the greater momentum of heavy freight trains.[35]

Assaults on staff by passengers, particularly in Auckland, was a concern expressed to the researchers. Auckland rail staff have previously threatened strike action unless action was taken in response to intimidation and attacks. Current initiatives to reduce the risk of assault include use of body cameras on ticket inspectors, security guards (at particular stations and roaming), Māori wardens, and greater engagement with schools and police.

5.4.5.3 Network access control

Train control is a critical network safety function. In this section *train control* is used to refer to the complete system of rules, operating procedures, communication, signalling, control of train movements and protection of track maintenance activity. In this context train control includes mechanical and computerised automated train control systems that prevent deviations from permitted train movements. The researchers did not directly observe activities in these areas but have provided comment based on literature studied. A key component of train control is signal control and communication with train drivers and track workers. Formerly undertaken locally, train control has been largely centralised into the National Train Control Centre (NTCC), located at the Wellington Central Railway Station.

There has been a significant focus on train control in recent times including:

- the introduction of a new signalling system (incorporating automatic train protection) as part of Auckland metro area electrification
- recommendations from TAIC arising from investigation of incidents where train control failures were a central or contributing factor (TAIC 2009; TAIC 2010a; TAIC 2013a; TAIC 2013c; TAIC 2014b)
- establishment of methods to improve visibility of trains to train controllers
- removal of local signal boxes and centralisation of train control in the NTCC in Wellington
- a special safety assessment of the KiwiRail NTCC conducted by the Transport Agency in 2014 (NZ Transport Agency 2015b)

[35] For example Hordorf, Germany in 2011 (10 killed), Chatsworth, California in 2008 (5 killed), Zoufftgen, France in 2006 (6 killed) Hinton, Canada in 1986 (23 killed).

- an independent assessment and benchmarking review of NTCC by the national operator
- a review of train protection in the Wellington metro area (currently underway in conjunction with Wellington Regional Council and the Transport Agency).

These activities are within a context of national operator initiatives, reviews, audits and improvements to train control. Passenger numbers on the Auckland and Wellington rail systems have been rising, new rolling stock for passenger services in the Auckland and Wellington metro areas has been introduced and the peak time frequency of passenger services has increased.

The Transport Agency undertook a special safety assessment of the NTCC. In summary, it found resource management and capacity lay at the heart of the issues concerning the NTCC. Deficiencies in transfer of information between signal boxes were a central feature of a number of incidents investigated by TAIC, for example *Rail inquiry 10-101* (TAIC 2012a).

There has been a recognition that train control needs to improve and a range of measures have been put in place to improve the overall system, ranging from how the NTCC operates through to driver training. The national rail operator is recruiting more train controllers and has increased the formalisation of training systems, alongside other measures. Given the Transport Agency's recent scrutiny of the NTCC's operations, the researchers consider the internal operations at the NTCC are under sufficient regulatory attention. Accordingly the focus of this research relating to train control has been to understand the interactions with other safety systems, as opposed to more operational matters within the NTCC. Potential strategic issues are discussed in appendix I.

5.4.5.4 Safety management system

Safety management systems are a formal and systematic approach to managing safety.

An example of an active safety management programme can be found in the national operator. Their programme includes a series of initiatives, called critical risk networks, in four areas: SPADs, level crossings, tunnels and track occupations.[36]

Elements of these safety management and reporting systems are excellent:

- A Zero Harm policy has been adopted.
- A Zero Harm compliance guide has been prepared and issued to implement the vision.
- The potential outcomes of incidents are assessed and high potential outcomes are reported to the board.
- Monthly reports with extensive use of graphics provide senior executives and the board subcommittee with visibility.
- The critical risk networks enable cross-cutting teams to work across internal organisational boundaries within the organisation.

The operator monitors other metrics of safety, including lead indicators of potential catastrophic events such as derailments, mainline collisions and SPADS (KiwiRail 2015) and the reporting framework within the organisation (up to board level) appears to be comprehensive.

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[36] Four critical risk networks were formed at the time of the research. A fifth has since been established for contractor management.

Injury frequency rates

Rates of rail worker injuries have reduced, which can be viewed as a result of successful safety programmes.[37] Effective programmes to reduce workplace injury are good. However, as discussed in chapter 4, reducing worker injury formation rates do not necessarily indicate disaster is less likely. For instance, the BP Texas City refinery reportedly had one of the best safety records, until it exploded in 2005 killing 15 workers. Investigation found management had focused excessively on reporting on lost time injuries, which were linked to performance bonuses, and effectively ignored increasing fire counts, which indicated escalating process control risks (Hopkins 2007). For these reasons, while still an excellent result for managing more frequent sources of harm, annual worker injury formation rates as a good indicator of safety in relation to less frequent but catastrophic events.

The researchers observed two apparent paradoxes:

1 General managers consistently advised that cost constraints did not prevent selection of risk treatment options requiring capital investment, whereas the researchers observed a heavy focus on rules and procedures rather than engineering controls.[38]

2 Quality control processes are diligently reported, yet visits to operations by the researchers quickly identified a range of activities that did not comply with the relevant rules and procedures.

In making these observations the researchers acknowledge they only visited a few sites out of many. Those sites may simply not be representative. However, the predominance of non-compliances found in TAIC investigation reports suggests there is an issue and it is leading to serious incidents.[39]

Taking the research observations at face value, one possible interpretation of the first observation is a cultural bias: historically, the rail industry has minimised investments, with procedures and rules being adopted as preferred risk treatments. A culture of underinvestment may linger on at lower management levels.

The apparent failure of quality control processes to detect the disconnect between rules and behaviour is not unique to any single operator (G Hight, pers comm). For the national rail operator, the rules and procedures books are thick, with 84 pages of shunting procedures alone, but this does not seem to be the whole answer. A clue may lie in an observation made by the Ministerial Board of Inquiry in 2000. In reference to audits commissioned by the national rail operator of the time, the inquiry cited evidence from a recognised UK rail expert, David Raynor, who commented:

> *Moreover, it is in the area of occupational safety management, with its strong cultural influences, that the quality-assurance style of compliance auditing is at its least effective, and can fail to uncover weaknesses in attitudes and behaviours that prejudice personal safety.*

As this comment has resonated with the researchers over 15 years later, it suggests this is a long-standing issue. As discussed in section 4.3.5, such human factor issues are gradually becoming better recognised.

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[37] Reductions in the total recordable injury frequency rate and the lost time injury frequency rate are reported in the 2015 KiwiRail Annual Report (KiwiRail 2015a) and the 2015 KiwiRail Annual Safety Report to the Transport Agency (KiwiRail 2015d).

[38] The general section of the national rail operator rule book is 1,294 pages (version 2 issued December 2015). Local district rules can amount to a further 100 pages.

[39] The TAIC observations are post-event and may therefore not be representative of typical operations, but they are representative of the state of operations at the time that incidents occur, which is relevant.

If auditing style is overly quality-system based, this could lead to an overt focus on paper systems, which can come to be regarded as a form of compliance activity, remote from actual front-line activities and behaviours. A cut-through solution may be to supplement quality-system style audits with more direct work practice observations by independent parties, drawing on a human factor perspective.

This issue is recognised in the design of the Safety Star Rating Scheme (SRSS) currently in development by WorkSafe NZ, MBIE and the ACC. The SRSS has adopted a 'deep slice' approach. In this methodology the assessor not only looks at systems, but also follows a few critical issues all the way to the shop-floor, talking to workers and supervisors and observing work practices.[40]

Safety performance metrics

The researchers observe that if safety targets only relate to total recordable injuries frequency rate (TRIFR), it may direct the health and safety focus towards common and less serious incidents at the expense of less frequent and more catastrophic events. What is missing from some safety cases is long-run safety performance information, numeric targets for key safety performance metrics other than TRIFR, identification of performance gaps for those metrics and expectations for how the proposals described by the annual report will close those gaps. Without these it is not possible to identify the safety result attainable from the safety case.

5.4.5.5 Other areas of risk

Tunnels and infrastructure maintenance risks are outlined in this section. The researchers did not directly observe activities in these areas but have provided comment based on literature studied.

Tunnels

Fires in tunnels have the potential to be catastrophic, as illustrated by the Kaprun Alpine rail tunnel fire in 2000 where 170 people died when a fire destroyed everything but the train chassis. Smoke inhalation and carbon monoxide poisoning are other key risks resulting from tunnel fires. For example, in the 1999 Mont Blanc road tunnel fire 38 people died of smoke inhalation (Duffé and Marec 1999). Lethal fires in tunnels may be deliberate acts, as illustrated by the 2003 Daegu Subway fire in South Korea in which 192 people died, or accidental.

There may be significant constraints on incident response when fires occur near tunnels, as illustrated by the 2010 T&H incident in the box out below.

CASE STUDY: Train fire in New Zealand
In 2010 one of two locomotives on a passenger train caught fire on a bridge, just before a tunnel. The crew could not put out the fire, nor could they drive the train from the bridge due to the tunnel ahead or push back due to the fire in the loco. Crew evacuated passengers from the train, detached the locos, rushed to meet the fire service and left the carriages on the bridge, where passengers were able to return after the locos were removed.

Rail tunnel safety is a focus of WorkSafe New Zealand, is part of a current Transport Agency high-risk programme (C Ballantyne, pers comm), and is one of the national operator's critical risk network focus areas. The national operator's analysis of tunnel incidents reports an escalating count over time.

[40] Disclosure: One of the researchers, Kevin Oldham, is a member of the Expert Design Group, advising WorkSafe NZ, MBIE and ACC on the design of the SSRS. The national rail operator has participated in a pilot trial of the SSRS (P. O'Connell, pers. comm.)

This may be due to both generally increased reporting of incidents across the whole network and increased awareness of tunnel safety issues in particular. This view is supported by the ongoing low count of derailments in tunnels; we expected derailments would be reported consistently over the period, but these have shown no increasing trend.

The national operator prepared a *Tunnel safety strategy FY16–18* (KiwiRail 2015c). The strategy adopts the UNESCO recommended priority order (UNESCO 2003):

- prevention of incidents
- mitigation of impact
- facilitation of escape
- facilitation of rescue.

The tunnel strategy also identifies five 'pillars' of safety measures for safe tunnel operations:

- infrastructure
- rolling stock
- freight
- passenger
- network services.

The tunnel strategy identifies risk treatments, some of which, such as fire suppression on passenger locomotives, have been completed. Item 22, '…benchmarking against overseas railway operator practices and peer review of national rail operator practice by independent experts', has been deferred. Such benchmarking and independent peer review could be expected to deliver fresh insights and valuable inputs to the systematic risk assessment and strategy development.

Overall the research team views fire in tunnels as a potential catastrophic risk that merits attention. Design and construction of the City Rail Link will also require close consideration of tunnel fire risks. Accordingly the researchers consider improvements to the management of mainline tunnel safety risks are in hand and do not require further comment.

Infrastructure maintenance

Track possession refers to work gangs taking control of a section of track, typically for construction or maintenance work. A related activity is maintenance crews using the railway for access for inspections and for maintenance activities, either by way of HRVs, or by dedicated work trains. These are unscheduled activities to the extent they are not part of the normal railway timetable.

Some maintenance activities may be completely unscheduled, for instance when responding to a civil works failure, a track failure or a derailment.

Aside from normal construction hazards, of which there are many, there are four principal additional hazards with track work:

- conflicts between mobile track maintenance vehicles and trains
- trains entering work sites
- dangers from rail activities on adjacent tracks
- contact with overhead traction power catenary lines.

The last two hazards apply only in areas of the network with multiple tracks and overhead electric traction respectively.

The risks to both train drivers and track workers from trains entering track possessions, or passing nearby are obvious. Maintenance activities are a classic example of non-routine operations, which are well known to have an elevated risk of error. For instance workloads for train controllers are significantly increased when they have to fit track access requests in with scheduled services.

Maintenance access has been either a central feature or contributing factor to many incidents, including narrowly avoided head-on collisions with HRVs at the Staircase in 2011 (TAIC 2013a) and Otira in 2013 (TAIC 2014b). Direct risks to track workers also featured in other incidents including the 2010 Tamaki wrong route setting (TAIC 2012a), the 2011 wrong routing of a train onto a section of track occupied by a work gang (fortunately stopping 97m short of a collision) (TAIC 2013b), and the 2007 collision with a work train on an adjacent track, where one worker was killed (TAIC 2008). In a more recent incident, a train collided with a digger on the Raurimu Spiral in 2014, seriously injuring a contractor.

Loss of control of HRVs due to defective braking systems is another hazard. In March 2016, a contractor was seriously injured when he leaped from the cab of a runaway hi-rail dump truck.[41]

Initiatives taken by the national operator over the last few years to reduce the risk of such incidents include:

- increased visibility of trains to train controllers through GPS and the cell phone network
- eProtect (secondary protection using GPS technology to automatically bring a train to a stop if it incorrectly enters a predefined worksite)
- provision of key control to enable work gangs to lock signals to danger as part of the Auckland metro signalling upgrade
- introduction of the visual 'lock on lock off' system to provide enhance visibility of workers and equipment location before allowing a train to pass[42]
- braking reliability has been addressed in the latest version of the national rail operator HRV Code[43].

There is also a project underway by the national rail operator to apply technology similar to eProtect to operations within track warrant territory (ie to reduce the risk of SPADs in these areas as well). While these initiatives will not render maintenance and construction work free of danger, they do illustrate a commitment to improvement and can be expected to help to keep improving the safety performance of rail maintenance and construction activities.

5.4.6 Discussion

Mainline operations (excluding T&H) have relatively good risk management capability in central staff and greater access to resources, including links with industry bodies. However, it is the researchers'

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[41] This worker has since passed away but at this time has not been recorded as a rail worker death, a coronial investigation is expected.

[42] Disclosure: Greg Hight, advisor to the Navigatus research team, was involved in establishing the lock on lock off initiative for KiwiRail in addition to some of the other initiatives referenced in this report.

[43] The code requires that brake systems must be configured so a failure that affects one axle does not cause such loss of braking from the other axle (eg by split or duplicated brake systems) (KiwiRail 2016).

perception that the New Zealand rail industry as a whole has lower levels of safety management capability than other advanced economies, such as Australia and the UK.

Some of the risk management initiatives observed by the researchers was advanced and innovative. Although to work well risk management has to be integrated throughout organisations at all levels. The researchers perceive that, while there are islands of excellence in both planning and execution, such high standards of risk management are not being achieved throughout the rail operators. A degree of unevenness is to be expected, but it is the researchers' view, based on the limited observations undertaken, there is a need to achieve greater alignment between systems and practices within each operator.

'Organisational drift' is a common theme in safety investigation reports and in the safety literature, and may be an important area of investigation in New Zealand's mainline operations. Busby (2006) observes that generally catastrophic failure does not take place in pristine systems where organisational mechanisms are functioning in the way they were designed. Reason (1990) suggests the preconditions of failure accumulate until an event turns them into a failure. Such degradation can take the form of a gradual incorporation into organisational practice of short-cuts and 'patches' that move such practices steadily further from their normative forms. This accumulation tends to go unnoticed which can lead to the discounting of signals of an impending disaster (refer boxout). 'One-up' safety reviews may be of limited effectiveness in detecting and correcting institutionalised shortcomings in field practices and some form of independent review may be required.

CASE STUDY: Clapham Junction collision
The signal wiring shortcuts that led to the 1988 Clapham Junction collision (35 killed) had been made by the signal technician for many years, having become his standard working practices, and were a widespread way of working amongst signal technicians and supervisors at the time (Hidden 1990). Required checks following his work that should have detected the causative errors, appeared not to have been effectively carried out. While the technician concerned assumed responsibility for the disaster, and his work was indeed the proximate cause, the independent inquiry found the systemic cause was a failure of monitoring, supervision and management.

Lack of adherence to procedures is a common theme in TAIC incident investigation reports[44]. The researchers interpret such findings as illustrating that embedding compliance with operational procedures is difficult to achieve. This observation is not limited to any particular operator or to the rail sector in general, but is common to all fields of human endeavour.

The TAIC investigation outcomes and the researchers' direct field observations point to a lack of adherence to normative procedures as an issue that merits further investigation and possible attention.

A question asked of the researchers was whether any particular examples of the more advanced risk management approaches described in chapter 4 would be recommended for each sector. Each of the approaches set out in chapter 4 has advantages and disadvantages. We do not perceive that one should be recommended over others for NRS operations, but rather that it is a matter of selecting the right tool for the job. That choice will differ depending on the context of each issue. In some cases several tools might be applied to bring fresh perspectives on difficult problems. The researchers consider operators in the NRS have the capability to select and apply the appropriate tools and the capacity to act on the resulting insights.

[44] Recent examples include the wrong route setting and SPAD at Tamaki in 2010 (TAIC 2012a), the 2011 track occupation irregularity leading to a near collision at Staircase (TAIC 2013a), the 2013 near collision with the TranzAlpine Express (TAIC 2014b), and the high-speed rollover of an empty passenger train at Westfield in 2014 (TAIC 2015).

5.4.7 Conclusions

The researchers' approach to NRS operations was to use incident statistics to provide an indication of safety performance and in turn infer the capability of the industry's risk management practices.

The data analysis showed New Zealand has a higher freight occurrence rate per km travelled for both derailments and level crossing collisions compared with Australia and the UK. Derailments are considered by the researchers to be a good measure of the overall quality network operations for the following reasons:

- derailments are 'binary' events: it is obvious when they have occurred
- derailments are likely to be reported – as dealing with them usually takes significant resources[45], which needs to be justified
- derailments involve interactions between track, rail vehicles, loading and operations – so are an integrative measure of overall performance
- derailments are a common metric of performance across other railway systems.

The downward trend in freight derailments indicates there has likely been an improvement in risk management practices.

From the researchers' observations there did not seem to be a lack of risk management capability in staff in management roles (in both national and metro operations). There was some evidence of a lesser understanding of risk management in some areas of operations.

At an organisational level for passenger operations, there appeared to be frequent risk reporting occurring at different levels and through different mediums in all the organisations included in this research. Staff the researchers spoke to seemed to have good awareness of the major safety risks in the rail industry.

An apparent lack of reliable adherence to normative procedures in operational areas (eg freight operations) is an issue that merits further attention. Best practice is for engineering controls to be implemented in preference to procedural controls (see control hierarchy in section 4.5.1), although these are not always practicable to implement. Monitoring, auditing and aligning procedures and practices is vital but can become a victim of its own success. To paraphrase James Reason, effective risk management is about working hard to ensure that nothing happens. When allocating precious resources, such essential work can be displaced by activities with more clearly visible outcomes.

5.5 Industrial

5.5.1 Introduction and approach

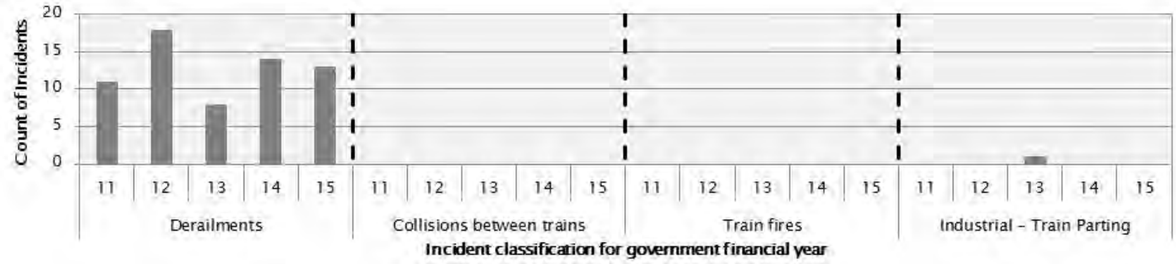
The research team visited an industrial operator site where national rail operator locomotives and wagons are used but the operator owns its own siding and uses its own drivers for shunting and manages operations under its own rail licence. Shunting movements occur regularly, with frequency and the number of wagons varying with the operator's freight needs. This is one example of an industrial operator site; others may differ in using national rail operator drivers and having different operating procedures and equipment depending on the type of business (eg freight logistics, forestry, agricultural).

[45] This may not necessarily be true for sidings.

5.5.2 Data analysis

Figure 5.18 shows the number of occurrences in the industrial sector for each occurrence classification by government financial year.

Figure 5.18 New Zealand industrial occurrences over time



Operators classified as industrial reported no collisions between trains, train fires, and only one train parting over the period of the data. This may reflect poor reporting of these classes of occurrence throughout the sector, lower activity levels or lower traffic density. No overall trends are apparent in the number of derailments over time.

5.5.3 Observations

At the site visited, there appeared to be a good awareness of the significance of risks arising from the rail operations. Shunting movements featured within the risk management system as critical or priority risks, indicating the organisation had appropriately identified the risk level of this rail activity. Risk management practices appeared to be mature, with a high degree of focus on safety management. There was also high visibility of safety at all levels of the organisation through different mediums and with different frequencies. The organisation appeared to be owning the risks they were responsible for and be cognisant of interface risks. In practice, their rail operation was separated within the site, marked by physical barriers.

The research team suspects the site visited and the organisation involved is likely to be one of the better industrial siding operators. In particular, the reporting systems appeared to be well embedded within the organisation. The rail siding operation appeared to benefit from the strong safety and risk-focused culture in the wider organisation. While this was considered likely to be one of the better industrial operators, their safety performance report identified a range of incidents that had occurred over a one-year period, one with the potential to have caused injury. This also indicated there was likely a good level of reporting of incidents in this area. There appeared to be no tolerance for workers who wilfully violated safety procedures.

One risk the operator identified as one of their concerns was the potential for their own workers or other workers (eg contractors) to be harmed (ie those not involved with the shunting movements) due to a lack of understanding of rail risks. Compared with shunting in other areas of rail, there was a greater likelihood of workers or others being onsite who did not have the same awareness of the dangers of rail-specific hazards.

The operator also identified as a risk the interface with road traffic at a nearby public road level crossing once the national rail operator shunt had collected the wagons and left their site. The operator identifying this risk showed they were cognisant of risks outside their direct responsibility and would consider taking actions within their ability to reduce that risk.

Other risks the operator raised were processes not being followed and managing interface risks (ie between themselves and the national rail operator). These risks show areas where the operator may feel they have less control or influence.

In the OCWHaS survey (see appendix G), industrial operator/freight responded most negatively to the statement 'people are not shot down for reporting information that might stop operations' (50% favourable). This was much lower than the second most negatively rated statement for industrial operator/freight – 'when someone raises a doubt or concern, people do not dismiss it' (77% favourable). Both of these fall under the rule 'hear bad news' and indicate that industrial operator/freight operations are weaker in this area.

5.5.4 Conclusions

The researchers are unable to draw conclusions about risk management capabilities at industrial operator rail sites in New Zealand as a whole based on the single visit undertaken. However, the observations at the site visited are consistent with a hypothesis that rail siding safety and risk culture will be strongly influenced by the parent industrial organisation. Accordingly, we expect capabilities will differ strongly based on the risk management maturity of each industrial business concerned. Data analysed over the five-year period did not show any clear trends.

The fact that rail is not the core business for industrial operators, sets them apart from other rail operators in ways that might impact risk management capabilities. At the site visited, a strong focus on safety and risk in the wider organisation appeared to directly benefit safety of the rail operations. Recognising that rail is not the core operation for industrial operators is an important factor to consider when attempting to influence rail safety outcomes. Consider, for instance, that WorkSafe New Zealand currently has a strong focus on forestry; it is possible this increased scrutiny may lead to improved risk management performance that extends to rail aspects of their business. Conversely, if changes in risk management are needed for the rail aspects of an industrial operator, this change may be difficult to establish and maintain if the new approach and necessary safety culture are not supported by the wider business.

5.6 Tourist and heritage

5.6.1 Introduction and approach

The researchers visited a sample of T&H rail operators, interviewed staff, inspected records and systems and observed operations in practice. Taking a risk-based approach the T&H operator site-visit selection was biased towards larger operators who carry more passengers and conduct the most train journeys, but the selection also included some smaller operators.

Table 5.4 Types of operators visited during research on tourist and heritage operations

Type	Role in New Zealand rail	Operator	Track owner	Rolling stock owner	Main maintenance provider	Industry role (eg governance, regulatory)
Tourist and heritage	Tourist operator with heritage rail vehicles on NRS/non-NRS track					
	Excursion operator with heritage rail vehicles on NRS track					
	Operator with heritage rail vehicles on non-NRS track					
	Rail cart operator					
	Tram operator					
Other	Tourist and heritage rail organisation					

A review of operators' ordinary safety assessment reports showed there was an increase in the expectations of the level of documentation required of safety management systems (this was apparent in the types of recommendations and actions arising from successive assessments).

Following completion of the research, the researchers held a workshop at the 2016 FRONZ conference to get a better understanding of the risk capabilities and attitudes of the T&H rail sector. The results from the workshop are available in appendix F (as circulated to FRONZ members).

5.6.2 Data analysis

The researchers analysed data on trains from the T&H rail sector separately from trams and rail carts because of the difference in these operations. This included those operating on their own track and those operating on the NRS.

Due to there being only two rail cart operators operating during the data period, occurrence data from this category is not reported for confidentiality reasons. However, in general this sector has a high rate of collisions between rail vehicles and derailments of rail vehicles on their main railway lines. This is because members of the general public are driving the vehicles and do not have the same level of training and are often distracted. The consequences of collisions and derailments are very different from those of trains and trams; however, events could include tip-overs on steep embankments, disabled vehicles queued in tunnels (fume hazards), striking people on tracks or axles breaking on bridges.

5.6.2.1 Trains

Figure 5.19 shows the number of occurrences in the T&H rail sector for each classification by year.[46] This excludes operations not involving passengers. Due to the low count of occurrences the graph does not show any clear overall trends.

[46] Financial year 1 April–31 March.

Figure 5.19 New Zealand tourist and heritage passenger rail operation occurrences over time

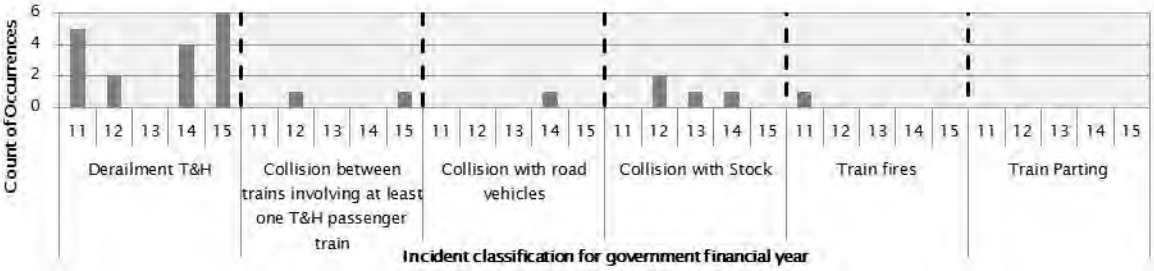
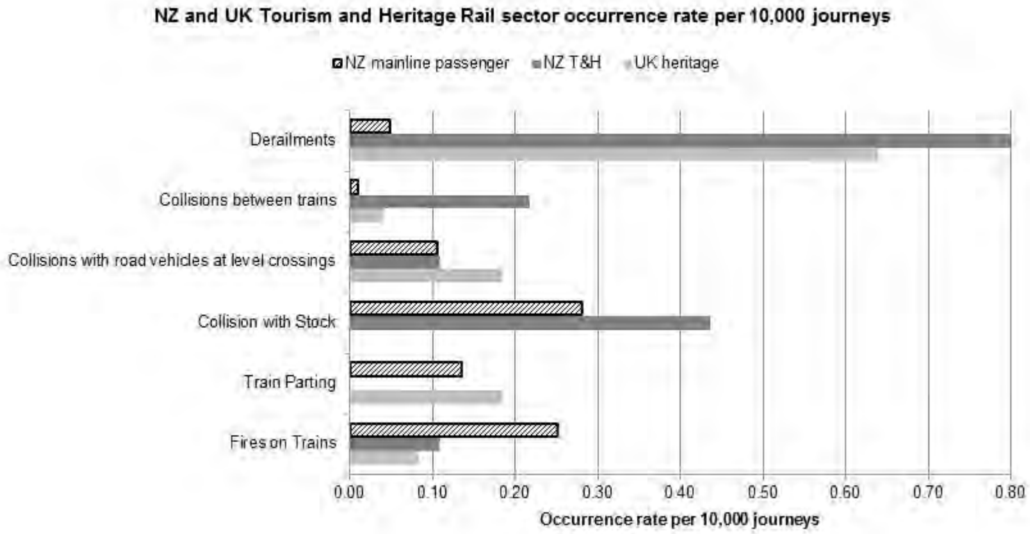


Figure 5.20 New Zealand mainline passenger, tourist and heritage passenger and UK tourism and heritage rail sector occurrence rate per 10,000 journeys



A comparison between the New Zealand T&H, New Zealand mainline passenger (ie metro and long-distance passenger operations) and UK tourism and heritage rail sectors is shown in figure 5.20. The comparison was made on a per journey basis to account for differences in the amount of activity.

Compared with the New Zealand mainline passenger sector, New Zealand T&H rail operations show a higher rate of reported collisions with stock, which may reflect the more rural setting of these operations. They also exhibit a substantially higher rate of derailments and collisions between trains than New Zealand mainline passenger operations. The New Zealand T&H rail sector shows a lower rate of reported train fires and no train parting occurrences. The lower rate of train fires may reflect a reporting bias, as these classifications encompass occurrences which may appear to be of less consequence, or easier to dismiss.

The comparison with the UK tourism and heritage rail sector reaffirms the high occurrence rate for collisions between trains and derailments, but shows a similar rate of level crossing occurrences and train fires in the New Zealand T&H sector. Collisions with stock were not obtained from ORR at the time of extract so a comparison for this category is not available. However, due to the inherent differences between the New Zealand and UK operating environments this comparison is unlikely to provide any insight.

5.6.2.2 Trams

Figure 5.21 shows only a small count of reported occurrences in the tram sector. The drop in the number of reported occurrences in 2013 and 2014 is probably due to the temporary suspension of some inner city tram services during this period.

A comparison between the New Zealand tram and T&H rail sectors, New Zealand mainline and UK tourism and heritage sectors is shown in figure 5.22. The tram sector has a similar occurrence rate to the New Zealand T&H sector for collisions between rail vehicles, with fewer derailments and no tram fires.

The rate of tram collisions with road vehicles is much higher than T&H rail collisions with road vehicles at level crossings. However, collisions with vehicles involving trams tend to be at a lower speed and often result in relatively minor vehicle damage. Inner city tram operators run on roads, exposing them to greater contact with cars and other vehicles.

Though performing better than the New Zealand rail sectors in some areas, the rate of occurrences in the tram sector is high in comparison to the UK tourism and heritage sector.

Figure 5.21 New Zealand tram occurrences over time

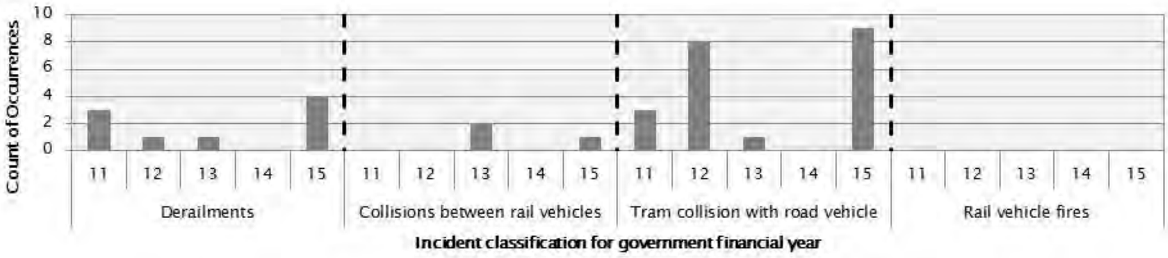


Figure 5.22 New Zealand tram sector occurrence rate per 10,000 journeys[47]

5.6.3 Observations

5.6.3.1 Maintenance

Risk management of maintenance issues appears to have improved since the 2009 review by Australasian Transport Risk Solutions Pty Limited (ATRS 2010) of T&H passenger cars on the main line. The ATRS review found there was a considerable amount of further improvement needed in the areas of rolling stock

[47] For trams, collisions with road vehicles are presented; for trains, collisions with road vehicles at level crossings are presented. These results should be compared with care given the differences between tram and train operations.

restoration engineering design and validation, general risk management and risk mitigation that can and should be achieved.

Despite this improvement, T&H vehicles have recently suffered significant mechanical failures, including a steam locomotive shearing off a main driving wheel and a diesel locomotive breakdown in a tunnel, both in late 2015.

In the FRONZ conference survey (appendix F), participants indicated an intent to reduce risks SFAIRP, but there also seemed to be reluctance from some respondents to make any changes in practice that could affect the heritage value of rolling stock. Given many participants' passion for heritage rolling stock, this position could be anticipated. The researchers interpret this response as pointing to a belief in the sector that heritage rolling stock is safe when operated at or below the speeds they were originally licensed for. The survey was not answered exclusively by rail operators nor covered the entire T&H rail sector so care should be taken in interpreting results. However, the information gathered from the survey does provide a useful input into building an accurate picture of the strengths and weaknesses of the sector.

Track maintenance is also indicated as a potential issue in the T&H rail sector, and lower performance in this area is a likely contributor to the high rate of T&H train derailments. A survey participant commented:

> *Track work is hard, dirty and not what an ageing volunteer workforce wants to do. Everyone wants to drive the train. It's hard to find people to go out in the middle of winter and replace sleepers.*

While detecting and fixing track issues is a challenge for all operators, the difficulty is heightened in an operation that relies largely on volunteers for such tasks.

5.6.3.2 Safety and risk understanding

The operators the researchers visited recognised safety is critical to their business and were committed to meeting their obligations. A similar theme came through in the FRONZ conference survey (appendix F); in general there seemed to be a good overall understanding of safety risk and most participants identified a good attitude to safety at their organisation (eg 'We have a duty to care so far as is reasonably practicable…'). This may have reflected to some extent the proportion of survey respondents who had a governance role at their operation.

The researchers observed during their field visits that risk assessments tended to focus mainly on the familiar and insufficiently on more rare but catastrophic outcomes.

5.6.3.3 Risk assessment quality

While the quality of risk assessment appears to have improved since the 2009 review (ATRS 2010), it is often a theoretical exercise somewhat divorced from operations. Best practice in risk management is to view safety as an integrated system, rather than as an isolated process. Just as with commercial organisations, risk management should be part of all processes in an organisation, including projects, strategic planning and change management.

Examples the researchers observed that indicate risk assessment may be treated as a theoretical exercise include:

- risk assessments commonly cover the core activities, but do not cover the full scope of operations (eg one-off excursions, end-of-season or jigger operations or isolated emergency activities)
- risk registers usually cover a range of standard issues that could be imagined from a desk-top review, but in some cases do not address critical safety risks that the organisation is actually spending a lot of effort to carefully manage

- risk assessments are not always updated with significant changes to operations and infrastructure
- safety cases referring to standards that are found to be of no material relevance
- safety processes that fail to take advantage of best practice standards (such as non-NRSS operators adopting the NTC National Standard for Health Assessment of Rail Safety Workers 2012 for safety critical roles)
- citation of a lack of reported incidents as an indicator of organisational safety, being incorrect in both fact and logic
- risk assessments ignoring critical risks that could arise from the actions of others (eg freight train colliding with T&H passenger train excursion).

Every risk register examined by the research team failed to identify and manage at least one risk that had a potential for catastrophic outcome. These findings indicate, while safety cultures in T&H rail organisations appear to have improved in recent years, there is still room for further improvement. The ISO 31000 standard and the relevant guidelines (summarised in section 4.4) may be of benefit to T&H rail operators.

5.6.3.4 Pathway to safety advancement

Another key observation is the perceptions that the operators visited in the T&H rail sector have regarding the pathway to safety advancement. In the past the national rail operator may have had greater involvement in the T&H rail sector through their role as access provider. More recently there has been a perception by some T&H rail operators that the national rail operator is disinterested in being involved due to lack of funding and competing commercial priorities.[48] Regardless of whether the perception is accurate, it indicates a gap in the system which none of the parties involved have filled.

While possibly originating from a lack of consensus around ownership, the issue may be exacerbated by a lack of capability in the T&H rail sector if they have previously relied more on standards set by others rather than constructing their own risk-based arguments. In the FRONZ conference survey (see appendix F), many participants did not think all operators had the capability to meet current (and increasing) expectations in terms of risk and quality management. The issues raised with meeting expectations were not surprising for a sector that has many small organisations heavily reliant on volunteers (eg funding, guidance, training/experience and administrative burden).

In the OCWHaS survey (see appendix G), the most negative T&H response was for ‘people are not shot down for reporting information that might stop operations’ (61% favourable). The second most negative response was to ‘when someone raises a doubt or concern, people do not dismiss it’ (66% favourable). While these results were positive on balance, the answers reveal a perception by at least some T&H workers that could foster poor levels of reporting in an operation.

Former approaches to safety in rail (ie prescriptive standards remain entrenched in the T&H sector but are at odds with current health and safety legislation (ie flexible, performance based). Elements of heritage operations (eg preservation) may conflict with the intention of health and safety legislation (continuous improvement and progressively higher safety standards).

[48] At the 2016 FRONZ conference the national rail operator announced a number of initiatives to resolve some of these longstanding issues.

Taking these direct observations and survey results together as a whole the researchers conclude the risk management capability of the T&H sector is limited and some operators struggle to meet rising health and safety expectations despite good intentions.

As the T&H operators visited were likely to be among the better resourced, there are no compelling reasons for thinking that other parts of the T&H sector are better than the parties visited. Some smaller T&H organisations will likely struggle at times to build and maintain the institutional capability required to operate rail services safely. As such the above observations are likely to be a 'best case' view, with the performance of some, smaller, operators falling below these standards. The 2009 review highlighted an overall deficiency in the areas of quality and meaningful risk assessment and risk management within the T&H sector (ATRS 2010). Based on the researchers' observations, this statement is still accurate although significant improvements have since been made.

There was no single identifiable cause for the lack of risk management maturity in T&H organisations, but a number of potential barriers were identified closely related to the nature of many T&H organisations. For instance, many were reliant on volunteer workers with varying backgrounds, skill levels and competencies. This means the organisations potentially have limited control over attracting personnel with risk management experience and are otherwise limited (by both financial means and volunteer time) in regards to training or upskilling volunteers. T&H rail operators also tend to have volunteers with many years working experience (including specifically in rail) who may be more resistant to changes in risk management (eg a move from a more prescriptive, standards-based approach to a safety management system approach).

5.6.3.5 Level crossings (top risk most often identified by the operators visited)

The majority of T&H rail operators visited identified level crossings as being one of their highest risks. The risks here stem mainly from the interface with people (pedestrians and drivers) and their behaviour. The control hierarchy (see section 4.5.1) starts with elimination, but in the case of level crossings this is expensive (ie closure, grade separation) and unlikely to be feasible for T&H rail operators. After elimination, minimisation is considered. For level crossings, this might include barrier arms or bells, in which case there is also an important interface with other agencies.

The consequence of principle concern to operators was a single or multiple fatality event – either to the pedestrian, driver and/or occupants of a road vehicle, or to occupants of the train (resulting from damage to the locomotive or carriage, overriding and derailment).

Many of the operators identified ownership of the risk as an issue. Some operators felt rail was expected to own the risk, and to do so without corresponding and critical buy-in from other parties, such as road controlling authorities, in terms of collaboration, funding and understanding. Of course, the road parties involved may have a similar perception of rail. This points to the difficulty in managing interface risks.

Despite this perception, some of the following controls have been introduced by operators (or have been required of them) to lower risk:

- speed restrictions
- development of operational procedures
- further training of drivers
- manning of level crossings on some occasions
- approaching others with suggestions for changes in the control of level crossings, types or positions of signage, roading painting or road layout (public and private)

- collaborating with others at potentially high-risk crossings (eg schools), for instance to change scheduled services.

Often speed restrictions put in place by operators at level crossings are more stringent than those required by the regulator. Level crossing incidents and fatalities are a regular occurrence in New Zealand, and there is potential for the consequence of such events to be much worse.

5.6.3.6 Communication and risk ownership (risk identified by researchers)

Operators were frustrated that matters of importance to them were not being progressed. Examples include requests by operators for a review of speed restrictions at level crossings, uncertainty about requirements for upgrading carriage safety, and a perspective of a declining pool of suitably qualified national rail operator locomotive driving staff and limited training opportunities for heritage operator train management staff.

The lack of progress indicated to researchers there was no strong consensus among different parties in the rail sector about where responsibilities lay and that perhaps communication between parties was not effective at resolving issues. While none of the examples given here are likely to constitute a priority safety risk in themselves, each has a safety dimension. Collectively they contribute to an environment where further improvements in safety matters relating to operations on the NRS appears to some as being too difficult. Such an environment is not consistent with continuous improvement, which is a core principle of effective safety cultures.

A question asked of the researchers was whether any particular examples of the more advanced risk management approaches described in chapter 4 would be recommended for the T&H sector. In general we perceive that while the T&H sector could benefit from some of the approaches set out in chapter 4, and in some cases they may be necessary, in most instances the advanced approaches will be too sophisticated and complex. Rather we would recommend the sector applies more simple approaches but does so transparently and well. This starts with an appreciation that operating to the rules and regulations and standard practices when the equipment was first built and in operation may no longer meet the passengers' and regulator's expectations of safety today. While risk matrix analyses have certain limitations, with the improvement of considering multiple scenarios for each risk we believe they can continue to add value. Several important factors ensure all the relevant scenarios are identified and assessed and integrate the risk analysis into the operations. We would also recommend consideration is given to the Swiss cheese and bow tie models to aid exploration of the most important and challenging risks. As risk registers can be very detailed, a top down approach to identifying the most important risks to safety from an organisational objective perspective can be used as an effective way to engage with leadership.

In addition, in terms of the best practice in considering incident causation, close attention should be paid to the human factors involved in a commonly older workforce and in taking the time to learn from minor incidents that may be a precursor to serious accidents. In principle, these approaches are simple and intuitive and provide useful alternative perspectives that can lead to fresh insights on difficult problems. Organisations need to have the courage to go where the analysis takes them and to act on the findings: the correct answer may be that status quo is no longer acceptable and something different needs to be planned, fundraised for and implemented.

5.6.4 Conclusions

The organisations we visited recognise safety is critical to their business and are committed to meeting their obligations. However, risk assessments tend to focus mainly on the familiar and insufficiently on more rare but catastrophic outcomes. Additionally, while the quality of risk assessment appears to be improving, it is still more likely to be paper exercises that are somewhat divorced from operations.

The risk management capability of the T&H sector is low and operators may struggle to meet rising health and safety expectations despite good intentions.

Reference to resources in chapter 4 may help T&H operators better understand their risk management obligations and provide methods that operators can consider for risk management in their own operations. No one template or approach (eg use of a risk matrix) is likely to be appropriate for all risks in an operation, which is why building risk management capability within an organisation, and building on best government practices, is important.

5.7 Special (cable car)

5.7.1 Introduction and approach

The Wellington cable car is a funicular railway owned and operated by Wellington City Council as a council controlled organisation. The cable car is a popular transport option for commuters, for students accessing Victoria University campus and for tourists. The cable car is unique in terms of New Zealand rail operations.

5.7.2 Data and observations

No data analysis was undertaken for the cable car given there is only one operator and the small sample size would be unlikely to provide useful trend information.

The researchers' view from visiting the cable car and observing the operator was that the cable car appeared to implement appropriate measures for safe operation, including retaining advice on international best practice from supplier Doppelmayr. The comments from operational staff indicated Doppelmayr advice on continued improvement was being followed as items of equipment reached the end of their rated service lives. After the research period, the cable car closed for several months in 2016 to undergo a $3 million upgrade (new computer control equipment, new electric motor, new steel cable).

Improvements to risk management were being implemented at the time of the visit, this showed there was a strong drive to continuously improve risk management and also that some elements of risk management might still be in an earlier stage of maturation. A review of ordinary safety assessment reports for the operation indicated management of driver requirements and documentation might be a weaker area for the operation compared with the management of equipment.

A risk identified by researchers was the continuity of personnel, particularly the inspecting officer/maintenance manager, who held a significant proportion of knowhow around system operations, maintenance and proposed upgrades. This risk is somewhat mitigated by having access to Doppelmayr for technical support. The dependency on a few people for technical knowhow is shared by other smaller rail organisations.

5.7.3 Conclusions

Although it was not possible to draw firm conclusions on risk management capability from the visit, there appeared to be a strong drive to continuously improve risk management. The very small size of the organisation presents a challenge to assuring continuity of technical competence to safely operate and maintain the system. Good management systems, paying attention to succession, and maintaining a strong relationship with the equipment provider will be important influences on the ability to sustain good safety performance over the longer term.

5.8 Conclusions (all rail operations)

Several general observations are provided here, while more specific observations and conclusions are provided in each of the sections for NRS operations: industrial operators, T&H operators and the cable car.

The researchers found metro and long-distance rail operators appeared to have relatively good risk management capability (at least centrally), as well as access to greater resources (eg industry bodies and other organisations). Some operators were seen to be following international best practice. For instance, moving from blaming the individual to seeing failure as a symptom or outcome of a systemic issue or weakness, and recognising organisational culture lies at the heart of achieving high levels of safety performance.

T&H rail operators tend to have lower risk management capability and may struggle to meet rising health and safety expectations despite good intentions. In terms of best practice, some of the more traditional safety control methods that tend to be used by T&H operators may no longer represent modern standards of best practice. Safety challenges for T&H operations include the use of older heritage equipment that often has lower levels of in-built safety and the difficulty of maintaining competencies in a volunteer labour force. Reducing speed is a common response and partially addresses some, but not all, of these challenges. T&H operators may also struggle with the move from viewing risk management as an isolated process to thinking of it as an integral part of an integrated system.

The researchers visited a single industrial operator so cannot draw strong conclusions but expect risk management capability of industrial operators in managing their rail operation safety risks will vary considerably depending on the wider business type (eg logistics, forestry, agriculture) and its safety culture.

In general, best practice internationally is to move away from an emphasis on rules as a safety intervention and to instead focus on hazard elimination and engineering controls (eg move up the control hierarchy). As a whole, the New Zealand rail industry is beginning to go down this path with some examples of advanced and innovative controls being tested and implemented.

6 Industry and regulatory bodies

6.1 Introduction and approach

This section is concerned with parties who are in a position to influence and support improvements in safety performance. This includes the Transport Agency, in its role as the rail regulator, but also includes TAIC, MoT and WorkSafe New Zealand. Coroners can be influencers, and the RMTU can be both an influencer and partner in safety initiatives. Agencies, such as RISSB, also have a role to play in spreading good practice.

In New Zealand, as in some other jurisdictions, a co-regulatory model is applied to the rail industry. For instance, while the Transport Agency has the authority under the Railways Act to issue rules and to make regulations, to date the regulations issued by the Transport Agency pertain mainly to fees. A co-regulatory approach can be appropriate where there is a single network, as the network operator is usually best placed to undertake certain technically related safety aspects of access control for other operators. This approach is common across a range of jurisdictions (eg Australia, Canada, UK, Europe) (ATRS 2013).

A summary of safety-related functions of regulators and participants in the New Zealand rail industry is presented in appendix B.

6.2 NZ Transport Agency

6.2.1 Goals and objectives

The Transport Agency's vision is to be:

> *A professional, risk-based and effective regulator, providing safety leadership and regulatory services, for a safer rail system*

Following a review by consultants ATRS (ATRS 2013), the Transport Agency adopted an improvement plan, *Continuous improvement in rail safety regulation* (NZ Transport Agency 2013a). This document succinctly articulates the role of the agency as:

> *Our role is to ensure rail operators operate in a way that secures the safety of passengers, rail workers and the public when in, or in the vicinity of the rail corridor.*

The plan outlines 39 specific milestones, grouped into six thematic areas. In turn the plan is summarised well in the April 2014 edition of the Transport Agency's industry newsletter *Rail safety update*. This document states:

> *Ultimately we seek to reduce the rate of death and serious injury associated with our industry and that precursor events show a declining trend.*

Given that the ISO 31000 definition of risk is *the effect of uncertainty on objectives*, it is vital to have a clear understanding of the objectives. In our view these two statements, taken together define the objectives. The first statement defines whose safety is of concern: passengers, workers and members of the public in the rail corridor. The second sets the direction and the key metrics: death, serious injury and precursor events.

The Transport Agency has commendably acknowledged a need for improvement, has published the ATRS (2013) report, and has identified its response and an action plan. Areas where ATRS considers the regulator could enhance performance are summarised in the April 2014 newsletter as including:

- Item 1: Lifting the position of the rail safety regulator to a more senior level within the Transport Agency
- Item 2: Promoting and reinforcing to stakeholders the role of a visible and respected safety regulator
- Item 3: Improving resourcing and specialist competencies on the rail safety team
- Item 4: Establishing a closer working relationship with the Australian Office of the National Rail Safety Regulator to take advantage of the sharing of information and specialist expertise
- Item 5: Taking a greater role in the leadership, education and provision of information to the New Zealand rail industry

Item 1 has been completed, with the appointment of a Director of Rail Safety in the Transport Agency.

Item 2 is ongoing and will take time, with the Transport Agency electing to focus on tunnel safety, SPAD As, Auckland electrification safety case approvals, train control, level crossings and other rail corridor incidents. For example, in 2015 the Transport Agency undertook a special safety assessment of the NTCC, the first such special safety assessment conducted under the 2005 Railways Act (Transport Agency 2015b).

Item 3 is underway as the rail regulatory team continues to grow in numbers of personnel and capability. More resources will allow the rail regulatory team to take a more active role in influencing and regulating various aspects of the industry, and to play a more direct role in those regulatory activities.

Item 4 is discussed later, in section 6.12 on the ONRSR.

We see this current research, which the Transport Agency has commissioned as an industry good, as one step towards meeting the fifth item. Another piece of research contributing towards the fifth item is a study completed earlier this year which identifies and defines 26 metrics to benchmark New Zealand rail safety performance against the UK and Australian rail systems (Brown 2016). The Transport Agency now intends to adopt the metrics and is to start populating the benchmarks (C Ballantyne, pers comm.). The research that is the subject of this report has advanced towards the goal of actually producing benchmarking data, albeit with comparison to a more limited range of published benchmarking data from the UK and Australia.

6.2.2 Sanctions

Effective regulation requires the regulator to have a toolbox of responses ranging from education of the willing through to termination of participation from the industry for those who are high risk and uncooperative. Effective regulation requires a credible reason for participants to believe if they do not meet societal expectations of running a safe railway operation, as represented in the eyes of the regulator, there will be a just process that will ultimately result in removal of their licence to operate. The process is explained well in the following text and figure drawn from the Transport Agency's prosecution policy (NZ Transport Agency 2013c).

> *The right regulatory tool needs to be used to achieve the right outcome in the particular circumstances presented. The tool used should intend a change in behaviour, while also addressing the risk in question. The possibility of prosecution (and other forms of enforcement) is in most cases a deterrent – as part of a strategy to promote compliance before it is required to be applied. In most cases, a graduated response to non-compliance will be appropriate, whereby prosecution or revocation of a licence is the last resort after a range of other tools have been deployed but proved ineffective.*

Prosecutions are only one of the regulatory tools available to the Transport Agency. Beyond the provision of advice and information to transport operators and the general public, the Transport Agency is enabled to take other administrative actions under a range of legislation, including:

- *Revocation (of permits and transport service licences)*
- *Financial penalties (unpaid tolls and road user charges)*
- *Suspension or revocation of a transport service driver (where a safety risk is identified)*

Building the Transport Agency's ability to make it easy to get it right (and hard to get it wrong), and creating maximum willing compliance, is an underpinning philosophy critical to enabling an effective, efficient, safe, responsible and resilient transport system.

Figure 6.1 Regulatory enforcement objectives (NZ Transport Agency 2013c)

Some participants will doubt powers will be exercised if they never see the regulator exercising any sanctions. Consequently, it is vital the regulator has available a range of sanctions that are appropriate for the task. Examples of these include additional fees for late submission or incomplete safety performance reports[49], through to limitations on operating licences. Ideally, there would be a graduated series of steps well before the ultimate sanction of revocation of an operating licence. The researchers are not aware if these sanctions are available to the regulator under existing legislation.

6.2.3 Safety cases

A key tool for regulatory control is the safety case, which the Transport Agency must approve. This is an overarching document underpinned by the organisation's safety management system. The safety case must describe operations and summarised safety arguments with reference to supporting documents (eg quality manuals, procedures, codes). Few of the safety cases reviewed by the researchers were of sufficient quality to enable the researchers to confidently understand the safety result attainable, and whether the participant was capable and competent to safely operate the rail system. Under section 31 (2) (c) of the Railways Act 2005, the rail sector must be capable of maintaining, regularly reviewing and improving its safety case and safety system. In the researchers' view, it follows that approvals of safety cases should

[49] Safety performance reports are less than 75% complete on average.

expire after a term. The term could depend on factors such as the risks posed by the operations and the level of competence demonstrated by the operator.

6.2.4 Ordinary safety assessments

Ordinary safety assessments are generally conducted annually by a quality auditor, through in-house resources or contracted by the Transport Agency. Such audits have undoubtedly helped to make the system as safe as it is today. The Transport Agency has trialled and will soon implement a risk-profiling approach to assessments, in terms of organisations' risk profiles and subsequently increasing or decreasing assessment frequency and potentially scope of the assessments. In the researchers' view, this change creates an opportunity to bring in fresh approaches such as the *deep slice* audit and human factors.

6.2.5 Investigations

The Transport Agency undertakes investigations of rail incidents in some circumstances. Recently, the Transport Agency investigated the incident in 2015 where a toddler fell from a carriage and was seriously injured.

Investigations into rail incidents are also undertaken by TAIC (see section 6.4) and WorkSafe New Zealand (see section 6.5). The Transport Agency notifies TAIC of all accidents, as well as any incidents they consider TAIC might investigate. The investigative legislative powers of WorkSafe New Zealand are stronger than those of the Transport Agency, and they are also more experienced in prosecutions. Transport Agency capability in this area is discussed further in the WorkSafe New Zealand section (6.5).

6.2.6 Transport Agency summary

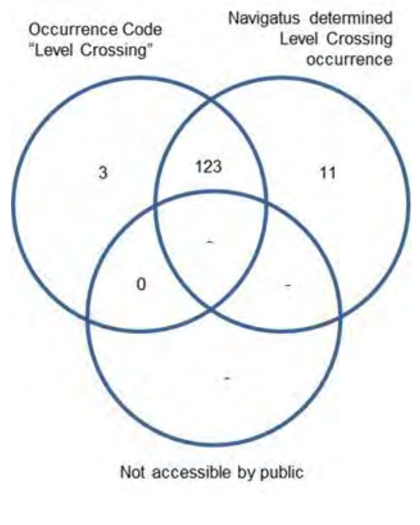
The Transport Agency is in transition towards becoming a more effective rail regulator, of which this research is one part. Increases in staffing and capability create opportunities for the Transport Agency to choose where to direct its effort to have the greatest effect. Applying a systems view of efficient and effective delivery of government regulation as a whole, it may be appropriate that some regulatory activities currently outsourced to other arms of government stay there, whereas others are reallocated to the regulatory organisation as it progressively develops and demonstrates its capability.

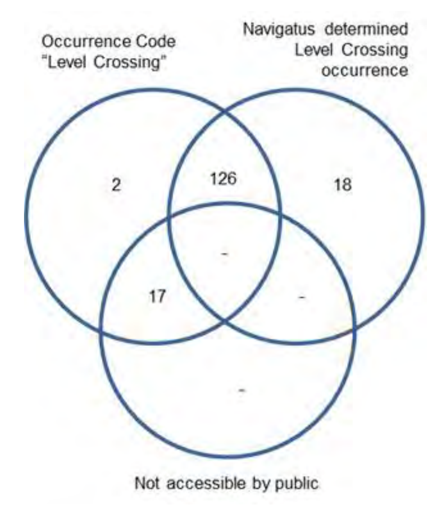
6.3 Measuring occurrences

An old mantra is 'what gets measured gets done'. The data repository used by the Transport Agency is called the RIS. The RIS follows the structure set out in NRSS 5 *Occurrence management* (TAIC 2012b). NRSS 5 is the standard that applies to the NRS, which is where the bulk of incidents occur. Data in the RIS is populated from the year 2008 and is considered to be more reliable from 2010.

Figure 6.2 Venn diagram comparing level crossing classification

Collisions with heavy and light vehicles	Near collisions with heavy vehicles





The national operator runs a similar system called IRIS, which has robust incident records going further back. A limited subset of occurrence data recorded in IRIS, which meet agreed criteria, are automatically notified to the Transport Agency. The occurrences are quality assured by Transport Agency personnel before acceptance in RIS on an on-going basis. Any occurrences meeting criteria defined by TAIC are notified by the Transport Agency to TAIC. This is additional to any direct notification by the operator. The Transport Agency also receives and enters occurrence notifications from other rail participants.

The RIS data set has required data cleansing for this research study, and shows how definitions are critical. NRSS 5 goes some way towards this, but greater clarity would help, for instance the NRSS protocol and software could restrict the availability of occurrence classifications to only those pertinent to each operating process. Process improvements to enhance the quality of data in RIS could include[50]:

- receive and accept updates when notified incidents are updated
- more focus on the quality control cycle to ensure the national rail operator and Transport Agency arrive at a common understanding of the occurrence classification and why
- clarification and better usage of occurrence class (major/moderate/minor/negligible)
- generation and publishing of reports, including data cleansing and feeding back both the cleansed data and improvements to processes
- generating and publishing regular benchmarking reports, on say an annual basis
- development of benchmark-driven classification codes[51]
- reclassification of historic occurrences recorded before recent changes to classification codes (eg SPADs)
- consistency of classification types within a category[52]

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[50] The Transport Agency is currently undergoing an internal review of potential RIS improvements.

[51] That is, the need to identify the benchmarks in other jurisdictions that are going to be used for comparison and arrange the New Zealand classification to allow New Zealand benchmarking statistics to be prepared on the same basis.

- implementation of a tiered level of classification[53]
- investigating and resolving why so few injuries are categorised in RIS
- actively searching and cross-referencing injuries in the Transport Agency's Crash Analysis System
- ensuring data supplied by operators in their safety performance reports is timely and complete.[54]

In general, investigations of incidents often find that accident precursors existed for some time but were not recognised for the danger they presented, as the outcome had previously always been minor.

The rail industry is very good at treating SPADs seriously (as they are a lead indicator for collisions); however, other types of incidents with equal potential may go unremarked, for instance loose rail connections as a lead indicator for derailments.

The national rail operator reports high potential occurrences to their board where the outcome could have been serious. An option could be for information to be collected and high potential outcomes recorded by the regulator and all rail participants required to consider and report on potential outcomes. For results to be comparative a definition of potential outcomes would have to be agreed, such as the likely consequence if one more control had failed.

Considering high potentials not only has the advantage of generating more meaningful data (Threadgold 2011), but also requires rail operators to identify and think about their layers of defences against the particular safety risks. This can be expected to lead some operators to develop their own insights, through creating an opportunity to move from reporting a strict narrative (what happened), and from blaming the person involved (he didn't follow the rules) through to a more systemic view (how is that our system allowed that to happen).

6.4 Transport Accident Investigation Commission (TAIC)

TAIC is a standing Commission of Inquiry and an independent Crown entity. The principal purpose of TAIC is to determine the circumstances and causes of incidents with a view to avoiding similar occurrences in future, rather than to ascribe blame to any person. TAIC investigates significant aviation, rail and marine incidents (TAIC 2016).

The independent investigations and reports by TAIC form an invaluable service to safety in the transport sector. This research team has drawn extensively on TAIC reports to understand the circumstances and underlying causes of a range of rail incidents. A system strength is that any interested party or member of the public can do likewise.

TAIC reports are generally issued within an 18–30-month timeframe (which is similar to investigation agencies overseas). In Europe and the UK, reports are generally issued within one year (S Hughes,

[52] For example, occurrence code 1 includes level crossings, mainline operations, passenger operations and freight operations. Each occurrence can only be classified once, resulting in an inability to determine level crossing collisions which occurred during passenger operations. Additionally, if classified to mainline operations, it cannot be determined whether the occurrence was during a passenger or freight operation.

[53] For example, level crossing could be occurrence sub code 1, collision (or near miss, damage etc) as occurrence sub-code 2 and heavy road vehicles (or light road vehicles, pedestrian etc) as occurrence sub code 3. This gives a lot more flexibility to the data, allowing a high-level picture, as well as a more detailed view. The Transport Agency may already have a project underway for alignment with incident classification.

[54] Eg SPR data was incomplete for passenger journeys analysed by researchers for approximately a quarter of operators in any one year.

pers comm). Some operators might consider TAIC reports are less useful to them when they are published because of this time delay. However, TAIC aims to have all the recommendations of a report taken before the report is published. TAIC issues preliminary recommendations for critical safety improvements while the incident is being investigated and discusses safety actions with operators throughout the process.

6.5 WorkSafe New Zealand

WorkSafe New Zealand has recently emerged as a well-resourced and determined regulator. Given the background of the Pike River mine tragedy it is understandable that the agency has a strong interest in tunnels and explosion risks in particular.

The main interaction between WorkSafe New Zealand and rail is in the area of tunnels (via the High Hazard Unit) and they have used their mining capability to bring best practice to the issue. WorkSafe New Zealand has performed a number of inspections on rail tunnels to provide improvement recommendations and has issued improvement notices for the most critical concerns.

WorkSafe New Zealand appears to be leading the inspections and prosecutions, working alongside the Transport Agency. WorkSafe New Zealand is also able to issue improvement notices or enter into an enforceable undertaking. A question is which agency should prosecute if gross safety breaches occur. To date it has been WorkSafe New Zealand.[55]

Prosecutions require specific organisational capabilities, such as collecting and maintaining a chain of custody for evidence, and taking prosecutions. The prosecuting agency also needs the competency to assess the case has a reasonable prospect of conviction and prosecution is required in the public interest (Crown Law 2013). These are not easy skillsets to acquire and maintain in an agency with only a small proportion of functions that have the potential for complex prosecution such as the Transport Agency. The Transport Agency has a prosecution policy but road transport enforcement is generally outsourced to the NZ Police. The Transport Agency does take some prosecutions, such as for non-payment of tolls and for commercial land transport operators who systematically abuse the land transport rules.[56] Given the low count and financial nature of Transport Agency prosecutions to date, WorkSafe New Zealand may be better equipped, currently, to handle incident-related prosecutions (although this is an area where the Transport Agency is intending to build its capability).

WorkSafe New Zealand rail prosecutions to date include events where:

- A contracted track worker was seriously injured when his digger was struck by a train (2014).
- Seven contracted workers were exposed to risk of carbon monoxide poisoning when working in Otira Tunnel (2013).

[55] For example, WorkSafe led the 2015 prosecution of KiwiRail over the injury of a digger driver at Raurimu spiral (Worksafe New Zealand 2015).

[56] In 2010 an Auckland transport firm had its Transport Service Licence revoked after it was successfully prosecuted by the Transport Agency for allowing its drivers to breach work time and logbook rules (NZ Transport Agency 2010). In 2012 the Transport Agency prosecuted an Auckland driver who repeatedly refused to pay tolls when using the Northern Gateway Toll Road – the first prosecution of its kind since the road opened four years prior (NZ Transport Agency 2012).

6.6 Ministry of Transport

The Ministry is the government's principal transport adviser and was a member of the Steering Committee for this research. The majority of the Ministry's work is in providing policy advice and support to Ministers. The Ministry aims to:

- improve the overall performance of the transport system
- improve the performance of transport Crown entities
- achieve better value for money for the government from its investment in the transport system.

The Ministry helps the government give effect to its policy by supporting the development of legislation, regulations and rules. The Ministry also assists the government in its relationship with the transport Crown entities to ensure they are effectively governed, and are accountable for their performance.

The Ministry's focus over the short to medium term is to work to establish the appropriate governance, institutional, funding and legislative frameworks that will position rail to contribute positively to the transport system in the future. The Ministry also aims to make the New Zealand rail industry progressively safer and reduce the distress and trauma arising from death and injury in the rail sector (Ministry of Transport 2016a).

A key role of the Ministry, along with Treasury, is to set commercial performance expectations of the national rail operator. The NRS makes a positive return in 'above track' operations, but makes an overall loss when infrastructure maintenance requirements (so called 'below track') are taken into account. In effect, the national rail operator is dependent on periodic allocations of funds from the public purse to enable it to undertake all the maintenance and improvements required to run a safe and reliable service. This situation has the potential to diffuse responsibility for achieving safety performance. This is especially the case when significant capital investments are required to move to the next level of safety performance. There are other indirect benefits of rail when viewed from a New Zealand Inc perspective, including safety and environmental benefits from keeping some bulk freight off the road.

The Ministry publishes a range of useful road and rail safety statistics, including six monthly reports on rail statistics. The Ministry does not publish safety statistics for the maritime and aviation sector, which are instead published by the respective specialist regulators. There is an obvious duplication of effort when the Transport Agency maintains its own rail statistics. Measuring performance and publishing relevant information are key roles of a regulator, which for rail is the Transport Agency.

6.7 Coroners

The role of the Coroner is to establish when, where, how and why the death happened, and also to work out whether anything can be done differently that might stop similar deaths in the future. If so, they make recommendations. The coronial process is fact finding, not fault finding, with the aim of improving public safety (Coronial Services 2016).

Effectively the coronial process provides an ad-hoc inquiry into matters causing death. While the coronial enquiry is not one of fault finding, they tend to attract greater public interest when deaths occur without apparent accountability. The coroner is currently performing a detailed inquiry into two level crossing deaths.

6.8 National Rail System Standards (NRSS)

The NRS access provider administers the NRS executive. Two technical committees for heritage activities on the NRS are administered by FRONZ.

Activities on the NRS are governed by a set of standards endorsed by the NRSS-E. These standards help manage the risks associated with multiple operators interacting on a common network. With the exception of health assessment, in general the policies are out of date, both in terms of named participants and concepts. As part of this research specific recommendations have been provided in appendix D for NRSS4 (risk management). Comments on the Heritage Technical Committee and Heritage Operations Committee are provided in section 6.11.

The Transport Agency has commissioned a review by consultants, MartinJenkins, of the governance, operations and management of the NRSS system. The observations referred to above are offered as inputs to the review.

6.9 Rail and Maritime Transport Union (RMTU)

As part of this study the researchers had contact with the RMTU. From conversations with existing and past national rail operator management personnel the RMTU has been a valuable partner in designing and implementing safer work practices. This impression is reinforced by safety messaging in the member publication, *The Activist*, and is consistent with observations made by the ministerial inquiry in 2000. The RMTU works for the interests of its members, and sometimes these may not always be seen by the RMTU to align with proposed safety measures, for instance, a concern by members that a measure might impinge on their rights. Examples of this might include in-cab audio or video (the purpose of which would be to help understand human factor elements of significant incidents) and expanded random drug and alcohol testing. Similar scenarios have occurred in other industries (eg cockpit recording in aviation).

With its ability to speak directly to the workforce and to represent their concerns we expect the RMTU would be an essential partner in implementing successful safety initiatives. This is consistent with the role of worker representatives under the HSWA. The RMTU is also on the NRSS-E.

6.10 Rail Industry Safety and Standards Board (RISSB)

The following description of the Rail Industry Safety and Standards Board (RISSB) is summarised from the *Independent review report into rail systems team* for the NZ Transport Agency (ATRS 2013).

The RISSB is responsible for the development and management of rail industry standards, rules, codes of practice and guidelines. An example is the Rail Safety Worker Health Assessment Standard.

The RISSB is wholly owned by its funding members and is responsible for the development and management of the rail industry standards, rules, codes of practice and guidelines. The RISSB was originally established in 2003 and modelled on the UK Rail Safety and Standards Board.

The RISSB is a 'not for profit' company, accredited by Standards Australia and New Zealand as a Standards Development Organisation. All new standards commenced by RISSB after 31 July 2007 are published as Australian Standards. The RISSB was established with the following objectives:

- To develop, own, amend and manage a suite of documents, called the 'Australian Code of Practice' (ACOP). The ACOP includes codes, standards, rules, guidelines and other documents necessary and desirable to promote standardisation in the Australasian rail industry.

- To promote and implement initiatives on behalf of the Australasian rail industry including rail safety, rail level crossing safety, industry harmonisation to promote efficiency and other initiatives.

Access to developments from organisations such as RISSB is important to bring best practice to New Zealand operations. New Zealand's national rail operator is a member organisation and is actively involved[57].

6.11 Federation of Rail Organisations of New Zealand (FRONZ) and Heritage Technical Committee

The Federation of Rail Organisations of New Zealand (FRONZ) is an incorporated society representing the T&H rail industry of New Zealand. Major functions of the federation include:

- represent members' interests to government departments and public organisations
- monitor and make submissions on legislation affecting members
- negotiate access agreements to the NRS
- negotiate agreements and liaise with other major rail industry participants
- define industry standards and training
- provide technical information to members
- provide a forum for members to exchange ideas
- provide public liability insurance for members.

FRONZ is a tier 2 member of the NRSS Executive and provides the chair and support to the following NRSS committees:

- Heritage Technical Committee
- Heritage Operations Committee.

FRONZ is an important component of the co-regulatory model, albeit currently active over a more limited range of rail industry T&H matters. A FRONZ representative is a member of the steering group for this research.

The responsibility of the committees is specific to heritage vehicles running on the NRS. However, looking at the co-regulatory architecture of the industry as a whole over the New Zealand T&H sector we observe the following gaps:

- The technical standards published by FRONZ do not include a standard for inspection and maintenance of track and civil works operated by T&H licence holders.
- The Heritage Technical Committee and/or the Heritage Operations Committee have not addressed rolling stock standards and codes of practice for additional requirements that may be required to meet modern safety expectations. These might include matters such as:

[57] For instance, KiwiRail has been involved and provides input into a number of RISSB standards, committees and RISSB Safety Management Group, and has been involved with the Internal Rail Safety Council. P O'Connell and C Mills (2016) of KiwiRail recently presented a paper at the 2016 RISSB Safety Conference in Adelaide in leading edge research incorporating human factors and technological solutions to mitigate driver risks.

  - recommended maximum speeds for wooden bodied carriages of different types, coupling configurations and levels of refurbishment
  - design criteria for strengthening wooden bodied carriages for mainline operations such as coupling requirements, rollover protection and end-collision strengthening
  - level crossing speed restrictions for strengthened and unstrengthened wooden bodied carriages
  - mode of operation of passenger activated emergency stops (eg driver advisory).
- The tramway technical section standards on the FRONZ website are in need of an overarching code of practice that identifies which rail standards apply to tram operations. The code of practice should also set out any special tram-related requirements such as:
  - requirements for traction circuit devices to ensure power is cut immediately if a tram derails or overturns
  - minimum requirements for single-person tram operation carrying members of the public (eg vigilance devices, cameras at doors).

The survey the researchers undertook of attendees at the 2016 FRONZ conference (see appendix F) highlights the importance of some of these gaps. Former approaches to safety in rail (ie prescriptive standards) are still entrenched despite the current move in health and safety legislation towards more flexible and performance-based requirements. Some operators are struggling to meet rising health and safety expectations despite good intentions, due to a lack of capacity or capability. As a result FRONZ guidance and resources remain a critical resource, which need to adapt with the changing health and safety landscape. From the researchers' examination of the RIS data, safety cases, TAIC investigation reports and from direct observations and interviews we find that matters not addressed by FRONZ are typically not well managed in the T&H sector. If FRONZ were to address these additional matters on behalf of the T&H sector then we expect that additional funding would be required, as some of these matters will require expert engineering input and/or expert risk assessment.

6.12 Office of the National Rail Safety Regulator (ONRSR) (Australia)

The ONRSR is an independent body corporate established under the Rail Safety National Law (South Australia) Act 2012. The primary objectives of the ONRSR are to encourage and enforce safe railway operations and to promote and improve national rail safety (ONRSR 2016).

ONRSR has responsibility for regulatory oversight of rail safety law in the jurisdictions of South Australia, New South Wales, Tasmania, Northern Territory, Victoria, the Australian Capital Territory and Western Australia. Subject to the passage of applied or mirror legislation, it is expected Queensland will also be regulated by the ONRSR. ONRSR's goals are to:

- maintain and improve rail safety through a risk-based approach to regulation
- reduce regulatory burden on industry
- promote greater self-regulation by industry
- prepare for and support the entry of other state regulators into the ONRSR
- promote safety awareness and safety improvement initiatives and research.

As a newer agency a range of initiatives can be expected by ONRSR. The mixed freight and passenger nature of the rail systems under ONRSR jurisdiction has similarities to New Zealand and the rail regulators face some similar issues. There are therefore opportunities for cross learning. These are recognised by the Transport Agency which has set a goal of establishing a closer working relationship with the Australian National Rail Safety Regulator to take advantage of the sharing of information and specialist expertise.

The Transport Agency, as a rail regulator, has similarities in scale and scope to the former Australian state rail regulators that have now been folded into ONRSR. Due to the similarities between the Australian rail industry and the New Zealand rail industry, there are opportunities to learn from regulatory approaches being used by ONRSR. There is a close relationship between the two regulators, with best practice exchanges frequently occurring. ONRSR provided expert assistance for the 2015 national rail operator safety assessment, and has provided material and advice to Transport Agency staff.

6.13 Conclusions

The range of industry and regulatory bodies illustrates both the complexity and strength of the industry. All of these parties are committed to safety improvement. Each brings a valuable perspective to encouraging and working with the operators to achieve improved safety performance in a co-regulatory environment.

PART C: RISK ASSESSMENT

7 Risk assessment

7.1 Research question and approach

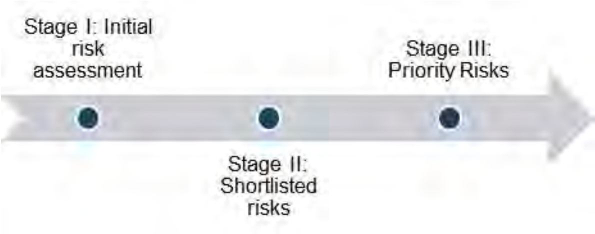
The researchers were asked to:

Undertake a risk assessment of safety hazards in the New Zealand rail industry.

The research undertaken in Parts A and B formed the foundation for this risk assessment.

The risk assessment was undertaken in three distinct stages as outlined in figure 7.1 and the following text.

Figure 7.1 Risk assessment stages



1 Stage I: Initial risk assessment

First, a list was compiled of the risks with potential to become a priority. The list was determined from qualitative risk assessments drawn from written safety documents, historical performance, interviews and field operations. The list was also circulated to the Steering Committee and other rail industry members for comment.

A semi-quantitative analysis was undertaken of this list, which enabled the highest risks to be identified using average estimated fatalities per year and maximum credible fatalities.

2 Stage II: Further assessment of shortlisted risks

The highest risks[58] (approximately 20) from stage I were then taken forward for further assessment. Using a risk matrix approach the risks were plotted with a range of consequences and general areas of risk identified.

This approach provided greater confidence in the evaluation of the average estimated fatalities per year (for those assessed), particularly for scenarios where multiple fatalities were likely to occur in a single event. The outputs from this stage provided a useful vehicle for presenting the risks and associated uncertainties.

3 Stage III: Priority risks

In this stage, weightings were applied to the shortlisted risks to reflect the degree of control that the rail system has over outcomes, and to reflect broad societal values on acceptable risks. The final list of priority risks was based on this assessment.

[58] The shortlisted risks do not necessarily contain all risks that could kill or injure a lot of people, either because these risks are already well controlled or are very rare.

7.2 Stage I: Initial risk assessment

7.2.1 Assessment method

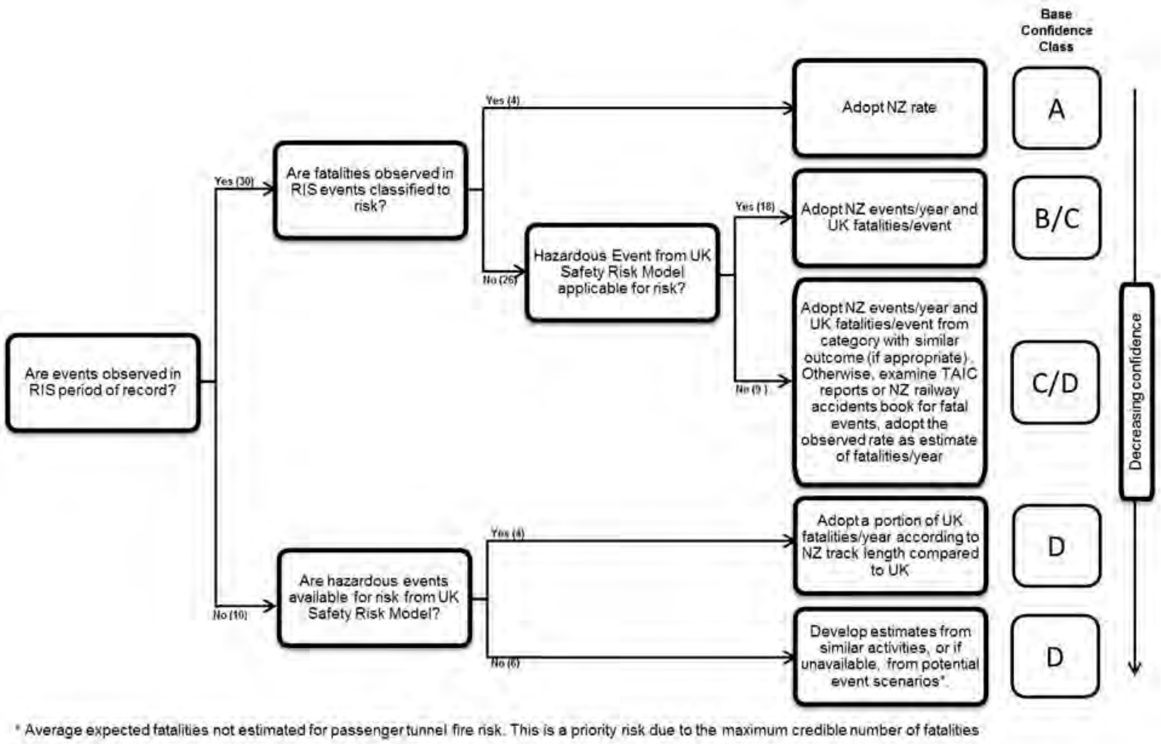
The risk assessment began by compiling a list of risks, each with the potential to be a priority risk. This initial high-level assessment was based on classes of assets, not individual assets. The analysis focused mainly on national rail network assets and services. The assessment adopted current treatment as the baseline (eg existing signalling systems).

Historic New Zealand data (RIS 2010–2015) was examined for each risk, providing a count of the number of instances and number of fatalities observed. The estimated average fatalities/year was then calculated using the following formula:

$$\textit{Average (Fatalities/Year) = Average (Events/Year) * Average (Fatalities/Event)} \qquad \text{(Equation 7.1)}$$

Given New Zealand's limited industry size, the data on incidents was also limited, particularly for rarer, higher consequence events. In this case, international data (specifically the UK SRM outputs ((RSSB 2014b)) were drawn on to provide estimates). The circumstances of available data and the corresponding methodologies, together forming the Navigatus Safety Performance and Casualty Estimates (SPACE) risk model, was used to estimate the rate of fatalities per year (as shown in figure 7.2).

Figure 7.2 Navigatus Safety Performance and Casualty Estimates (SPACE) risk model



The confidence class indicates our confidence in the resulting average expected fatalities. Levels of confidence depend on the methods used. In general our level of confidence is higher for more frequently observed risks and lower for rarer risks.

In addition the maximum credible number of fatalities from a single event was assessed by the researchers. This was estimated by examining historic New Zealand and international incidents for comparable events. The maximum credible is not intended to be the worst possible case but is conceptually based on the researchers' assessment of a likely 90th percentile figure. Given the lower number of relevant incidents for some scenarios the maximum credible was derived from inspection of the record of similar incidents, assessing what was known to the researchers of each event through the literature search (and direct industry experience in some cases), considering how relevant each event was to the New Zealand context, then collectively discussing and agreeing on an appropriate figure that, in the collective view of the research team (including the specialist rail advisor) best represents an estimate of the number of fatalities in a 90th percentile event in the current New Zealand context. The maximum credible figure was used to ensure no high fatality–low probability events escaped assessment, and was used to assist the scenario development in the risk matrices in stage II of the assessment.

7.2.2 Results for all assessed risks

Table 7.1 All assessed risks

Type	Operations	Average expected fatalities (10^{-3})[59]	Max credible fatalities from a single event	Estimation method and confidence class
Collision (level crossing)				
Pedestrian	All	1,200	1	A
Bus	All	75	30	C
Heavy vehicle	Mainline	343	15	A
	Tourist and heritage	16	15	D
Car	All	1,543	6	A
Collision (non- level crossing) – unauthorised member of the public				
Unauthorised member of the public on the track	All	6,857	2	A
Collision (non- level crossing) - train vs train				
Train vs train	At least one passenger train on NRS	60	30	D
	Passenger train on tourist and heritage line	33	10	C
	Mainline - freight trains only	40	1	D
Other collision				
Freight train with out of gauge load	Mainline – passenger train struck	50	10	C
	Freight train struck	8	1	C
Unplanned movement of rolling stock (leading to collision or derailment)				
Unplanned train division, rollaway	Mainline – freight wagons or empty passenger carriages	64	1	B
	Passenger train (loaded)	68	10	B

59 Average annual expected fatalities for the overall system. 1,000 = 1 fatality per year on average

Type	Operations	Average expected fatalities (10^{-3})[59]	Max credible fatalities from a single event	Estimation method and confidence class
Civil works failure (leading to collision or derailment)				
Washout, bridge failure, slip onto track, fallen trees, tunnels, excludes earthquakes and tsunami	Mainline passenger	383	150	D
	Freight	50	1	D
Derailment (not involving collision or parting)				
Includes failure due to track or wheel issues, or speeding	Mainline passenger	182	10	B
	Tourist and heritage	177	10	D
	Freight trains only	126	1	C
Train fire				
In tunnel	Passenger train	Not assessed	200	Not assessed
In open	Mainline – freight train	93	1	B
	Mainline – passenger train	3	1	B
Shunting incidents				
Worker injured	All	200	1	C
Assault				
Passenger vs passenger or member of public	All	2	1	B
Passenger vs worker	All	0	1	B
Civil emergency				
Fire at station	Mainline passenger	132	30	B
Tsunami	Mainline passenger	921	500	C
Earthquake	Mainline passenger	26	10	C
Slips, trips and falls				
Passenger at station	Passengers	15	1	B
Workers	Mainline	5	1	B
	Tourist and heritage	0	1	B
Track work incident				
Malfunction of hi-rail vehicle	All	50	1	D
Collision with infrastructure maintenance worker (incl HRV)	All	220	3	B
Falls from height	All	7	1	B
Fire/explosion during maintenance	All	4	10	D
Collision with buffer stop				
	All mainline	3	5	B
Electric shock				
Person injured	Passengers	1	1	D
	Rail personnel	10	1	C
	Unauthorised member of the public	158	1	D

Type	**Operations**	**Average expected fatalities (10^{-3})[59]**	**Max credible fatalities from a single event**	**Estimation method and confidence class**
Collision stock				
(resulting in derailment)	All	28	10	C
Tunnel gas				
(exposure to)	All	77	3	C

For these results, we have:

- higher confidence in estimates of the numbers of persons in cars killed at level crossings as these are more frequent, are well-defined events and are directly observable from the RIS data (Class A)
- moderate confidence in estimates of passenger deaths from mainline derailments as we have combined New Zealand incident data with UK observations of the number of casualties per incident (Class B)
- lower confidence in estimates of mainline passenger deaths from *collisions with out of gauge load* as we have combined New Zealand incident data with the UK estimate of the number of casualties per incident for train vs train collisions. This is due to *collision with out of gauge load* being unavailable from the UK data, and assumes the outcome of both incidents would be similar (Class C)
- we have lower confidence in the number of persons likely to be killed in T&H derailments as estimates have been inferred by adjustment of present day casualty rates with adjustments for speed and carriage construction (Class D)

The likely accuracy of the estimates depends on the method used for that particular estimate. In each case we chose the method that in our judgement was likely to provide the most accurate estimate of the true value of the 'underlying' risk. Confidence limits have not been estimated for each variable as there is insufficient data to do so. However as a rule of thumb, the researchers expect the true 'underlying' fatality rates will mostly lie within the range of -50% to +100% of the rates determined in this analysis. At first sight this may appear to be a wide range, but is perhaps simply more realistic than most estimates of uncertainty.[60]

7.3 Stage II: Further assessment of shortlisted risks

The highest 10 risks ranked by each of average estimated fatalities and maximum credible fatalities were selected for further assessment. Once overlaps were eliminated, 16 risks remained and were grouped into three classes: rail operations, civil emergency and public interface. The classes were used to aid discussion and comparison of the risks in stage II of the risk assessment.

The shortlisted risks are as follows:

[60] This is most clearly seen in the scientific realm of carefully crafted experiments to determine the value of natural physical constants. Often the ranges found by competing groups of scientists do not overlap.

Table 7.2 Shortlisted risks

Rail operations

• Passenger train fire in tunnel
• Derailments
  - tourist & heritage
  - mainline passenger
  - freight
• Civil works failure
• Collision with infrastructure maintenance worker (including HRV)
• Shunting incident
• Train vs train
  - train vs train collision involving at least one passenger train on the NRS
  - train vs train collision on a private tourist & heritage line
  - freight trains only

Civil emergency

• Tsunami
  - Wellington
  - Auckland
• Fire at station

Public interface

• Member of public electric shock
• Collision with unauthorised member of public
• Level crossing collision
  - bus
  - truck
  - car
  - pedestrian.

Each of these shortlisted risks is assessed and discussed in section 7.3.2.

7.3.1 Assessment method

At the end of stage I, the researchers had assessed all risks considered to have the potential to be a priority risk (see table 7.1). These risks were then ranked by the calculated expected fatalities per year and the assessment of the maximum credible fatalities to produce a shortlist (see table 7.2).

In this stage of the assessment, a risk matrix method was applied to the shortlisted risks so they could be understood further by exploring different scenarios, and to allow a more visual comparison of risks. The rationale behind the matrix developed is explained in more detail in appendix J.

The selected likelihood and consequence scales are provided below:

Table 7.3 Consequence and likelihood scales developed for the assessment method

Consequence scale	
Descriptor	**Description**
Minor	Minor injury
Serious	Single serious injury
Major	Multiple serious injuries
Fatal	1–3 fatalities
Catastrophic	4 or more fatalities

Likelihood scale		
Descriptor	**Description**	**Return period (years)**
Frequent	Occurs routinely	<1
Occasional	Occurs often	1–5
Infrequent	Occurs infrequently	5–20
Improbable	Unlikely to occur, but possible	20–100
Extremely improbable	Occurs very rarely	100+

These scales have been carefully chosen for the context of an industry-wide assessment, and with a geometric ratio of approximately 4–6 between intervals.[61] The terms 'minor' and 'serious' injury are used in the consequence scale. In NRSS/5 (occurrence management) serious injury is defined by the Health and Safety in Employment Act 1992 definition – injury that amounts to, or results in, permanent loss of bodily function, or temporary severe loss of bodily function.' The Act also refers to inclusion of fractures. Review of the RIS data has found it is classified unreliably with respect to serious injury.

Provided the geometric ratios are the same on both scales then for a neutral assessment, cells on a diagonal have equivalent expected outcomes. This can be seen in the left-hand matrix in figure 7.3.

We have elected to explicitly introduce an element of major risk aversion by departing from the diagonal approach, by increasing the risk by one level for one risk (circled in figure 7.4). This modification has been introduced by the researchers for the following reasons:

- As catastrophic events become less common, through successful risk management, societal tolerance of catastrophic outcomes has reduced further.
- Catastrophic outcomes in which many people die are increasingly seen as evidence of systemic failures, including regulatory failure, and can lead to profound impacts across the whole industry. The Pike River mine disaster is a case in point.

Particularly for safety-related risks, using a risk matrix with bias against higher consequence events is an accepted practice.

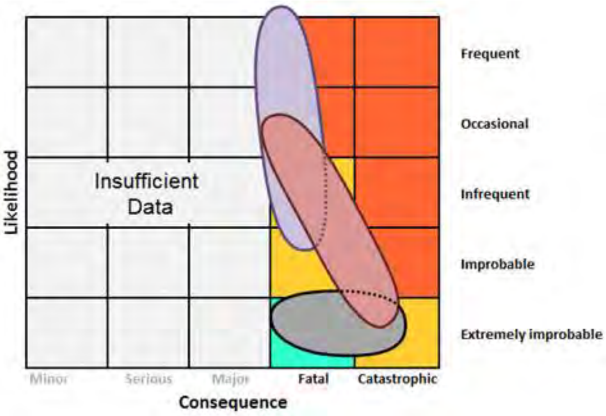
Figure 7.3 Unbiased matrix based on geometric scale (not used)

Figure 7.4 Modified matrix with higher risk aversion

[61] The exception is the step from 'minor' to 'serious' in the consequence scale, which is approximately 20.

Within this risk matrix approach, we present the assessment results as a zone of risk (see figure 7.5). The zone is evaluated by considering potential outcomes. Between one and three scenarios are plotted for each risk, as appropriate, to create the zone. Judgement was used to plot the estimated frequency of these scenarios – when the scenarios are added together, the total risk is the same as the overall average number of fatalities per year that was estimated.

Figure 7.5 Risk matrix assessment example



While we have developed the scale to range from minor to catastrophic consequences, in practice we have only plotted risks at the fatal and catastrophic levels. This is because the assessment in stage II only considered fatality risk – the data available was inadequate to assess severity of injuries for different risks.

7.3.2 Results

The risk matrices for the shortlisted risks (as shown in table 7.2) are presented in the following subsections by the three classes they were grouped into:

- rail operations
- civil emergency
- public interface.

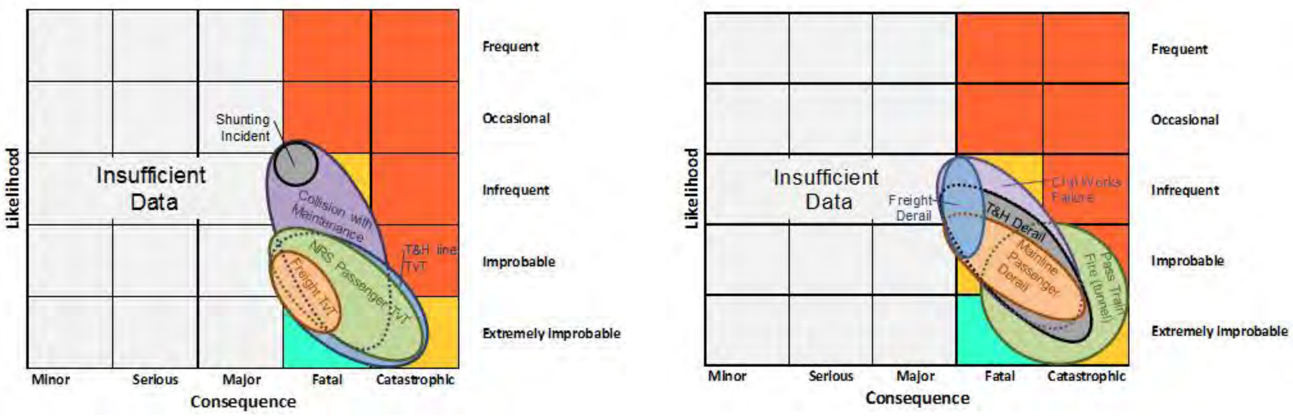
There is a brief discussion of the shortlisted risks following each of the risk matrices. The discussion is informed by the research undertaken so far and additional research and observations where appropriate.

7.3.2.1 Risk group 1: Rail operations

The risks included in this grouping were those for which rail has primary responsibility and the most control over:

- derailment (freight, mainline passenger and T&H rail scenarios) (not involving collision or parting)
- shunting incident (worker injured)
- civil works failure (leading to collision or derailment)
- train fire in tunnel
- train collision with infrastructure maintenance worker, including in HRV
- collision – train vs train (freight, NRS passenger and T&H rail scenarios).

Figure 7.6 Rail operations risk matrix



Most of the plotted risks occurred infrequently. However, fatal shunting incidents and fatal collisions with maintenance vehicles bordered on being occasional. Almost all risks (except shunting incidents, freight train vs train, and freight derailment) were potentially catastrophic, but the likelihood was generally extremely improbable or improbable for that consequence.

There was the greatest uncertainty around train fire in tunnel. Average estimated fatalities were not calculated for this risk as none have been observed in situations that were considered sufficiently analogous to enable estimates to be developed within the context of this study. Consequently, train fire in tunnel has a larger margin of uncertainty.

Discussion – cause and impact

1 Derailment (freight, mainline passenger and T&H rail scenarios)

The definition adopted by the researchers for this risk excluded derailment caused by collisions or by civil works failures (eg level crossing, land slip, bridge failure, train vs train). Derailments can have a number of causes, including track faults, train faults, and human factors such as excess speed.

Derailments can range from relatively minor (eg back wagon dragged for a short distance by a freight train) to serious (eg rollover or derailment spills onto an adjacent road or dwelling). In particular, passenger and T&H trains running at mainline speeds can potentially have multiple fatality events. The maximum credible scenarios were assessed as 10 people for mainline or T&H trains[62], and one person for a freight train. While there have been derailments with greater fatality counts internationally[63], New Zealand's lower line speed makes a greater number of casualties less credible.

National rail operator data indicates that track faults and vehicle defects are leading causes of derailment. Issues here potentially lead back to maintenance management systems, current age and condition of track and vehicles, maintenance backlogs, fault detection systems and availability of capital for improvements.

2 Shunting incident (worker injured)

Shunting is by nature a higher risk as it involves very heavy moving objects. There are many potential hazards in shunting yards and sidings. Shunters may be run over, crushed or otherwise injured while

[62] Running line derailments on dedicated T&H tracks would be expected to have a lower casualty rate due to lower speeds for carriages of equivalent construction.

[63] For example, the Eschede train crash in Germany in 1998 (caused by a wheel failure) that led to 101 deaths. This was around one third of the passengers on board.

coupling/uncoupling wagons, may be dragged by trains, or caught between objects. All of these hazards can seriously injure or kill.

Historically there have been many fatalities in shunting and much work has been undertaken to improve safety in this area. Tranz Rail set up a Shunt Review Team in 1995 following a series of serious shunting accidents, which resulted in safety improvements being made. In 2000, a ministerial inquiry was launched after five Tranz Rail employees were killed over a one-year period (Ministerial Inquiry into Tranz Rail Occupational Health and Safety 2000).

Safety performance has since improved; the last fatality[64] was in 2004. A danger is this could lead to complacency in management of this risk.[65]

Incidents can occur when procedures are not followed or where there are communication failures. There are many reasons why rules and procedures may not be followed – they may be overly strict and unworkable in practice, training may be inadequate, or other issues, like fatigue or drugs, may play a role. Culture can have a strong impact and where the reason for rules are not well understood, shortcuts may be taken regularly to save time and effort.

3 Civil works failure (leading to collision or derailment)

This risk definition encompasses all types of failure of the civil works, ranging from fallen trees or a landslip onto tracks, through to bridge collapse. The definition excludes civil works failures caused by earthquake or tsunami as these are assessed separately. A derailment or collision can range from relatively minor consequences (especially at low speeds) to a multiple fatality event (eg the Tangiwai disaster, where 151 people were killed). The calculated risk excluded the time period in which the Tangiwai disaster occurred; if this had been included, the average expected fatalities from civil works failures per year would be much higher.

The maximum number of credible fatalities was assessed to be an event with 150 fatalities, given this has already occurred in New Zealand's history (see boxout).

Causes of civil works failure may include inadequate maintenance and inspections (quality or frequency of inspections) and financial constraints. Poor infrastructure (eg sleepers, construction materials) and backlog of deferred works could also contribute.

[64] Killed at an Otaki aggregate yard after falling off a shunt, which then reversed over him.

[65] For example the Auckland Electrification Project had a major focus on safety, yet workers were observed riding wagons in a manner that had been prohibited decades before for shunting due to the safety risk. While the project safety risks would not have been identical to shunting, no-one involved was aware of why the practice had been banned for shunting (G Hight, pers comm).

<table>
<tr><th colspan="3">CASE STUDY: Tangiwai, 1953</th></tr>
<tr><td>Lahar washed away piers and a rail bridge collapsed as a passenger express was crossing.</td><td rowspan="2">Outcome</td><td rowspan="2">151 fatalities</td></tr>
<tr><td>Immediate cause and response
Mount Ruapehu’s crater lake discharged thousands of tonnes of water. The water carried away the concrete piers of the railway bridge minutes before the train arrived. About 200m from the bridge the train’s emergency brakes were applied, but the train could not stop in time and six carriages plunged into the river below.
Surviving passengers helped rescue others, and external help was on the scene relatively quickly (alerted by a road user who witnessed the crash).</td></tr>
<tr><td colspan="3">Changes made
A lahar warning system was installed upstream of the bridge, which alerts train controls and train drivers to stop until the bridge has been inspected if a lahar occurs. The system is tested at the beginning of each train control shift.</td></tr>
</table>

4 Train fire in tunnel

A train fire can originate from electrical faults, engine fire or passenger behaviour (eg smoking/arson). Tunnel conditions, such as gas, airflow, incline, length and width also impact on the severity of fire and ability of the driver and passengers to safely evacuate or to allow emergency services to enter safely. Narrow unventilated tunnels can also be unsafe for emergency services to enter. The fire in tunnel scenario assumes the train comes to a stop in a tunnel, this may be because the train has lost power, emergency braking has been applied (eg by a passenger) or other reason (eg driver takes this action).

There was significant uncertainty around this risk and it was not possible to estimate average expected fatalities per year given the paucity of data available and the rarity of fires in tunnels involving passenger trains.

Between 1 January 2010 and 30 October 2015, the RIS recorded 81 events we classified as fires, or fire precursors such as smoke which occurred on the running line. To ensure the data was pertaining to fires on trains we excluded reports of diesel fumes, other reported odours, false alarms and fires in track infrastructure. Of those events 55 were on freight trains (68%) and 26 were on passenger trains (32%). Passenger trains comprised 39% of train movements over the period 1 July 210 to 30 June 2015, indicating they were slightly less likely to have had fire issues in that period. The current risk of passenger train fires on a per journey basis is likely to be lower again, as some of the passenger train fire incidents were on older EMU and DMU sets which have since been retired from service.

The impact of a train fire in tunnel can be potentially catastrophic, with up to 200 fatalities being assessed as credible[66]. Staff training and the quality of an emergency/evacuation plan (and practice of the plan) can have a strong impact on the outcome. Historically, several rail cars have been burnt out completely in New Zealand. Our extended historical record identified 17 notable passenger train fires between 1975 and 2010, including two rail cars which burnt out entirely in 1975 and 1978. Fortunately all the fires occurred in the open and all passengers and crew were able to escape without injury.

Fire in tunnels is regarded by the researchers as an important risk because of the potentially catastrophic consequences. Fires in tunnels are particularly dangerous due to the heat load, build-up of noxious fumes

[66] Historically fires on trains in tunnels have had high lethality, with an average of 80 people killed per incident (Krausmann and Mushtaq 2005). In Europe maximum credible fatalities are likely to be lower on modern rail systems due to the provision of pedestrian escape tunnels and refuges and use of fire-retardant materials on modern rolling stock. No one has died in five fires since the Channel Tunnel opened.

and limited means of egress. Fortunately there have been few fires in rail tunnels resulting in loss of life. Although not directly analogous to New Zealand rail because of the incline, in 2000 a fire in a tunnel on a steep funicular railway in Kaprun, Austria, killed 170 people (Beale 2002). A deliberately lit fire in an underground railway in South Korea killed 192 people in 2003.

While fires in tunnels can be catastrophic, this risk presents the greatest area of uncertainty for this research in terms of average expected fatalities due to the paucity of data. This risk is already a focus of WorkSafe New Zealand and the Transport Agency and is one of the national rail operator's critical risks. Assessment of this risk would require detailed evaluation and assessment of each higher risk tunnel which is beyond the scope of this assessment. Given that evaluation and treatment of this risk appears to be well in hand, it has not been evaluated further in this analysis.

5 Train collision with infrastructure maintenance worker, including in HRV

A train collision with maintenance workers or vehicles can occur due to track occupancy rules being followed incorrectly by workers, a SPAD by a train driver, an error made by the train control centre, or other systems errors. There are a large number of sites operating every day. Communication and planning are also very important.

A train collision with infrastructure maintenance workers can severely injure or cause fatalities, and potentially multiple fatalities in a single event (a triple fatality was assessed as the maximum credible).

6 Collision – train vs train (freight, NRS passenger and T&H rail scenarios)

This includes both a head-on or tail-end collision between two trains. Exposure to this risk is in part due to the high reliance on human controls (the driver and in train control). Mixed passenger and freight is a particular concern as lighter passenger trains can be expected to fare more poorly in such a collision. In addition, freight, T&H rail, long-distance passenger locomotives nationally and Wellington metro passenger trains do not currently have the same level of automatic train protection as Auckland metro passenger trains, which is effectively a gap in the automatic train control system. A train-on-train collision can cause multiple fatalities, particularly those involving NRS passenger and T&H trains.

CASE STUDY: Bad Aibling rail crash 2016 (summarised from The Guardian (2016) and Railway Gazette (2016)

Head-on collision between two passenger trains in Germany in February, 2016.

Cause and response

The trains were scheduled to pass each other at a railway station; however, one was running slightly behind schedule. A train dispatcher was thought to have made the error and no technical fault appeared to have occurred in either the trains or the signalling system. The dispatcher upon realising the error attempted to issue an emergency call but dialled the wrong number for both trains.

The dispatcher has been arrested on the basis of a serious breach of duty as he had been playing a game on his phone for a 'long period' of time before the incident occurred.

The trains collided on a curved section of rail and likely did not see each other until the last moment before the collision. The German rail system has automatic train protection and the trains involved were built to the latest standards of crashworthiness. One of the trains may have been authorised to pass red signals at a restricted speed.

There is an ongoing investigation into the crash by Germany's Federal Railway Agency.

Outcome

12 fatalities

85 injured

7.3.2.2 Risk group 2: Civil emergency

The following risks have been grouped under civil emergency:

- tsunami (Auckland and Wellington)
- fire at station.

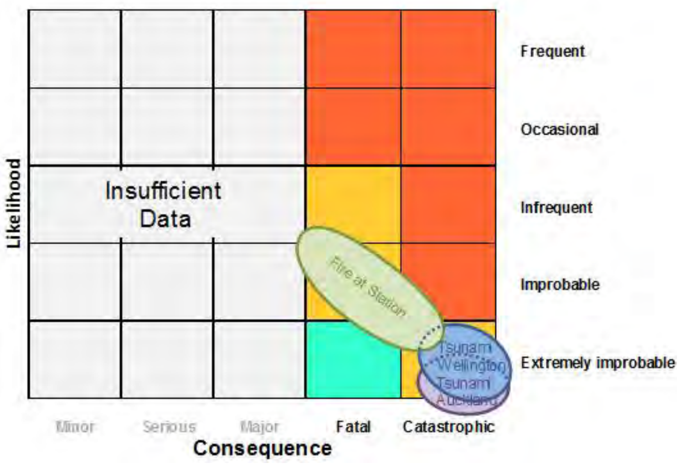
A tsunami in either Auckland or Wellington was assessed as the risk with the highest maximum credible fatalities (500 persons).[67] This was a much higher number of fatalities in a single event than any other scenarios assessed. Tsunami risk was not calculated for other coastal routes due to lower risk (elevation and frequency of service). A fire at the station was also one of the scenarios with a higher maximum credible fatality estimate of 30 people. However, both scenarios also made it onto the shortlist via the average expected fatalities per year (approximately one per year on average for tsunami, and one every 10 years on average for fire at station)[68].

The Auckland and Wellington tsunami risk scenarios are separate events and were calculated separately (see appendix K for further information on how these were estimated). In short, both scenarios were based on Power's (2013) estimates for tsunami frequency. We then took into account tsunami amplitude and tidal conditions, and likely amount of warning for a tsunami (eg tsunami from more distant sources with more than one hour warning time were excluded). Lastly we estimated fatality scenarios based on peak traffic (20% of day), non-peak traffic (60% of day) and night (20% of day). These factors were combined to calculate average expected fatalities per year for Auckland and Wellington.

The Auckland scenario is for the existing rail network with Britomart acting as a terminus. Risks when the City Rail Link comes into operation are likely to be similar.

In the risk matrix, both tsunami scenarios are plotted in the extremely improbable but catastrophic area. A tsunami in Wellington has a higher risk, in part due to the greater size of one expected to hit Wellington. Fire at a station covered a wider area on the risk matrix and edged into the highest colourisation because of the potential for a catastrophic outcome.

Figure 7.7 Civil emergencies risk matrix



Discussion – causes and impact

1 Tsunami

For a tsunami, the cause of the event is an earthquake. The event itself is not preventable, but there are a number of pre and post-event controls that could have a significant impact on the likelihood of fatalities

[67] See appendix K for further information on how the maximum credible fatalities was calculated.

[68] These are expected averages over long periods of time. In both cases it is more likely that there will be multiple casualties at each event, with events spaced far apart.

in the rail system. The maximum credible fatalities for either Auckland or Wellington were 500.[69] Globally, the worst case of a tsunami on rail was the death of more than 1200 passengers in Sri Lanka, when a wave overturned a passenger train stopped at a track section covered in water (Sirisoma et al 2013) (refer boxout).

In Wellington, the main concern is a tsunami hitting trains on the exposed stretch between Petone Station and Ngauranga Station, where there is a very limited ability for passengers to evacuate to safe ground as the Hutt Road has no pedestrian crossings between the stations, and the hillside is too steep in most places to ascend. If a train is stationary on this section (eg the earthquake causes trains to stop due to power supply failure or as a precaution) or a train does not have clearance to exit the section in the quickest way (eg perhaps to back out of section) then the tsunami could be fatal to many on board the train.

In Auckland, the below ground Britomart station is the main concern in case of a tsunami, to those in the station and on trains that may be stopped in tunnels entering the station due to earthquake. The City Rail Link will increase this risk as well. For instance, increased trains in multiple directions will likely lead to increases in the counts of passengers at Britomart and access tunnels during peak hours.

<table>
<tr><th colspan="3">CASE STUDY: Sri Lanka tsunami rail disaster, 2004 (summarised from Boyle (2014)</th></tr>
<tr><td>Train stopped at a section of track inundated with water from a previous tsunami wave, was struck by a later and larger tsunami wave and overturned.</td><td rowspan="2">Outcome</td><td rowspan="2">1,200+ fatalities</td></tr>
<tr><td>Cause and response
There were 15 minutes between the first and second tsunami waves – potentially enough time to evacuate passengers to safety – but there were no mechanisms available to identify the threat and evacuate passengers. Railway authorities had tried to contact the train while it was at an earlier station, but the only way to contact was through the station master and the phone was not picked up. The driver did not have a cell phone on him.</td></tr>
</table>

2 Fire in train station

Fire in train stations can arise from various ignition sources and exacerbated by a range of different factors (Kletz 2001; Radio New Zealand 2015; Rusk 2016; McAvinue 2015; CNN 1997). Ignition sources can include electrical faults, train initiated, arson, smoking/cigarette butts and fires started by other station tenants (eg fire in food outlet).

Exacerbating factors can include poor maintenance (eg grease, rubbish build-up), building materials and design, fire engineering (including sprinkler systems), as well as staff training, dire service response and the evacuation/emergency plan and procedures.

Fires in stations have the potential to kill many people in a single event. The maximum credible scenario the researchers assessed was 30 people, based on the Kings Cross fire in London (refer boxout). It could be argued that a station fire event of this magnitude is unlikely to occur in New Zealand as wooden escalators do not exist in New Zealand railway stations, which are generally located above ground.[70] However evacuation can be difficult if smoke and fumes follow evacuation routes, and can also cause confusion about the location of exits. This risk is most obvious at Britomart station and is expected to increase with the completion of the City Rail Link given the increased number of underground stations.

[69] See appendix K for further information on how the maximum credible fatalities were calculated.

[70] Factors which reduce the incidence of fire, such as prohibitions on smoking, are automatically taken into account in the Navigatus SPACE risk model via reductions in incident rates.

CASE STUDY: King’s Cross Station fire, 1987 (summarised from Kletz (2001))		
King’s Cross underground railway station, London **Immediate cause** A lighted match was dropped by a passenger on a wooden escalator and fell between tread and skirting board, setting fire to accumulated grease and dust on the running track.	**Outcome**	31 fatalities 60+ injured
Response A passenger stopped the escalator and alerted people; the fire service was summoned but the fire spread rapidly before water was applied. The fire service was only called if a fire seemed to be getting out of hand and no smoke detectors were installed. While there was a water spray system on the escalator running tracks, the inspector on duty walked pasted the unlabelled water valves (that had to be activated manually). He was only an acting inspector and did not know their location. During the event, the station was not closed/evacuated.		
Underlying causes Escalator fires were treated as inevitable and not serious. ‘Safety advisers are often told, “It must be safe as we have been doing it this way for twenty years without an accident”.’ Personnel were unsuitable and poorly trained, lessons were not learnt from past events, and safety management was poor.		

7.3.2.3 Risk group 3: Public interface

The risks presented in this section were grouped together as they are risks where rail shares a significant proportion of responsibility with others. The risks presented are:

- collision (non-level crossing) – unauthorised member of the public
- collision (level crossing)
  - pedestrian
  - car[71]
  - heavy vehicle (mainline)
  - heavy vehicle (heritage)
  - bus
- electric shock – unauthorised member of the public.[72]

For collisions with members of public in unauthorised areas[73], level crossings and electric shock risk to unauthorised members of public, rail shares responsibility with members of the public (eg road users), the roading authorities and private land owners.

On the risk matrix, collisions with persons not at level crossings, and level crossing collisions with pedestrians and cars are the most frequent fatal events. These three public interface risks are the only risks assessed that clearly sit in the highest risk colourisation of the matrix (due to their frequent and fatal nature).

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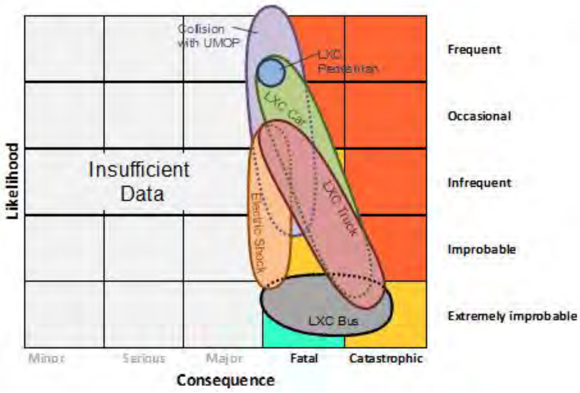
[71] Includes all types of light vehicles, such as vans and utilities.

[72] Electric shock to workers was assessed separately but was too low to be included in the shortlisted risks.

[73] Instances such as a member of public falling off a platform onto the tracks are not included in this risk.

Figure 7.8 Public interface risk matrix



The risks that have potentially catastrophic consequences are level crossing collisions with cars, trucks, or buses. However, these events are much less likely than fatal events. Risk of electrocution of an unauthorised member of public was assessed as bordering on occasional.

Discussion – causes and impact

1 Collision (non-level crossing) – unauthorised member of the public

This risk, as assessed, excludes suicides and suspected suicides[74] (which we consider to be a societal issue). For members of public that are hit, there is a high chance of fatality. While there is no significant risk of direct fatality to the train driver or passengers, there are well documented psychological impacts on the train driver, such as post-traumatic stress.

There can be any number of reasons for members of the public to be in the rail corridor. For instance, using a rail bridge to jump into the river, photo opportunities, playing chicken on the tracks, taking shortcuts across the tracks, mistaking tracks for being closed, and using the corridor as a pathway.

A lack of education about the dangers of rail is a contributor to this issue, as well as impairment of people's decision making (eg due to drugs/alcohol, fatigue). Children in particular, may not understand the potential consequences of their actions. Another contributor may be inadequate fencing or signage in areas that are attractive to people (eg where trespass is attractive as a shortcut).

2 Collision (level crossing)

The impact on the train driver and passengers involved in different collision types varies. In a pedestrian collision, only the pedestrian has a realistic fatality risk. Although there is no direct risk of fatality to the train driver or passengers, there are well documented psychological impacts on the train driver. A collision with a car, heavy vehicle or bus has the potential for multiple fatalities – to vehicle occupants, the train driver and rail passengers. New Zealand's worst level crossing collision was Rolleston in 1993, when a concrete mixer truck struck a passenger train. Three passengers were fatally injured and seven seriously injured (TAIC 1993). A similar accident occurred in Australia in 2007 (refer to the boxout below).

The primary cause of a collision at a level crossing is their existence – this risk could be removed entirely by grade separation between rail and road.

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[74] As identified by the researchers – instances where suicide was specifically identified or the description includes jumped in front of train, lying on track and other similar descriptions indicating intention.

At a level crossing, the train always has right of way. Pedestrians and drivers are sometimes clearly at fault, particularly at an active crossing where a pedestrian or driver has chosen to deliberately traverse barriers and alarms.

However, design of crossings and design of surrounding roads and intersections – alarms and barriers, lines of visibility and stacking distances all have a strong impact on likelihood of an event occurring. There is also the potential for alarms and barriers to malfunction. Likelihood of mistakes can also be influenced by impairment of the road driver (eg fatigue, alcohol), environmental conditions (eg sunstrike, heavy rain, buildings or vegetation obscuring track), or complacency (eg thinking they know when trains are due). Pedestrians can be very unaware of their surroundings, particularly when listening to music or looking at their phone.

Reducing the likelihood of an event occurring is critical. During an event, the train driver can only sound the horn and apply the brakes, which are limited in effectiveness. Only the pedestrian or road driver are likely to be able to react sufficiently to prevent the collision occurring.

<table>
<tr><th colspan="3">CASE STUDY: Kerang level crossing, 2007 (summarised from Salmon et al (2013); Coroners Court of Victoria (2013))</th></tr>
<tr><td>Semi-trailer truck struck passenger train on level crossing in Victoria, Australia</td><td rowspan="2">Outcome</td><td rowspan="2">11 fatalities
20 injured</td></tr>
<tr><td>Immediate cause
Failure of the truck driver to stop at the active crossing (lights, bells) or react to the train driver sounding the horn. The truck's cabin and front corner of the trailer peeled open the second train carriage. Seats were torn from their mountings and the truck's refrigeration condenser was thrown through the window of the third carriage.</td></tr>
<tr><td colspan="3">Response
The train driver and conductor did not know they were required to act in the role of Interim Site Controller and had no training in what was required of this role. Additionally, first aid equipment was inadequate for the purpose. Sixteen minutes after the collision there were police and ambulance officers at the scene, and more resources had been activated. In only one of the fatalities was the emergency response a possible influence on the outcome.</td></tr>
<tr><td colspan="3">Underlying causes
No underlying cause was found. The driver looked at the lights but failed to see they were on and did not hear the bells/horn until it was too late to avoid the collision. A coronial investigation into a cluster of 26 level crossing deaths (including the Kerang incident) made 25 recommendations. The recommendations addressed failures throughout the system and included preventative measures around level crossings (sign distances, visibility, sound direction etc), maintenance of trains, data collection/investigation/risk analysis, cooperation between road and rail, and response end recommendations, like train driver training, first aid supplies and tools, and scenario emergency training.</td></tr>
</table>

3 Electric shock – unauthorised member of the public

A portion of New Zealand rail is electrified (ie has traction overhead wires), particularly around urban areas. Generally the worst case scenario will be a single fatality, although multiple fatalities are conceivable. Members of public may not have an adequate understanding of the risk, or may purposely seek out high-risk activities which inadvertently bring them too close to overhead power lines, resulting in electric shocks.

7.4 Stage III: Priority risks

7.4.1 Foreword

Why have these priority risks been chosen and what does this mean for rail?

The priority risks listed have been chosen because the risk assessment method the researchers used identified them as having the highest average expected fatalities. The railway industry has many different stakeholders and each will have different viewpoints. No single list of prioritised risks addresses the needs of all stakeholders. This list essentially shows the risks with the highest average estimated fatalities per year, with some weighting given to the control rail has over the risks.

The list of priority risks is not intended to signal to the Transport Agency or to any railway participants that efforts should immediately be funnelled towards reducing only these particular risks. We would not want a perception they should be prioritised over risk work currently being undertaken (eg the focus on fires in tunnels, track work occupancies).

What the list does indicate is because these risks are high, the priority should be to assess whether each of these risks has been reduced SFAIRP. If they have been – if the cost of reducing risk further is grossly disproportionate to the benefits – then although the risk is higher than others, it may be ‘acceptable’.

The analysis undertaken for this project has not gone so far as to assess whether potential controls would be grossly disproportionate to the reduction in risk. Such an assessment would not be appropriate for the necessarily broad national-level assessment undertaken here and is beyond the scope of this research.

Including a collision with an unauthorised member of the public as a priority risk, while other risks, such as a track worker fatality, are not included, does not mean rail operators should put less effort into managing risk for their workers. It means rail is currently managed in such a way there is a lower fatality risk for workers compared with some members of public. It does not speak to whether in either case the risks are managed SFAIRP and therefore where additional effort is most justified.

7.4.2 Method for Stage III: Priority risks

Determining the priority risks required the weighing up of priorities between parties ranging from persons committing illegal acts to innocent bystanders. As a society we want to dissuade people from acting in unsafe ways if possible, but this needs to be weighed against other affected parties. Decisions must reflect the value of society at large on what risks are unacceptable, tolerable or broadly acceptable (HSE 2001).

There has been much research on what makes risks acceptable or unacceptable. Key factors include volition (command over exposure) and control (command over outcome). For instance, acceptance of a risk imposed upon us is much less acceptable than one we voluntarily take. Other factors include dread, where unfamiliar and unseen risks such as nuclear radiation are feared more than familiar risks such as vehicle crashes.

When prioritising risks we face a choice. We can prioritise risks on the basis of treating every circumstance equally. This has the appeal of equity at the most simplistic level. An alternative approach is to weight the assessment based on relevant factors, in an effort to reflect broad societal values on acceptable risks. In this analysis we present rankings by both methods and explore the differences.

7.4.2.1 Societal risk sensitivity

It is normal risk practice to assess sensitivity to risks by the parties involved.[75] In table 7.4 we identify and rank five types of parties by risk sensitivity.

Table 7.4 Sensitivity risk ranking by party involved

Level	Party	Comment
1	Unauthorised member of the public	Unauthorised members of the public have a high degree of volition in that they can choose whether or not to undertake the unauthorised activity (so far as they understand the danger). They also have a high degree of control over outcomes through the level of awareness of risks they develop prior to the act and the level of care they choose to exercise.
2	Level crossing user	This category includes both motorised and non-motorised users of road level crossings. Such users generally have a high degree of volition and control. In some cases volition is compromised in that practical alternatives to using an at-grade crossing may not realistically be available. Road users at level crossings must give way to rail so are unauthorised to be in a position where they can be struck by a train. However collisions are usually due to an error of judgement or lack of situational awareness.
3	Railway worker	Railway workers have volition in that they choose to work in the rail industry but their level of control is moderate, as incidents may arise from the actions or inactions of others. Railway workers will sometimes have control over events, but at other times events will be controlled by others, possibly due to actions or inactions occurring well in advance of the incident itself.
4	Passenger	This category includes all commercial passengers on railway property, and commercial passengers on bus services who are affected by rail incidents. Passengers can choose whether to travel by rail or bus, so have high volition, but have little or no control of consequences.
5	Member of the public (bystander)	While bystanders have a degree of volition in that they chose to be where they are, in general they are regarded as having low volition as they are not deliberately interacting with the rail system. In general members of the public have no control of rail system risks that may affect them.

7.4.2.2 Rail system influence on outcomes

Another consideration is the degree of influence the rail industry has on outcomes of events. For instance, suicides are not considered in this assessment as the victim has intentionally exposed themselves to a rail hazard and these events are viewed as a societal issue. On the other hand, if a risk is totally within the control of the rail industry, then it is a reasonable societal expectation that the risk is treated as far as practicable.

In table 7.5 we classify risks by the degree of control rail operators have on outcomes:

[75] More detail on risk sensitivity can be found in appendix C.

Table 7.5 Rail operator control of outcomes

Risk class	Name	Comment
1	Unauthorised access	Unauthorised access to the rail corridor for a variety of reasons. The rail industry has some opportunity to prevent or discourage unauthorised access, particularly those using the rail corridor for convenience (eg as a shortcut), but overall has a relatively low level of influence on outcomes.
2	Level crossings	Level crossings represent an intersection of cultures as well as transport systems. Vehicles are required to give way to rail, so almost every level crossing incident includes a lack of situational awareness or an error of judgement on the part of a level crossing user in its causation. The rail industry has some influence on outcomes at level crossings through protection devices and precautionary procedures.
3	Natural events	In a country that is prone to natural events there is some acceptance of inability to control outcomes for the most severe natural events, which strike without warning. However the rail system can be resilient to moderate events of all types and has full control of responses to minimise casualties where warnings are available. This includes tsunamis, earthquakes, slips (including subsidence) and lahar.
4	Technical risks	These are technical risks under full control of the railway system. Examples include collisions due to a SPAD, derailments due to faulty rolling stock, line maintenance or over-speeding, shunting incidents and track work site incidents and fires.

We apply a multiplicative factor identical to the risk class to reflect the degree of control the rail system has over outcomes. This reflects that, all other things being equal, it would be reasonable to expect rail operators to focus first on those matters which they have the greatest control over.

In our assessment we present the top risks ordered by:

- average expected fatalities by year
- party weighted order (ie weightings from table 7.4)
- party and outcome control weighted order (ie weightings applied from both tables 7.4 and 7.5).

Examining the risks through a variety of lenses tests robustness; if the same risks keep appearing on the top of the list, for differing ranking methods, then the analysis can be considered robust.

7.4.3 Results

Table 7.6 shows the highest risks ranked by the three methodologies described in section 7.4.1. The second column shows the risks prioritised on the basis of treating every circumstance equally. The third and fourth columns show the highest risks applying weightings based on the party involved for the former and a weighting for the control over outcomes in addition to the party involved for the latter.

The results show the top seven ranked risks are largely similar between the three methods. The main difference is the equal weighting method had 'mainline passenger level crossing collision with heavy vehicle' in the seven highest risks and did not have 'mainline passenger derailment'. This similarity in outcome lends confidence that the resulting list of priority risks is robust. The priority risks chosen to take forward to the next stage are the seven highest risks rated by both party and outcome control (refer shaded area in last column).

Table 7.6 Ranked highest risks – societal rankings

Rank	Top risks ordered by average expected fatalities per year	Top risks in party weighted order	Top risks in party and outcome control weighted order	
1	Collision with unauthorised member of the public	Collision with unauthorised member of the public	Tsunami	Priority risks
2	Level crossing collision with light vehicle	Tsunami	Collision with unauthorised member of the public	
3	Level crossing collision with pedestrian	Level crossing collision with light vehicle	Level crossing collision with light vehicle	
4	Tsunami	Level crossing collision with pedestrian	Passenger train collision with civil works failure	
5	Passenger train collision with civil works failure	Passenger train collision with civil works failure	Level crossing collision with pedestrian	
6	Mainline passenger level crossing collision with heavy vehicle	Mainline passenger derailment	Mainline passenger derailment	
7	Collision with infrastructure maintenance worker	Tourist and heritage derailment	Tourist and heritage derailment	
8	Shunting incident	Mainline passenger level crossing collision with heavy vehicle	Collision with infrastructure maintenance worker	
9	Mainline passenger derailment	Collision with infrastructure maintenance worker	Shunting incident	
10	Tourist and heritage derailment	Shunting incident	Fire at station	
11	Unauthorised member of the public electric shock	Fire at station	Freight derailment	
12	Fire at station	Freight derailment	Mainline passenger level crossing collision with heavy vehicle	
13	Freight derailment	Level crossing collision with bus	Collision between trains involving at least one passenger train	
14	Level crossing collision with bus	Collision between trains involving at least one passenger train	Level crossing collision with bus	
15	Collision between trains involving at least one passenger train	Unauthorised member of the public electric shock	Unauthorised member of the public electric shock	
16	Tourist and heritage level crossing collision with heavy vehicle	Tourist and heritage level crossing collision with heavy vehicle	Tourist and heritage level crossing collision with heavy vehicle	

Note: The risk of a train fire inside a tunnel could not be calculated, but this does not mean it should not be treated as a critical or priority risk.

We draw attention to the decreased reliability of estimates for rare events. With any type of rare event one or two new observations of fatal outcomes, in either the New Zealand data set or in the reference data we have drawn from, can have a large impact on estimated risk levels. Such uncertainties should be borne in mind when interpreting the outputs of this study.

The above rankings are intended to represent an overall societal view of risks. However certain groups will have their own lens to view risks. For instance:

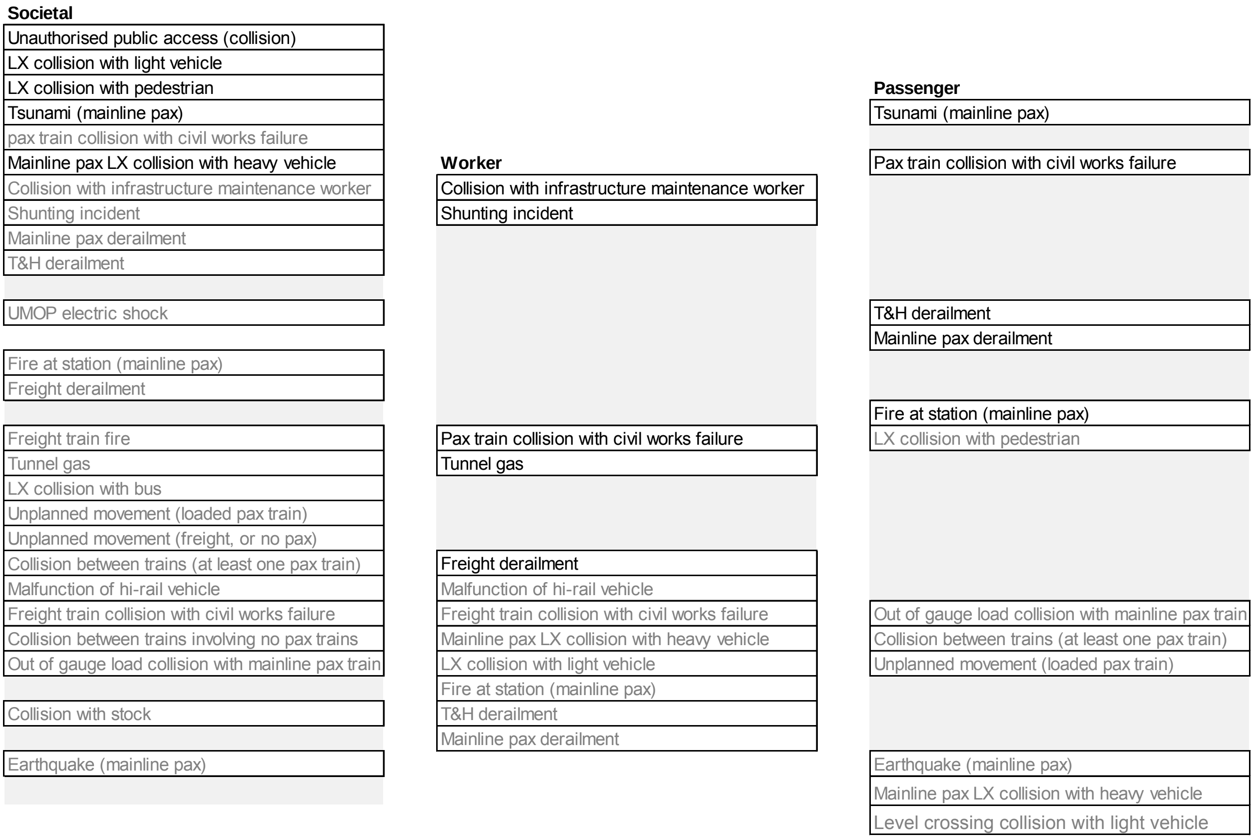
- railway operators, WorkSafe New Zealand, the Transport Agency and the RMTU will have a particular interest in the priority risks for workers
- passenger risks hold the prospect of becoming a focus of societal concern.

To show how the different lens affects risk, the researchers have also evaluated risks from these two perspectives (worker and passenger), as shown in section 7.4.3.1. These results are shown to give perspective to the results, but are not carried through in this report (the societal lens is used).

7.4.3.1 Risk results through different risk lenses

We have evaluated the priorities from two perspectives: worker risk alone and passenger risk alone. The relationship between the societal assessment (which is carried through in this report) and the worker and passenger centric assessments is illustrated in figure 7.9.[76] The figure shows the priorities are quite different depending on the lens used.

Figure 7.9 Comparison of risk priorities



For workers the top two risks were track work and shunting, with each having an estimated fatality return period of five years. This was followed by eight further risks grouped with an estimated fatality return period each of 10 years or more (tunnel gas, civil works failures for both freight and passenger trains, freight train derailment, malfunction of a HRV, collisions with vehicles at level crossings, and fire at a station). The remaining risks were each rated at an estimated 40 years or more.

[76] Figure 7.9 is arranged so the hazards are presented in the correct sequence, ordered by average expected fatalities. The passenger and worker centric hazards are plotted in positions that have equivalent AEF values of AEF to the societal assessment.

For passengers, most of the highest risks had greater average expected fatalities than for workers (reflecting the greater number of persons involved). However, on an individual basis, worker risks will be higher due to their greater exposure. The highest passenger risk assessed was a tsunami at nearly one person per year average expected fatality rate. The next four following risks had a five to seven-year average expected return period (civil works failure, derailments (both NRS and T&H), and fires at stations). A further cluster of risks had an 11 to 40-year average return period.

7.4.4 Discussion of priority risks

7.4.4.1 Tsunami

As was shown in the risk matrix, a tsunami could kill hundreds of people on the rail system, although the likelihood of this is very low. Other areas of New Zealand rail than Auckland and Wellington are at risk of tsunami but risk was not calculated, as they do not have high frequency commuter rail services operating in the nearshore areas[77]. Tsunami was our highest rated priority risk.

For this priority risk we undertook further analysis to assess the risk across a range of tidal cycles. There are significant uncertainties with our analysis of tsunami risk, as outlined in appendix K. Accordingly the following estimates of levels and return periods should be taken as indicative and should be confirmed by more detailed modelling and analysis. We are confident it has the potential for catastrophic outcomes, and on this alone the tsunami risk merits closer evaluation and possibly attention.

In Auckland, Britomart was assessed by the researchers as being at risk of inundation from tsunami levels above approximately 3.5m, which is the general pavement level in the vicinity of the Britomart precinct and tunnels entrance cutting as assessed from contour maps. In Wellington, the tracks along the foreshore were similarly assessed as being at around 3.0m to 3.5m above datum. Assuming passengers who remain on a stationary train would be safe in tsunami water depths of up to 0.5m, then a critical height of 3.5m, above which passenger losses would occur, was also selected for trains on the foreshore segment of the Hutt Valley line. We then estimated the probability and return periods for a tsunami reaching above those levels. To test sensitivity and the effect of modest defences we also looked at critical levels of 4.0m.

In Wellington, we further examined the effect of a defence to a height of 5m, as might be achieved by raising track levels, or by a seawall built into the proposed cycle way.

The results are shown in table 7.7 below. The return period shown is for locally generated tsunami events that will be equal to or greater than the level given.

Table 7.7 Tsunami risk analysis

Level (above MSL)	Return period	
	Auckland	Wellington
3.5m	1,200	170
4.0m	1,900	250
5.0m	Refer text	440

There are no tsunami design standards in New Zealand and the SFAIRP principle applies to rail activities. Assessing in accordance with SFAIRP is beyond the scope of this study. As an indication of risk levels we

[77] The national rail operator has mapped tsunami rail elevation risk maps for the network.

have evaluated the above return period against earthquake design standards. Earthquakes have similarities as they are often the originating events for tsunamis and are natural hazards with a similar potential for loss of life. The design standards for earthquakes are summarised in table 7.8.

Table 7.8 Earthquake design standards[78]

Importance Level	Definition	Examples (abridged)	Design earthquake return period
1	Structures presenting a low degree of hazard to life and other property	Farm buildings, fences, masts, walls, in-ground swimming pools	100 yrs
2	Normal structures and structures not in other importance levels	Hotels, offices, apartments < 15 storeys, car parking buildings, shopping centres <10,000m^2 gross area	500 yrs
3	Structures that as a whole may contain people in crowds or contents of high value to the community or pose risks to people in crowds	Emergency medical facilities, airport terminals, main railway stations, prisons, educational buildings. Hotels, motels, apartment buildings, offices > 15 floors Public assembly buildings, museums, galleries >1000m^2 Shopping malls >10,000m2 Grandstands for >10,000 people	1000 yrs
4	Structures with special post-disaster functions	Major infrastructure - power stations, air traffic control. Civil emergency centres, emergency services (police, fire, medical)	2500 yrs
5	Special structures	Dams, extreme hazard facilities	(out of scope)

As a main railway station Britomart station would have an importance level of 3, for which a 1,000 year return period applies. Our analysis, if accurate, suggests the current status of the Britomart terminal and access tunnel is close to and possibly just over this standard for a locally generated tsunami[79]. Noting SFAIRP still applies, the analysis suggests Britomart may have a broadly acceptable risk of inundation by a local tsunami.

For the Hutt Valley line along the Wellington harbour foreshore, bearing in mind trains run only part full for much of the day, we would regard the concentration of people on a Wellington commuter train as presenting a risk profile equivalent to an importance level of 2. The earthquake design standard for importance level 2 is 500 years. Referring to table 7.7, it can be seen, without treatment, the Hutt Valley line along the foreshore is exposed to locally generated tsunamis at much more frequent intervals than the earthquake design standard deems acceptable. The analysis suggests, if a full protection option is desired, a sea wall or ground raising to over 5m above mean sea level (MSL) (ie 1.5 to 2m above track level) would be required to provide suitable protection.

[78] Source: Tables 3.1 and 3.2 of AS/NZS 1170/0:2002 as cited in (Taig and GNS Science 2012).

[79] We would expect the station to flood more frequently, from more distant tsunamis, where there should be adequate warning to evacuate.

While we have concentrated in this analysis on the Hutt Valley line along the foreshore, the platforms of Wellington Central Railway Station lie just 170m inland from the current foreshore and the lines north also run along the foreshore for some distance. Distance inland affords some protection. The rule of thumb is that tsunami water levels decrease by one metre for every 200 metres inland (Power 2013). Accordingly, at the railway station tsunami water levels can be expected to be around 0.85m lower than on the Hutt Valley line. While this would significantly reduce the frequency of a local tsunami affecting the railway station, the importance level of the station is also higher at level 3, with a 1,000-year return period standard called for in the earthquake protection. Fortunately the railway station also has an elevated concourse immediately adjacent which presents a solution to move people quickly to higher elevations, provided the ramps and gates are wide enough to allow masses of people to move quickly, and provided the concourse withstands any associated earthquake shaking.

Discussion

This is not likely a priority risk for T&H operations, which tend to be located further inland or run relatively infrequently (eg mainline excursions).

Knowledge of tsunami risks is increasing, spurred by both the Boxing Day tsunami in 2004 in the Indian Ocean and by the graphic images of the 2011 Tohoku tsunami in Japan. Good work has been undertaken by GNS and others to explore the scale of tsunami risks in general terms, and some of that has been drawn on in this analysis. However, given that tsunamis have not previously been considered in depth in New Zealand, this risk may not have been considered and addressed as comprehensively as other risks and hazards (eg in risk/hazard registers, rules and procedures).

One potential viewpoint is that this risk may be given less attention as it is a wider civil defence issue rather than being specific to rail. However, there may still be reasonably practicable actions that could be taken. The intention of these actions would be to prevent fatalities in a tsunami event (eg get passengers to a safe zone) rather than transfer risk (eg evacuate passengers from trains but not to safety).

It may be appropriate to consider whether tsunami risk could be considered in the rules and procedures for earthquakes. If there is imminent danger of a tsunami, then some rules around earthquakes may increase risk. For instance, stopping until a track inspection has been undertaken, if there is imminent danger of a large tsunami.[80] However, if there is no or little risk of a tsunami then it would be much riskier to continue to drive on a track that has not been inspected following a significant earthquake. Any consideration of controls for a tsunami would need to carefully consider the impact on earthquake risk measures.

This is an area where the ability to decentralise may be important for safer emergency response, for example, whether there are circumstances where it could be appropriate to circumvent train control in an emergency situation. Processes would need to be in place beforehand and would need to be well understood and practised by drivers and by train control to allow clearance of unsafe areas of track. Raising the level of risk competency generally can help drivers and conductors undertake their own assessment of risks during an event. This is important as they may not be able to make contact with train control given time pressures.

In the 2011 tsunami in Japan, there were no passenger deaths on any of the trains (Fischer 2011). When the earthquake occurred, all trains stopped – either automatically or manually after receiving an automatic

[80] Some types of earthquake, called ‘tsunami earthquakes’ do not make severe ground motions at coastal areas, for example, the 1947 Gisborne tsunami (Power 2013)

radio alert (Haga et al 2011). A tsunami alert came three minutes later. Train drivers and conductors evacuated passengers from their trains and guided them to the nearest tsunami shelters. Five trains were swept off the tracks. Train drivers made their own decisions – one train stopped on a hill and kept passengers on board at the advice of a local passenger and against the dispatcher's instruction. In this case non-compliance meant all passengers and crew survived.

The Japanese example shows how preparedness and competencies of train drivers contributed significantly to an outcome with no rail-related fatalities. However, Japan is currently the only country that has a warning system for tsunamis caused by locally generated earthquakes. In the absence of centralised warnings train drivers in New Zealand might recognise signs, such as a sudden rise or fall in sea level, but there may be no official warning in time. This could be improved by the installation of earthquake sensors and tsunami monitoring buoys as part of the general civil defence network, which the rail industry could have automated access to. Even a few minutes of additional advance warning could make a critical difference to outcomes. The cost of any control should be kept in mind – if it leads to increases in passenger fares, there is the potential for people to be diverted to less safe transport modes.

Civil works options to protect from a tsunami could include general track raising or protection by a sea wall. Such works would be expensive and potentially unsightly if undertaken as standalone projects. New Zealand spends relatively little on tsunami mitigation although we face a comparatively high risk (Gill et al 2015). If there is societal acceptance that tsunami risks should be provided for there may be value in exploring other options, such as the practicality of pedestrian access over Hutt Road between Ngauranga and Petone stations, or provision of elevated tsunami shelters, such as recently installed in a school in a tsunami-prone area of Washington State (Doughton 2016). These would require significant investment and would unlikely be reasonably practicable for any rail operator to achieve alone. There may be opportunities to work with other interested parties to develop coordinated civil defence solutions (eg which might also provide for drivers caught on the roads and for cyclists and pedestrians using the proposed coastal pathway).

7.4.4.2 Collision with unauthorised member of public

Collision with unauthorised members of the public is by far the most common fatality (after suicides, which are not evaluated in the study). This prioritisation took into account that the person has generally put themselves in harm's way while not intending to be injured or not fully understanding the risk. Regardless of this, rail operators have strong motivation to reduce risk. If this risk is higher than it could practicably be, it should be of concern to rail and wider society. Fatal events also have a significant impact on drivers' wellbeing.[81]

Comparing New Zealand's performance with other countries helps provide a gauge of how we are performing. The European Railway Agency includes fatality weighted serious injuries to unauthorised persons as one of their common safety targets. A comparison of New Zealand's performance[82] with EU member states[83] and Australia[84] shows we are not performing as well as many other countries (see figure

81 While this risk assessment is based on estimated fatality risk only, any cost–benefit analysis would also take into account harm to drivers.

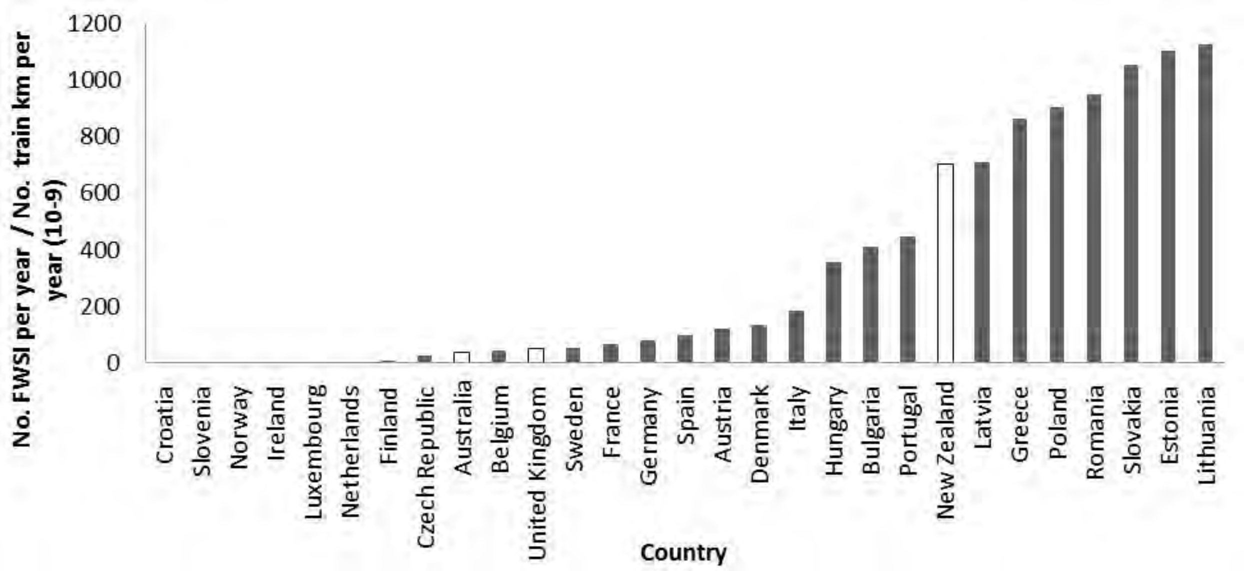
82 For New Zealand, researchers used data from the 2012–2013 financial year and FWSIs were calculated from incident descriptions.

83 2012 year (data from ERA (2014))

84 For Australia, researchers used data from the 2012–2013 year for South Australia, New South Wales, Tasmania and Northern Territory. Fatalities (rather than FWSIs) were used for Australia.

7.10). However, this should only be taken as indicative as differences in classifying unauthorised incidents (such as suicides or suspected suicides) can have significant impacts on rates.

Figure 7.10 Rates of fatality weighted serious injuries to unauthorised persons on railway premises



There have been resources put towards managing this risk, in particular public education campaigns, education in schools and improvements to fencing. TrackSafe NZ is a rail safety focused charitable foundation funded by KiwiRail, the Transport Agency and Transdev Auckland. Rail Safety Week is one example of an education campaign strongly promoted by TrackSafe NZ. Current activities include a 'Trust Me' safety campaign encouraging pedestrians to obey the flashing lights and take additional care when crossing the tracks on Auckland's Western Line. Higher priority already seems to be given to areas where young people are likely to be, particularly schools. This is appropriate given society's higher concern for the more vulnerable members of public and because young age can contribute to poor decision making. Closed-circuit television and police patrols are also used. This is an area where many different organisations and community members have worked together, eg KiwiRail, TrackSafe NZ, Auckland Transport, schools, Transdev Auckland, the Transport Agency, NZ Police, and local and regional councils.

Education does not necessarily have as much of an effect on trespass behaviour as access prevention (Lobb 2006; Lobb et al 2001), which is line with the risk hierarchy. While maintaining effective fencing against determined trespassers may be impracticable sometimes, it has shown to be effective in some areas (TAIC 1999). Near-miss data may be useful for prioritising efforts for fencing and other methods to discourage shortcuts (such as landscaping).

A 2004 analysis of incidents in New Zealand found alcohol was the biggest contributing factor (Patterson 2004); however, these included suicides. The researchers have, so far as possible, excluded suicides or likely suicides from the data. The rail industry might not be able to directly address contributing factors such as alcohol, but might be more able to influence factors such as the ease of trespass in particular areas.

Another factor to consider is the consequences of crossing the rails where access is not allowed. If or when a collision does occur there is a high chance of fatality or severe injury. However, a person could conceivably habitually trespass every day for years without having a close call. The worst that might happen is a rail worker shouts at them. The day-to-day consequences of trespass may seem close to non-existent.

While there are instant fines (infringement notices) available for road users and pedestrians at level crossings (issued by police), there are no instant fines available for rail trespassers. Risk of being fined could have some effectiveness as a deterrent – if fines are regularly issued (Havarneanu et al 2015). It may be worth exploring whether this could be a feasible option in New Zealand, although it is a police matter, not rail.

In Victoria, Australia, there are 'authorised officers' who are employees of public transport operators. The officers can report people to a government department, which can then decide whether to issue an AUD$303 fine to adults trespassing (AUD$76) for those under 18 years). The authorised officers are able to arrest people until the police arrive if they, for instance, refuse to give their name and address. This is very different from the approach New Zealand takes and would not necessarily be acceptable to the public or be politically feasible.

There is danger in this risk increasing in areas where housing development is intensifying, so public planning aspects may be particularly important for the future. For instance, a new development may be located in a place that makes rail trespass an attractive option or may exacerbate current issues. Where developments result in adverse impacts on rail safety, there needs to be an investment into reducing that increase in risk, for instance by installing an overbridge, or by contributing to fencing costs. Development contributions may be an avenue for financing such work.

7.4.4.3 Level crossing collision with light vehicle/level crossing collision with pedestrian

Of the level crossing risks assessed, light vehicles and pedestrians were identified as priority risks. While bus and heavy vehicle collisions are potentially more catastrophic, their much lesser likelihood meant they did not rate as highly. While there are differences between the different types of collision, in general, controls that reduce light vehicle risks will also reduce bus and heavy vehicle risks.

There are 681 legal pedestrian crossings on the NRS. Of these crossings, 49 have their own active controls, 507 rely on the adjacent road crossing alarms. It is presumed the remaining 125 have no active controls at all. There are around 1,320 public road level crossings. Of these crossings, 12% have half-arm barriers, 37% have lights and bells, and 47% are passively controlled (signage, road markings etc). There are also 1,343 private crossings.

For rail, level crossings are special in requiring a higher level of active engagement with other parties to implement risk control measures. Even where rail solely funds an improvement (eg instalment of barriers), road controlling authority (RCA) engagement is generally needed. There are over 60 RCAs in New Zealand, so relationship management is important.

There are also differences of opinion over where funding should come from. Between the parties involved, there is an obvious conflict in prioritisation of the risk. While nominal risk is the same for both rail and road[85], the proportionate risk for each party is significantly different (level crossings make up only a small proportion of road risk). Furthermore, while this is a significant risk for rail, if a collision occurs at a crossing, generally a road user has made an error in judgement as rail has right of way. Regardless of this, rail operators have strong motivation to reduce risk. Fatal events also have a significant impact on drivers' wellbeing.

The most effective controls – grade separation or closure – are costly. An active crossing – with lights, bells and barrier arms – is also costly to implement (TrackSAFE 2015). At New Lynn, a trench was dug to achieve grade separation of five road crossings, with a below ground station. This project cost over $200

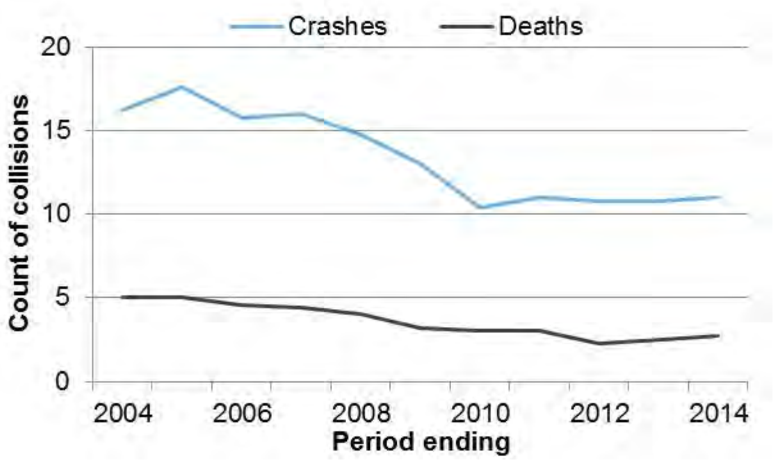
[85] In fact, fatalities are generally road users and pedestrians. Train driver and passenger fatalities are less common.

million (Beca 2012). The cost of grade separation is relevant to the test of whether the cost of the control is grossly disproportionate to the risk. Other controls include clearing vegetation around crossings to improve lines of sight.

The national rail operator recognises level crossing collisions as a critical risk and is finalising a strategy for 2016–2020. Their draft strategy outlines a number of actions they are taking or are proposing, and adopts lessons from Australian experience. The strategy approaches the risk from many different angles, including focusing on relationships and agreements with other parties involved, opposing creation of new crossings, exploring new technological options for alerting heavy vehicle drivers and assessing risk with ALCAM. There is a limit to how many upgrades can be made in any one year with the available funds, and this stresses the importance of using ALCAM as a prioritisation tool.

Overall the frequency of level crossing collisions and fatalities reduced significantly over the period to 2010, but appears to have levelled off since (figure 7.11). One possible explanation is the rate of level crossing improvements is broadly keeping pace with the increased frequency of passenger metro services. Another is that rural areas account for a disproportionate share of level crossing incidents on a per capita basis, so the observed reduction in level crossing collision rate may reflect reductions in rural services as the national rail operator focuses more on the 'golden triangle' (Auckland – Hamilton – Tauranga).

Figure 7.11 Five- year average level crossing incidents



The researchers undertook a straightforward rating of level crossings based on the number of collisions that have occurred at a crossing, presence of metro (passenger) trains, and short-stacking (see appendix L). This is a simpler assessment than the ALCAM tool and is based on different metrics; it may be interesting as a comparator if results are dissimilar to ALCAM[86]. We understand the highest rated crossings identified in our assessment may have already been upgraded.

ALCAM may not currently be as accurate for prioritising pedestrian crossings as for light vehicles. This is partially because there is less data available for these crossings, for example, volume of pedestrian traffic at each crossing. RCAs are the source of all count data.

[86] ALCAM has been carefully developed over a substantial database of Australian and New Zealand level crossings and should give a reliable prioritisation of risks. A difference with the Navigatus priority might suggest input data should be reviewed and confirmed.

In general, the researchers do not feel it is useful to identify specific control types the network operator might choose to investigate for this risk, as the national rail operator appears to have undertaken significant analysis and research in this area. In the long run, further grade separation, such as at New Lynn, is likely to be required.

For pedestrians, there has recently been work undertaken in Australia on pedestrian behaviour at level crossings. A study by McMaster et al (2014) found pedestrians were more likely to deliberately violate than make errors at crossings. However, it is possible that a genuine error is more likely to result in a fatality at a level crossing than a deliberate violation. The study found the threat of transit or police officers was the most effective deterrent and surveillance cameras also had the potential to reduce rule breaking. New Zealand police are able to issue infringement fines at level crossings to pedestrians (and road users) of $150. New Zealand does not have transit officers. There has also been work on different approaches to investigating and understanding pedestrian behaviour at crossings (Read et al 2016; Stefanova et al 2015).

T&H rail operators visited by the researchers clearly identified level crossings as one of their highest risks. Some of the controls they have in place are summarised in section 6.6, eg speed over level crossings. The researchers have also undertaken a brief analysis, which provides some evidence that a less restrictive speed might be justified for heritage operators at level crossings with barrier arms.

One T&H rail operator (Goldways Railways Inc) was recently recognised for their proactive approach to raising level crossing awareness in their community. Goldfields Railway worked with the NZ Police to raise community awareness through local media (including radio and newspapers). They also changed their reporting so they could provide police with better information about near miss incidents (which can lead to prosecutions).

Train frequency on the Auckland Western Line has increased, and now trains will operate every 10 minutes (in both directions) at peak times. A rail safety campaign was launched in conjunction with this increase by Auckland Transport, KiwiRail and TrackSafe.

The Transport Agency has unique oversight of both road and rail (Auckland Transport also has oversight of both road and rail within Auckland).[87] An opportunity to reduce risk may come in the form of development of a national, formal policy on closure of level crossings. This is an action that has been taken by states in Australia. Victoria, in particular, has taken a strong stance with the establishment of the Level Crossing Removal Authority (LXRA) in 2015. The LXRA oversees planning and delivery of level crossing removals. In 2015–2016, the Victorian Government allocated AUD$2.4 billion to removing at least 20 level crossings by 2018. Level crossing incidents in Melbourne claimed 139 lives between 2002 and 2012; in the same period in New Zealand, there were about 37 fatalities (MoT 2016b). Nominally, this is around 25% of the fatalities of Melbourne. Melbourne also had a greater ratio of level crossing to road fatalities compared with New Zealand (and therefore was a more pressing issue).

The Melbourne experience may be indicative of a potential future state for metro rail services in West Auckland as the frequency of services increase, road traffic is impeded by frequent train movements across level crossings, leading to road user frustration and driver error.

While provision of new level crossings is currently discouraged (NZ Transport Agency 2007), a formal policy may more strongly influence RCAs in decision making and may support the rail access provider when they are faced with external pressures. A formal policy may also help to action the closure of the

[87] While Greater Wellington Regional Council has oversight of rail, unlike Auckland Transport, it does not manage roading (this is done by city and district councils).

most at-risk crossings, where it is practicable to do so. The formal policy might include the explicit requirement for the risks of any new level crossing to have been reduced SFAIRP. This is potentially a highly political area, so potentially greater formal involvement of the regulator would bolster efforts made by access providers. There is an opportunity to lead with industry in this area.

7.4.4.4 Civil works failure leading to collision or derailment

Civil works failures can be caused by many different factors and can range from minor to major consequences. The major events could potentially kill 150 people. This risk excludes civil works failures caused by earthquakes and tsunamis. Wash outs, slips, subsidence and fallen trees on tracks are a contributor to this risk, as well as potential for bridge or tunnel collapse.

There are many controls in place around this risk. For instance, the national rail operator undertakes additional inspections during and after severe weather and takes action when lines are at risk of being damaged or obstructed. There are also track design and inspection programmes, and continuous track circuiting in some areas (to detect broken rails). Maintenance spending has increased over the last decade (Imran et al 2014) and there is more capital investment in structures. The national rail operator has taken lessons from past experiences, eg following the passenger train derailment on the Wairarapa line in 2009 due to a slip onto the tracks (TAIC 2010b), the national rail operator implemented a slope rating process, to allow for prioritisation across the whole network. There is also a programme for replacement works. There is an opportunity to expand prioritisation ratings across all civil assets.

New Zealand’s worst rail disaster, Tangiwai, is unlikely to happen again because there have been specific controls put in place to address that specific risk (eg lahar warning system to alert train control and drivers to stop). But bridge failures with no unexpected external forces have also happened, such as the Nuhaka bridge in 2005 (TAIC 2007).

Major maintenance is underway on the Makatote viaduct and the national operator has a programme for replacement of wooden bridge structures, prioritising the most heavily trafficked routes.

As a whole, New Zealand’s rail assets are relatively old. The average rail bridge is 80 years old, compared with 40 years for road bridges. A further capital injection in this area might be needed. The work backlog can mean work becomes more reactive than proactive. With priority rating systems in place, the total amount of money dedicated to maintenance and inspection programmes becomes increasingly important. Assets have a lifespan and if not enough money is dedicated to replacing those assets then the rail network will degrade further.

Other possibilities may include closing branches to retreat to a core network. Although this is not necessarily a good strategic move, it could improve safety risk in the shorter term. A range of strategic options have been considered by the board of the national rail operator and Treasury and put to the government as options (KiwiRail 2014). The decision was to continue with the existing network, while making savings where available.

7.4.4.5 Mainline passenger derailment

The analysis found derailment of passenger trains is a priority risk. The definition of derailment here excludes derailment from civil works failures, collisions, or derailments in sidings/yards that have been assessed under other risks.

We have higher confidence in our estimates of mainline passenger derailment risk and are confident it is a priority risk. Mainline derailments have trended down over time but are still one of the higher risks. For mainline rail, track and vehicle defects are the main causes of derailments. Significant track faults include cant (cross level) irregularities and misalignment (or curvature) irregularities. Other track fault causes include track buckling and worn or collapsed rails, bolts and joints. The national rail operator has procedures in place to reduce risk, for instance, speed restrictions when temperatures are high, in case of heat buckling.

New Zealand's track is essentially built for freight, rather than passengers (as it is in the UK), so has a lower overall track condition standard comparatively. This makes derailments more likely. As has been discussed for other priority risks, maintenance backlogs are a contributor to this risk. Availability of capital for improvements will always have a strong effect.

In terms of vehicle defects, bogie faults and axle boxes are an ongoing cause of derailments. The national rail operator appears to have robust maintenance management and fault detection systems. The age and condition of vehicles may have an impact.

Excessive speed and staff errors can also be a cause. New Zealand's second worst rail disaster, the Hyde derailment, killed 21 people in 1943. The disaster was caused by excessive speed (the driver had been drunk). In 2012 and 2013, staff errors were a significant cause of derailments. They tended not to be by locomotive crew, but rather track and mechanical staff. This may indicate an area that could be strengthened, eg staff training and systems and independent audits.

Other human errors include loss of pressure to brakes. The national rail operator has explored many contributors to human error, eg training and rostering, fatigue management, medical assessments.

7.4.4.6 Tourist and heritage derailments

There is more uncertainty about the derailment risk from T&H rail operations. No-one has been killed in the last five years by T&H derailments in New Zealand.

The New Zealand T&H sector experiences many running line derailments of passenger operations (ie outside of terminals), so the absence of fatalities suggests the casualty rate is low. This may be due in part to the generally lower running speeds of T&H trains compared with mainline passenger operations.

In risk management the possibility of an effect when none have been observed is often called a 'black swan event'.

The researchers chose to examine the casualty rate of T&H mainline derailments from two directions:

- Apply mainline UK derailment casualty rates with a modifier for decreased speed of T&H train operations (decreases risk) and for typically lower crash-worthiness of T&H rolling stock[88] (increases risk). Weighing these two factors the researchers chose to adopt an estimate of one third of the UK mainline passenger derailment casualty rate.
- Evaluate New Zealand historical[89] mainline passenger derailments with an allowance for unreported derailments (decreases risk) and for lower speeds (further decreases risk). The historical record assembled by the research team had 25 mainline passenger train derailments[90], in 9 of which 48 people died (average of 1.9 casualties per recorded event). If there were a further 10 non-recorded derailments for every recorded event, and if the effect of slower T&H speeds was a further 2 times

[88] At least one mainline T&H excursion operator has imported BR Mark 2 carriages which are of integral steel-bodied construction. Mark 2 carriages will have a much higher degree of crash worthiness than older wooden-bodied carriages. Rail carts are constructed with little roll-over protection.

[89] The year 1992 was chosen as the upper boundary for 'historical' events as that marks the point in the Navigatus historical record where the primary sources of recorded events change from railway history books to TAIC reports.

[90] This includes events from TAIC reports and the books *Tragedy on the track* and *Danger ahead*. Wikipedia events were excluded from this method due to the sporadic nature of these records.

reduction in casualty rates[91] then the estimated casualty rate per event is 0.96 deaths per derailment. The SPR records show modern day mainline passenger trains typically carry five times the number of passengers on T&H trains. Assuming current mainline usage is representative of historical passenger loading, then adjusting for this ratio gives an estimated casualty rate of 0.019 deaths per T&H derailment event.

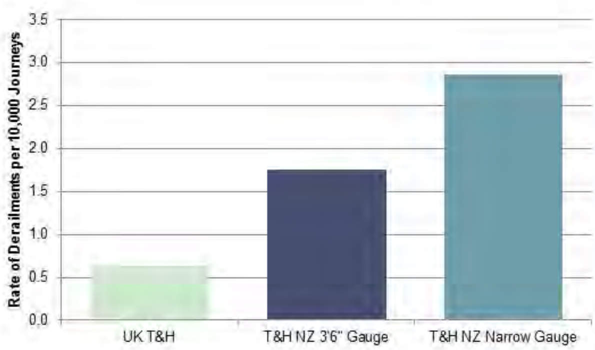
The first estimate has the appeal of requiring just one judgement. On the other hand the historical New Zealand approach has the strength of reflecting actual New Zealand terrain and types of rail vehicle likely to be involved. Noting that neither estimate is particularly robust and the average of a range of estimates is usually more accurate than any single number, we have elected to adopt an arithmetic average of these two estimates, being 0.045 deaths per T&H derailment.

On this basis the researchers conclude there is a real potential for casualties arising from T&H derailments in New Zealand. Combining a small but positive probability of casualties with the high frequency of derailments experienced by the New Zealand T&H sector elevates these events to a priority risk.

While this analysis has resulted in T&H derailments being placed in the priority risk category, we also note there is a higher degree of uncertainty about this risk, and the true level of underlying fatality risk from T&H derailments could differ significantly from our estimates.

What is clear is that derailments occur frequently across the New Zealand T&H rail sector, and more so on narrow gauge railways (figure 7.12).[92]

Figure 7.12 Tourist and heritage running line derailments[93], [94]



Some examples of running line derailments are provided. These occurred on standard gauge T&H railways. The events were extracted from the RIS data for dates between 1 Jan 2010 and 31 Oct 2015. There were 12 events on standard gauge and 11 further derailment events that occurred on narrow gauge T&H railways over this period. Incident descriptions are only available for the 12 running line derailments on standard gauge.

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91 Note that restricting speed does not mitigate all risks. For instance several of the deaths when the Silver Fern railcar derailed at Waiouru in 1981 occurred when passengers fell through windows and were then crushed by the rail car as it rolled over.

92 'NZ standard gauge' refers to 3' 6'' gauge.

93 Excludes one operator who had multiple events and who is no longer operating.

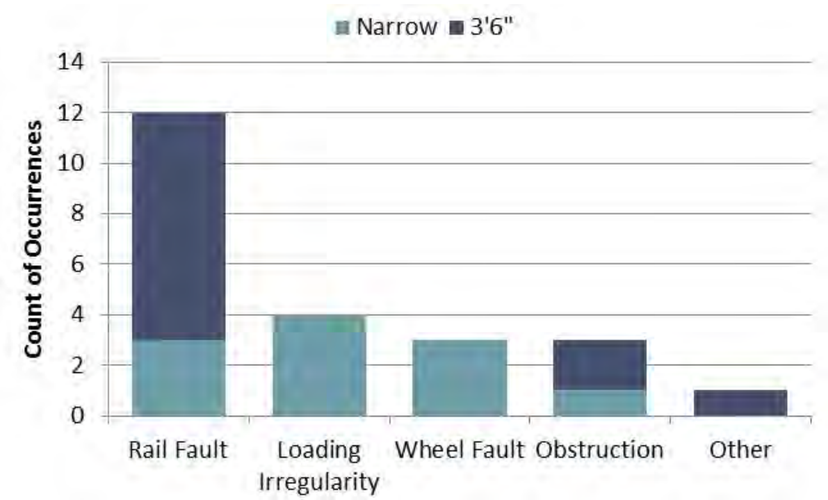
94 2011 to 2015 financial years.

Tourist and heritage standard gauge running line derailment descriptions (Jan 2010 – Oct 2015)

- Derailment from track spread due to rotten sleeper.
- Derailment due to a sleeper on a joint left unscrewed. Nearby sleeper had also been removed and left unscrewed (inexperience by new track ganger).
- Derailment from build-up of road metal on track.
- Derailment, no apparent track fault. Wind may have been a factor.
- Derailment due to sleepers having given way at the ends allowing the rail to drop.
- Derailment as a result of sleepers and fitting failing, allowing track spread of 50mm.
- Derailment due to spread rail and fittings not holding.
- Points at turnout spiked, unknown motor vehicle driven along railway corridor resulting in the spike being pulled out and the points being free to move. Loco struck points blade at 'half-cocked' position causing derailment.
- Derailment caused by out of gauge track. Previous five trains over track that day did not derail.
- Derailment as a result of track spread.
- Derailment due to dip in track on inside of rail. Possibly as a result of a soft spot caused by rain.
- Derailment due to track being over gauged.

An analysis of derailment causes shows track faults were the most common cause (figure 7.13).

Figure 7.13 Causes of derailment – tourist and heritage operations



This suggests improved inspection and maintenance of the track infrastructure should reduce derailment rates. The survey of 2016 FRONZ conference attendees revealed many were aware track maintenance could be an important contributor to potential derailments. We expect it would help if a party was to take a lead in defining standards for track maintenance and inspection for track owned or maintained by T&H operators. For instance, FRONZ could be a suitable party, keeping in mind it has limited resources. Where rail operators rely largely on volunteer labour for track maintenance there may be ongoing challenges (eg achieving appropriate level of resourcing with necessary skills to meet standards).

Narrow gauge operators also have track issues. In addition some narrow gauge operators have experienced incidents with cars derailing following partial tip over, particularly at photo opportunity locations.

In our view, derailment through partial tip over is indicative of a broader stability issue and should be addressed by appropriate controls, based on the control hierarchy. Options for engineering controls to reduce tipping risks might include changes to carriage design such as a means to restrict the ability of passengers to crowd onto one side and additional external stabilising methods at particular higher risk locations.

Transport Safety Victoria undertook an analysis of T&H incidents and identified 10 key areas of risk (see Transport Safety Victoria (2015)). Many of these areas of risk are relevant to derailment risk for T&H rail operators in New Zealand – depending on whether operators maintain their own track makes some more or less applicable. Some that may be important in the New Zealand context are poorly defined maintenance schedules, poorly maintained railway infrastructure and rolling stock, inadequate controls, and standards and criteria not being applied.

PART D: RESEARCH DISCUSSION AND CONCLUSIONS

8 Closing the loop

In the preceding sections we have identified and prioritised a set of risks. We have also shown the list of priority risks depends on the viewer's perspective. Undoubtedly different parties will have their own views on what the priority risks should be. We expect the transport sector will form its own views on priorities for intervention following discussion and input from industry. This research paper is intended to inform such discussions.

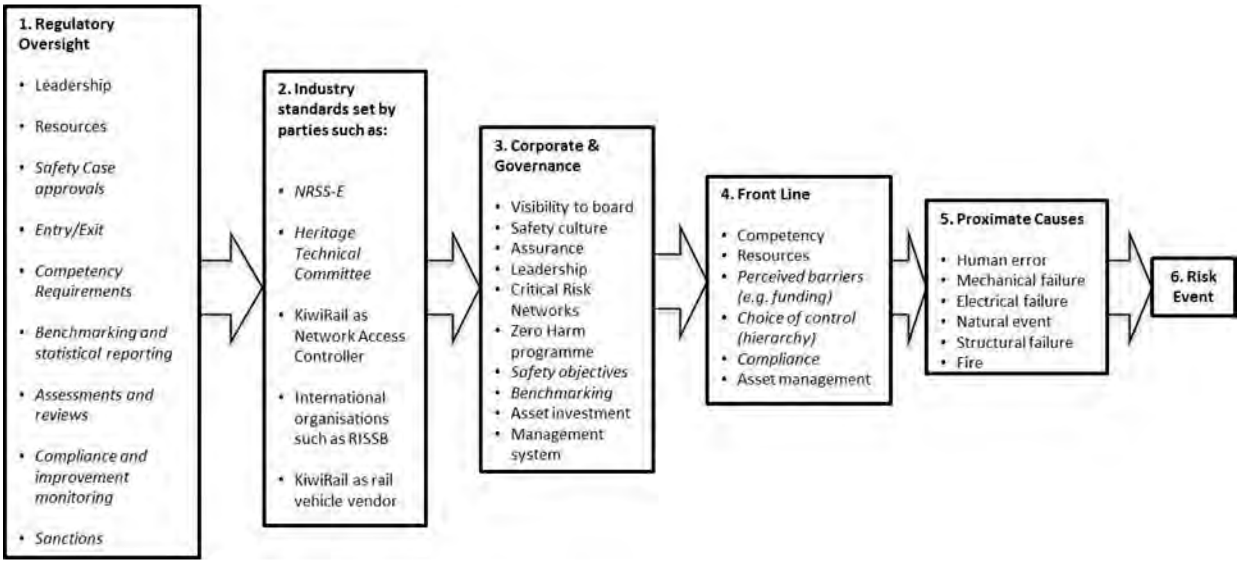
During the course of this research we have been able to observe not only the risks, but also the performance of the overall system for the management of safety in the New Zealand rail industry. This section suggests ways the underlying system of safety management could continue to improve over the long term through addressing the question:

> *What can be done to make it more likely that the priority issues will continue to be identified and well managed in the future?*

A shorthand term used within the research team was: 'what good looks like'. To figure out what good looks like, first you need an appreciation of the safety management system as a whole. We present a simplified model of the industry in figure 8.1. The figure is a simplification as the overall system is complex.

In the figure, each of the leftmost four boxes represent a systemic layer of defence to an adverse event occurring. Within each layer there are many activities, only a few of which are shown. The priority risks are represented in the box on the right. Each layer of systemic defence to the left is conceptually more distant from the priority risk event. The italicised items are activities where, in the view of the researchers, there are the greatest opportunities for systemic improvement. For simplicity, the diagram represents NRS operations, although similar views are held by the researchers for other types of rail operations.

Figure 8.1 National rail system of safety management



Most of the identified opportunities for improvement are in the oversight and frontline areas. The objective must be to enable the New Zealand public, through the regulator, to be assured the New Zealand rail system can deliver on the overall safety objectives articulated by the Transport Agency. In making the following systemic suggestions the researchers have drawn on not only the rail sector[95] but have also had regard to the way safety is managed in the maritime and aviation sectors. The aviation sector has led the way in safety management over the last 50 years, both internationally and in New Zealand and has safety management features rail can learn from.

8.1 Safety case

Like the New Zealand rail system, aviation operators must be licensed. Aviation activities are divided into broad classes known by the pertaining rules (eg passenger operations for large aeroplanes with more than 30 seats is Part 121). Rules are set by the regulator and follow a common model throughout the world. Every aviation operators is required to have an *exposition,* which is similar in concept to the safety case required under the Railways Act. *Safety cases* are used in aviation, but tend to pertain to significant changes in activities.

Safety cases can have either of two purposes: to demonstrate the safety of current operations and to demonstrate the safety of a proposed change. As an example of the latter, each airline currently proposing to commence Queenstown night operations was required to prepare and submit a safety case for approval by the regulator[96].

Safety cases are prescribed by the Railways Act and guidance is provided in appendix 1of the *Rail safety licencing of safety assessment guidelines* (Land Transport NZ 2006). Nevertheless, understanding of safety cases in the New Zealand rail industry appears to be weak. We find useful the definition from the UK Civil Aviation Authority (CAA 2010):

> *A documented body of evidence that provides a demonstrable and valid argument that a system is adequately safe for a given application and environment over its lifetime.*

In our view *demonstrable and valid* lies at the core of the judgement required for section 31(1)(b) of the Railways Act: for the regulator to be able to understand the safety result attainable. That requires an evidence-based and valid argument. What 'good looks like' is that participants' safety cases do not rely on invalid logic such as 'we haven't killed anyone' as sufficient evidence of safety. Good T&M rail operators genuinely review their safety cases and recognise why simply following the old New Zealand Railways rule book that applied when heritage vehicles were in national service, may no longer be safe enough.

8.2 Licence period

Lessons from aviation have informed operational safety management across many industries. Several other aspects of the aviation system are particularly pertinent to issues faced by the rail industry. First, entry by aviation operators is for a defined period – typically five years. Audits conducted by the regulator take place at intervals within that five-year period. Towards the end of the period a new application is required. This creates an ongoing incentive for the operator to check they meet required standards and

[95] Including the UK Office of Rail Regulation Rail Risk Maturity Model (ORR 2011).

[96] Disclosure: Navigatus has assisted Queenstown Airport with the overall night operations safety case and is currently assisting a number of international airlines with safety case preparation.

rules. It also provides an opportunity to lift standards to comply with current best practice, as will often be the case over a five-year period. Accordingly aviation operators must constantly improve or exit. The equivalent safety certificate/authorisation in the UK rail industry has to be resubmitted for each five-year review period or if there is a significant change to the scope of the railway.

These observations raise the question about whether a similar approach could be used in the New Zealand rail industry. However, the Railways Act embodies a concept of continuous licensing. It appears a five-year licence period would be inconsistent with the legislation. It can also be argued that avenues for continuous improvement are available by way of the ordinary safety assessments, which are currently held annually.

8.3 Strengthening the ordinary safety assessment

In addition to the current ordinary safety assessments, it would seem a strengthened and more structured approach to ordinary safety assessments could be appropriate. For instance, the ordinary safety assessments could work to an enhanced work plan that addresses key areas of concern for each industry segment. If an assessment work plan was to be set out well in advance (even years in advance) to each segment of the industry, this would allow time for the development and dispersal of industry solutions to persistent problems. We would also expect in ordinary safety assessments, general safety management would continue to be reviewed, and any issues identified for the operator concerned (eg through incidents or prior audits) followed up on. In summary, this would build on and strengthen the existing system of ordinary safety assessments, rather than seeking to replace it with something new.

8.4 Capability of personnel in safety critical positions

Another relevant aspect of the aviation regulations is the ‘fit and proper person’ test. In essence key safety roles in the organisation need to be held by named individuals.[97] The regulator needs to be satisfied the named individual is a fit and proper person to hold the role. Certain documents can only be signed by the named individual. In our observation the process serves to focus minds: everyone in an aviation organisation tends to know who the fit and proper persons are. That clarity also focuses the minds of the persons concerned: they are taking important safety decisions, they are responsible and they must exercise due care.[98] Another benefit of this requirement is the regulator is alerted to changes in critical positions which can be taken into account when assessing operator risk profiles.

The concept of persons in defined safety critical positions being required to hold certain defined competencies, by way of recognised qualifications and experience is referenced in section 30(1)g of the Railways Act and appears to be contemplated under the rule-making provisions of section 53 of the Railways Act. This is not a new concept for the industry. It is already generally accepted that locomotive engineers need appropriate training, and that structures need to be assessed by professional engineers. In the researchers’ view, more explicit competency requirements for a wider range of safety critical roles would do much to enhance professional standards in the industry and to increase the organisational focus of rail participants on safety management. In implementing any such recommendations cognisance would

[97] Another example is the 2013 mining regulations which identify 10 types of positions in an underground mining operation which need to be filled by people approved by WorkSafe New Zealand which holds specified certificates of competency (NZ Parliament 2013).

[98] Section 21 of the Railways Act (2005) requires licence holders to have a nominated safety liaison officer as their primary contact with the Transport Agency in relation to the licence. The Act does not require any particular competencies nor require any particular actions be undertaken by the safety liaison officer.

need to be taken of the general shortage of personnel trained in rail safety, so a grace period during which people can attain suitable qualifications would be recommended. We would expect such shortages to be particularly acute in the T&H sector. For smaller operators in the aviation industry it is common that a person may have a supervisory role, including regular field visits, across a number of enterprises.

8.5 Benchmarking

We have commented previously on data management and publication. In our view published benchmarking comparisons have the potential to be a powerful driver of safety performance improvement. We are supportive of the Transport Agency initiative of researching benchmarking metrics and we encourage the populating of those metrics with data and publishing the results. However, it is important to ensure benchmarking compares like with like. We have reservations about whether it is reasonable to expect the same level of safety performance as the passenger services dominated UK railway system and would suggest that benchmarking against the public Australian rail system[99] is appropriate.

8.6 Follow up

Change is occurring as the Transport Agency considers how it gets the best value from one of its core tasks, including ordinary safety assessments. This is an excellent opportunity to change expectations by introducing initiatives such as the 'deep slice' and human factors approaches, as discussed earlier. The ordinary safety assessments also create another way of closing the loop: by following through on recommendations of incident investigations by the operator, TAIC, WorkSafe New Zealand and the Transport Agency. By consistently following up such recommendations with expectations of improvement, the regulator can apply investigative insights more effectively. Our picture of 'what good looks like' does not necessarily involve more investigation directly by the Transport Agency, but would see further strengthening of overt, systematic and persistent follow-through, irrespective of who conducted the original investigation.

8.7 Continuous improvement

In figure 8.2 we set out a concept for how the system elements can combine to form a virtuous circle of continuous improvement. This concept sits at the heart of successful safety management and is referenced in section 30(1)l of the Railways Act.

The figure illustrates that the operator is responsible for the safety performance. In addition there are opportunities for the regulator to influence safety performance. Usage of a range of methods of influence, from guidance to sanctions, is vital – to nudge the willing into compliance, to deter the reluctant, and if necessary to separate unsuitable parties from participating in the rail industry. In the UK, regular meetings between the regulator and major operators are used to assess the status of safety initiatives and to encourage on-going improvement.

Sanctions do not need to be prompted only by a safety incident. For instance, open recommendations that the operator is unable to follow through may require an operational limitation (which may be considered as a form of sanction) until the operator can address the matter. This type of action has already been deployed by the Transport Agency on at least one occasion, which is a useful precedent. In our view,

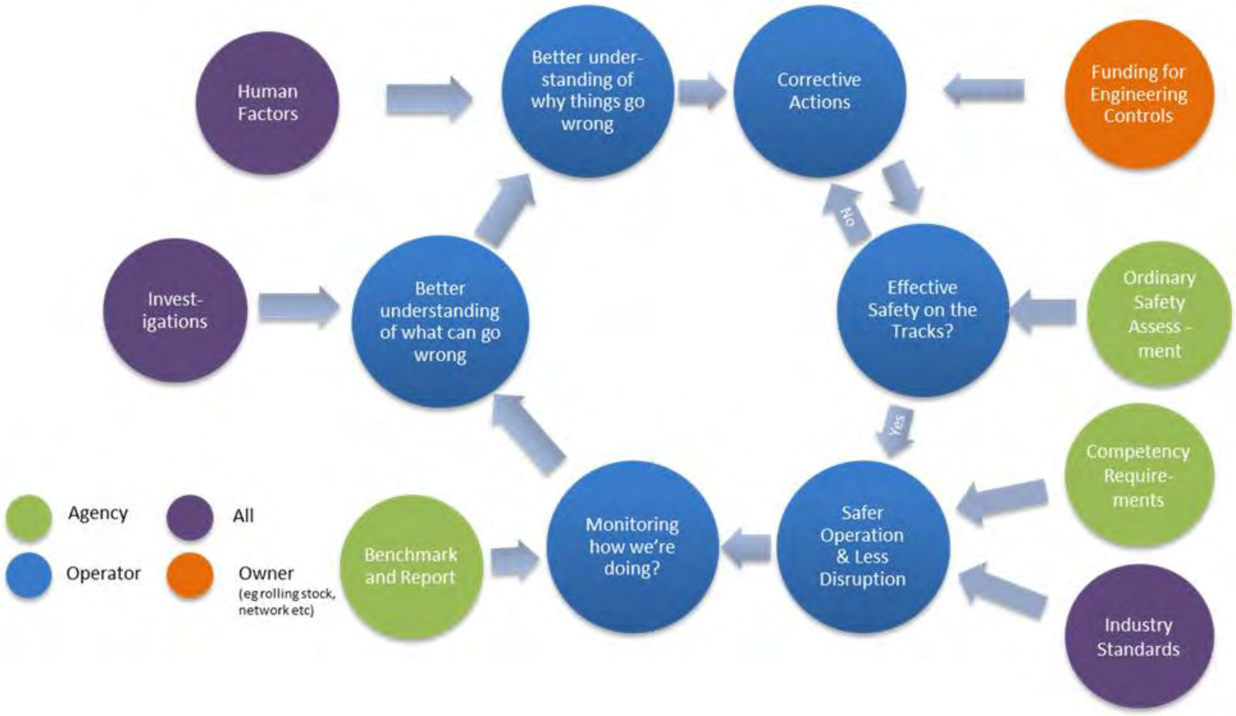
[99] Excluding private railways, such as dedicated mine-to-port bulk minerals export railroads.

safety performance of the industry will be enhanced by safety leadership, competence, good communication and a proper range of actions, justly applied by the regulator.

Ordinary safety assessments could provide an excellent platform for identifying areas for improvement. As a result of an insightful ordinary safety assessment, a rail operator might be expected to prepare forms of an improvement plan that map out how the operator plans to address particular safety issues. The more advanced operators already create such plans for important risks. Such plans might not be called *Safety improvement plans* as that has a particular, possibly shorter-term connotation under section 37 of the Railways Act.

A challenge for the regulator is to find ways to foster continuous improvement under the existing legislative framework. Allowing sufficient time to make safety improvements in a planned and cost-effective way would have a significant impact on operators' willingness to participate voluntarily in such programmes.

Figure 8.2 Rail systems of safety management – improvement loop[100]



8.8 Tourist and heritage

'What good looks like' is about building on best practice to encourage all participants to strive towards appropriate levels of safety. This is especially true in the T&H sector, which struggles to attain and maintain the required risk management competencies. There is a need for T&H rail operators to complete the transition from risk management as a compliance activity to risk management as an operating philosophy. In short, risk management in the T&H sector needs to complete the move off the page and onto the tracks.

100 Simplified conceptual diagram necessarily only shows some elements of the overall system of safety management.

Our picture for what good looks like in the T&H sector does not involve excursion trains slowing down unnecessarily at controlled level crossings, but it does include T&H operators who:

- understand customers expect risks to be managed to a similar level as any other modern entertainment or learning experience
- always keep high consequence but low frequency events, such as fire, collision and derailment risks, at the top of their mind
- recognise some historical safety standards are no longer acceptable
- use good practice controls such as:
  - using rolling stock and train configurations that keep volunteers and customers safe
  - recognising passenger-operated vacuum dump emergency stops may be counterproductive in tunnel, bridge and other high-hazard situations and have converted these to driver advisory warning systems
  - limiting speed as one of a wider range of controls to manage all risks
  - replacing carriage furnishings such as seat coverings and padding with non-flammable materials as they reach the end of their service lives
  - regularly inspecting tracks and civil works
  - providing couplings, which hold rakes of carriages together under all circumstances, such as a collision or derailment to reduce the risk of carriages climbing over each other and telescoping[101]
  - refurbishing wooden-bodied carriages in an agreed programme that provides end and roll-over protection as priorities, as well as enhancing side protection to the extents appropriate for the intended use
- recognise that incidents such as derailments, collisions and infrastructure faults are indicative of safety systems failure and actively investigate causes, take corrective action, monitor effectiveness and take further corrective actions if required
- always regard safety as a higher value than authenticity on rail vehicles transporting people[102]
- actively share good practice with other T&H rail operators to help lift safety performance across the sector.

We also envisage adequately resourced Heritage Committees that, recognising safety expectations have changed, take a leadership role in setting appropriate standards for heritage rail vehicles in modern use. The Heritage Committees are chaired by FRONZ. It is our view that FRONZ has a pivotal leadership role to play in achieving improved safety performance in the T&H rail sector. As such it is important FRONZ is supported by all parties as appropriate to enable the organisation to continue to fulfil this important role. Some of the currently available risk management resources presented in section 4.4 may be of benefit to T&H operators, such as 'ISO 31000', the 'common safety method' and 'taking safe decisions'. A fundamental understanding of risk management principles and competency is critical – risk management needs to be tailored to the operator and needs to be an integral part of the operator's processes (not a

[101] Refer ORR (2007, section 428). This may require the fitting of drawbars and couplers that are not period-authentic.

[102] For instance by installation of a modern vigilance device or a CCTV camera at door. A corollary is that some vehicles with elevated risks, preserved in their original form, may need to be separated from public use and access.

stand-alone activity). Resources such as the iESM may be useful as a good practice reference for T&H rail operators, but consideration must be given to how to apply practices to New Zealand's particular operating environment.

8.9 National rail operator

A commendable range of safety improvements are being taken by the national rail operator. Opportunities for further improvement have been canvassed in chapter 6 of this report and no further comment is offered here on those opportunities. For a larger operation, such as the national rail operator, benchmarking against similar operators in other jurisdictions is likely to be informative.

9 Conclusions and recommendations

The research undertaken identified best practice in risk management and possible improvements for the New Zealand Rail Industry, including to NRSS4. This report has described current practice in risk management and provided comparison with other countries. It has also discussed the implications of the introduction of 'so far as is reasonably practicable' for rail, and explored the quantification of acceptable risk for rail in New Zealand.

A risk assessment was completed to provide an evidence-based, semi-quantitative list of priority risks for rail. The risks were explored and possible mitigations were discussed. Recommendations were made to address broader drivers of risk and for next-steps on addressing priority risks.

9.1 SFAIRP

The new SFAIRP requirement in health and safety legislation is considered to be the same, for the most part, as the ALARP concept already used by many operators.

However, information on ALARP (as presented in current rail risk assessment guidelines in New Zealand, such as NRSS4) would be unlikely to be sufficient as a standalone resource for rail operators to meet the SFAIRP requirement. The Health and Safety at Work Act 2015 and amendments to the Railways Act 2005 clearly signal to duty holders there are different expectations required of them, and they will need support and guidelines to help them with their interpretation of the law (and implementation of appropriate practices).

9.2 NRSS4

The researchers were asked to suggest enhancements to NRSS4 (risk management). The researchers found NRSS4 to be no longer fit for purpose as it does not represent good practice. The researchers recommend the NRSS2 standard (safety management) be expanded to cover risk management. The principal reason for recommending this option is to more explicitly recognise the integral role of risk management in the wider risk management framework (the safety management system).

9.3 Acceptable risk levels

In terms of acceptable risk levels (as presented in current rail risk assessment guidelines in New Zealand), the researchers suggest the boundary between tolerable and intolerable risk for rail workers may be lenient. A bound of a 1 in 10,000 annual fatality risk may be more appropriate for rail workers than the current 1 in 1,000, given rail's improved safety performance over the last 15 years. The purpose of the bound would be for the regulator to track safety performance for the industry as a whole (rather than for operators or individual risks). If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry. However, changing the tolerability limit for rail may have wider impacts for other industries and these should be considered before any changes are made.

9.4 Best practice

As in other industries, best practice continues to evolve in the international rail industry. Key themes of that evolution include:

- moving from blaming the individual to seeing failure as a symptom or outcome of a systemic issue or weakness
- recognising organisational culture lies at the heart of, and is the foundation for achieving, high levels of safety performance
- placing less emphasis on rules as a safety intervention and more focus on hazard elimination and/or engineering controls
- moving from viewing safety as isolated processes and activities to thinking of it as an integrated system
- monitoring precursors (buckled rails, level crossing failures etc) to low probability, high consequence events, even if they did not result in any actual harm, as they give more insight than monitoring the levels of unrelated minor injuries.

9.5 Current New Zealand practice

The researchers benchmarked rates of New Zealand incident occurrences against Australian and UK data. Generally the New Zealand rail industry performed more poorly than rail operations in these other jurisdictions. Although the benchmarking shows New Zealand has room for improvement, there are some differences between the rail systems between the countries that mean it may not be practicable for New Zealand to reach the same level of safety. For instance, while New Zealand rail is dominated by freight, UK rail is dominated by passenger services. This means UK rail infrastructure is maintained to a higher standard (because of the passenger services), which also benefits the safety performance of freight services on those lines.

The researchers found metro and long-distance rail operators appeared to have relatively good risk management capability (at least centrally), as well as having access to greater resources (eg industry bodies and other organisations). T&H operators tended to have lower risk management capability and may struggle to meet rising health and safety expectations despite good intentions.

9.6 Specific recommendations

Looking at the rail sector as a whole, care must be taken to direct efforts where they will achieve the greatest benefit. There is a need for balance, viewing safety not as an absolute to be pursued at all costs, but as a relative good, pursued to the extent that is reasonably practical, consistent with New Zealand law and with societal expectations.

Some specific recommendations are:

Recommendation 1: Consider whether competency requirements should be established for defined safety roles within the rail sector (eg recognised qualifications and experience).

Recommendation 2: Continue benchmarking initiative that is planned (populate the metrics with data and publish the results).

Recommendation 3: Update guidance available to operators on licensing and safety case requirements (currently set out in the *Rail Safety licensing and safety assessment guidelines* (Land Transport NZ 2006).

Recommendation 4: As part of the improvement project for ordinary safety assessments presently being carried out, consider introducing ‘deep slice’, human factors approaches.

Recommendation 5: Ensure safety cases remain valid through increased emphasis in ordinary safety assessments on continuous improvement of safety cases by operators in accordance with section 30(1)1 of the Railways Act.

Recommendation 6: More overt, systematic and persistent follow-up of investigations and recommendations made by the transport sector.

Recommendation 7: All parties should support FRONZ, as appropriate, to enable the organisation to strengthen resourcing of Heritage Committees.

9.7 Priority risk recommendations

A risk assessment was carried out to identify priority risks for the rail industry as a whole. The rankings were based primarily on societal risk (using average estimated fatalities per year) and weightings (to reflect the degree of control the rail system has over outcomes and broad societal values on acceptable risks). These priority risks indicated those that are highest and hence are a priority to assess whether they have been reduced SFAIRP. If they have been – if the cost to reduce these risks further is grossly disproportionate to the benefits – then although the risk is higher than others, it may be tolerable.

The priority risks are intended to inform discussion of priorities. The railway industry has many different stakeholders, each will have different viewpoints, and no single list of prioritised risks addresses the needs of all stakeholders.

There were a number of recommendations relating to the priority risks identified.

9.7.1 Tsunami

An unexpected outcome of the risk assessment was tsunami appearing top of the list. While the likelihood of the event was low, the potential fatalities occurring in any one event were higher than any other risk assessed. Recognising tsunamis are natural events and are a wider issue then just for rail, there is value in considering whether there are additional controls that could be reasonably implemented (either by operators, regulators, or other organisations as part of a wider societal response to tsunami risk). While a tsunami cannot be prevented, there may be societal actions the rail industry can influence and others the industry can take directly to reduce risk.

The following recommendations are made:

Priority risk recommendation 1: The national network access provider should consider whether imminent tsunami risk could be considered in the rules and procedures for earthquakes.

Priority risk recommendation 2: The national network access provider and the metro rail operator should work with central government, regional authorities and road transport funders to investigate, especially for the Wellington region:

1 Likelihood and consequences of tsunami risk on rail operations (as part of a wider assessment of risk to all transport modes)

2 Feasibility of civil defence warning and protection systems such as automated early warning buoy systems, tsunami defences and refuges

3 Feasibility of including elements of tsunami protection into projects currently under design such as the Wellington to Hutt cycleway and foreshore protection

4 How such systems should integrate with wider civil defence protection and response responsibilities.

9.7.2 Collision with unauthorised member of the public

Collision with unauthorised members of the public are by far the most common fatality (after suicides, which are not evaluated in the study). This prioritisation took into account that the person has generally put themselves in harm's way while not intending to be injured or not fully understanding the risk. Regardless of this, rail operators have strong motivation to reduce risk. If this risk is higher than it could practicably be, it should be of concern to rail and wider society. Fatal events also have a significant impact on drivers' wellbeing.

The following recommendation is made:

Priority risk recommendation 3: Rail operators might use the introduction of SFAIRP as an opportunity to formally assess whether any further controls regarding unauthorised members of the public might be reasonably practicable. [103]

9.7.3 Level crossing collisions with light vehicle/pedestrian

Of level crossing risks assessed, light vehicles and pedestrians were identified as priority risks. While bus and heavy vehicle collisions are potentially more catastrophic, their much lesser likelihood meant they did not rate as highly. While there are differences between the different types of collision, in general, controls that reduce light vehicle risks will also reduce bus and heavy vehicle risks.

The following recommendations are made:

Priority risk recommendation 4: The transport sector to consider whether there would be value in establishing a formal policy regarding new level crossings and/or closure of current level crossings.

Priority risk recommendation 5: The transport sector to consider actions to strengthen pedestrian-related data inputs into ALCAM.

9.7.4 Civil works failure leading to collision or derailment

Civil works failures can be caused by many different factors and can range from minor to major consequences. Acknowledging there are already many controls in place around this risk, the following recommendation is made:

Priority risk recommendation 6: Rail operators might use introduction of SFAIRP as an opportunity to formally assess whether any further controls regarding potential civil works failures might be reasonably practicable.

9.7.5 Mainline passenger derailment/tourist and heritage derailment

The analysis found derailment of passenger trains is a priority risk (with higher confidence in the estimates of mainline passenger derailment risk and lower confidence in the estimates for T&H risk). The following recommendations are made:

[103] This recommendation is not related to a legal requirement. HSWA requires that SFAIRP, the safety of 'other persons' is not put at risk from operations, but this requirement likely does not apply to trespassers. However, WorkSafe New Zealand states (in relation to other industries) if trespass is reasonably foreseeable, then 'barriers' may be appropriate.

Priority risk recommendation 7: Operators that have had derailments since 1 January 2010 due to passenger loading irregularities to undertake SFAIRP assessment of risks and options for additional controls.

Priority risk recommendation 8: Track inspection and maintenance to be added as a focus area for ordinary safety assessments for T&H rail operators.

Priority risk recommendation 9: A standard for track maintenance and inspection to be prepared or adopted for use by T&H rail operators on non-NRS tracks.

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Appendix A: Glossary

ACC	Accident Compensation Corporation
ACOP	Australian Code of Practice
ALARP	As low as reasonably practicable
ALCAM	Australian Level Crossings Assessment Model
ANCOLD	Australian National Committee on Large Dams
AT	Auckland Transport
ATP	automatic train protection
ATRS	Australasian Transport Risk Solutions Pty Limited
CAA	Civil Aviation Authority (UK)
CAF	Spanish railway company (Construcciones y Auxiliar de Ferrocarriles)
CRN	critical risk networks
CSM	common safety method
CSM RA	common safety method for risk evaluation and assessment
DMU	diesel multiple unit
EMU	electric multiple unit
ERA	European Railway Agency
ETCS	European Train Control System
FAID	fatigue assessment tool
FRONZ	Federation of Rail Organisations of New Zealand
FWI	fatalities and weighted injuries
GWRC	Greater Wellington Regional Council
Heritage Committees	Heritage Technical Committee and Heritage Operations Committee (New Zealand)
HRO	high reliability organisation
HRV	hi-rail vehicle
HSWA	Health and Safety at Work Act 2015
ICAF	implied cost of an avoided fatality
iESM	*The international rail industry's engineering safety management handbook*
LPHC	low probability, high consequence events
Maximum credible fatalities	Maximum credible is not intended to be the worst possible case but is conceptually based on the researchers' assessment of a likely 90th percentile figure. This was estimated by examining historic New Zealand and international accidents for comparable events.

MBIE	Ministry of Business, Innovation and Employment
MoT	Ministry of Transport
MSL	mean sea level
NRS	National Rail System
NRSS	National Rail System Standard
NRSS-E	National Rail System Standard Executive Committee
NTCC	National Train Control Centre
OCWHaS	Organisational Culture, Work, Health and Safety Survey
ONRSR	Office of the National Rail Safety Regulator (Australia)
ORR	Office of Rail Regulation, UK
PIM	precursor indicator model
PTC	positive train control
RCA	road controlling authority
RIS	rail information system
RISSB	Rail Industry Safety and Standards Board (Australia)
RSSB	Rail Safety Standards Board (United Kingdom)
RMTU	Rail and Maritime Transport Union of New Zealand
SA/SNZ	Standards Australia/Standards New Zealand
SFAIRP	so far as is reasonably practicable
SPAD	signal passed at danger
SPR	safety performance report
SSRS	Safety Star Rating Scheme
SRM	safety risk model
TAIC	New Zealand Transport Accident Investigation Commission
T&H	tourist and heritage
TPWS	train protection and warning system
Train control	Train control is used to refer to the complete system of rules, operating procedures, communication, signalling, control of train movements and protection of track maintenance activity (including mechanical and computerised automated train control systems that prevent deviations from permitted train movements).
TRIFR	total recordable injury frequency rate
UK HSE	United Kingdom Health and Safety Executive
VSL	value of a statistical life
WREMO	Wellington Region Emergency Management Office

Appendix B: Rail safety responsibility matrix

The following table has been updated and altered to our purpose using the basis of a 'New Zealand rail industry key safety responsibility matrix' developed by David Edwards, ATRS Pty Ltd.

Subject	Transport Agency	WorkSafe New Zealand	NRSS- E	T&H Technical Committee	Track Access Provider	Rail Operators	TAIC
Legislative							
Railways Act	■						
Railways regulations	■						
Licensing and safety assessment guidelines	■						
HSW Act		■					
HSW Regulations		■					
HSW Compliance Guidelines		■					
Standards & Codes of Practice							
General Rail Technical Standards			■				
General Rail Technical Guidelines			■				
Risk management guidelines			■				
Health Assessment Standard			■				
Heritage (Steam) Technical Standards				■			
Heritage (Steam) Technical Training			■			■	
Network Infrastructure Standards					■		
Network Access Standards					■		
Network Interoperability Standards					■		
Network Safeworking Rules					■		
Minimum Network Operating Standards					■		
Minimum Rolling Stock Access Standards					■		
Operator Specific Standards						■	
Safety Management System							
Rail Safety Management Leadership					■	■	
Safety at work leadership					■	■	
Organisation Safety Management System					■	■	
Organisation Policies					■	■	
Organisation Generic Procedures					■	■	
Organisation Site Specific Procedures					■	■	
Fatigue Management					■	■	
Drug & Alcohol Management					■	■	
Rail Accreditation and Licensing							
Preparation of Safety Case					■	■	
Assessment of Safety Case	■						
Issue of license (if approved)	■						
Annual Safety Performance Report					■	■	
Payment of Annual License Fees					■	■	
Safety Compliance Auditing							
Rail Safety Regulator Annual Audit Rail Safety (OSA)	■						
Regulator Compliance Inspections OH&S	■						

Subject	Transport Agency	WorkSafe New Zealand	NRSS- E	T&H Technical Committee	Track Access Provider	Rail Operators	TAIC
Compliance Audit of Organisations							
Network Access Conditions Compliance Audit							
Organisation Internal Compliance Audit							
Compliance Audit of Contractors							
Special safety assessments							
Incident Reporting and Response							
Emergency Response							
Disruption Management							
Security Management							
Customer Liaison							
Incident Reporting							
Incident database							
Investigation							
Rail Operator Investigation							
Network Access provider investigation of an Operator incident on the Rail Network							
External Regulator H&S Independent Investigation							
External Rail Safety Regulator Independent Investigation							
Independent transport accident investigation							

Appendix C: Quantifying acceptable risk

C1 Introduction and approach

This section addresses the following question in the project brief:

> *Quantify what is an acceptable risk level for rail operations, based on modern industrial safety expectations and the 'risk appetite' of the public in regards to rail travel as compared to other modes of transport.*

The main findings from this research are presented in section in the main text. This appendix provides a fuller description of the research undertaken and literature studied.

This table is a reference point for risk levels referred to throughout this appendix.

Table C.1 Risk levels reference table

Deaths per annum	Shorthand	Relation to current risk levels
1 in 1,000	1x10-3	Current tolerable/intolerable boundary for workers
1 in 10,000	1x10-4	Current tolerable/intolerable boundary for passengers
1 in 100,000	1x10-5	Falls within current tolerability bounds for workers and passengers
1 in 1,000,000	1x10-6	Current tolerable/acceptable boundary for workers and passengers

C2 Background on international and New Zealand standards for acceptable risk

C2.1 Individual fatality risk

One method of setting acceptable risk levels is to look at what is currently tolerated in other domains (Hunter and Fewtrell 2001). An individual fatality risk for members of the public of 10^{-6} (Land Transport NZ 2006) has been previously adopted for New Zealand railway operations and this is broadly in keeping with current earthquake standards. However, a central issue arises from such standards: how is the acceptable risk allocated between the many individual failure modes that may comprise the overall fatality risk standard? We address this question in this section.

Since the 2011 Christchurch earthquake much effort has been put into understanding the New Zealand building stock and the associated levels of risk. Historically, the annual average fatality risk from earthquakes in New Zealand has been approximately $2x10^{-6}$ over the period 1858–2011.[104] Looking at modern standards, for buildings of post-1980 design in sound condition,[105] the annual average individual fatality risk is typically expected to be in the vicinity of $1x10^{-6}$.

[104] Derived from Taig and GNS Science (2012, figure 8).

[105] Depends on form of construction and building height. Derived from Taig and GNS Science (2012, figure 22).

C2.2 Societal risk and scale aversion

Central to the concept of societal risk is debate around whether societies are more averse to many fatalities in one event compared with the same fatality count spread over a longer time (called 'scale aversion' by some commentators). Scale aversion initially came from the nuclear industry.

To illustrate the point we first consider a case with no mortality aversion. The Australian National Committee on Large Dams (ANCOLD 2003) developed the following risk guidelines:

- killing 1 or more people more than once in 1,000 years
- killing 10 or more people more than once in 10,000 years
- killing 100 or more people more than once in 100,000 years.

The standard for new large dams is 10 times more stringent. This is effectively equivalent to an individual fatality risk of 10^{-4} for new installations. A feature of the ANCOLD guidance is that it is linear: the acceptable risk for killing 10 people is one tenth the acceptable risk of killing one person, and so on.

In contrast, societal risk standards in the Netherlands have adopted a stronger aversion to multiple casualties by applying a squared function, with acceptable risk declining in accordance to the second power of the number of casualties (Vrijling and van Gelder 1997). This is an example of mortality aversion.

The core question regarding mortality aversion was posed by Slovic et al (1984) as:

> *How should a single accident that takes N lives be weighted relative to N accidents, each of which takes a single life?*

The answer to this question has important implications for risk-related resource allocation and decision making. All else being equal, a disproportionate weighting of one event type and therefore squandering of resources may lead inadvertently to weaker protections elsewhere and hence an increase in the frequency of lesser consequence events, resulting in greater overall fatalities.

Historically various proposals on how to quantify the societal impact of multiple-fatality crashes have been along the lines of asserting the social cost of N lives lost in a single crash is a function of N^a – it has been argued that a single large crash is more serious than many small ones producing the same number of fatalities, hence $a > 1$.

Analysis of crash statistics led Ferreira and Slesin (1976) to the conclusion that 'the value of each additional life lost in a single accident is greater than the one before'. However, this was based on the assumption that the observed relationship between severity and frequency was reflective of the controlling influence of society's value system. Griesmeyer et al (1979) (as cited in Slovic et al 1984) noted the observed relationship could be due to many other factors, such as the cost of crash prevention and physical limitations on the number of situations that could lead to large consequence events.

The UK HSE conducted a review of related prior research, case studies and social impact assessments, publishing a report entitled *Evidence or otherwise of scale aversion: public reactions to major disasters* (ERM 2009). Key findings of the report include the following[106]:

> *There is some research based evidence for scale aversion and some against. The greater weight of research demonstrates that, even where it is evident, scale aversion is not consistent and is*

[106] The report is available online at: www. Hse.gov.uk//societalrisk//evidence-or-otherwise-of-scale-aversion.pdf

> *dependent on numerous factors many of which are themselves subject to change and are subjective. Therefore, although scale aversion may exist in some situations, it is not a consistent phenomenon.*
>
> *As there is little by way of consistent, 'tidy', predictable evidence for scale aversion both in research and public reaction to major accidents, it is neither practical nor sensible to attempt to measure it in mathematical terms.*

It was also noted public reaction is very dependent on media coverage, which is an amplifier of society's reaction. Earlier research by Slovic et al (1984) found the societal impact of an incident is determined to an important degree by what it signifies, eg a system is not as well understood as previously thought. Other factors include the distinction between voluntarily accepted risks and involuntarily accepted risks, the level of personal control as well as 'vulnerability', eg children (Keeney 1980).

Taig and GNS Science (2012) comment that in the 1990s the railways in Great Britain introduced a higher monetary value to be attached to saving lives for crashes involving multiple fatalities than for individual crashes, in response to regulatory pressure.

Subsequent research showed there was considerable public disquiet about a public policy that would prioritise 'Saving lives in multi-fatality accidents' over 'Saving the most possible lives'. A research project funded by the UK RSSB (Covey et al 2008) found less than half the sample thought preventing a fatality in a multiple fatality event took priority over a fatality in a single fatality event.

The policy of attaching higher monetary values to multiple fatality crashes was widely consulted on, and then dropped. These findings are supported by Swiss research on road protection from avalanches, where the risk appetite of both lay people and natural hazards experts was assessed (Rheinberger 2010). The research found no evidence in either group of an overall appetite for non-linear increases in risk aversion with increasing fatalities.

In summary, while scale aversion relationships have been applied in some countries there is a growing body of evidence in favour of a simple linear relationship between risk aversion and casualty counts. This suggests scale aversion considerations should be applied with care, if at all.

C2.3 FN curves

FN-curves are a graphical presentation of the distribution of the numbers of fatalities in accidents. They plot the frequency F(N) of accidents with N or more fatalities, where N ranges upward from 1 to the maximum possible number of fatalities in the system.

Some examples of FN curves for global disasters and for OECD countries are provided in figures C.1 and C.2. The grey dashed line has a slope of -1 on this log-log plot. Event types with slopes flatter than -1 tend to have most fatalities in a few larger events (eg earthquakes). Event types with slopes steeper than -1 tend to have most fatalities in small counts (eg road transport). The graphs start on the left-hand axis at 10 fatalities as this is the cut-off limit of the data set.

Figure C.1 FN curves global major disasters (1962–2011). Source: Taig and GNS Science (2012)

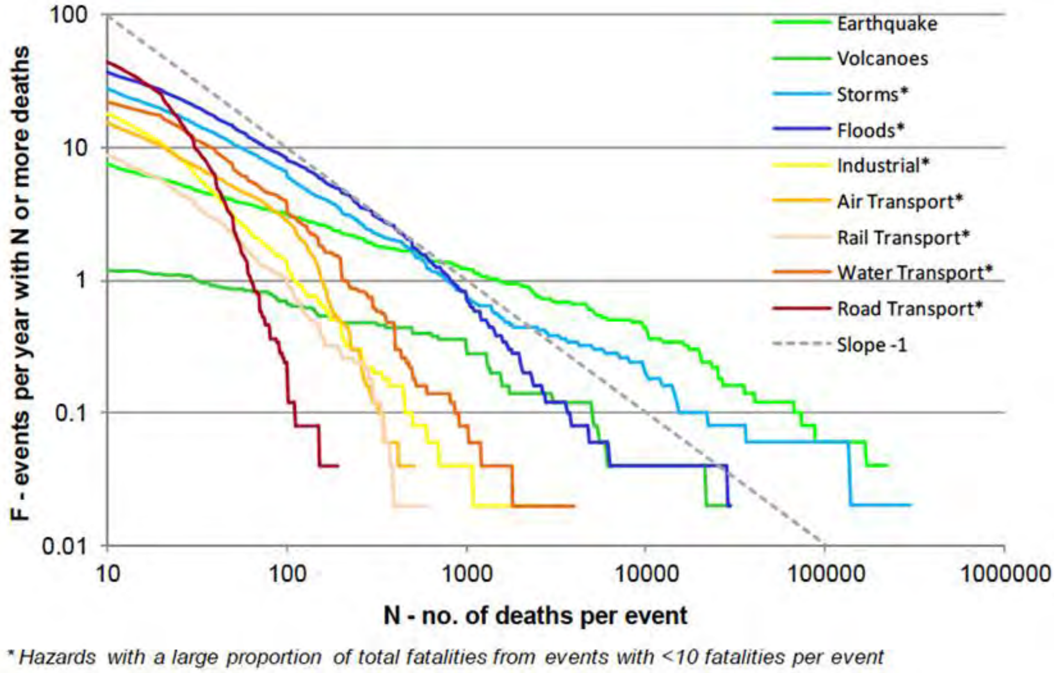
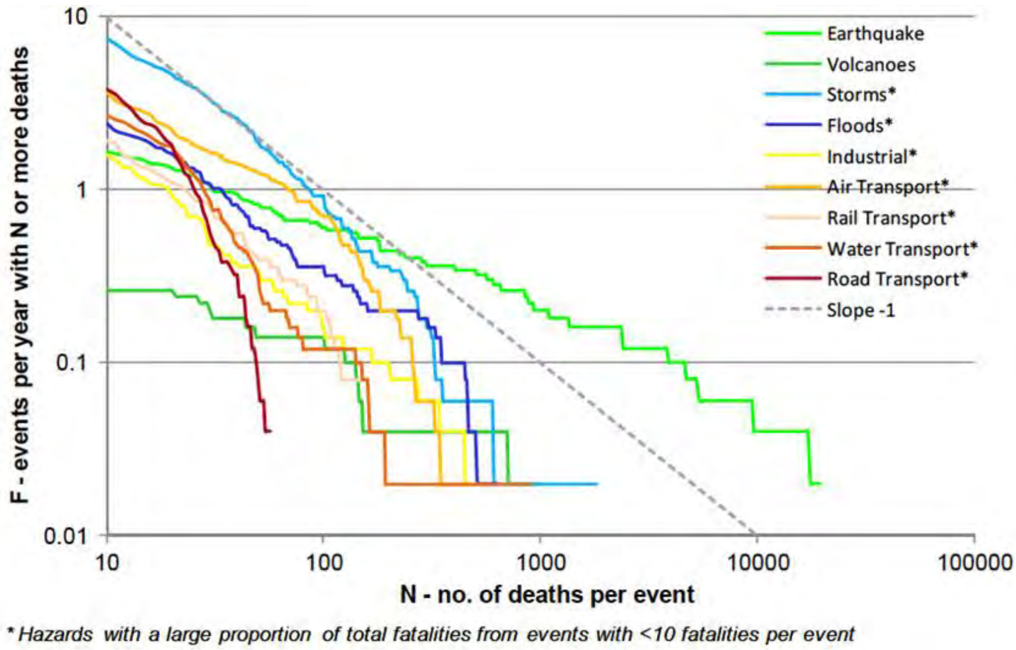


Figure C.2 FN curves OECD countries (1962–2011) Source: Taig and GNS Science (2012)



Comparing the two graphs shows storms and floods are better controlled in OECD countries, as can be seen by the absence of high casualty events. This illustrates what improvement in risk management looks like: all things being equal a lower risk will plot lower and to the left of a less well-controlled risk. For instance, over this period rail transport was safer in OECD countries than air transport. To the extent these risks were acceptable to the public in those jurisdictions the FN curves illustrate the public risk appetite over that period. However societal risk appetite is changing over time and always in the direction of lower risk. For instance:

- Improvements in aviation safety now render it the safest form of travel on a passenger km basis.
- The road toll has been cut through strenuous education and enforcement efforts, through heavy expenditure on roads, and through safer vehicle designs.

While the risk from road travel remains much higher than rail, expectations improving safety and reducing risk pervades across modes. Longstanding and intensive road transport safety campaigns have changed public perceptions of what is acceptable in terms of personal behaviours on the road. This changed culture is now translating into increased expectations for the care and safety provided by other transport modes, such as rail.

These changes in public risk appetite also have implications for heritage service operators. The public enjoys a heritage experience, but can also reasonably expect the service is provided in such a way it meets modern safety levels. The desire for an authentic experience is unlikely to extend as far as an authentic likelihood of being maimed or killed according to the safety standards of a bygone era.

C2.4 Accounting for injuries

The valuation of injuries is difficult. In the Netherlands it has been noted the number of people killed is a good proxy for the extent of a disaster, so risk assessment standards are set on this basis (Ale 2005). Accordingly there is a degree of international consensus on fatality risks, but not on injury risks.

For these reasons this section focuses on fatalities, while recognising hazards that mainly cause injuries also need to be well controlled.

In practice, application of the ALARP/SFAIRP principle results in fatality rates that are much lower than the maximum tolerable levels.

C2.5 Risk acceptance criterion

The general duties of rail participants are set out under section 7 of the Railways Act:

> *(1) A rail participant must ensure, so far as is reasonably practicable, that none of the rail activities for which it is responsible causes, or is likely to cause, the death of, or serious injury to, individuals.*
>
> *(2) No rail personnel of a rail participant may do or omit to do anything in respect of a rail vehicle, railway infrastructure, or railway premises if he or she knows or ought reasonably to know that act or omission will cause, or will be likely to cause, the death of, or serious injury to, individuals.*

Application of the SFAIRP principle is discussed in detail in chapter 5 of this report. Essentially SFAIRP is the same concept as ALARP; however, the change in terminology offers an opportunity to break from the previous practice of assuming no further improvement was required in the broadly acceptable region. So how can SFAIRP be applied in practice?

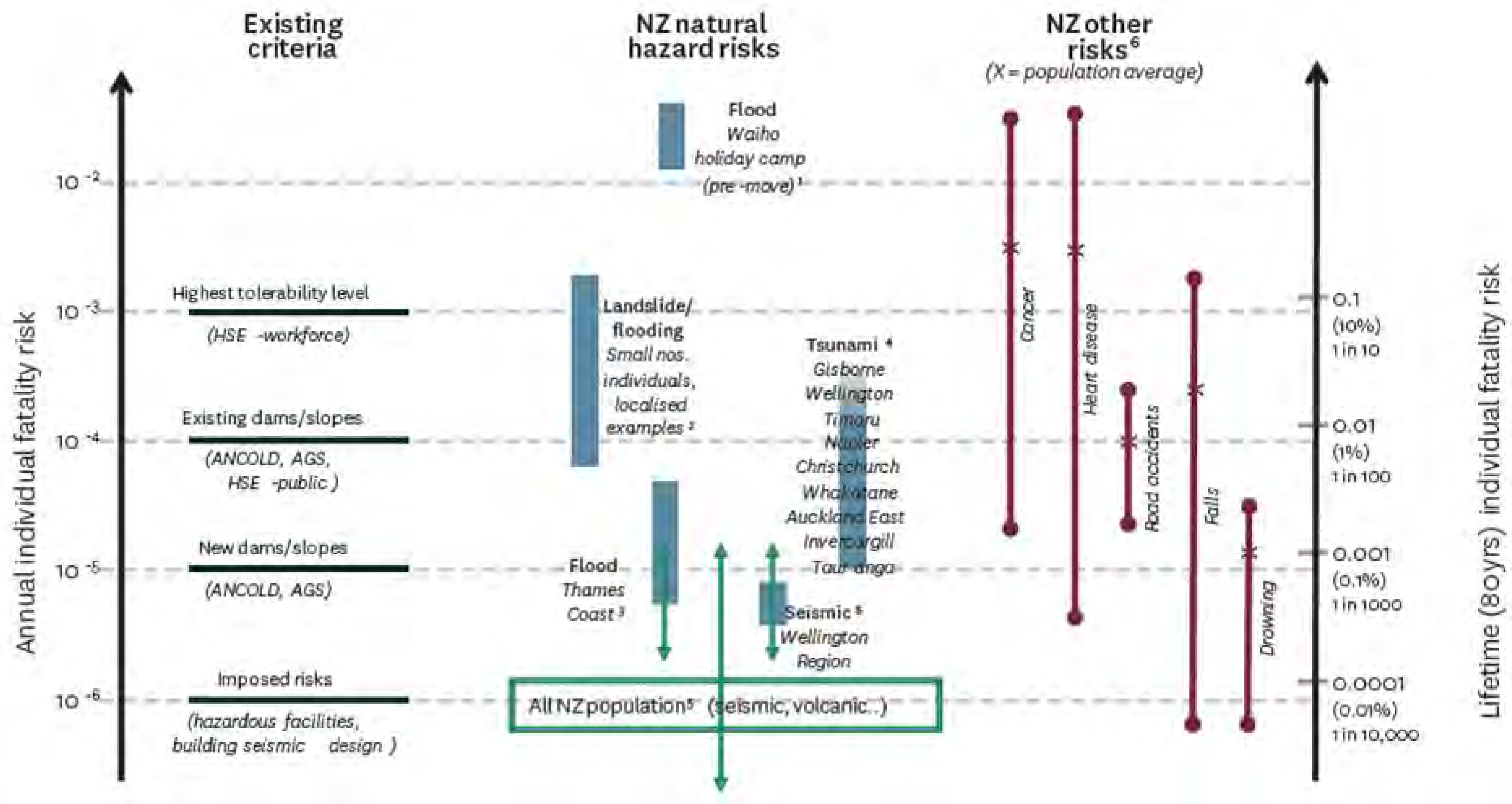
A comparison of the risk criteria discussed above alongside some New Zealand natural hazards and other hazards is provided in figure C.3. The range of individual probabilities varies enormously. In part this reflects that dying of natural causes is seen as inevitable and hence is accepted. However the expected standards for man-made and imposed risks are much higher.

What is also apparent from figure C.3 is that the 'risk-landscape' is complex. Implicitly, because these levels of risk are allowed to persist, there is a degree of acceptance by society. The level of acceptable risk depends on the circumstances. For instance a railway-related death may be viewed quite differently depending on whether it is a suicide (deliberate), a trespasser (voluntary and unauthorised), at a level crossing (voluntary and in control), a railway worker (voluntary, control varies), a passenger (voluntary, no control), or a bystander (involuntary imposed risk). This research has attempted to take this into account in the risk assessment method (see section 7.4.2).

A research project funded by the UK RSSB on the value of preventing a fatality (Covey et al 2008) found:

> *For cases in which adult victims are behaving irresponsibly (including adult trespassers engaged in acts of vandalism, car drivers behaving irresponsibly at level crossings, and drunks falling from platforms), as well as child trespassers engaged in acts of vandalism, and suicides, the VPSF ratios relative to the baseline case all lie in the region of 0.4:1 so that for such cases it is recommended that the VPSF is set equal at 40% of the baseline figure.*

Figure C.3 Comparison of New Zealand risks and existing criteria. Source: Willis (2014)



Notes:
1. Derived by the authors from results of MCDEM risk assessment (Optimx, 2002)
2. Estimated by the authors based on reasonable event return periods and likely consequences - see Report Section 4.1.2
3. Upper estimate for High Risk zones; arrow denots wide range of risks downward (URS, 2003)
4. AIFR at 2-4m above sea level, no effectiveness assumed for warning (Webb, 2005)
5. Averages over large populations; arrows denote likelihood of substantial groups of people at higher/lower risk
6. Bars show range of values across age bands for men and women (Ministry of Health, 2008)

Noting SFAIRP governs the protection afforded to hazards, how do operators know when to stop in their quest for improved safety? Put another way, when is it safe enough? The answers have important policy implications, as rules that are too lax will result in avoidable rail deaths and injuries. Conversely rules that are too strict may increase costs and charges, diverting users into less safe transport modes and ultimately resulting in a worse societal outcome. Alternatively, if funded from the public purse, additional costs to meet stringent safety standards may divert funding from more cost-effective means of advancing societal wellbeing, such as education and health care.

One tool of assisting with comparing and ranking alternatives, and with deciding on the cut-off is to calculate the implied cost of an avoided fatality (ICAF), where:

ICAF = C/ΔPLL

C= net cost of option

ΔPLL = change in potential loss of life

Conceptually ICAF is a type of incremental cost–benefit analysis. Useful guidance on applying such incremental analyses to Transport Agency funded projects is provided in appendix A19 of the recently updated *Economic evaluation manual* (NZ Transport Agency 2016a).

The current value of a statistical life (VSL) set by the Ministry of Transport is $4.06 million per fatality. Allowing for the other social cost components (such as loss of productive output and medical costs) gives an updated average social cost per fatality of $4,094,500 at June 2015 prices (MoT 2016c). In the UK, the baseline rail 'value of preventing a statistical fatality' is set at the same level as in road project appraisal (Covey et al 2008). In 2016 this was set at approximately £1.86 million[107] (RSSB 2016).

The VSL is derived from a 1991 study (Miller and Guria 1991). The original study asked approximately 600 people what they would be willing to pay for various improvements in road safety. While there are some reservations about extrapolating this value over such long periods of time (Radio New Zealand 2014), this is the basis of transport cost–benefit analysis in New Zealand. An important feature of this estimate of VSL is that it already factors in a willingness to pay for safety improvements, albeit for a voluntary activity (ie road usage) over which the user has direct control.

Advice published by the HSE gives several examples, suggesting an ICAF value of less than or equal to the VSL is clearly reasonably practicable, whereas a cost of 15 times the VSL would be disproportionate (Franks 2006). In the absence of definitive case law the HSE comments suggest each decision needs to be addressed individually taking account of both the level of individual risk and the extent and severity of the consequences of major incidents. As a rule of thumb a ratio of 3 is reported as being advocated by HSE for workers; and for the public the ratio varying from 10 for higher risks to 2 for lower risks (HSE 2016).

These observations provide a basis for decision making: if all available options are ranked by ICAF and implemented where ICAF is less than the appropriate ratio of VSL, then it may be reasonably argued that the system is in a SFAIRP state for that risk[108].

It is noted, however, this is not necessarily a permanent condition. If the cost of an option was to reduce, or less costly options were to become available, then the ICAF test would need to be run again. This is part

[107] Approximately NZ$3.15 million as at 2 November 2016.

[108] In the UK offshore petroleum industry an ICAF value of £6m was reported to be typical in 2006, representing an acceptable ratio of six times the life value applied by HSE at that time (HSE 2006).

of a continuous duty to maintain the system in a SFAIRP state. Also societal expectations are changing and becoming less tolerant of risks.

C2.6 Basis of decision making

In an open democratic society, decision making on acceptable risks should reflect broad societal values. However there have been significant shifts in the preferences, values and expectations of society over time. These changes are linked to factors such as the ease of access to information, the rise of social media and increasing affluence.

There is a growing propensity to scrutinise benefits against potential undesirable side effects. This is particularly true for risks which could lead to catastrophic consequences, where the consequences may be irreversible or which lead to inequalities because they affect some people more than others (HSE 2001).

C2.6.1 Alternative safety paradigms

Research by Ball and Boehmer-Christiansen (2002) and others suggest many institutions and their associated professions have carved out their own specific approach to safety decision making, sometimes in isolation from other professions, and in many cases are not consistent with each other. Inconsistencies in professional decision making are fodder for the media, and the subsequent public exposure of these differences may itself lead to the generation of societal concerns. Ball and Boehmer-Christiansen (2002) identify eight different concepts of safety (figure C.4), although not all may be applicable to New Zealand.

Figure C.4 Eight alternative concepts of safety (Ball and Boehmer- Christiansen 2002)

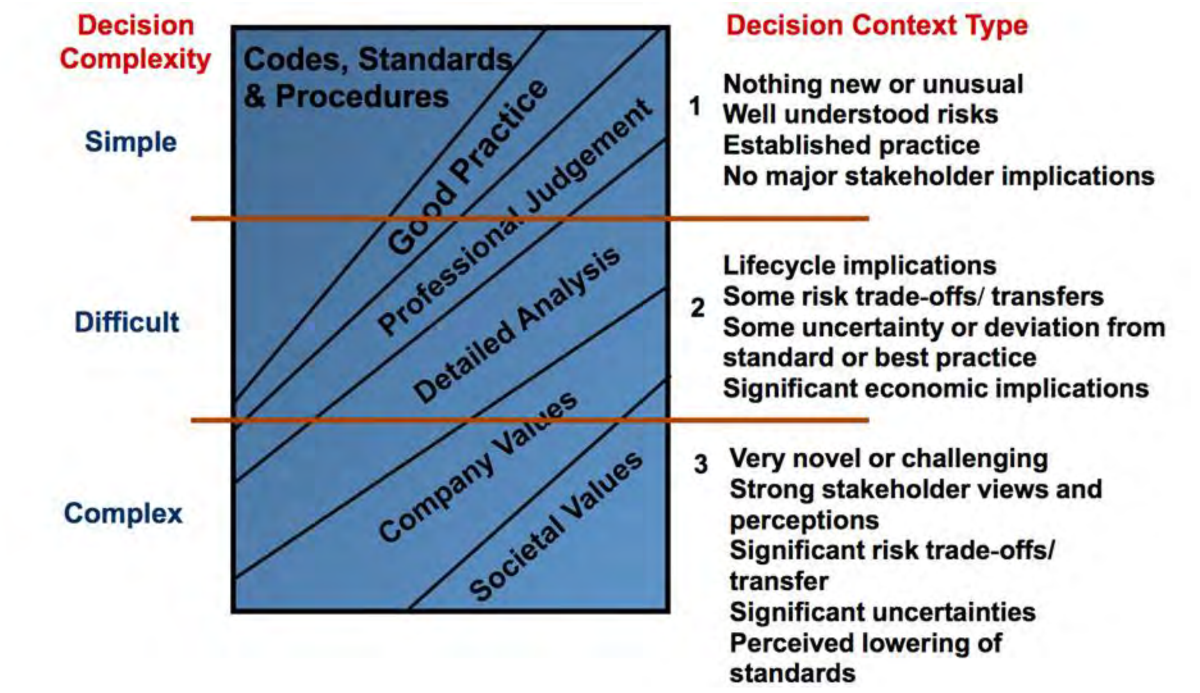
Safety criterion	*Zero risk*	*Safety targets*	*Standards, CoPs and guidance*	*Absolute risk*	*Risk factors*	*Risk assessment*	*Cost-benefit analysis*	*Risk tolerability and ALARP*
Typical adherents	Pressure groups	National and international agencies. Major industries	Traditional industries, lower courts, accident investigators	Actuaries and natural scientists	Epidemiologists and health scientists	Safety engineers and applied scientists	Economists	Higher courts, regulatory bodies, international agencies and major industries
Basis of approach	Commitment	Political desire	Expert judgement	Historical data	Evidence	Scientific simulation	Utility theory	Case law (in the UK)
Strengths	Simplicity, single-mindedness	Clarity of overall policy goal	Should reflect a broad swathe of expert opinion. Tested over time	Enables insurance companies to set premia	Scientific basis	Analytical tool. Ability to forecast the unknown	Considers both costs and benefits of safety measures	Considers wider implications of safety measures including cost, practicality etc
Limitations	Associated benefits foregone. Cost of control disregarded	Top down approach which may be inconsistent with the sum total of individual safety interventions	Validity and motivation of judgements unclear. A bottom up approach which may be inconsistent with policy goals	Other social priorities are disregarded	Uncertainties, causality, and the question of 'how safe is safe enough?'	Uncertainties in assumptions, probabilities and dose-response functions	Anchored in a particular philosophy. Hidden assumptions and methodological problems, particularly in valuing benefits	Difficulty of striking a balance between competing attributes of a decision
Examples	'Vision Zero', hand gun control, machinery guards, food additives	Injury targets. Air quality guidelines. Sustainability	Product safety standards. Workplace CoPs. Numerous personal injury court cases	Simple comparison of risks from different activities	Public exposure to radon and air pollution, playground safety	Occupational safety assessment	Railway and offshore safety investment decisions and major hazard control	Major hazard control, strategic planning applications

Figure C.4 shows there is a wide range of perspectives on societal concepts of safety. Parties who do not share the values implicit in a particular form of assessment may see the outcome of the exercise as invalid, illegitimate or even not pertinent to the problem (HSE 2001).

C2.6.2 Codes and standards

The diagram in figure C.5 integrates several of the processes listed in Ball and Boehmer-Christiansen's (2002) table, showing how codes and standards can guide simpler decisions, but that societal values become more important when there are significant risk tradeoffs. Public expenditure on rail safety versus safety performance could be regarded as such a tradeoff.

Figure C.5 Decision- making framework (HSE 2006)



C2.6.3 UK practice

HSE (2001) identifies three main methods of setting decision-making criteria:

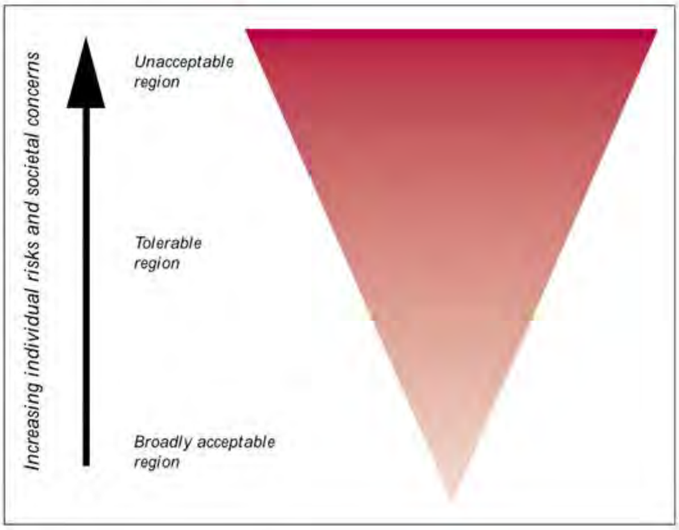
1 **An equity- based criterion**, which starts with the premise that all individuals have unconditional rights to certain levels of protection. This leads to standards, applicable to all, held to be usually acceptable in normal life, or which refer to some other premise held to establish an expectation of protection. In practice, this often converts into fixing a limit to represent the maximum level of risk above which no individual can be exposed. If the risk estimate derived from the risk assessment is above the limit and further control measures cannot be introduced to reduce the risk, the risk is held to be unacceptable whatever the benefits.

2 **A utility- based criterion** which applies to the comparison between the incremental benefits of the measures to prevent the risk of injury or detriment, and the cost of the measures. In other words, the utility-based criterion compares in monetary terms the relevant benefits (eg statistical lives saved, life-years extended) obtained by the adoption of a particular risk prevention measure with the net cost of introducing it, and requires a particular balance to be struck between the two. This balance can be deliberately skewed towards benefits by ensuring there is gross disproportion between the costs and the benefits.

3 **A technology- based criterion** which essentially reflects the idea that a satisfactory level of risk prevention is attained when 'state of the art' control measures (technological, managerial, organisational) are employed to control risks whatever the circumstances.

The HSE considers the three methods are not mutually exclusive but each was built into the tolerability of risk framework adopted by HSE (figure C.6).

Figure C.6 HSE framework for tolerability of risk (HSE 2001)



C2.6.4 Summary

Setting acceptable standards is difficult. By its nature the setting of standards raises questions about societal values and where the balance should be struck between competing demands. That does not mean it is an impossible task as some standards have been set; these are reviewed in the following sections.

C2.7 Historical safety performance in New Zealand

The HSE upper bound of tolerable risk for workers now appears to be lenient. For instance, in the New Zealand forestry industry over the five-year period 2011 to 2015 inclusive there were 23 deaths (WorkSafe New Zealand 2016c). From Statistics New Zealand data on average employment in the forestry industry over the period the cumulative exposure is estimated by Navigatus to be 22,000 employee years (Statistics New Zealand 2016b). The average annual individual fatality rate in forestry over the five-year period was therefore approximately $1x10^{-3}$. The recent societal concern over forestry deaths illustrates that such fatality rates are not regarded as acceptable in current day New Zealand, even for high-risk industries.

Over the same five-year period there were no recorded rail worker fatalities. There has since been one serious incident involving a worker using a HRV who subsequently died. However, this was recorded as a construction worker fatality by WorkSafe New Zealand. The vast majority of employees in the New Zealand rail industry are employed by the national rail operator. The cumulative exposure over the five-year period is estimated to be approximately 20,000 employee years.[109] If one fatality over five years is typical, this

[109] Estimated from employee counts in KiwiRail annual reports. Excludes counts of Cook Strait Ferry and corporate employees. Includes 15% loading to account for contractor staff engaged in activities in rail corridor and rail workers for other operators.

leads to an estimated average individual rail worker annual fatality rate of 5 x10^{-5}. Given the low count of fatalities there is a significant level of uncertainty around this estimate. However, taken at face value, this safety performance lies towards the middle of the range between the upper and lower HSE tolerable bounds for all workers.

A comparison of fatality rates across a range of New Zealand industries and transport modes is presented in figure C.7. The left-hand side of figure C.7 shows the annual individual fatality risk for New Zealand rail workers in comparison with other New Zealand industries[110]. The estimated individual fatality risk to rail workers is higher than in industries such as construction and manufacturing and lower than mining, agriculture and forestry.

The right-hand side of figure C.7 provides a comparison of passenger fatality risk for different modes of transport. The figure shows a range of rail passenger fatality risk estimates derived from the Navigatus rail risk model for the most exposed individual.[111] The figure shows the fatality risk per year for the most exposed rail passenger is lower than the average fatality risk of travel by road[112] and similar to the most exposed aviation passenger.[113]

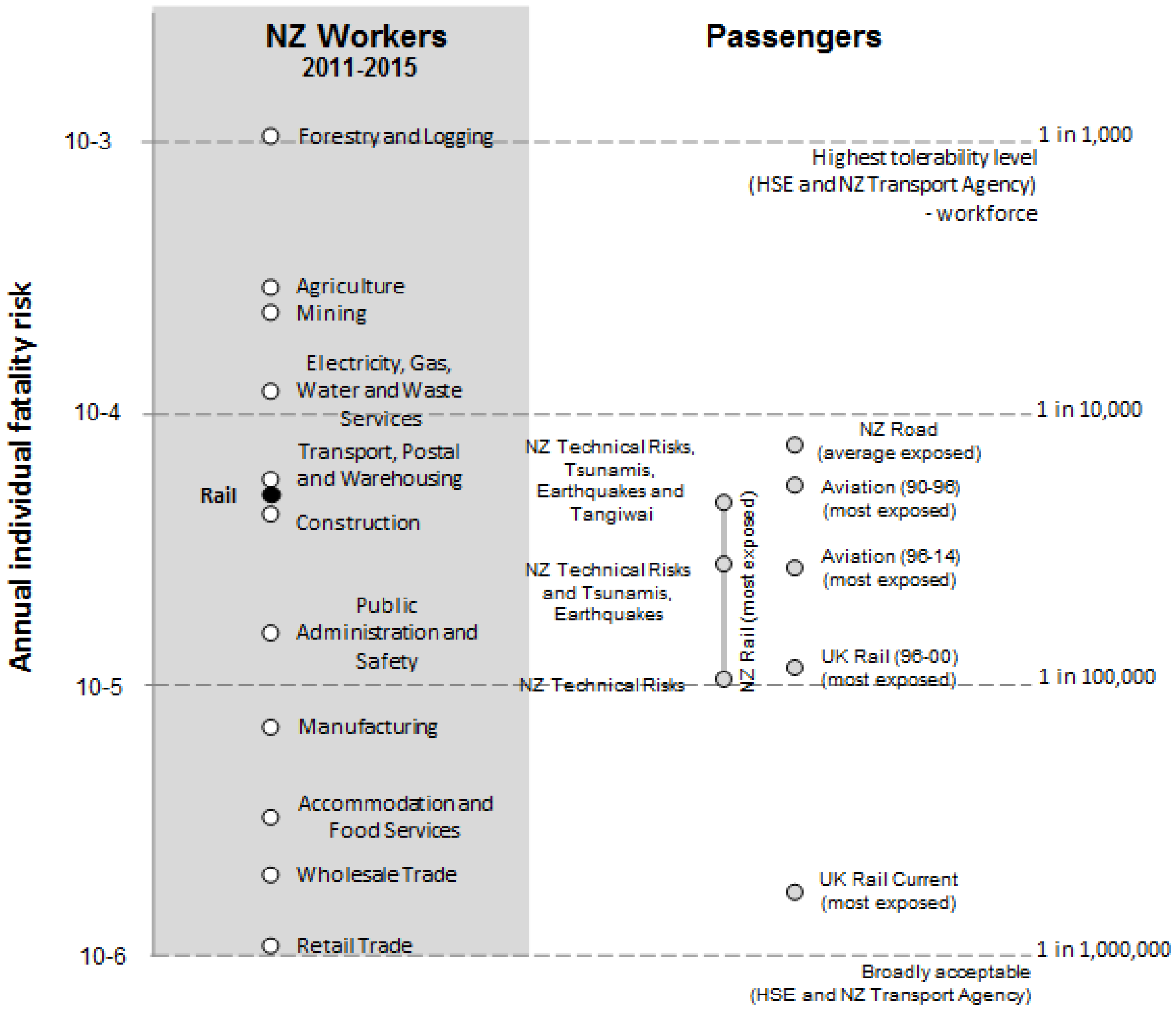
[110] Derived from fatality data by industry (WorkSafe New Zealand 2016c) and employment counts (Statistics New Zealand 2016b; Statistics New Zealand 2016c). All estimates exclude fatalities due to work-related road crashes. For clarity not all industries are shown.

[111] For a hypothetical most exposed passenger for rail, based on 500 journeys per year (5 return journeys a week for 50 weeks). The lower figure represents technical risks only such as derailments, collisions and civil works failures. The middle figure shows the effect of adding natural hazards such as tsunamis into the assessment. The upper figure includes the Tangiwai disaster, treating it as a 150-year return period event. The Navigatus rail risk model is described in chapter 7 of this report.

[112] Annual fatalities per person (Statistics New Zealand 2016a), taking 90% of New Zealand population as being exposed and includes drivers.

[113] Risk for a hypothetical most exposed passenger for aviation, based on 200 journeys per year (2 return flights per week for 50 weeks). The 1990 to 1996 estimate was derived from Savage (1999) estimate of fatality risk per 1,000 enplanements. The 1996 to 2015 estimate was derived by applying the proportion of passengers fatally injured in 'fatal accidents' from historic A320 crashes, (largely representative of the New Zealand fleet) (Aviation Safety Network 2017), to the average fatal crash rate reported by Boeing for the period (Boeing 2015).

Figure C.7 Annual individual fatality risk comparison[114]



The comparisons with other transport modes are on an annual individual fatality basis. If the comparison was made on a per passenger km travelled, then we would expect to see aviation as the safest form of transport, followed by rail, then road.

For comparison, estimates are also presented for passenger safety performance in the UK rail industry in the late 1990s along with a more recent estimate.[115] These indicate substantial progress in passenger safety in the UK rail industry, possibly reflecting substantial investments in rail safety systems. Similarly

[114] New Zealand rail technical risk estimate derived from Navigatus rail risk model. Technical risk estimate allows for 53% estimate of passenger fatalities as proportion of all fatalities on passenger services, derived from European accident statistics 2010–2012 inclusive (ERA 2014). Middle includes technical risks, and all fatalities estimated from tsunamis and earthquakes. Higher bound includes Tangiwai (as 1 in 150-year event).

[115] For a hypothetical most exposed passenger for rail, based on 500 journeys per year (5 return journeys a week for 50 weeks). UK 1996-2000 risk estimated from 1 in 43m journey fatality risk – refer HSE (2001, table 5). Current risk derived safety risk model for hazardous events classified by Navigatus as technical risks. Excludes trespassers, level crossings, assault, slips, trips and falls.

we expect safety performance improvements have also occurred in New Zealand rail safety performance through innovations such as the introduction of ATP in Auckland, new passenger train rolling stock and train control improvements. Similar improvements can be seen in the aviation fatality rates as regulators, manufacturers and operators continually improve safety performance.

All these assessments must be regarded as indicative estimates of the underlying level of risk, rather than based on actual fatalities within the system. No passengers were killed on either the New Zealand or UK rail systems in the latest periods of analysis. As the three plotted New Zealand rail points show, the answer is influenced by the risks included in the scope and how far back you look. For rare events such as fatal incidents there may always be a significant degree of uncertainty regarding the true levels of risk.

The UK rail data shows safety performance is improving internationally. This mirrors societal expectations of improved safety across all transport modes. We expect the pressure for improved safety performance will only accelerate. For instance some cars already have autonomous braking systems to avoid collisions. Once such systems become ubiquitous in the private car fleet, the public may come to expect the rail system to be equipped with at least equivalent levels of safety technology.

While improved rail safety performance seems self-evidently better, perverse societal outcomes are possible if demands for improved safety result in such increased rail charges that users opt for less safe transport modes. For example in the UK, on the competitive London to Manchester route, rail fares average 10 times the cost of long-distance bus fares[116]. Bus passengers, who tend to be poorer[117], use a less convenient and less safe transport mode. Levels of expenditure on rail safety may have social equity implications if they lead to more people, and especially those who are poor, using less safe transport modes.

C2.7.1 Further analysis on New Zealand rail worker risk

Figure C.8 shows a longer data series for annual fatality risk (represented as an annual data point and moving average annual rates (5- and 10-year)). The data for the number of fatalities has been compiled by the researchers from a number of resources[118] but is thought to be comprehensive for the period. Staff numbers are based on the numbers employed by the national rail operator of the time.[119] Staff numbers were rounded to the nearest 1,000 as numbers are not precise (eg some numbers include office staff and exclude contractors).

Measured on a single year basis, a single fatality in any year puts the rate into the highest tolerable risk band. This is due to the small size of the rail industry and likely does not represent an actual change in the industry's risk profile.

[116] In the UK both rail and bus services are open to competition so fares should reflect underlying costs. Fares compared for standard class for one person purchased one week in advance, for travel on Wednesday 1 June, 2016 for travel originating from London. Average of lowest one-way fares for direct services only with no concessions as offered across all departure times by one rail (46 services) and two bus operators (19 departure times). The cheapest rail fare was 2.3 times more costly than the most expensive bus fare.

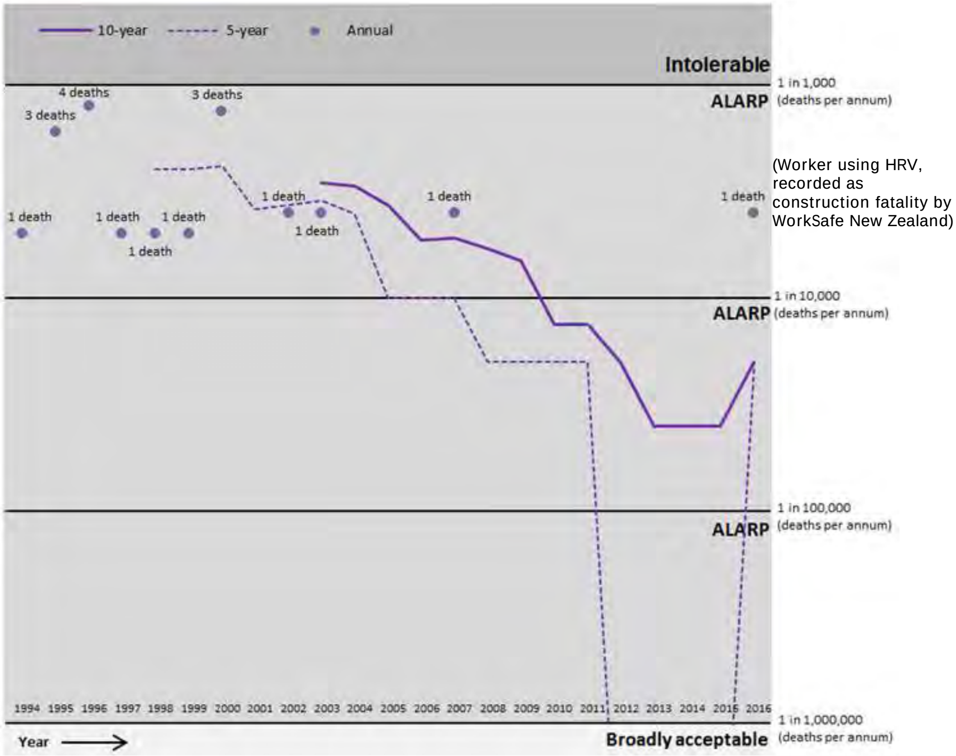
[117] In the UK the people from the richest quintile of households travel the greatest cumulative distance by rail on an annual basis, and the least by bus. Vice versa for the poorest quintile. Source: Department for Transport (2014).

[118] TAIC reports, the Ministerial Inquiry into TranzRail (2000), *Your life for the job* (Armstrong 2013) and Google searches.

[119] Staff numbers primarily came from KiwiRail annual reports, *Blood on the tracks; critically re-reading a Government Occupational Safety and Health Inquiry* (Prichard nd), (figure 1 Tranz Rail's key indicators 1993–2001), and Treasury (1999, figure on p53). Numbers between 2003 and 2010 were assumed to have remained constant with the following and preceding years.

Since 2010, both the 5- and 10-year moving average annual rates have been below 1 in 10,000. To stay within this band in the future, there could be no more than two worker fatalities within five years, or no more than four worker fatalities within 10 years (assuming employment numbers remain constant).

Figure C.8 Annual individual fatality risk to New Zealand rail workers. 10- and 5- year rates are a moving average.[120]



Given the improvement in safety performance over the last 15 years, and assuming the rail risk profile remains similar, we would suggest the bound between tolerable and intolerable risk for workers is too lenient. An upper bound of tolerability of a 1 in 10,000 annual fatality risk may be more appropriate to the risk profile the rail industry has achieved. This bound would relate to the rail system, but might not be appropriate for abnormal activities (such as debris excavation following a landslip or tunnelling). If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry.

The current 'broadly acceptable region' of risk has an upper bound of one in one million fatality risk for workers. We consider this appropriate, so long as risk is still reduced SFAIRP.

C2.8 Acceptable individual fatality risk in rail

Countries have struggled with setting acceptable individual fatality risks for rail transport. In part this may be due to societal concerns about rail transport which have led to the adoption of interventions that are in excess of the levels that would be justified in a standard cost–benefit analysis.

[120] The figure includes one serious incident involving a worker using a HRV who subsequently died and which was recorded as a construction worker fatality by WorkSafe New Zealand. There may have been other incidents related to rail activities that have been recorded as construction fatalities and have not been captured in the figure (eg construction of a train station).

There are three methods commonly used to develop such risk standards in railways:

1 Adopt a standard accepted for a similar activity

2 Ensure new systems are as safe as, or better than those they replace

3 Benchmark performance against other jurisdictions.

As an example of the first method, in the UK the standards for fixed installations have also been applied to a railway line along which hazardous goods are transported (HSE 2001).

The CSM RA is an example of the second method. The CSM offers three ways of demonstrating equal or improved safety over existing systems.

An example of using the third method, benchmarking, to drive improvement is given in the following description of European practice from a recently completed Transport Agency funded research project on international benchmarking of rail safety (Brown 2016):

> *The European Union (2004) Railway safety directive (2004/49/EC) includes the requirement for EU member states to ensure that safety is generally maintained and, where reasonably practicable, continuously improved. The ERA (European Rail Agency) is mandated to develop common safety targets (CSTs) and national reference values (NRVs) to monitor the performance of member states. The NRVs are designed to reflect observed baseline levels of safety in each member state. The ERA monitors each member state's performance against its NRVs to determine whether levels of safety are at least being maintained in each of the defined safety performance categories. These categories are defined as the common safety indicators (CSIs), with the national safety authorities submitting performance against each to the ERA as part of their annual safety reports.*

In New Zealand, the HSE individual fatality risk criteria were adopted in the *Rail safety licensing and safety assessment guidelines* (Land Transport NZ 2006) and into NRSS4 (NRSS-E 2007). The risk levels remain consistent with current HSE guidance, although actual safety performance is expected to be significantly better than the limits given through the application of SFAIRP.

C3 Risk acceptance modifiers

In this section we summarise modifiers which can influence acceptable levels of risk:

- scale aversion
- societal concern.

C3.1 Background

Events with particularly large fatality counts lead to intense scrutiny and can come to be seen not just as direct failings of the organisations involved but as a failure of the overall regulatory system (Black 2014). New Zealand examples include the Cave Creek Tragedy in 1995 (14 fatalities) which led to law changes holding government departments accountable to the same standards expected of others. More recently the Pike River Disaster (29 fatalities) has resulted in profound changes to health and safety regulation in New Zealand.

C3.2 Scale aversion

The term *societal risk* is often used for the concept of a single event that kills or injures a lot of people, such as the 1953 Tangiwai disaster, in which 151 people were killed.

Central to the concept of societal risk is debate around whether societies are more averse to many fatalities in one event compared with the same fatality count spread over a longer time period (called 'scale aversion' by some commentators).

C3.2.1 Societal concern

The HSE classes societal risk as a subset of a broader set of *societal concerns*. Societal concerns are defined by HSE (2001) as:

> *Risks or threats which impact on society and, if realised, could have adverse repercussions for the institutions responsible for putting in place the provisions and arrangements for protecting people, e.g. Parliament, of the Government of the Day.*

HSE (2001) identified societal concerns as including matters such as nuclear power generation, genetic modification of organisms and railway travel. Railway travel can seem strange to read in the same sentence as nuclear power and GMOs. Is this an aberration, representing societal concerns of the time in the UK and of little or no relevance to New Zealand in 2016?

In the 1990s, safety performance of the British rail system, while improved over historical levels, lagged behind continental Europe, ranking 12th out of 17 European nations[121]. The period preceding the HSE report had seen a number of high-profile UK rail crashes, including Southhall in 1997 (seven killed) and Ladbroke Grove in 1999 (31 killed). Both of these crashes could have been prevented by ATP. These crashes influenced the decision in 1999 to require installation of a form of ATP, known as a train protection and warning system (TPWS), from 2003.

In its standard form, TPWS stops a train once it has passed a signal set at danger. This means some collisions may still occur, if there is insufficient overrun distance before a critical conflict[122]. A European train control system (ETCS), as recently installed in Auckland, stops trains if they pass a signal set at danger (at a point beyond the SPAD signal). Such a system was deemed to be too expensive for the UK at that time. Despite being less expensive than a full ATP system, TPWS was estimated to cost £11m per life saved (Bray 2005). At that time, the HSE value of a life saved, derived from transportation studies, was £1m (HSE 2001). The introduction of the system was also related to interoperability benefits to allow trains to move through Europe. This represents a cost–benefit ratio of around 11. We interpret the magnitude of this ratio as reflecting the level of societal concern at that time to avoid the risk. This significantly supersedes the calculated benefit as determined by 'value of a life saved' or any other methods of valuing fatalities (Jones-Lee and Spackman 2013).

Ball and Boehmer-Christiansen (2002) cite the 'saga' of ATP in the UK as illustrating how inconsistencies in professional decision making can lead to the generation of societal concerns. British Rail and Railtrack did not seek to implement ATP, believing it was not justified on reasonable practicability grounds. Other groups, however, approached the matter from a different perspective and found it difficult to comprehend how the railways could avoid wishing to implement a system which was perceived to be working in some other European countries (ie 'is practicable' under considerations of SFAIRP) and which apparently saved lives.

A similar example of societal concern arose in New Zealand in the 1980s when cost–benefit analysis failed to justify the installation of median barriers on Auckland motorways. A series of well-publicised head-on

[121] European countries with over 1 billion train km during the period 1980–1999. Data sourced from (Evans 2011).

[122] Further protection can be achieved through additional TPWS installations ahead of critical signals to slow or stop trains in advance of the signal.

crashes and subsequent public clamour led to both the installation of barriers and to a fundamental change in the method used by the National Roads Board to value an avoided fatality (Clough et al. 2015).

As an illustration of the impact of societal concerns in another setting, in 2008 the US Congress passed a rail safety law requiring the implementation of positive train control (PTC) technology across most of the US rail network. PTC is a form of automatic train protection. The bill was developed following the 2008 collision of a passenger train with a freight train in California, which resulted in 25 deaths. At the time of being mandated, the cost of implementing PTC over 25 US commuter railroads was estimated to be USD$2 billion. If the system had been in place on commuter trains, it would have prevented two collisions claiming 27 lives over a 20-year historical period (Mann 2013). This represents an investment of US$74m per life saved for the commuter networks part of the US rail system. The measure has now been mandated for all Class 1 railways (including freight), and the total cost for the freight railways alone is now in excess of $7.9 billion[123].

These examples illustrate how safety performance can rapidly become a societal concern. Concerns in other countries have focused on passenger safety, leading to higher levels of investment in safety systems in relation to expected benefits. Evans (2013) provides a useful summary of these issues in his consideration of how the terminology ‘grossly disproportionate’ has been applied in practice in transport safety, influenced by societal concerns and the domino effect that the adoption of a preventive measure by one jurisdiction has on others. In the current New Zealand context rail passenger safety is not currently regarded a societal concern, but it has the potential to become so after any crash that results in a high casualty count. In effect the safety performance of the New Zealand rail system is one serious incident away from becoming a focus of societal concern.

C3.3 Apportionment of acceptable risks

Decision making for technical systems such as railways and other transport modes is usually concerned with one component of the system at a time. What is needed is some way to break down the overall acceptable risk between critical systems. This process is called *apportionment*.

An example of apportionment, as applied by Navigatus and others in the aviation sector, is to apportion risk between phases of flight (take off, cruise and landing), and then between failure modes in each of these flight phases, based on international crash rates.

Another example in the apportionment between failure modes is the European Aviation Safety Agency criteria for aircraft design. The risk target is the failure of a system resulting in catastrophic outcomes (eg hull loss), which should not occur more often than 1.0 x 10^{-9} per flight hour. Derivation of the 10^{-9} risk target is summarised in JAR AMJ 25.1309 (cited in (Det Norske Veritas 2010)) as follows.

- Historical evidence indicates a risk of a serious crash due to operational and airframe related causes of approximately 1 per million flights (10^{-6} per flight hour).
- It seems reasonable that serious crashes caused by systems should not be allowed a higher probability than this in new aeroplane designs.
- 10% of this risk is allocated to an aircraft system failure (10^{-7} per flight hour).
- It is assumed, arbitrarily, that there are about 100 potential failure conditions in an aeroplane which would prevent continued safe flight and landing.

[123] www.aar.org/policy/positive-train-control

- This leads to a maximum permissible frequency of 10^{-9} per flight hour per catastrophic failure condition.

In addition a fail-safe design concept is applied:

1. Failure of any single element during a flight, regardless of probability should not be catastrophic
2. Subsequent failures during the same flight should also be assumed, unless their joint probability with the first failure is shown to be extremely improbable.

This illustrates how an acceptable level of risk can be apportioned to technical subsystems. However apportionment based on first principles is prone to error, which is why many agencies and practitioners prefer to rely on historical precedent as a guide to apportionment.

The CSM used in the UK rail industry addresses the apportionment question by requiring any new proposals to be as safe as the systems they are replacing. As described in section 4.4.2 of this report, the CSM identifies three methods of assessing risks are acceptable (ORR 2015). All these methods reference existing standards or accepted systems. The CSM is a useful and practical tool to ensure safety performance is not degraded by new systems. The CSM implicitly assumes existing safety performance is satisfactory and the apportionment of risk between existing systems is near optimal.

The implicit assumptions of the CSM may be reasonable for the UK, which has a long history of operating railways and which has achieved high levels of safety performance. The UK ranked first in overall safety performance out of major European countries in 2007–2012[124]. This safety performance has been achieved despite lower levels of capital investment in safety systems, such as ATP, compared with other European countries.

Another method of apportionment is to comprehensively model the risks for existing and planned activities. The RSSB in the UK has carefully developed such a model, called the safety risk model (SRM), over a number of years (described in section 4.4.2 of this report). The Australia-based Rail Industry Safety and Standards Board (RISSB), proposes to develop an Australasian version of the SRM.

C4 Conclusion

The researchers suggest the ‘broadly acceptable’ risk level for rail passengers and workers of a 1 in 1,000,000 fatality risk by the Transport Agency guideline is likely to be in line with modern industrial safety expectations and the risk appetite of the public. The SFAIRP test governs, so this risk level remains acceptable only if it is reduced SFAIRP.

The researchers suggest an upper tolerability bound of a 1 in 10,000 annual fatality risk may be more appropriate for rail workers than the current 1 in 1,000, given rail’s improved safety performance over the last 15 years. If this bound was used, we would suggest a 5- or 10-year moving average rate would be the best way for the regulator to track safety performance given the small size of the industry. However, changing the tolerability limit for rail may have wider impacts for other industries, and these should be considered before any changes are made.

We suggest that while the 1 in 10,000 tolerability limit is appropriate, the rail industry should be working towards 1 in 100,000 as a likely future upper bound for passenger individual fatality risks for rail–specific hazards.

[124] For 2007–2012 rankings from figure 2 of *Railway safety performance in the European Union* (ERA 2014).

In general, a more stringent tolerability limit should be applied to new systems and system-related risks.

Society's perception of what is and is not reasonably practicable is likely to vary greatly depending on the circumstances. Accordingly, we do not suggest a set ratio for determining what is grossly disproportionate.

Quantified risk levels are more useful for assessing industry performance as a whole than for an operator to use in risk assessments for individual activities. Working out whether a specific risk is acceptable or tolerable introduces an apportionment issue, so is less useful at an operator level in the absence of accurate system-wide modelling of risk. This gap between system-wide performance expectations and operator decision making on individual system components is addressed by approaches such as the CSM.

Appendix D: Suggested enhancements to NRSS4 (risk management)

The research scope included preparation of a paper outlining any suggested enhancements to NRSS4 based on the research findings. The NRSS Executive (NRSS-E) committee is responsible for reviewing the standards.

While NRSS4 was undoubtedly fit for purpose when written, risk management has evolved since the standard's last update in 2007 and is no longer suitable in its current form. This opinion appears to be shared by the NRSS-E who have begun the process of updating the standard and are waiting to see the outcomes in this paper before making changes.

The enhancements identified are based on the research findings and this paper does not represent an exhaustive review of NRSS4 or any of the other NRSS standards. The researchers have referred to NRSS2 (which sets out the overall requirements of rail safety systems) in this section as well, as it is closely related to NRSS4.

D1 Background

The NRSS4 (risk management) was first issued in 2004 and was last updated in 2007. The standard is produced by the NRSS executive (NRSS-E) committee, an industry body currently comprising representatives from KiwiRail, Transdev, CAF and FRONZ.

The standard is intended to provide a general framework for risk management within the Rail Safety System and is intended to meet the requirements of legislation and the Land Transport NZ (2006) (now the NZ Transport Agency) document *Rail safety licensing and safety assessment guidelines*.

NRSS4 is one of 11 NRS standards and needs to be read within the context of all these standards. NRSS2, which sets out the overall requirements of rail safety systems, is of particular importance. Rail licence holders operating on the NRS are required to comply with the NRSS.

The Transport Agency guidelines vary in minor ways from NRSS4 in terms of risk management. As the guidelines were last updated in 2006 they are now out of date with respect to the railway industry structure, applicable legislation and current best practice.

D2 Site visit findings

Of the operators we visited, only one appeared to be using NRSS4 as the main reference for risk management. While compliance with NRSS4 is optional for operators who do not operate on the NRS, it is freely available and potentially could be used by smaller operators. However, we found the smaller operators we visited did not have much awareness of the standard and did not refer to it because it was not a requirement. Larger rail organisations operating on the NRS generally have their own risk management requirements that are better tailored to their operation and reflect more current risk management practices. Although based on a small sample size, our research suggested the direct audience for NRSS4 may be small. Familiarity with risk management varied between operators, but the majority were aware of ISO 31000.

D3 Potential enhancements identified

In the following table, we outline some issues we have observed from our research, including the site visits and comparison of NRSS4 to current best practice resources.

Table D.1 Possible enhancements to NRSS4

Possible enhancement	Examples of issue in standard
Needs to be aligned to the HSWA 2015 as the information provided in reference to the Health and Safety in Employment Act 1992 is now outdated.	• *Section 2.2. Risk policy*, eg information on 'all practicable steps' and as low as reasonably practicable • *Section 3. Key risk management responsibilities* does not include directors.
The standard should be aligned to ISO 31000:2009 (including terminology), which has been adopted by the Transport Agency as regulator and KiwiRail as network operator.	• Risk not defined in NRSS4 as 'the effect of uncertainty on objectives' • NRSS4 only refers to quantitative calculations as risk assessment, while the methods described under 'risk screening' are also a valid form of risk assessment • Principle of tailoring risk assessment to the organisation's context is not communicated.
Including principles of risk management (see ISO 31000) may help operators to better understand how risk management fits into their operation.	• Site visits showed many operators saw risk assessment as a somewhat academic task, sometimes undertaken after key decisions were made, rather than a tool that is an integral part of decision making and that can support their professional judgement.
The standard should explain the importance of risk management in terms of fitting into an overall safety system.	• *Section 2.3. Safety system* does not cross-reference NRSS2 (safety management), nor does it refer to safety cases required under section 29 of the Railways Act 2005.
Some risk management concepts and tools need to be made more explicit and less simplified as they lack important context.	• ALARP triangle is based on UK HSE guidance but does not carry over important caveats, eg it is a conceptual model, public expectations change with time, and broadly acceptable risks still must be reduced wherever it is reasonably practicable to do so.
The risk matrix needs to be reworked as it may lead operators to treat risk in a way that is unlikely to meet regulator expectations if an event occurs.	• A catastrophic but improbable risk is given a low rating (and considered broadly acceptable and to be monitored or accepted) • Consequence and likelihood tables do not appear to be appropriate for the New Zealand railway context • Simple mathematical products of consequence and likelihood rankings should be discouraged as they are likely to be misleading.
The detailed focus on a fatality rate calculation method is inappropriate and potentially misleading. As a minimum further context should be added.	• Fatality rate calculations do not give the context of the allocation issue (eg calculation for a single risk may be below an ALARP criterion, but this may be only one of many risks to which a passenger or worker is exposed). The allocation issue is a key element of transportation system risk management, which is not addressed at all in NRSS4.
Some statements around documentation should be modified as they are not good practice and are unlikely to meet regulatory requirements.	• *Section 8.2. Records required* states 'there is no immediate requirement to analyse or document current risks if no changes are proposed'.
Coverage of monitoring and auditing should be increased.	• *Section 3.4. Monitoring of risk management* does not distinguish between monitoring if controls are in place and monitoring if they are effective.

D4 Options analysis

The pros and cons of the options we have identified for updating NRSS4 are set out in the following table.

Table D.2 Options analysis for updating or replacing NRSS4

Options	Pros	Cons
Do not update standard	• No further time and financial cost to NRSS-E.	• Standard is out of date and does not represent good risk management practice • NRSS-E has already recognised the standard is out of date and has taken preliminary action towards updating it • May compromise safety of heritage operations on main line.
Minor update	• Time and financial cost to NRSS-E is minimised • Operators will have free access to standard presenting a more current approach to risk management.	• Minor updates to the standard are unlikely to fully address issues with the standard and may not bring it up to best practice • May compromise safety of heritage operations on main line.
Major update	• NRSS-E continues to meet its mandate • Operators will have free access to best practice risk management standard designed for their purposes.	• May represent significant cost to NRSS-E and may delay update of the standard • May not be used by enough operators to justify cost.
Replace NRSS4 with:	**Nothing** • No further time and financial cost to NRSS-E to update or maintain the standard.	• NRSS-E may not be meeting their mandate • Operators may find it harder to meet risk management requirements without more customised guidance • May compromise safety of heritage operations on main line.
	NZ Transport Agency rail licensing guidelines • More consistent approach for these operators in New Zealand • No further time and financial cost to NRSS-E to update or maintain the standard.	• The current guidelines (Land Transport NZ 2006) do not represent best practice and would need to be updated • In general it is preferable for standards to be produced by industry or through a co-regulatory approach, rather than by the regulator alone • Potential cost to Transport Agency to maintain and update a standard.
	ISO 31000 • No further time and financial cost to NRSS-E to update or maintain the standard • Operators will be encouraged to base their risk management on New Zealand/Australia best practice.	• Cost to operators of purchasing ISO31000. • ISO31000 alone may not provide sufficient practical guidance to operators and may need to be supplemented by supporting guidelines at further cost to operator.
	Other international standards (eg UK rail guidelines for CSM) • No further time and financial cost to NRSS-E to update or maintain the standard.	• Unlikely to ensure operators meet all New Zealand's specific regulatory requirements.

Options	Pros	Cons
Expanded NRSS2 (integrate risk management into NRSS2)	• NRSS-E continues to meet its mandate • More clearly integrates risk management within the wider risk management framework (ie the safety management system) • May align more closely with international practice (eg ONRSR (2013) *Preparation of a rail safety management system guideline*)	• May represent significant cost to NRSS-E and may delay update of the standard • May still be cost to operators if the new standard references ISO 31000 or other paid standards • May not be used by enough operators to justify cost.

D5 Conclusions and recommendations

In conclusion, NRSS4 is no longer fit for purpose and does not represent good practice. Land Transport NZ (2006) is not a suitable alternative as these guidelines share many of the same deficiencies as NRSS4. All options either represent potentially significant financial cost in the amount of work needed to produce a best practice standard, or represent a deficit in the guidance provided to operators.

Our recommendation is to expand NRSS2 to cover risk management (the last option in table D.2). The principal reason for recommending this option is to more explicitly recognise the integral role of risk management in the wider risk management framework (the safety management system). ONRSR (2013) provides an example of how this might be achieved.

Our recommendation is influenced by our overall observation that safety management activities undertaken by New Zealand rail industry operators are often not well joined together. This results in a series of disparate safety activities, including assessments conducted to NRSS4, often undertaken as desk-based processes with lower levels of connection with what actually happens in the field. In turn we view the low level of connection between NRSS4 and NRSS2 as symptomatic of such disaggregated approaches about safety systems in the New Zealand rail industry. Review of NRSS4 presents an opportunity to lift rail industry practice by leading all operators to consider safety as a system, rather than as a series of tasks.

A potential criticism of our recommendation is some operators with lower levels of capability need guidance of the type that NRSS4 provides. Our view is such guidance can be drawn from other sources. However, if the industry wants to provide a risk assessment matrix then we would recommend an updated matrix is not accorded its own standard but is provided elsewhere, perhaps as an appendix to a revised NRSS2, and only as one example of risk assessment processes.

In making this recommendation we do not endorse the contents of the current NRSS2, which we have not reviewed in detail. We note the Railways Act requires licence holders to prepare a safety case, with section 30 specifying the safety case contents. Safety cases are not addressed in NRSS2, which is a major omission in our view. A review of NRSS2 would be an opportunity to address this deficiency and to lift the performance of the rail industry in New Zealand in the development and implementation of safety systems.

While the research question addressed in this appendix is solely concerned with NRSS4, we note the Land Transport NZ (2006) guidelines would also need substantial revision, taking account of the approach adopted by the NRSS-E in response to these recommendations.

Appendix E: Questions asked operators

A Context

1 What types of rail activity does your organisation provide? (eg location, frequency, seasonality?)

2 Do you own and maintain your own track?

3 Do you own and maintain your own rolling stock?

4 Do you own and operate train operations?

5 Do you have an Interoperability Agreement with another railway organisation?

6 What are the main challenges faced by your organisation?

B Safety and risk management

NRSS/4

1 Does your activity include the National Rail System (NRS)?

2 If so:

a Are you aware of NRSS/4?

b Have you referred to NRSS/4 in the last year?

c Any suggested enhancements to NRSS/4?

3 If not, what method do you use to assess risks?

Risk management system

1 As a rail licensee, how do you understand the safety responsibilities and health and safety obligations of your organisation?

2 What is your view on risk management?

3 What are your top three safety risks?

4 How are these risks identified and managed in your organisation:

5 How do you incorporate safety/risk assessment and management in your operation?

6 Do you have and maintain a Risk Register?

7 How much understanding do you think your front-line staff have regarding safety risks and corresponding procedures, rules, and protocols?

8 Are you concerned about any potential issue in your organisation's risk management system or frontline operation that could affect safety performance?

Incident management

1 How are incidents managed in your organisation?

2 In your organisation, to whom are incidents reported?

3 Who has authority to stop or change operations after an incident?

C Organisational practice

1 In your organisation, are there formal standards/procedures/codes for operation across all functions?

2 How does your organisation notify personnel/contractors of changes to standards/procedures/codes?

D Supervision/inspection/audit

1 How do you make sure infrastructure/rail vehicles/plant/other safety critical equipment is maintained to specified standards and 'fit for purpose'?

2 How do you make sure all rail personnel are following rules and procedures?

E Culture

1 How would you describe the safety culture in your organisation?

F Comments and best practice

1 Within and outside New Zealand, is there any benchmark practice or regulation that you consider as a benchmark, whether implemented in your organisation or not, which is applicable to your organisation or the New Zealand rail system? Why?

2 What are the things your organisation has been doing particularly well regarding safety risk management?

Appendix F: Results from Navigatus Workshop at 2016 FRONZ Conference

This appendix shows the results of the Navigatus workshop at the 2016 FRONZ conference as circulated to members of FRONZ.

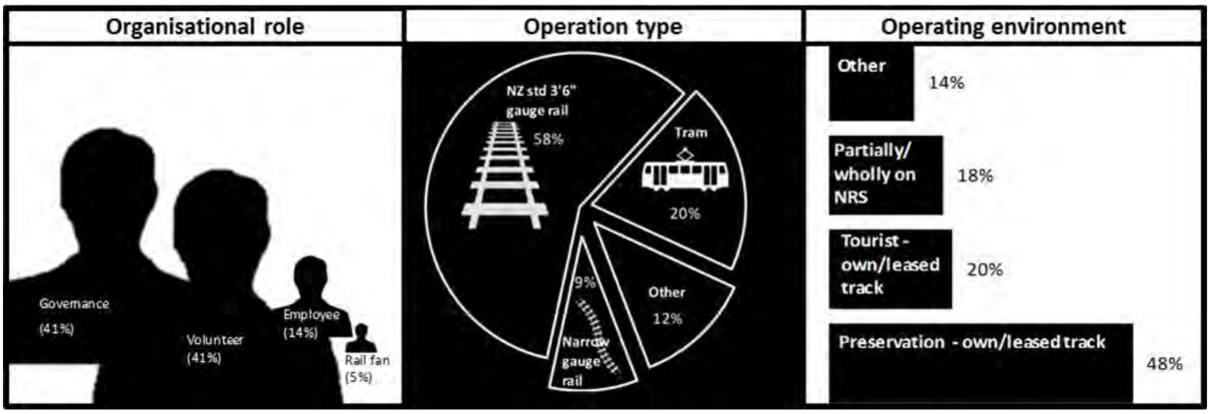
Introduction

Navigatus held a workshop at the 2016 FRONZ Conference to get a better understanding of the risk capabilities and attitudes of the tourist and heritage rail sector. Results from the workshop are reported here anonymously. There were a total of 70 responses, although not all questions were answered by all respondents.

Navigatus is currently undertaking a research project for the New Zealand Transport Agency on rail safety risks and as part of this research had already visited a number of tourist and heritage operators. The results from this workshop will help inform this research.

Demographics of workshop participants

The majority of participants identified most closely as having a governance or volunteer role. Compared to the sector as a whole, there were likely a higher number of people in governance roles attending the conference. Over half of participants were associated with an operation on New Zealand standard gauge rail, and around one fifth were associated with tram operations. The majority were tourist or heritage operators using their own (or leased track), while a minority operated partially or wholly on the NRS.



Risk management: safety objectives

The survey referenced the ISO31000:2009 definition of risk (*the effect of uncertainty on objectives*) and asked participants what they thought could be appropriate safety objectives for tourist and heritage rail operations. The vast majority of participants talked about keeping people safe (eg zero harm, minimise risk of injury or death, minimising incidents, or producing a safe environment). Many related these safety objectives to both passengers and staff/crew.

While a few participants did not state a safety-related objective or were not sure of the question, in general there seemed to be a decent understanding of risk at this level and many suggestions of appropriate safety objectives.

Capabilities

We asked participants if they thought all operators have the capability to meet current (and increasing) expectations in terms of risk and quality management; and if they did not think so, what they thought would help operators.

Based on the responses, we categorised answers as ‘yes’, ‘no’ or ‘other’. The suggestions for what might help are summarised in the boxes below. Of the participants, 32 did not think all operators had the capability, 23 were not sure (or had a more nuanced answer), and 13 participants did think operators had the capability.

No

32 of respondents did not think all operators had the capability.

Approx. one third of these said funding or money would help. Another third said they needed more guidance around requirements, that requirements were not workable, confusing or difficult to understand, or took too much time/resource to meet. The final third said an issue was lack of qualification, education, and governance experience with generally volunteer dependent organisations.

Some respondents mentioned that the attitudes of operators were an issue (ie people are there for the fun aspects and do not want to do paperwork).

Yes

13 respondents stated operators have the capability or ability, although some commented this did sometimes require assistance, education, frameworks and guidance, and for the regulator to check organisations are doing what they should be.

Other

23 respondents had a more nuanced answer or were not sure about capabilities of other operators.

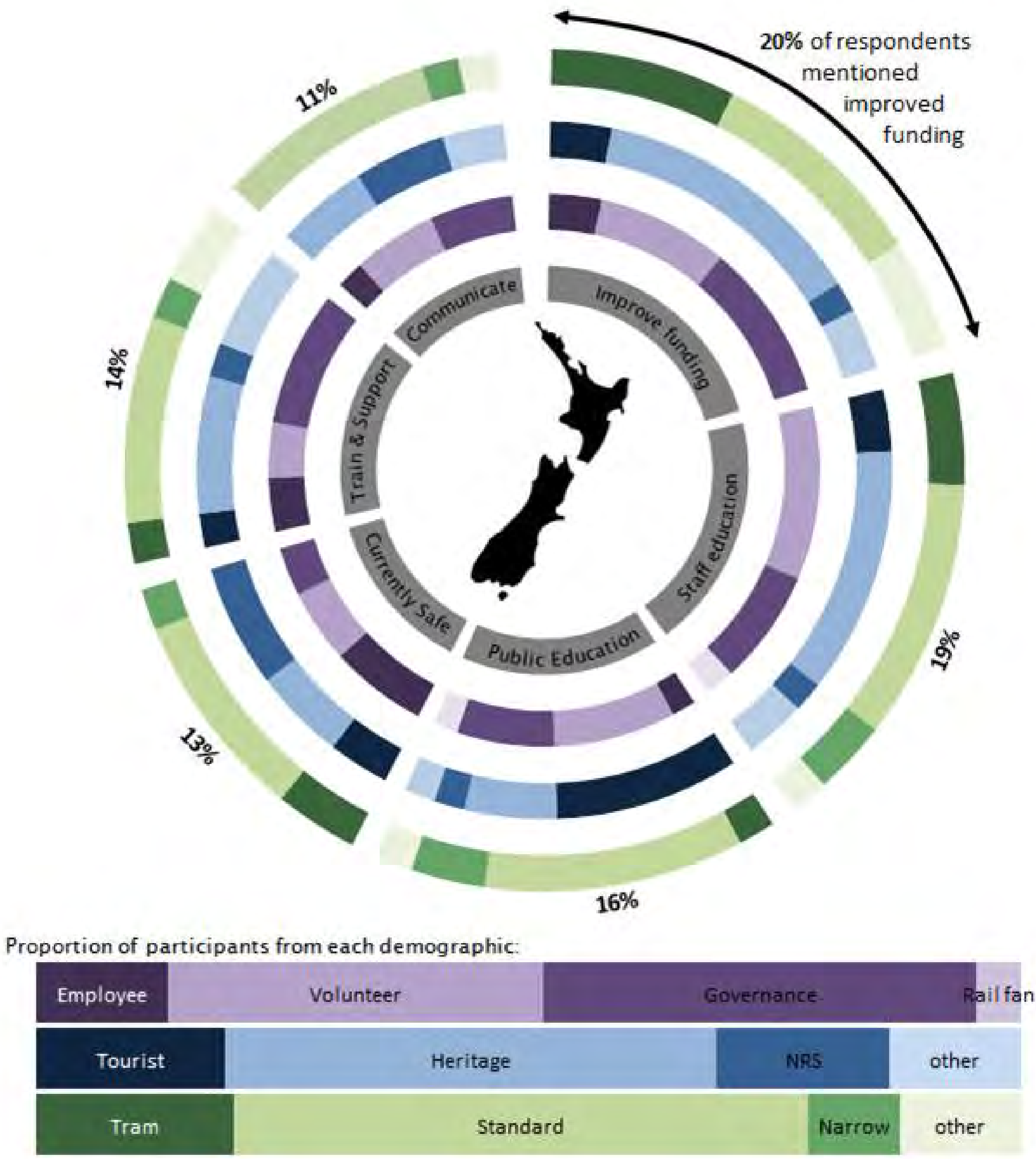
There were many suggestions on what might help, as well as some current issues referenced. These were: Develop better relationships with NZ Transport Agency and WorkSafe NZ; Better understanding should be communicated to operators; Expectations need to align with reality and need to be clear; There needs to be a will by operators to do the task; Operators need time to absorb changes; Lack of knowledge and training; Moving goal posts an issue; Administrative demands becoming an increasing burden – need to be people available and willing; If requirements too onerous then operators will have financial difficulties.

One respondent commented that to be in the sector operators needed to meet expectations.

Making it safer

Participants were asked what they would do to make tourist and heritage operations safer if they were in charge of the New Zealand railway industry. The answers to this question had a number of common themes, these included; **funding**, **education**, **support**, **communication**, and **no changes (currently safe)**.

The following graph shows the proportion of total respondents whose answers identified each of the actions below. This is then shown by demographic, noting that there were a larger number of participants in some categories. The proportion of participants in each of the categories is also show below for comparison.



Safety modifications

Participants were asked to imagine they are responsible for rolling stock at the tourist and heritage operation they are most closely associated with. They were then asked what types of safety modifications they would be willing to make to heritage carriages which carry members of public.

This question saw a wide range of answers, from no changes to all practical changes needed. The freeform answers were interpreted into groups of similar answers. Shown below are the most common responses and a sample of the types of comments received.

- **Practical / affordable solutions (6)**
- **Identify risks (5)**

• Cost-risk assessment.
• Consider what was practical and affordable to make safer.
• Understand impact of any proposed modification before and after risk to ensure safety improvement.
• Need to understand if there is a need.

- **Locking doors (10)**
- **Stop windows opening too far (6)**
- **Install safety glass (5)**
- **Retrofit collision ends (4)**

• Fit safety glass.
• Double locking doors / secondary latches.
• Make all means of exit from vehicle secure.
• Limit how far windows are able to open to prevent people falling out.

- **None (9)**

• Existing specifications are met.
• The ones currently implemented are sufficient.
• Carriages have been in use for hundreds of years.
• Brief passengers, they should accept risk.

The prevalence of respondents' answers regarding locking doors and stopping windows opening too far is likely influenced by recent events. This illustrates the importance of sharing learnings.

Following this, the respondents were asked what they would not do (and why). Again, the answers were interpreted into groups of similar answers. The most common responses and a sample of the types of comments are shown below.

- **There is nothing I wouldn't do (3)**
- **Change without proper assessment (6)**

• Rush to a solution without understanding if safety modifications are needed (and why).
• Change anything without due safety assessment.
• Modify without consulting our engineer and the HTC.
• When proof of upgrade produces no benefits.

- ***Blank* (15)**

- **Any irreversible changes (2)**
- **Major structural changes (7)**
- **Anything that compromises the heritage value (17)**

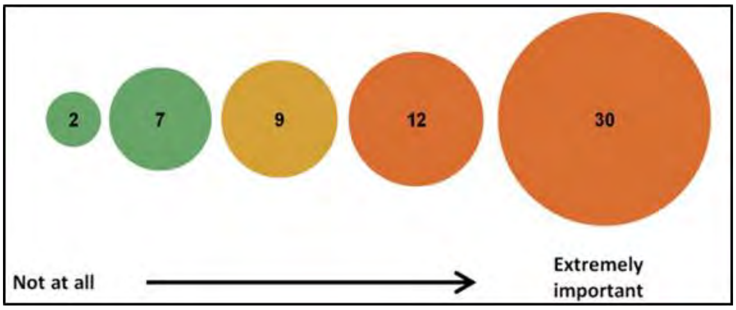
• Alterations which damage or materially alter vehicles in an irreversible way.
• Anything that changed the structure of the vehicle.
• Change the carriage in any way that would detract from its heritage value.
• Anything that would remove the 'historic rail experience' for passengers.

Overall, 25 individual respondents showed a reluctance for changes, valuing the protection of the heritage value of the carriages. Some believing the carriages were currently safe, or that safety talks were adequate, others citing the increased risk on the road or the fact heritage cars are able to operate without modification. However, the majority of the respondents made no mention of safety or assessment only citing the 'heritage experience' or 'purpose' of the operation.

High rate of derailments

Importance

The survey stated that the rate of derailments was high in the tourist and heritage sector and asked how important this rate was. The figure shows the response - the majority of respondents thought the high rate of derailments was very important or extremely important.



Respondents showed they understood there's potential for serious consequences (injuries, deaths, equipment damage) to occur and that the rate indicates failings in how the railway operation is maintained (track, rolling stock, training etc).

Respondents also showed concerns about reputation and ability to continue operating, as well as incidents detracting from the passenger experience. Respondents stated that understanding the cause was important in terms of rectifying issues and that those issues needed attention.

Those who responded that derailment rates were not at all important, of minor importance or were somewhat important generally did not believe that the rate was that high or thought that consequences of derailments were minor.

As a whole, the response showed there was a good understanding of potential consequences (even if they had not occurred previously), but not all individual responses necessarily had this understanding (eg mentioning time to re-rail but not potential of injuries).

Underlying, systemic reasons

Respondents gave the following answers for the underlying, systemic reasons for the rate of derailments in the tourist and heritage sector:

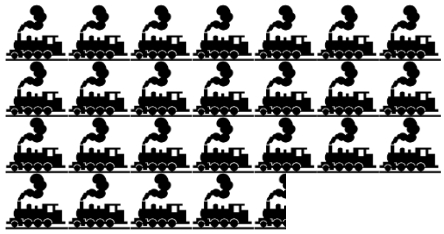
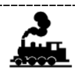
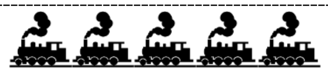
- Not sure/don't know/many reasons
- Track faults or defects/poor track condition/track out of gauge/bad sleepers/spreading/lack of fastenings
- Lack of finance/track maintenance expensive (eg sleepers)/rolling stock maintenance expensive
- Lack of resources for maintenance/lack of knowledge/lack of skill/lack of experience or expertise/ substandard maintenance/track maintenance not desirable task for volunteers (particularly for older volunteers)
- Old equipment/standard of infrastructure/condition of rolling stock/worn tyres/wheel wear
- Driver inattention/human error/speed
- Lack of good governance/inspections insufficient (track, rolling stock)/deficient safety checks/lack of standardised track standards for heritage groups

- Natural disasters/sabotage of track/vehicle collision/foreign objects on track/objects falling off vehicles onto tracks
- More likely to have volunteer non-adherence and lack of understanding of rules and regulations/different attitudes than in fully commercial operations.

Attitude to safety

Respondents were asked which of the statements in the following table best described the attitude to safety at their railway operation.

The vast majority thought the statement that best described the attitude was 'We have a duty to care so far as is reasonably practicable. We will make limited alterations if required to make the operation safe, while keeping a heritage look and feel'.

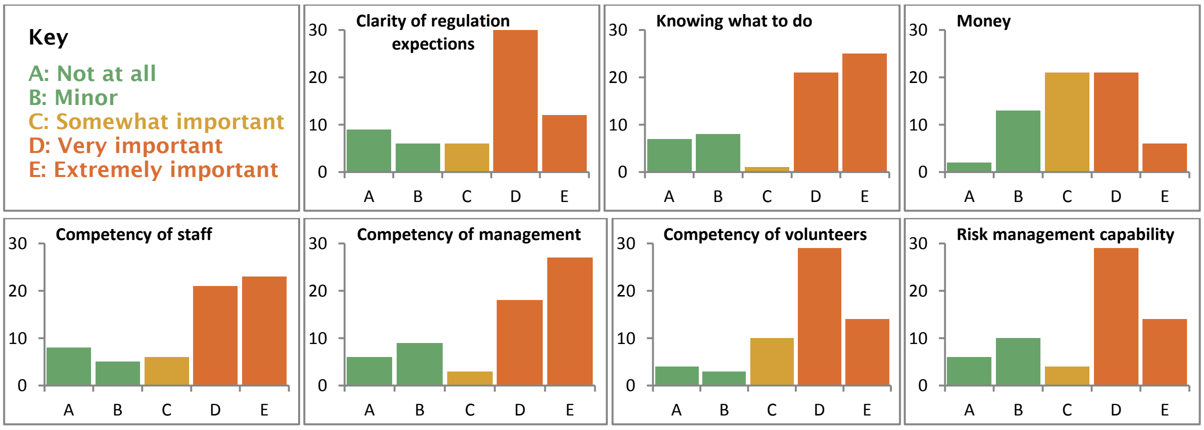
Statement	Key:  = 2 respondents
It's a heritage operation so it should be operated in the same way as at the time that the rolling stock was made.	
We run to slower speeds than back in the day. That addresses all the safety risks that matter.	
We don't have any money, so we rely on procedural controls.	
We recognise a duty to care, but we won't do anything that is inauthentic.	
We have a duty to care so far as is reasonably practicable. We will make limited alterations if required to make the operation safe, while keeping a heritage look and feel.	
These are inherently dangerous pieces of machinery. They should be locked away in sheds and brought out only for stationary start up days.	
None of the above – please specify:	

Most respondents who answered 'none of the above' felt the question did not apply to them as they were not a railway operator or did not yet have equipment.

Some respondents specified that while the 'so far as is reasonably practicable' answer was applicable, they felt the heritage look and feel was less important in this context. Others referenced their duty of care, benchmarks, and running to the highest practical safety standards possible

Limitations to safety performance

Respondents were asked to what extent they found the following aspects a limitation on the safety performance of their organisation.



The majority of respondents rated most aspects as very or extremely important. However, for money, most respondents rated money as between minor and very important. It is suspected that some respondents may have interpreted the question as the importance of the aspect generally, without respect to their own organisation.

Discussion and conclusions

In general there seemed to be a good overall understanding of safety risk and most participants identified a good attitude to safety at their organisation (eg ‘We have a duty to care so far as is reasonably practicable…’). This may have reflected to some extent the number of participants attending who had a governance role at their operation.

Despite this, many participants did not think all operators had the capability to meet current (and increasing) expectations in terms of risk and quality management. The issues raised with meeting expectations were not surprising for a sector that has many small organisations heavily reliant on volunteers (eg funding, guidance, training/experience, and administrative burden).

While participants were theoretically on board with reducing risks so far as is reasonably practicable, there also seemed to be reluctance to make any changes that could affect the heritage value of carriages. Given many participants’ passion for heritage carriages, this position could be anticipated, and this response appeared to be supported by the belief that carriages (and current standards) were safe enough.

Former approaches to safety in rail (ie prescriptive standards) seem to still be entrenched but are at odds with current health and safety legislation (ie flexible, performance based). Elements of heritage operations (eg preservation) may conflict with the intention of health and safety legislation (eg continuous improvement and progressively higher safety standards).

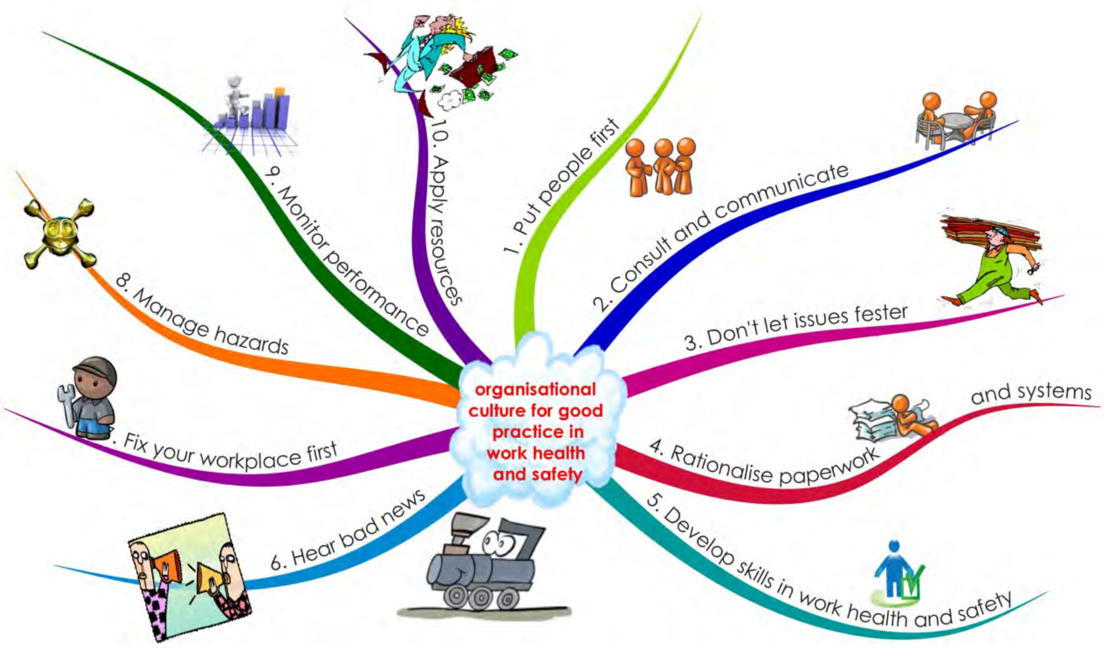
It can be inferred from this survey that the risk management capability of the tourist and heritage sector is generally lower and that some operators may struggle to meet rising health and safety expectations despite good intentions.

Appendix G: Organisational culture, work health and safety survey – New Zealand rail industry

A customised version of the Organisational Culture, Work Health and Safety (OCHWHaS) survey was undertaken for the New Zealand rail industry in late 2016. The survey received funding and support from the Australasian Centre for Rail Innovation (ACRI) and was undertaken by Dr Larissa Clarkson and Associate Professor Verna Blewett (CQUniversity, Appleton Institute).

The survey was an outcome of 'Keeping rail on track' research, which looked at good practice in work health and safety in the Australian rail industry (Blewett et al 2012; Blewett et al 2013). This research, located in urban passenger, national freight and heavy haul rail firms, developed a model of good practice in work health and safety using a mix of qualitative and quantitative methods. A new survey, the Organisational Culture, Work Health and Safety (OCWHaS) survey, was developed as a result. This was validated in eight rail organisations in Australia and New Zealand. A set of 10 rules (adapted from the mining industry) were used as the survey dimensions. These 10 rules are shown in figure G.1.

Figure G.1 Model of good practice organisational culture for a healthy and safe rail industry (from Clarkson and Blewett (2016))



The OCWHaS survey is intended to be used within individual organisations. It was modified for use across the whole of New Zealand's rail industry (with a limited number of selected participants per organisation). The survey was conducted between 9 October and 3 November 2016. Of 183 potential participants emailed, 118 (66%) completed the survey. The majority of respondents were male (88%) and the mean age was 53.6 years (range 18–78).

The tourist and heritage rail sector was the most represented (59% respondents), with industrial operator/freight (25%) and commercial NRS (15%) making up a smaller proportion. The industrial operator/freight grouping was intended to capture organisations such as freight logistics, manufacturers and agriculture, while 'commercial NRS' was intended to capture commercial rail services on the NRS (passenger, freight, maintenance etc).

While the majority of respondents were paid workers, there was also a significant proportion (41%) who were volunteers (all volunteers were within the tourist and heritage sector) (figure G.2). Operational management was most represented, followed by frontline workers, and senior leadership and governance (figure G.3).

Figure G.2 Position type of respondents

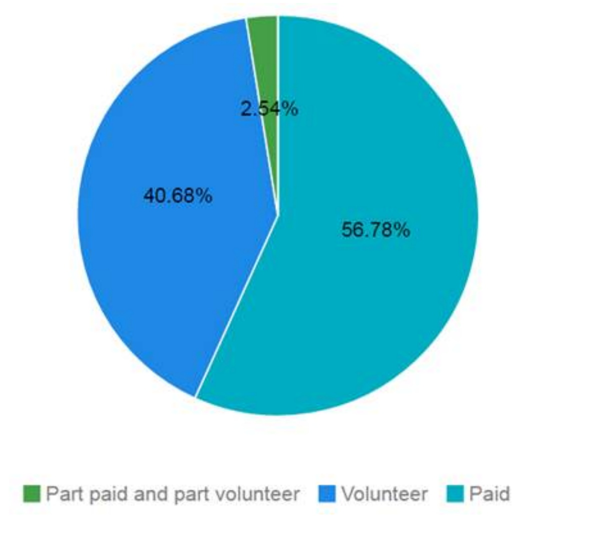
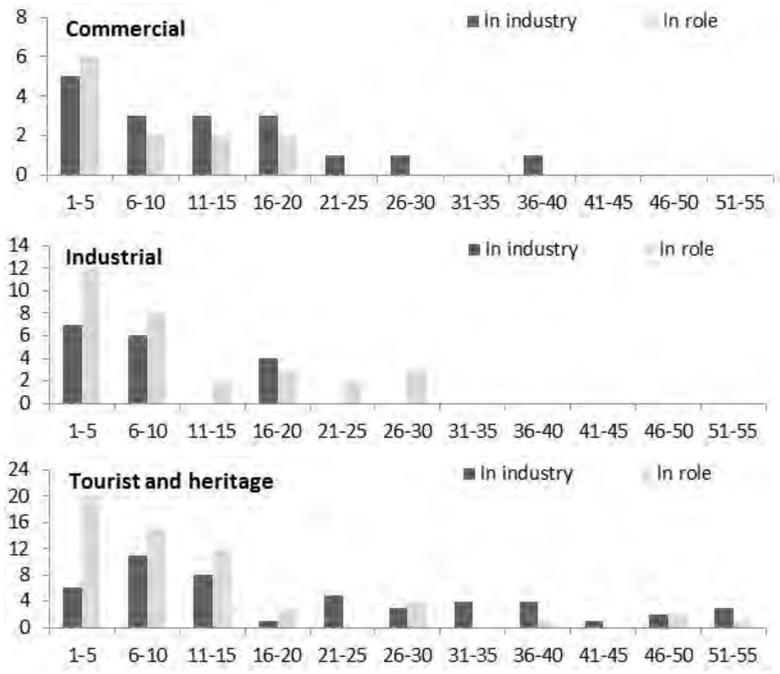


Figure G.3 Role of respondents

The mean age of industrial operator/freight respondents was 52 with an average of eight years in the industry and 11 years in the role.

Figure G.4 Years in industry and in role of respondents



The length of time in the industry and years in the role of industrial operator/freight respondents suggests they came from other industries and moved into rail later in their career. In contrast, respondents in commercial NRS (average age 46, 13 years in industry and five years in role) and tourist and heritage (average age 57, 20 years in industry and 11 years in role) spent longer in the industry and spent less time in the same role.

Figure G.5 Response side by side comparison to average

	Average	Commercial NRS	Industrial Operator / Freight	Tourist and Heritage
Rule 1 - Put People First	90%	-12	0	+3
Rule 2 - Consult and Communicate	85%	-19	+5	+3
Rule 3 - Don't Let Issues Fester	81%	-31	+6	+5
Rule 4 - Rationalise Paperwork and Systems	85%	-10	+4	+1
Rule 5 - Develop Skills in Work Health and Safety	87%	-17	+3	+3
Rule 6 - Hear Bad News	79%	-14	+1	+3
Rule 7 - Fix Your Workplace First	86%	-17	+5	+2
Rule 8 - Manage Hazards	86%	-16	+6	+1
Rule 9 - Monitor Performance	87%	-17	+5	+2
Rule 10 - Apply Resources	87%	-19	+4	+3

Overall, the respondents' reported perceptions of their organisational culture and work health and safety were very positive.

Commercial NRS had lower average scores (compared with industrial operator/freight and tourist and heritage) for all rules, but this was most apparent for rule 3 (don't let issues fester) (-31 of average). Commercial NRS had the youngest average respondent age and the greatest proportion of frontline worker respondents, which may have influenced these results. Across operator types, the youngest age bracket (18–40) had more negative responses than older age brackets. Frontline workers had more negative responses than operational management, while senior leadership and governance had the most positive responses.

Rule 6 (hear bad news) had the lowest average score (79%). Within this rule, the question 'People are not shot down for reporting information that might stop operations' had the least favourable response, with 38% responding negatively ('never/hardly ever' or 'sometimes'). The second least favourable response was to another question under rule 6 – 'When someone raises a doubt or concern, people do not dismiss it' (21% responded negatively).

Rule 3 (don't let issues fester) had the second lowest average score. The questions under this section were 'reported issues are fixed promptly' and 'there is prompt feedback on reported workplace health and safety issues'.

Appendix H: SPAD categories

A SPAD is a signal passed at danger (without authority). SPADS are considered as potentially catastrophic events as they are precursors to events with significant potential for fatalities, such as train collisions, or collision with maintenance providers.

A new form of categorisation has been adopted in New Zealand recently (2015), where previously categorised as A through D, subcategories have been adopted for category A and B SPADs. This is consistent with Australia (Australian Railway Association 2014) and similar to the UK (B3 and B4 are named C and D in the UK) (RSSB 2013). Below is the current definition of each category of SPAD (KiwiRail 2015b).

Figure H.1 Categories of SPAD

Classification	Description:
A	**A1** When a SPAD has occurred, and according to available evidence, a stop aspect, indication or end of movement authority1 was displayed or given correctly and in sufficient time for the train2 to be stopped safely at it.
	A2 When a SPAD has occurred, and according to available evidence, the stop aspect, indication or end of movement authority concerned was not displayed or given correctly, but was preceded by the correct aspects or indications.
	A3 When a SPAD has occurred, and according to available evidence, verbal permission/or a hand signal pass a signal at danger was given by a hand-signaller or other authorised person without the authority of the signaller/train controller.
	A4 When a SPAD has occurred, and according to available evidence, a stop aspect, indication or end of movement authority was displayed or given correctly and in sufficient time for the train to be stopped safely at it, but the operator was unable to stop the train owing to circumstances beyond their control. (eg poor rail head adhesion, train braking equipment failure or malfunction etc).
B	**B1** When a SPAD has occurred because a stop aspect, indication or end of movement authority1, (that previously showed a proceed indication), was displayed because of infrastructure failure (eg signalling or level crossing equipment failure or malfunction, track circuit bridged or interrupted).
	B2 When a SPAD has occurred because a stop aspect, indication or end of movement authority, (that previously showed a proceed indication), was displayed because it was returned to danger or displayed in error.
	B3 When a SPAD has occurred because a stop aspect, indication or end of movement authority was not displayed in sufficient time for the train2 to be stopped safely at the signal, indication or end of in-cab signalled movement authority as it had been returned to danger automatically or in an emergency in accordance with the network controllers' emergency plans.
	B4 When a SPAD has occurred because vehicles without any traction unit attached, or a train which is unattended, has run away past a signal at danger, or without an in-cab movement authority.

Appendix I: Strategic risk

This section outlines strategic risks observed by the researchers. These matters have been classified as strategic risks as they share several of the following characteristics:

- They will be likely to require significant capital investment if a decision is made to address them.
- The investment decisions will require consideration of societal values.
- Mitigations are likely to be difficult to reverse from a societal acceptance basis.
- These matters are likely to be addressed once or less in a generation.

While four of the following issues are risks, the fifth is an enabler.

1: Wellington metro train protection. The Wellington metro rail system has an older form of partial train protection which relies on mechanical train stops to arrest a train that passes a signal set at danger. In comparison to the European Train Control System (ETCS) installed in the Auckland metro area, this is a simpler and less complete form of protection. In addition the train stop system is partially implemented: only some signals have train stops and freight trains do not have the requisite equipment fitted. A review is currently underway of train protection in the Wellington metro, being undertaken jointly by KiwiRail, Wellington Regional Council and the Transport Agency. Given this review the researchers have made no specific recommendations on train control in the Wellington area

2: Mixed freight and passenger services. From the interviews the researchers undertook, most of the focus by parties operating in the network appeared to be in avoiding and mitigating collisions between the rolling stock they operated. This is appropriate provided the dangers posed by other operators are also recognised and allowed for. For instance, the main focus of metro operators appeared to be on collisions between EMUs. A review of railway incidents identifies that collisions between freight trains and passenger trains have given rise to some significant railway disasters, eg 2016 Saint-Georges-sur-Meuse, Belgium (three fatalities); 2006 Zoufftgen, France (six); 1997 Southall, UK (seven); 1986 Hinton, Canada (23); 1962 Tokyo (163).

Compared with passenger trains, freight trains typically have higher mass and less capable braking systems, which leads to lengthy stopping distances. Freight trains, including those running through Auckland, do not have ETCS fitted. We understand the SPAD risk assessment for the re-signalled Auckland network concluded the cost–benefit for fitting freight trains with ETCS was not justified at the time. The national rail operator is planning to install ETCS on Auckland mainline freight shunt locomotives over the next few years (C Mills, pers comm). That such trains do not currently have any form or automatic train protection represents an ongoing hazard in the safety management of Auckland and Wellington metro services. These factors raise the likelihood and consequences of collision, should an incident occur.

In the Auckland metro area, a ‘third main’ has long been proposed. The third main would run from Westfield to Wiri. Some parts exist already. The third main would provide more capacity on a congested area of track where metro passenger services and freight operations overlap. The third main would serve to reduce the risk of collision between passenger and freight trains, possibly through use as a dedicated freight line. While such a project may be difficult to justify in purely economic terms, it may be a worthwhile safety improvement project, should the separation of passenger and freight become a matter of societal concern. One option is to have the project designed and consented, ‘shovel ready’ for times when the government wants to engage in fiscal stimulus through public works.

A further concern arises from freight shunting movements (eg between Port of Auckland and Wiri) as movements may occur at unplanned times, although operating/signalling systems should be sufficiently robust to cope with changes to schedules, including breakdowns and service disruptions. However, deviation from scheduled operation is a situation where control error is more likely. For example a local freight shunt in Auckland was a confusing factor in the passenger train wrong routing and SPAD at Tamaki in 2010 (TAIC 2012a). The national rail operator has commented the network routinely handles unscheduled movements of all types and the signalling system is a very robust defence against harm.

3: Heritage excursions operating in metro services areas. The visibility to NTCC controllers of heritage excursions operating in the Wellington and Auckland metro areas is a source of risk. The 1990 Cowan collision in Sydney, illustrates the dangers (refer boxout).

CASE STUDY: Cowan collision, NSW
In the 1990 Cowan collision in New South Wales, a steam passenger train stalled while attempting to climb a steep gradient. Sand applied to the rails to improve traction interfered with the signalling system. A following passenger service train was given a green signal and collided with the rear of the steam train.

The TAIC lists tracking and locating technologies on a watchlist which highlights the most pressing of TAIC's concerns with respect to safety across the air, sea and rail transport modes. Incident investigations by the commission have led to the view there are significant safety advantages in using technologically advanced tracking and locating devices. These have been installed by the national rail operator. It is understood such devices have no formal role in train control in the NRS at present, but it is reasonable to expect greater functionality will eventuate in the future (eg geofencing as a form of track warrant over-run protection).

A potential risk for heritage excursions arises if train control on the NRS becomes reliant on such newer technologies, as seems likely over the longer term. Mainline operations of steam engines are currently infrequent so the likelihood of an incident is low, but resurgence in heritage excursions could raise the level of risk.

4: Continuity of NTCC service. The concentration of all train control services nationally into a heritage building in an earthquake prone city has replaced a series of tactical operational risks (maintaining continuity, safety and quality of service in remote signal boxes) with a strategic risk (maintaining a national train control system). A report by the National Infrastructure Unit in 2014 described the NTCC resilience as low because there is only one in the country. While the Wellington Railway Station has been earthquake strengthened and the building is designed with resilient power and communications, an event that causes the building to be evacuated for an ongoing period could be catastrophic for rail service delivery. The potential effects of such a risk are illustrated by the 2012 power failure at the NTCC in Wellington which shut down four train control stations for Auckland for one hour and caused loss of all control communications. The Wellington outage resulted in commuter passenger services in Auckland being disrupted for the remainder of the evening (TAIC 2014a). Currently, a partially equipped replica control room for the Auckland metro area (located in a room at Britomart) and a stand by facility at Palmerston North that can be stood up in approximately 48 hours, provide a degree of back-up facility for such emergencies.

The consequences of loss of the national train control function would compound the effects of a natural disaster in Wellington and transmit the effects throughout the country, potentially hampering disaster recovery. Development of an alternative NTCC facility in a permanent second location would be prudent. We have been advised a second NTCC is planned to be constructed by KiwiRail and Auckland Transport jointly no later than 2023 (subject to Crown funding).

Also of concern is the ability to mobilise train control staff into another control centre, which may be a long distance from Wellington, in a disaster scenario when family demands are also likely to be high. In the view of the research team it is unrealistic to expect all the train controllers to be available for relocation after a major disaster, which could lead to overwork of those who can relocate. Such factors would increase the risks of train control error. Acknowledging the benefits of gathering train control staff into few locations, and the substantial investment in time and resources to develop the requisite skills of train controllers for each ‘desk’, it may be prudent to consider moving national train control to a purpose built centre, constructed to a higher standard in a safer location and with reliable power and communications.

5: New technologies (enabler). As noted in section 2.6 of the special safety assessment report (NZ Transport Agency 2015b) new technologies are likely to enable improvements to safety. KiwiRail has investigated and is implementing a range of new systems, such as GPS enabled geo-fencing (O’Connell and Mills 2016). Similar systems have been introduced into other locations such as Queensland and Tasmania (G Hight, pers comm). Such systems have the potential to significantly reduce error. A potential residual risk is that operators may come to be over-reliant on such systems and may have difficulty operating safely if the systems fail.

I1 Other strategic matters

The following, which have been identified and commented on in the main body of this report, can also be considered as strategic matters:

- capital works funding: provision of sufficient funding from central government for the national rail operator to make the capital investments required to meet safety requirements
- tsunami risk: identified as a risk affecting the wider community, and for which a community-wide response would be appropriate
- strengthening capability in the rail sector to manage safety
- further strengthening of regulatory capability and industry institutions to positively influence safety performance within a co-regulatory framework.

In the longer term, as train frequency on the Western Line increases in response to population growth, safety performance considerations and road congestion are likely to lead to further grade separation at level crossings.[125]

I2 Discussion

Classifying some of these matters as strategic is not intended to signal they are of greater or lesser importance than any other matters considered in the main body of this research. In general these longer-term strategic issues are less amenable to the assessment methodology adopted for this research project and may require separate assessment. Assessment by others of some of these matters is currently underway.

[125] As was undertaken at New Lynn during the double tracking and electrification project and is currently underway in Melbourne under the Level Crossings Removal project.

Appendix J: Risk matrix

A key decision for this research was the selection of an appropriate tool for the risk assessment. We considered the risk assessment tool needed to meet the following criteria:

1 Usefully discriminates between higher and lower risks
2 Can be applied to a wide range of risks
3 Can be applied to risks with varying levels of knowledge
4 Is not unreasonably demanding of resources in its application
5 Is simple to understand
6 Allows uncertainties to be communicated.

Taking the above criteria into account we chose to apply a form of semi-quantitative risk matrix.

The full suite of risk assessment tools reported in the AS NZS ISO31000 handbook (SA/SNZ HB89) (SA/SNZ 2013a) was briefly considered. A risk matrix allows for commonality in assessment across the different types of risk and where there are differing levels of understanding and data availability.

The form of risk matrix selected for this research had the following features:

- 5 x 5 consequence vs likelihood scales
- geometric scale intervals (ie each step is set ratio greater than the one before)
- a deliberate bias towards major hazard aversion
- explicitly represents uncertainty by representing each assessment as a zone.

J1 Scales

The SA/SNZ HB89 comments that an appropriate design, including definitions, must be used for the circumstances. The selected likelihood and consequence scales are provided below:

Consequence scale	
Descriptor	**Description**
Minor	Minor injury
Serious	Single serious injury
Major	Multiple serious injuries
Fatal	1–3 fatalities
Catastrophic	4 or more fatalities

Likelihood scale		
Descriptor	**Description**	**Return period (years)**
Frequent	Occurs routinely	<1
Occasional	Occurs often	1–5
Infrequent	Occurs infrequently	5–20
Improbable	Unlikely to occur, but possible	20–100
Extremely improbable	Occurs very rarely	100+

These scales have been carefully chosen for the context of an industry-wide assessment, and with a geometric ratio of approximately 4–6 between intervals.[126] This ratio can be seen most clearly in the likelihood scale, while the fixed ratios in the consequence scale becomes more obvious with reference to fatality weighted injuries (eg where one seriously injured person is equivalent to 0.1 fatalities; see (ERA

[126] The exception is the step from ‘minor’ to ‘serious’ in the consequence scale, which is approximately 20.

2013). In summary, the scales are geometric with similar scaling intervals of around 4-6 on each axis. This conforms with the recommendations of (Duijm 2015), for an unbiased risk matrix design.

While a 5x5 matrix is the most common size other choices are feasible. For instance a generic 6 x 7 matrix has been recommended for application in the UK rail industry (RSSB 2014a). As risk practitioners we find 5x5 matrices work well when they are tailored for the circumstances. A well-designed 5x5 matrix will usefully discriminate between important risks without being overly large and cumbersome to operate.

J2 Colourisation of risk matrix

Almost all risk matrices assign regions to the table, usually by means of colours to designate a form of equivalence. This is usually done by assigning between three and five colours to the cells, with accompanying qualitative descriptions. Usually the regions are designated by colours with red being traditionally higher risk and green for lower risk. This colourisation process is another important feature of the risk matrix design and reflects risk appetite. Our chosen four-level colourisation is shown in figure J.2.

Figure J.1 Unbiased matrix based on geometric scale (not used)

Figure J.2 Modified matrix with higher risk aversion

Provided the geometric ratios are the same on both scales then for a neutral assessment, cells on a diagonal have equivalent expected outcomes. This can be seen in the left matrix.

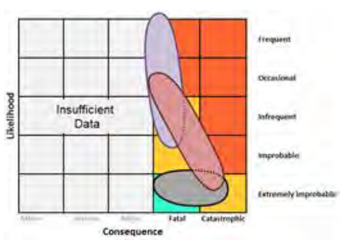
We have elected to explicitly introduce an element of major risk aversion by departing from the diagonal approach, by increasing the risk by one level for one risk (circled in the right matrix). This modification has been introduced by the researchers for the following reasons:

1. As catastrophic events become less common, through successful risk management, societal tolerance of catastrophic outcomes has reduced further.
2. Catastrophic outcomes in which many people die are increasingly seen as evidence of systemic failures, including regulatory failure, and can lead to profound impacts across the whole industry. The Pike River mine disaster is a case in point.

J3 Risk zones

A further feature of our risk matrix approach is that we present the assessment results as a zone of risk.

Figure J.3 Risk matrix assessment example



The zone – dashed in the above example, illustrates the area of assessed risk. The zone is evaluated by considering potential outcomes. Between one and three scenarios are plotted for each risk, as appropriate. Judgement was used to plot the estimated frequency of these scenarios – when the scenarios are added together, the total risk is the same as the overall average number of fatalities per year that was estimated.

For instance, for train collisions with buses at level crossings the average expected number of fatalities per year is 0.08 (or one per 13 years). However, there is a possibility of greater numbers of deaths than one. In this instance, three scenarios are developed, one resulting in a single fatality (approximately 200-year return period), one with five fatalities (approximately 110-year return period), and a third with 15 fatalities (approximately 500-year return period). These scenarios are consistent with the calculated average expected fatalities per year of 0.08 (as shown below).

$$\mathbf{1} * \frac{\mathbf{1}}{\mathbf{200}} + \mathbf{5} * \frac{\mathbf{1}}{\mathbf{110}} + \mathbf{15} * \frac{\mathbf{1}}{\mathbf{500}} = \mathbf{0.08} \qquad \text{(Equation J.1)}$$

These different outcomes are represented by points on the matrix, which are then used to draw a dashed line to represent the region of outcomes, drawing on judgement to allow for other uncertainties.

As the points are an intermediate stage of the assessment, they are then dropped out for clarity, leaving the regions of assessed risk. It is the regions which are the risk assessment output, combining quantitative information where available with judgement to present an overview of the range of possible event outcomes.

J4 Summary

We consider our method of plotting a range of consequences for each risk is an advancement on traditional usage of risk matrices and overcomes many of the potential disadvantages. It has successfully been deployed by at least one leading New Zealand entity in the aviation sector.

While risk matrices have been the subject of criticism (Cox 2008), many of these criticisms can be mitigated by appropriate design and usage (Duijm 2015) and have been mitigated in this design. This includes design features such as:

- preserving the notional ratios between intervals
- explicitly acknowledging and showing uncertainty
- communicating how the matrix design reflects risk appetite.

This further assessment was undertaken on the shortlisted risks. The tool represents the current state of the art and meets the design objectives. While it takes more effort to apply, the outcomes are simple and intuitive, and are a simple evolution of the matrix process that many are now familiar with. The process of plotting scenarios on the risk matrices has lent us more confidence in the evaluation of the estimated fatalities per year (for those assessed). Through decomposing the risk into scenarios we were able to use judgement to assess the estimates and ensure reasonability of outputs. The outputs provide a useful vehicle for presenting the risks and associated uncertainties.

Appendix K: Assessed tsunami risk

K1 Wellington frequency:

The Hutt Valley line between Petone and Wellington is approximately 3.0 to 3.5m above mean sea level (MSL) and lies mostly within the 'orange' evacuation zone (Wellington City Council 2016; WREMO 2016). Assuming a stationary train can withstand a tsunami level of 0.5m, the critical level above which fatalities would occur is assumed to be approximately 3.5m.

The tidal range in Wellington is approximately 0.75m, mean low water neaps (MLWN) is 0.7, mean high water neaps (MHWN) is 1.45, and MSL 1.08 (see www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/tidal-level-information-for-surveyors).

These values are used to calculate the tsunami amplitude needed to impact on the Hutt Valley line in each of the three scenarios.

Tsunami amplitude needed for impact at MLWN

$$Impact\ amplitude\ MLWN\ (m) = Impact\ Height\ (relative\ MSL) + \Delta(MSL - MLWN)$$

$$Impact\ amplitude\ MLWN\ (m) = 3.5 + (1.08 - 0.7) \approx 3.9m$$

Tsunami amplitude needed for impact at MSL

$$Impact\ amplitude\ MLWN\ (m) = 3.5m$$

Tsunami amplitude needed for impact at MHWN

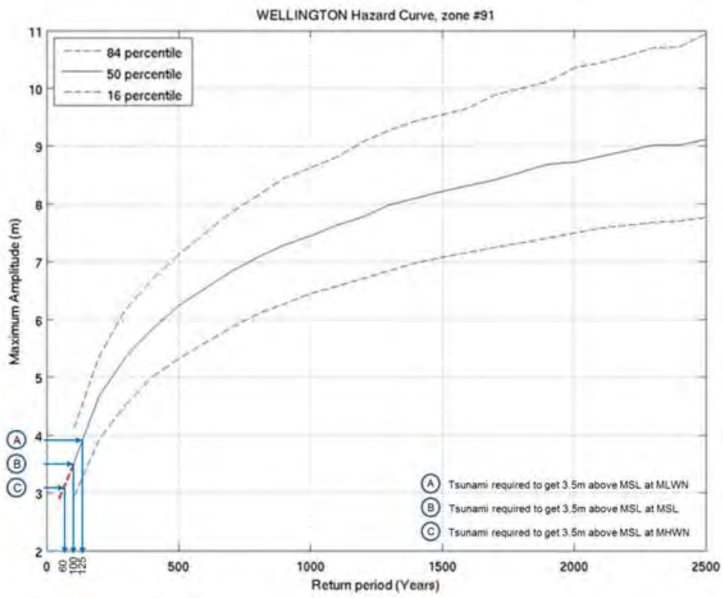
$$Impact\ amplitude\ MLWN\ (m) = Impact\ Height\ (relative\ MSL) + \Delta(MSL - MHWN)$$

$$Impact\ amplitude\ MLWN\ (m) = 3.5 + (1.08 - 1.45) \approx 3.1m$$

Note MLWN and MHWN have been used in this analysis to represent tide level towards the lower and upper ends of the typical daily range, as it is unlikely for a tsunami to occur exactly at MLWN or MHWN.

Review of tsunami hazard in New Zealand (Power 2013) presents the return period for tsunamis greater than a specified maximum amplitude. Each of the amplitudes calculated above are read from the graph as shown in figure K.1, resulting in an estimated return period for each scenario. Note the graph did not extend low enough for the MHWN scenario, so the line has been extended by Navigatus to estimate an approximate value.

Figure K.1 Area map and tsunami hazard curve for Wellington (all sources) (Power 2013)



Assuming 25% of the time is spent in the vicinity of MLWN, 50% at MSL, 25% at MHWN, the average return period can be calculated as per below, weighting the three scenarios.

Average return period (all tsunami sources):

$$Average\ Return\ Period\ (all\ tsunami\ sources) = 1/(\frac{0.25}{60} + \frac{0.5}{100} + \frac{0.25}{125}) \approx 90$$

In Wellington, 54% of tsunamis[127] originate from local sources[128] on the New Zealand continental shelf and margins (Power 2013). For tsunamis from more distant sources it is assumed there will be sufficient warning to evacuate before arrival.

Probability of a tsunami from a local source:

$$P(Local\ tsunami) = \frac{1}{90} * 0.54 = 0.006$$

Return period for a local tsunami impacting on the Hutt Valley rail line along the foreshore:

$$Return\ Period = \frac{1}{0.006} \cong 170 years$$

This results in an estimated return period of approximately 170 years.

K2 Auckland frequency:

From inspection of contour plans (Auckland Council nd), the ground levels in the vicinity of Britomart station and approach tunnels are approximately 3.5m above MSL.

The tidal range in Auckland is approximately 1.8m, MLWN is 0.95, MHWN is 2.78 and MSL is 1.87 (see www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/tidal-level-information-for-surveyors).

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[127] From inspection of figure 6.32 in Power (2013)

[128] Defined as tsunamis arriving at the nearest coastline within an hour (many can arrive within minutes).

These values are used to estimate the tsunami amplitude needed to impact on Britomart in each of the three scenarios.

Tsunami amplitude needed for impact at MLWN

$$Impact\ amplitude\ MLWN\ (m) = Impact\ Height\ (relative\ MSL) + \Delta(MSL - MLWN)$$

$$Impact\ amplitude\ MLWN\ (m) = 3.5 + (1.87 - 0.95) \approx 4.4m$$

Tsunami amplitude needed for impact at MSL

$$Impact\ amplitude\ MLWN\ (m) = 3.5m$$

Tsunami amplitude needed for impact at MHWN

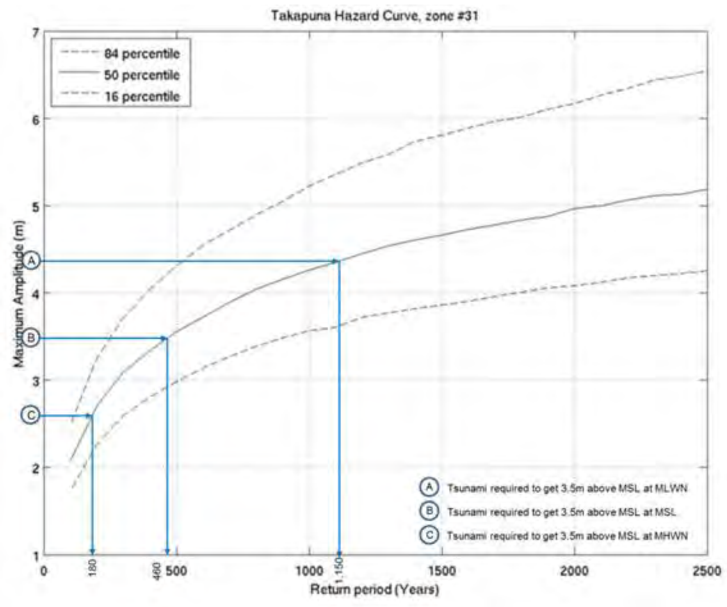
$$Impact\ amplitude\ MLWN\ (m) = Impact\ Height\ (relative\ MSL) + \Delta(MSL - MHWN)$$

$$Impact\ amplitude\ MLWN\ (m) = 3.5 + (1.87 - 2.78) \approx 2.6m$$

Note that MLWN and MHWN have been used in this analysis to represent tide level towards the lower and upper ends of the typical daily range, as it is unlikely for a tsunami to occur exactly at MLWN or MHWN.

Power (2013) presents the return period for a tsunami greater than a specified maximum amplitude. Each of the amplitudes calculated above are read from the graph as shown in figure K.2, resulting in an estimated return period for each scenario.

Figure K.2 Area map and tsunami hazard curve for Auckland (all sources) (Power 2013)



Assuming 25% of the time is spent in the vicinity of MLWN, 50% at MSL, 25% at MHWN, the average return period can be calculated as per below, weighting the three scenarios.

Average return period (all tsunami sources):

$$Average\ Return\ Period\ (all\ tsunami\ sources) = 1/(\frac{0.25}{1{,}150} + \frac{0.5}{460} + \frac{0.25}{180}) \approx 370$$

Only tsunamis originating from local sources would have insufficient warning time to evacuate. Figure 6.6 of Power (2013) indicates approximately 30% of Auckland east coast tsunamis originate from the New Zealand continental shelf and nearby waters.

Probability of tsunami from a local source:

$$P(Local\ tsunami) = \frac{1}{370} * 0.3 = 0.0008$$

Return period for a local tsunami impacting on the Hutt Valley rail line along the foreshore:

$$Return\ Period = \frac{1}{0.0008} \cong 1{,}200 years$$

This results in an estimated return period of approximately 1,200 years.

K3 Consequence

To estimate the average expected fatalities per year from local tsunamis, the number of people the tsunamis will have an impact on needs to be estimated. This is dependent on the time of day the tsunami hits. The following table summarises the impact scenarios and proportion of time each is assumed for both Auckland and Wellington.

Table K.1 Estimated fatality scenarios

Scenario	Estimated fatalities	Proportion of day
Peak traffic	2 trains on line, each with 250 fatalities	20% of day
Non-peak traffic	1 train on line partly loaded, 50 fatalities	60% of day
Night	No trains running, no fatalities	20% of day

$$Average\ Consequence = 500 * 0.2 + 50 * 0.6 + 0 * 0.2 = 130\ fatalities\ per\ event$$

K4 Average expected fatalities per year

Combining the average frequency and average consequence, provides an estimate of the expected fatalities per year for both Auckland and Wellington.

$$\boldsymbol{E}\left(\frac{Fatalities}{Year}\right) = \left(\frac{1}{1200} + \frac{1}{170}\right) * 130 \cong 1\ fatality/year$$

K5 Discussion

There are significant uncertainties with estimating tsunami risk. One uncertainty is that obtaining specific survey data is beyond the scope of this research. A second uncertainty is t we do not have access to separate size–frequency distributions for local tsunamis versus more distant tsunamis. Our analysis method implicitly assumes the distribution of local tsunamis is the same as the overall population of tsunamis for smaller, more frequent tsunamis this analysis is concerned with. Third, we are using the extreme left-hand end of the tsunami size–frequency charts prepared by GNS (especially in Wellington), so these predictions may not be as accurate as more central estimates.

Appendix L: Level crossing analysis

L1 Type of control (speed restrictions)

L1.1 Purpose

The purpose of this analysis is to explore whether incident records support proposals for different speed restrictions to apply to heritage rail vehicles at rail crossings with barrier arms.

L1.2 Analysis

This analysis was undertaken on collisions with both heavy and light road vehicles between 1 January 2010 and 15 October 2015 extracted from the Transport Agency Rail Information System (RIS) database. RIS data prior to 2010 is not regarded by Transport Agency rail staff as suitable for aggregated analysis. Because there is no universal way of identifying a near miss at passive level crossings (ie without bells or barriers) there may be some degree of reporting bias between the categories of crossing protection for near misses. For instance it is more clear cut to a locomotive driver if a vehicle is on a level crossing when barriers are moving. As such, near miss incidents were excluded as they are unlikely to be a good indicator of the relative level of risk and may introduce bias to the analysis.

L1.3 Classification of collisions

The field Occurrence Sub Code 1 in the RIS data was filtered for 'collision heavy road vehicle' and 'collision light road vehicle'. This resulted in 215 records. For these collisions, the description field was then reviewed to select incidents that identifiably occurred either on a public level crossing or a private driveway (136 collisions). Collisions that occurred on a siding, port road with no public access, non-level crossing section of tracks, private yard and any incidents involving trams were excluded.

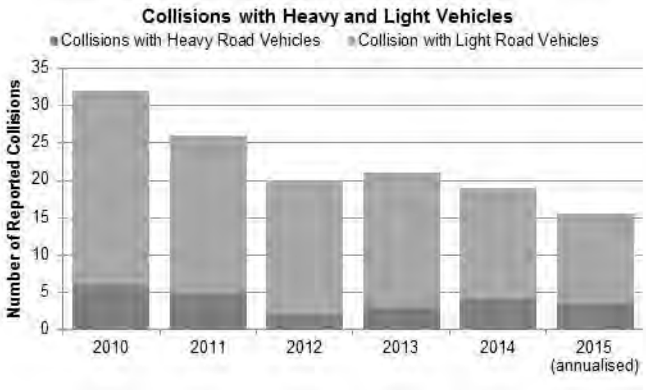
Using the description field, the level crossing location of the subset of collisions identified above was determined (where available) and viewed on Google Earth Street View. The crossing was then classified as either private or public. Following this, public crossings were classified as either protected by half-arm barriers, flashing lights and bells, or passive. Those which could not be classified due to lack of location information in the description or not being available via street view were excluded from the analysis (two collisions). If a crossing's protection level had changed in the time since the collision or since the Google Street View was captured, the classification may have been incorrect for the incident. This would only affect a small number of incidents, if any, and was unlikely to be material to the analysis.

L1.4 Counts and trends

Figure L.1 shows no evidence of a trend in the number of collisions with heavy road vehicles, as the annual number is small. Accordingly a change in the number of collisions may seem proportionately large. For example, 2014 saw four collisions, compared with the three that occurred in 2013; while this is a 33% increase in the number of collisions from the prior year it represents only one additional incident.

Overall, however, collisions with vehicles seem to exhibit a reduction over time (since 2010). This is mainly due to a reduction in collisions with light road vehicles, as collisions with heavy road vehicles do not show a clear pattern over time.

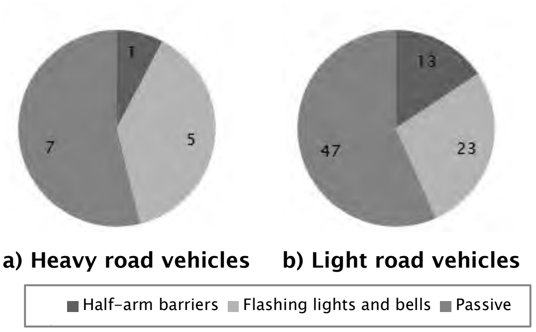
Figure L.1 Number of reported level crossing collisions with vehicles per year (public and private crossings).



L1.5 Pooling of data

Counts of collisions with vehicles on public level crossings by crossing type are shown in figure L.2. The majority of collisions occurred on passive crossings, followed by flashing lights and bells, and lastly, half-arm barriers. The graphs indicate heavy and light road vehicles have a similar distribution of collisions across the different crossing types. This similarity of distribution is important as it suggests (at least for crossing type) light vehicle collisions may be indicative of heavy road vehicle collisions.

Figure L.2 Number of collisions with road vehicles on public level crossings (1 Jan 2010 – 15 Oct 2015)



On this basis the data from heavy and light vehicle crossing collisions has been pooled to create a larger dataset of collisions by all vehicle types. This larger data set allows close examination of the association between crossing type and collision rates.

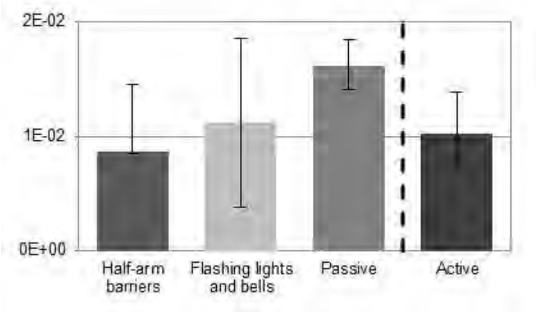
L1.6 Rates

Though there are more collisions on passive crossings than crossings protected with flashing lights and bells or half-arm barriers, there is also a greater number of passive road crossings. The level crossing risk assessment guide (NZ Transport Agency 2013b) specifies a total of 1,268 public level crossings in New Zealand. Of these, 274 are protected by half-arm barriers, 424 by flashing lights and bells, and 570 are passive.

Combining the collisions for the heavy and light road vehicle categories and using the above counts of crossings, yields rates of level crossing collisions per crossing per year shown in figure L.3. This allows direct comparison between the crossing types on a per crossing basis.

Half-arm barriers and flashing lights and bells can be considered as forms of active level crossings. The analysis identifies active crossings as having a lower rate of collisions per year than passive crossings. This is indicative of the risk level at passive and active crossings, but due to the limited dataset may not be representative of the relative risk in the long run.

Figure L.3 Rate of public level crossing collisions with vehicles per crossing per year (1 January 2010 – 15 October 2015)



L1.7 Significance

Using the statistical software package R, a Poisson regression was built for the number of collisions each year at both passive and active level crossings. The calculated p-value for the active/passive factor was 0.03. This indicates a 3% probability of the result being by chance.

L1.8 Conclusions

Active crossings have a lower rate of collisions per year than passive crossings. This supports proposals for different speed restrictions to apply to heritage rail vehicles at rail crossings with barrier arms.

L2 Short stacking

L2.1 Purpose

A level crossing is defined as short stacked if a maximum-sized (22m as shown in figure L.4) heavy motor vehicle could block either the crossing as shown in figure L.5, or the intersection when stopping short of the rail lines (NZ Transport Agency 2007).

Short stacking presents a significant risk to both heavy road vehicles and train drivers and passengers. The purpose of this analysis is to determine whether there is a significantly elevated risk at short stacked level crossings.

Figure L.4 Maximum dimensions for heavy trailers and combination vehicles (NZ Transport Agency 2011)

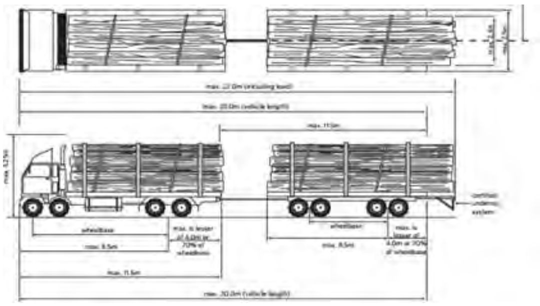


Figure L.5 Short stacking, Crown Road, Auckland (TAIC 2012c)

L2.2 Background

L2.2.1 Historic recommendations and improvements

TAIC has raised the issue of short stacking in at least three rail reports, one in 1996, another in 2002 and a third in 2011 (TAIC 2012c; TAIC 1997; TAIC 2002), recommending to the Chief Executive of the NZ Transport Agency that as a matter of urgency this safety issue be addressed.

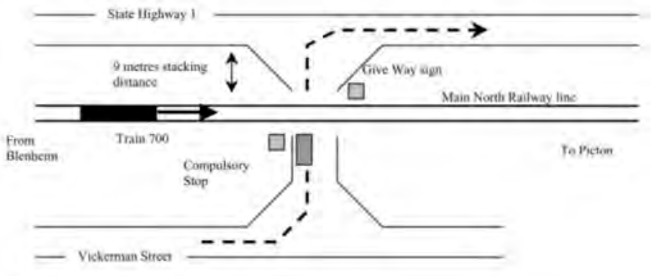
Between the 2002 and 2011 reports there has been improvement to the general standard of sign posting required at all level crossings. A Rail-Road Level Crossing Safety Forum working group was also convened to investigate, recommend or propose projects or practices to improve safety at railroad level crossings to prioritise and implement projects and programmes (TAIC 2012c).

In the final report for Rail Inquiry 11–104 (TAIC 2012c), TAIC identified nine crossings that had two or more collisions over the space of 10 years. Five of those had alarm upgrades during this period and there were no further collisions. This illustrates the importance of continually reviewing crossings and implementing appropriate strategies to reduce risk.

Following the Paekakariki collision in 2011, at the Beach Road level crossing, remedial work was undertaken creating space for large vehicles to make a left turn where a right turn is not possible (TAIC 2012c). However, following this modification there was a further near miss incident with a bus in 2013. On that occasion as the train approached there was a bus stopped partially on the crossing with a taxi behind it.

Figure L.6 Road sign indicating short stacking distance (NZ Transport Agency 2007)

Figure L.7 Site plan of Vickerman Street level crossing, the site of a near miss with a petrol tanker in 2002 (TAIC 2002)



L2.2.2 Controls

The *Traffic control devices manual* (NZ Transport Agency 2007) recommends where there is short stacking, consideration should be given to providing:

> *a. auxiliary road space (slip lanes or shoulder widening) to allow a vehicle to escape or wait clear of the railway line or road traffic*
>
> *b. where an alternative route exists, partial closure (to vehicles over a defined length) or complete closure*
>
> *c. channelisation, realignment or relocation of the road*
>
> *d. realignment of the railway line*
>
> *e. active control of the level crossing and intersection.*
>
> *Where queues of traffic block the level crossing, options (c) and (e) would be indicated. If the intersection and level crossing are signalised, the intersection signals and railway signal circuits should be linked.*

L2.3 Incidents

The field Occurrence Sub Code 1 in the RIS data was filtered for 'collision heavy road vehicle' and 'near collision heavy road vehicle'. For these collisions, the description field was reviewed to identify public level crossing incidents as per the methodology set out in section L1.3. Using the description field, the level crossing location (road name) of these collisions was determined (where available).

L2.4 Short stacked level crossings

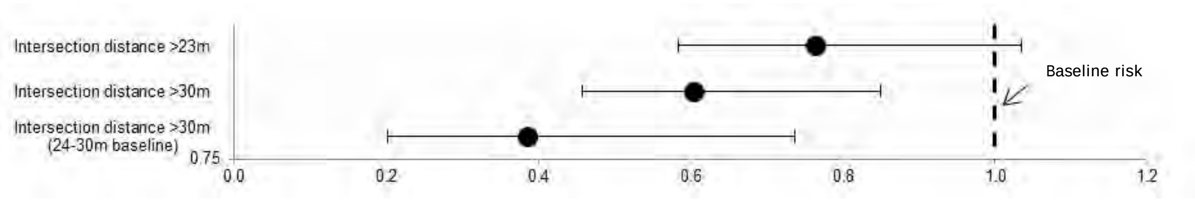
A schedule of short stacked level crossings in New Zealand was obtained from the Transport Agency. This schedule was originally compiled by KiwiRail and was referred to in TAIC report 11–104 (TAIC 2012c). As per report 11–104, the stacking distance is measured between the centreline of the nearest railway line and the continuity/edge line at an adjacent intersection.

Of the 1,268 public level crossings in New Zealand (NZ Transport Agency 2013b), 213 crossings were identified as having a stacking distance no more than 23m in the schedule provided to Navigatus, a further 54 had a stacking distance between and including 24m and 30m. There are probably many more rural private crossings used by heavy and long vehicles delivering and removing stock.

L2.5 Rates

The basis for this analysis was the rate of reported collisions and near collisions with heavy vehicles per crossing. Using the statistical software package R, a Poisson regression was built for the number of collisions each month at both short stacked and non-short stacked level crossings. Three cases were run, the first comparing crossings with at most 23m stacking distance with all other crossings, the second comparing crossings with at most 30m stacking distance with all other crossings, and the last comparing crossings with 24m to 30m stacking distance with crossings with at least 30m clearance. The results of this analysis are shown in figure L.8.

Figure L.8 Risk ratios for regular crossings compared with short stacked crossings with 95% confidence intervals



The above figure shows intersections with stacking distance >23m as having approximately 80% (confidence interval between 60% and 100%) of the rate of incidents in comparison with all other crossings. Intersections with >30m stacking distance have approximately 60% of the incident rate compared with all other crossings.

The third scenario compares crossings with >30m stacking distance with crossings with a stacking distance between 24m and 30m. This shows the biggest difference. This result suggests having a stacking distance >30m significantly improves safety even compared with 24m–30m.

All these results are statistically significant. This analysis finds that collisions or near misses with heavy road vehicles are much more likely to occur at a short stacked crossing.

L2.6 Short stacked crossings in Auckland and Wellington metro

Table L.1 lists all the short stacked crossings in the Auckland and Wellington metro areas identified according to section L2.4.

Table L.1 Auckland metro short- stacked crossings

Street	Line section	Primary control	Train speed (km/h)	Daily train count	Left (m)	Right (m)	Comment
Crown Road	North Island Main Trunk–- Ak metro	Half boom flashing lights	80	75	18	-	6 near collisions with heavy road vehicles
Logan Road	North Island Main Trunk – non-metro	Half boom flashing lights	110	31	12	-	1 near collision with heavy road vehicles
Sherrybrooke Place	North Auckland Line – Ak metro	Half boom flashing lights	80	101	10	13	–
Bruce McLaren Road	North Auckland Line – Ak metro	Half boom flashing lights	80	101	10	10	–
Glenview Road	North Auckland Line – Ak metro	Half boom flashing lights	80	101	28	40	Short stacking distance greater than the 23m identified as recommended.

Street	Line section	Primary control	Train speed (km/h)	Daily train count	Left (m)	Right (m)	Comment
Victoria Street	Onehunga Branch	Half boom flashing lights	60	51	6	182	May not be a significant risk as Victoria Street has right of way after crossing. Two near collisions with heavy road vehicles.
Galway Street	Onehunga Branch	Half boom flashing lights	60	51	7	175	May not be a significant risk as Galway Street has right of way after crossing.

Following from the findings in section L2.5, where short stacked crossings are significantly more likely to have a heavy vehicle collision, safety of these crossings should be reviewed if there is a proposal to increase the frequency of metro passenger services on these lines. The safety of these level crossings in their current configuration should be reconsidered as part of the operator's risk assessment process for the timetable change.

Table L.2 Wellington metro short stacked crossings

Street	Line section	Primary control	Train speed (km/h)	Daily train count	Left (m)	Right (m)	Comment
Simla Crescent	Johnsonville Line	Half boom flashing lights	50	79	-	17	–
Beach Road[129]	Kapiti Line	Half boom flashing lights	Not known	Not known	-	11	Remedial work[130] undertaken 2012. One near collision with heavy road vehicles since then.

L2.7 Conclusions

Short stacking presents a major risk to both heavy road vehicles and train drivers and passengers. There is a significantly elevated risk at short stacked level crossings compared with other crossings. The risk is higher when the stacking distance is slightly longer. This second finding indicates a modest increase in stacking length may not be an effective mitigation. This finding lends support to considering alternative mitigations such as widening the road or creating room for a large vehicle to make a left turn in the situation when a right turn is not possible as in the Beach Road alterations.

[129] Not mentioned in list provided to Navigatus, but the scene of a serious collision and the subject of a TAIC report (TAIC 2012c).

[130] Re-profiling the intersection and redesign of the splitter island to create room for a large vehicle to make a left turn in the situation when a right turn is not possible (TAIC 2012c)

L3 Priority crossings

L3.1 Purpose

The purpose of this section is to compile a list of level crossings which may be a priority for remedial work. This may be due to a higher number of collisions at the crossing, potentially involving metro trains or being on short stacked level crossings (the latter two leading to higher consequence collisions).

L3.2 Analysis

A list of priority crossings (shown in table L.3) was compiled using the same data as in section L2. Each crossing was assigned a risk score according to whether metro services operate over the crossing, the number of collisions with vehicles and near collisions with heavy vehicles and whether the crossing is short stacked. The following formula was used to calculate the total points column.

Risk score = M * C * S

M = if metro services operate over crossing then 2 otherwise 1

C = 2*Collision heavy vehicle + 1*Near collision heavy vehicle + 1*Collision light vehicle

S = if crossing is short stacked (<= 30m) then 2 otherwise 1

A total of 388 level crossings were assessed (crossings with at least one collision with a vehicle or near collision with a heavy vehicle or which were short stacked). Crossings with a risk score of 4 or more are shown in table L.3.

Table L.3 Priority level crossings – risk assessment

Road	Area	Metro	Collision	Short stacking	Risk score
Crown Road	Paerata	2	6	2	24
Hoskyns Road	Rolleston	1	7	2	14
Woodward Road	Mt Albert	2	4	1	8
Hinemoa Street	Wellington	2	3	1	6
Northpark Rd	Ashburton	1	6	1	6
Racecourse Road	Taumaranui	1	3	2	6
Curries Road	Christchurch	1	5	1	5
Beach Road[(a)]	Paekakariki	2	2	1	4
Creyke Road	Darfield	1	2	2	4
Hunter Road	Blenheim	1	2	2	4
Judds Road	Solway	2	1	2	4
Manuroa Rd	Auckland	2	2	1	4
Morningside Drive	Auckland	2	2	1	4
Spartan Rd	Takanini	2	2	1	4
Victoria Street	Onehunga	1	2	2	4
Waitangi Road	Awatoto	1	2	2	4
Wiltsdown Road	Lichfield	1	2	2	4
Kainui Road	Taupiri	1	2	2	4

[(a)] Due to the extensive works carried out at Beach Road in 2012, incidents from before this period were removed, and incidents that occurred after were doubled due to the reduced period of record

L3.3 Conclusions

Two level crossings stand out; Crown Road in Paerata, south of Auckland and Hoskyns Road in Rolleston, although these may have already been improved.

L4 Collisions and near collisions with buses

Collisions and near collisions with buses presents an important subset of incidents as the consequence is potentially catastrophic with a large loss of life. Two of the 10 biggest loss of life incidents in Europe between 1980 and 2009 were the result of collisions with buses, with 33 and 39 fatalities respectively (Evans 2011).

Of the two collisions with buses identified in the RIS, both had passengers aboard, with one being a school bus. There were a further 17 near collisions with heavy vehicles in which the description identified ‘bus’, five of which were identified as school buses with a statement in one indicating they were ‘close enough to see the children pointing at them’.

The prevalence of incidents involving buses is a concern. This may be an enforcement issue.