Improving Road Safety Barrier Effectiveness: Issues and Opportunities

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Abstract

A key element of the Safe System approach is safer roads and roadsides. Roadside safety interventions commonly default to road safety barrier installations to shield hazards; due to budget limitations and constrained road reserves. But the significant safety benefits possible through advances in barrier hardware technology and improvements in the understanding of design have not been fully realised. Achieving fit for purpose installations continues to challenge the capabilities of the roading infrastructure industry. The emerging challenge will be to meet the aspirations of the road controlling authorities through improving road safety barrier design, specification and installation.

The likelihood of sophisticated barrier hardware performing as designed, tested and accepted becomes increasingly questionable as the installation conditions vary from those that were tested. A survey of legacy road safety barrier systems in New Zealand provides some guidance in the development of a strategy to advance the general improvement in road safety barrier design, hardware specification and installations towards improving roadside safety.

There are a number of systemic challenges facing industry that need to be addressed to get the most out of the investment in road safety barriers. These include:

- implementing the most effective compliance regime,
- accepting compliant hardware and moving away from legacy hardware that cannot achieve compliance,
- developing a certification regime for both designers and installers.

This paper reviews issues and opportunities to achieving improved road safety barrier installations.

Introduction

A key element of the Safe System approach is safer roads and roadsides (New Zealand Road Safety Strategy 2010-2020). A safe road system is one where drivers rarely leave the road; but when they do, the vehicle and roadside are both designed to help protect vehicle occupants from death or serious injury. Roadside safety interventions commonly default to road safety barrier installations to shield hazards. This is often due to the higher costs of other interventions such as removal of the hazard.

A legacy of road safety barrier systems exists on the New Zealand State Highway network. The majority of these have been installed through the last 50 years. Current performance expectations have continually evolved through a greater understanding of how road safety barrier systems contain and redirect impacting vehicles. Consequently, most of the older legacy systems will have been designed and installed without the benefit of the more recent knowledge, and consequent performance standards and hardware. In 1999 the New Zealand Transport Agency (then Transit New Zealand) adopted the United States Federal Highway

Administration National Cooperative Highway Research Program (NCRHP) 350 test regime to ensure that all new installation hardware met reasonably robust performance standards.

The likelihood of barrier hardware performing as designed, tested and accepted becomes increasingly questionable as the installation conditions vary further from those that were tested. As technical advances in barrier hardware and design have not been well understood by practitioners significant faults that will affect performance continue to be common place.

The New Zealand Transport Agency (NZTA) undertook this study to provide a more informed assessment of the nature and size of the potential performance liability of legacy systems. This information would then to be used in the development of network safety management strategies. These strategies could include industry training to increase capability amongst those involved in the design, installation, and maintenance of road safety barrier systems.

Scope of Research Study

Highway segments were selected to be representative of the rural two lane State Highway network. This was to enable the findings to be used more broadly in the development of a network strategy. A sample of State Highway road safety barrier installations on those segments were assessed to broadly gauge overall crash performance risk. The surveys were undertaken in June 2010. The road safety barrier installations were drawn from:

- Napier Region: State Highway 2 – Woodville to Hastings
- Tauranga Region: State Highway 2 – SH33 to Matata
- Tauranga Region: State Highway 2 – Athenree to Katikati.

This risk assessment was derived through the identification and gauging of design, installation or maintenance deficiencies. The deficiencies were categorised based on an assessment of their potential contribution to a crash outcome, as being minor, significant or serious. The aggregate risk assessment for each installation was deemed to be that of the worst deficiency.

Significant or serious design and installation deficiencies were generally attributable to inadequate length of need, inadequate approach grading and clear areas at end treatments. On older installations, this often will be a reflection of how the understanding of crash performance has progressively improved since their installation. An end treatment that was appropriate when installed many years ago may not be compliant with current performance standards.

However it may be that more recent installation problems are a consequence of a poor understanding of not only how a barrier system operates during an impact, but also what the implications are of not achieving the design and test conditions. For example, inadequate approach grading can potentially result in an impacting vehicle not engaging an end terminal properly, with a poor crash outcome.

Poor routine maintenance could potentially compound design and installation deficiencies. In the event of an appreciable impact, those installations with significant or serious maintenance deficiencies could potentially experience a system failure, and consequently a poor crash outcome.

On completion of the surveys, common deficiencies were categorised as design, installation, or maintenance issues and assigned relative treatment priorities.

Survey Methodology

Survey procedures were developed to readily identify the deficiencies and grade the associated risks. The procedures are a screening tool rather than a substitute for the more detailed fit for purpose inspections. The screening enables the road controlling authority or network management consultant to identify those locations where more detailed, specialised assessments may be warranted.

Barrier installations were inspected along the selected representative highway lengths. Surveys were not done at locations where they could not be undertaken safely without additional positive temporary traffic management measures. Reasons for this included the lack of shoulder and verge width for positioning the survey vehicle, inadequate sight distance, or a limited ability to do most of the survey work from behind the barrier. As these locations accounted for less than 30% of the total number of sites on the surveyed highway lengths, the results are on balance representative.

The assessments for each location included:

- General
  - Leading end location reference.
  - An indicative assessment of age to nearest 5 years.
  - Hazard description that required the barrier system.
  - Overall length estimate to nearest metre.
- Design
  - An indicative assessment of the length of need.
  - An indicative assessment of the clear area at the ends of the barrier.
  - An indicative assessment of the appropriateness of the installed end treatment.
- Installation
  - An indicative assessment of the end treatment installation including compliance with current performance standards, applicable supplier or agency installation guidelines and delineation.
  - An indicative assessment of the installation of the barrier to the mid-length of the installation including height, rail and post condition.
- Maintenance
  - An indicative assessment of the general condition and outstanding routine maintenance that could affect performance.

Assessment Criteria

Overview

Austroads has produced a list of common roadside hazard types, including barriers, with relative crash severities (Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers, 2009). Roadside features such as poles, trees and cliffs represent significant hazards to vehicles that leave the roadway. Although the installation of barriers will generally reduce this risk, poorly designed or installed barriers could negate any risk reduction. This is

particularly the issue when these deficiencies are associated with end terminals that are in crash prone or high risk locations.

Poor installation and maintenance of a barrier system can lead to snagging or pocketing of an impacting vehicle and, ultimately, rupture or override of the barrier. Whereas, inadequate length of need indicates that the length of barrier is unlikely to be sufficient to prevent an errant vehicle from impacting a roadside hazard rather than reflecting the likely impact performance of the barrier itself. Similarly, inadequate approach grading can also potentially result in an impacting vehicle not engaging an end terminal properly.

A suitable survey assessment methodology for barrier installations was not found. Consequently, indicative evaluation criteria were developed by the surveyor to enable the simplified assessment of the installations. These criteria are fundamentally relative measures, whereby the further a particular element is out of the norm the greater the significance and relative risk. They are not precise and were used only as a coarse gauge in assessing an installation. The grading criteria for the generalised deficiencies are summarised in the following sections:

Design

- Length of Need: Measure = length deficiency

Risk	**Percent**
Minor	< 25
Significant	25 - 50
Serious	> 50

- Clear Area: Measure = length or width deficiency

Risk	**Percent**
Minor	< 25
Significant	25 - 50
Serious	> 50

- Barrier System Selection

Risk	**Description**
OK	Compliant – Optimal Choice
Significant	Compliant – Sub Optimal Choice
Serious	Compliant – Incorrect Choice
Serious	Non-Compliant

Installation

- Height: Defined by worst condition.

Risk	**Height**
OK	Within +/- 20mm
Significant	Outside +/- 20mm But Within +/- 50mm
Serious	Outside +/- 50mm

- Installation Errors: Defined by worst condition.

Risk	Description
Minor	Incorrect or Missing Delineation
M/S/S	Approach & Clear Area Grading Deficiency
M/S/S	Fill Support Behind Posts Deficiency
Serious	Incorrect Bolting
Serious	Missing Components

Where M/S/S is Minor or Significant or Serious.

Maintenance

Defined by worst condition.

Risk	Description
Minor	Impact Head Droop
Significant	Loose Anchor Cable
Significant	Post Condition 5/10 to 7/10
Serious	Post Condition < 5/10
Serious	Broken Components (e.g. posts)
Serious	Blocked Impact Head

Relative Priority

The relative priority to address the deficiencies was also estimated including:

- Priority 1 (P1) refers to a deficiency or condition that can either be easily corrected or is fundamental to the safe operation of the barrier system, or both. Examples would be missing or loose anchor cables, or an impact head that is blocked by detritus.
- Priority 2 (P2) represents a more generalised deficiency such as a significant or serious height variation, which would best be addressed through an area wide treatment.
- Priority 3 (P3) represents a more extensive intervention that would effectively result in the complete redesign and installation of the system. An example of this would be a significant or serious shortfall of the length of need requirement.

The priority was adjusted where a higher risk issue would require attention sooner. For example a serious length of need deficiency that would generally have required Priority 3 action that also included a non-compliant terminal was raised to a Priority 2.
In addition, absent or incorrect delineation was rated as a minor installation deficiency. However, that rating was given a higher rank when the corrections of design or installation deficiencies were not likely to occur in the short term. Delineation becomes more important in that situation, as the ongoing exposure of traffic to these end treatment hazards requires that they at least be warned of their danger.

Survey Results

Overview

The basic survey results for the installations are presented in Appendix A. The development of management strategies to address the problem requires an understanding of the type and

extent of these faults. Consequently, the faults were further aggregated for comparison, and inferences drawn that could lead to a range of management interventions. A summary of the significant and serious deficiencies are summarised in Table 1.

Table 1: Significant and Serious Deficiencies Summary

	Napier	Tauranga	Total	Total %
Design				
LoN	26/40	37/40	63/80	79
Clear Area	24/40	23/40	47/80	59
Selection	11/40	20/40	31/80	39
Installation				
Terminals	34/40	35/40	69/80	86
Barrier	29/40	40/40	69/80	86
Maintenance				
Terminals	23/40	35/40	58/80	73
Barrier	2/40	15/40	17/80	21

Deficiency Patterns

Deficiency patterns were broken down by the estimated age of the installations. In those cases where there had been significant work more recently, an estimate of the latest intervention age was made. Tables 2 and 3 summarise the significant and serious deficiencies by age.

Table 2: Napier Significant and Serious Deficiencies - Percentage by Age

Years	< 5	5-10	10-15	15-20	> 20
Design					
LoN	15	54	8	19	4
Clear Area	13	54	8	17	8
Selection	18	18	0	46	18
Installation					
Terminals	12	47	18	18	5
Barrier	10	45	21	17	7
Maintenance					
Terminals	13	61	13	13	0
Barrier	0	0	100	0	0

Table 3: Tauranga Significant and Serious Deficiencies - Percentage by Age

Years	**< 5**	**5-10**	**10-15**	**15-20**	**> 20**
Design					
LoN	19	22	8	27	24
Clear Area	13	18	4	35	30
Selection	5	0	5	55	35
Installation					
Terminals	14	17	14	52	3
Barrier	20	20	13	40	7
Maintenance					
Terminals	13	6	26	46	9
Barrier	13	13	7	47	20

Generally, the deficiency patterns between the Napier and Tauranga surveys were similar for the newer installations less than 5 years. However, the design and installation deficiencies were more pronounced in the 5 to 10 year range in Napier, compared to the 15 to 20 year range for Tauranga. These could for example be due to a change in network managers or contractors.

The maintenance issues related to terminals reflect the characteristics of the terminals installed in those age brackets. Issues with the 15-20 year old end treatments in Tauranga relate to non-compliant end terminal installations. Generally, these have also not been maintained routinely. The more recent Napier terminal maintenance faults are predominately loose anchor cables, particularly in the 5 to 10 year old range.

Interpretation of Findings

A barrier system can have deficiencies that fall into any combination of the design, installation or maintenance categories, for either of the end treatments or the barrier system. The deficiencies are not mutually exclusive, in that an overall installation could have a combination of deficiencies and locations.

The design and installation issues found in older systems are likely a consequence of being completed when barrier design and performance was less well understood. Similar problems found in more recent installations suggest that design and installation quality processes are failing to achieve acceptable installations.

Most of the road safety barrier installations surveyed had significant or serious deficiencies that could affect their performance and consequently the crash outcome. There were no installations that had no significant or serious deficiencies.

Between 60% and 80% of the surveyed installations had design deficiencies due to inadequate length of need or safety clear area. About 40% of installations had non-compliant or inappropriate end treatments. The inappropriate end treatments were generally legacy systems such as BCT treatments used in leading end applications. Most of these would have been installed long before the current performance standards were developed and adopted.

About 86% of the surveyed installations had significant or serious installation deficiencies. However, most installation deficiencies are readily repairable. Typically these include end treatment issues associated with height, grading, or missing or incorrect terminal bolting patterns.

About 75% of installations had issues relating to outstanding end treatment maintenance, and about 20% of installations had barrier maintenance issues. Most of the significant and serious maintenance issues could be easily identified and remedied. Typical examples include anchor cable tightening. It could be that network managers or contractors were not trained to identify appropriate maintenance issues, or are avoiding contractual obligations.

Conclusions and Recommendations

The following recommendations would contribute towards addressing the various road safety barrier legacy issues identified, help to raise industry capability and help to improve the quality of future barrier installations. They need not proceed together as some may require more immediate action, while others will take longer to initiate and should be considered with other roadside safety priorities. The recommendations are:

- General
  - Adopt the road safety barrier compliance regime that most effectively represents the vehicle fleet distribution.
  - There should be no further installations of non-compliant hardware. At risk non-compliant legacy hardware installations should be programmed for replacement relative to risk.
  - Establish performance measures in design, installation, and maintenance contracts to reflect progress towards achieving road safety barrier quality assurance system, deficiency databases, and the monitoring and reporting of progress.
  - Develop an industry training regime that addresses design, installation, and maintenance issues.
- Design
  - Develop a quality assurance regime based on having appropriately trained people responsible for approving the design and installation of barrier systems. The quality assurance system should include an audit program for design, installation and maintenance areas.
  - Develop and disseminate standard plans for typical design and installation details (e.g. transitions and curved rail end treatments).
  - There is a large proportion of existing systems that have inadequate length of need, clear area, or have non-compliant terminal ends that will require funding to address. On balance most of the serious and significant risk installations will effectively require replacement, given the extent of the faults.
- Installation
  - Develop a road safety barrier installation and maintenance manual to cover the identification, installation and maintenance checklists for common barrier hardware.
  - Have the maintenance consultant assess all installations and develop a prioritised deficiency database. The redress of legacy design and installation deficiencies older than existing contacts would likely require program funding, as it could be outside the scope of current maintenance contracts.

    - All installation deficiencies that can be readily addressed (e.g. incorrect bolting patterns, missing bolts, delineation and grading) should be remedied when addressing routine maintenance deficiencies.
- Maintenance
    - Have all maintenance contractors review their current barrier inventory, noting that they are required to *maintain the barriers in a condition fit for purpose.*
    - Changes should be made to contract documents to reinforce the need for routine rather than random maintenance, at least to the same level of emphasis as barrier repairs are now covered in these documents.
    - Audit the inventory and use whatever sanctions are available to achieve the intended purpose of having all installations fit for purpose. All installations should be routinely maintained to standard, irrespective of whether they have design or installation issues that cannot be readily addressed.

Further, as a large proportion of this aging infrastructure nears the end of its life cycle, costly replacements will need to be considered and programmed. Replacements will generally involve more extensive installations to meet the higher levels set out in current standards.

The development of retrofit or replacement programs will need to be considered in the context of overall roadside safety protection and improvement priorities. The cost effectiveness of improvements to road safety barrier legacy systems must be balanced not only with that of new barrier installations, but also with those of other safety interventions.

References

New Zealand Ministry of Transport, New Zealand's Road Safety Strategy 2010-2020, 2010.
Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers, 2009.

Appendix A

Plate A1: Road Safety Barrier Legacy Survey Deficiencies – Napier

ROAD SAFETY BARRIER LEGACY SURVEY - NAPIER SUMMARY JUNE 2010

Location	Age (years)	LoN	DESIGN		INSTALLATION		MAINTENANCE	
			Clear Area	Terminal	Terminal	Barrier	Terminal	Barrier
Napier 1 - Leading	10 to 15	significant	significant	OK	serious	serious	serious	OK
- Trailing	10 to 15	serious	serious	OK	significant	serious	OK	OK
Napier 2 - Leading	20 +	serious	serious	serious	serious	serious	OK	OK
- Trailing	<10 & 20 +	serious	serious	significant	serious	serious	OK	OK
Napier 3 - Leading	< 10	OK	serious	OK	serious	OK	OK	OK
- Trailing	< 10	NA	significant	OK	serious	OK	OK	OK
Napier 4 - Leading	< 10 & 10 to 20	OK	significant	OK	OK	serious	OK	OK
- Trailing	< 10 & 10 to 20	significant	OK	OK	minor	serious	OK	OK
Napier 5 - Leading	< 5	serious	OK	OK	OK	OK	OK	OK
- Trailing	< 5	serious	OK	OK	significant	significant	significant	OK
Napier 6 - Leading	15 to 20	serious	serious	serious	serious	minor	serious	minor
- Trailing	15 to 20	NA	serious	OK	serious	serious	serious	OK
Napier 7 - Leading	< 10	NA	serious	OK	serious	OK	serious	OK
- Trailing	< 10	serious	serious	OK	serious	OK	serious	OK
Napier 8 - Leading	10 to 15	OK	OK	OK	serious	significant	OK	significant
- Trailing	10 to 15	NA	OK	OK	serious	significant	OK	significant
Napier 9 - Leading	< 10	serious	OK	OK	OK	serious	serious	OK
- Trailing	< 10	serious	OK	OK	minor	serious	serious	OK
Napier 10 - Leading	15 to 20	serious	significant	serious	serious	significant	OK	minor
- Trailing	15 to 20	serious	serious	serious	serious	significant	OK	minor
Napier 11 - Leading	< 10 & 20 to 25	serious	minor	OK	significant	significant	OK	OK
- Trailing	< 10 & 20 to 25	serious	minor	OK	significant	significant	serious	OK
Napier 12 - Leading	> 20	NA	serious	significant	serious	significant	serious	OK
- Trailing	< 10	serious	serious	serious	serious	significant	OK	OK
Napier 13 - Leading	< 5	serious	serious	serious	serious	OK	OK	OK
- Trailing	< 5	NA	significant	serious	serious	significant	serious	OK
Napier 14 - Leading	< 5	NA	significant	OK	serious	significant	serious	OK
- Trailing	< 5	serious	OK	OK	minor	OK	serious	OK
Napier 15 - Leading	10	NA	serious	OK	serious	minor	serious	OK
- Trailing	10	serious	serious	OK	serious	OK	serious	OK
Napier 16 - Leading	< 10	serious	serious	OK	serious	significant	serious	OK
- Trailing	< 10	serious	serious	OK	serious	significant	serious	OK
Napier 17 - Leading	< 10	serious	serious	OK	serious	serious	serious	OK
- Trailing	< 10	NA	serious	OK	serious	serious	serious	OK
Napier 18 - Leading	10 to 15	NA	OK	OK	serious	significant	serious	OK
- Trailing	10 to 15	NA	minor	OK	serious	significant	serious	OK
Napier 19 - Leading	15 to 20	serious	OK	serious	serious	serious	OK	OK
- Trailing	15 to 20	serious	OK	serious	serious	serious	serious	OK
Napier 20 - Leading	< 10	significant	OK	OK	serious	OK	serious	OK
- Trailing	< 10	serious	OK	OK	serious	significant	serious	OK

Priority 1
Priority 2
Priority 3

Plate A2: Road Safety Barrier Legacy Survey Deficiencies – Tauranga

ROAD SAFETY BARRIER LEGACY SURVEY - TAURANGA SUMMARY JUNE 2010

			DESIGN			INSTALLATION		MAINTENANCE	
Location		Age (years)	LoN	Clear Area	Terminal	Terminal	Barrier	Terminal	Barrier
Tauranga	1 - Leading	20	serious	OK	serious	significant	significant	serious	significant
	- Trailing	20	serious	serious	serious	serious	significant	serious	serious
Tauranga	2 - Leading	20 to 25	serious	serious	serious	serious	serious	serious	serious
	- Trailing	20 to 25	serious	serious	serious	serious	significant	serious	serious
Tauranga	3 - Leading	20	serious	serious	serious	serious	serious	serious	significant
	- Trailing	20	serious	serious	serious	serious	significant	serious	significant
Tauranga	4 - Leading	20+	serious	OK	serious	serious	serious	serious	serious
	- Trailing	15	serious	OK	serious	serious	serious	serious	serious
Tauranga	5 - Leading	< 5 & 10 to 20	serious	OK	OK	serious	serious	serious	serious
	- Trailing	< 5	serious	serious	OK	serious	significant	minor	serious
Tauranga	6 - Leading	10	serious	significant	OK	serious	serious	significant	OK
	- Trailing	10	serious	OK	serious	serious	serious	serious	serious
Tauranga	7 - Leading	15	serious	serious	serious	serious	serious	serious	OK
	- Trailing	15	NA	NA	significant	serious	serious	serious	OK
Tauranga	8 - Leading	15 to 20	serious	serious	serious	serious	significant	serious	OK
	- Trailing	15 to 20	serious	serious	serious	serious	serious	serious	significant
Tauranga	9 - Leading	15 to 20	serious	serious	serious	serious	serious	serious	significant
	- Trailing	15 to 20	serious	OK	serious	serious	serious	serious	OK
Tauranga	10 - Leading	< 5	NA	OK	serious	serious	significant	serious	OK
	- Trailing	< 5	serious	significant	OK	minor	significant	serious	OK
Tauranga	11 - Leading	< 5	serious	serious	OK	OK	serious	serious	OK
	- Trailing	< 5	serious	OK	OK	serious	significant	serious	OK
Tauranga	12 - Leading	10	serious	OK	OK	serious	serious	serious	OK
	- Trailing	10	serious	significant	OK	serious	significant	serious	OK
Tauranga	13 - Leading	10	serious	serious	OK	serious	significant	serious	OK
	- Trailing	10	serious	serious	OK	serious	significant	serious	OK
Tauranga	14 - Leading	< 10	significant	OK	OK	minor	significant	minor	significant
	- Trailing	< 10	serious	minor	OK	minor	significant	minor	OK
Tauranga	15 - Leading	< 5	serious	OK	OK	minor	significant	OK	OK
	- Trailing	< 5	serious	minor	OK	significant	significant	minor	OK
Tauranga	16 - Leading	15 to 20	serious	minor	OK	significant	significant	significant	OK
	- Trailing	15 to 20	serious	OK	OK	serious	significant	serious	serious
Tauranga	17 - Leading	15 to 20	OK	OK	serious	serious	serious	serious	OK
	- Trailing	15 to 20	serious	serious	OK	significant	significant	serious	OK
Tauranga	18 - Leading	15	serious	significant	OK	serious	significant	serious	OK
	- Trailing	15	serious	serious	serious	serious	significant	serious	OK
Tauranga	19 - Leading	15 to 20	serious	serious	serious	serious	significant	serious	OK
	- Trailing	15 to 20	serious	serious	serious	serious	significant	serious	OK
Tauranga	20 - Leading	20	serious	serious	OK	serious	significant	serious	OK
	- Trailing	20	serious	significant	OK	serious	serious	serious	OK

Priority 1
Priority 2
Priority 3