How to preserve and improve safety with tight maintenance budgets

Fergus Tate

New Zealand Transport Agency

fergus.tate@nzta.govt.nz

Abstract

While there has always been a need to ensure road maintenance funds are spent wisely, funding reductions have moved the industry from an *"optimum whole of life outcomes*" focus, to one that focuses more on meeting short term budget constraints. This has prompted a number of road network managers to propose making cuts to safety related infrastructure standards.

This paper looks at a number of safety related infrastructure items the various networks have suggested could be dropped or scaled back. The paper then looks at the role these items play in terms of user safety and warns about the need to understand the context of crash reduction research when identifying the crash implications. We then look at the cost savings that might typically be derived from no longer maintaining these items.

Finally the paper proposes a methodology that could be used to prioritise the various items. Although the paper focuses on state highways, the proposed prioritisation could be used by other road controlling authorities.

1. Introduction

While there has always been a need to ensure road maintenance funds are spent wisely, funding reductions have moved the industry from an *"optimum whole of life outcomes*" focus, to one that focuses more on meeting short term budget constraints. This has prompted a number of road network managers to:

- question the value or need of some safety related infrastructure,
- consider no longer maintaining and ultimately removing elements of infrastructure, and
- question the appropriateness of standards.

Some examples to date have been proposals to turn off street lighting during the early morning hours, not replacing destination signage when reflectivity levels drop, and not to replace audio tactile profiled markings (ATP).

One area of particular focus has been delineation devices, edgelines, centrelines and edge marker posts. Some of the proposals to date have included:

- No longer repainting edgelines and/or centrelines and not remarking these following resurfacing
- No longer maintaining and ultimately removing edge marker posts and/or markings either:
    - o over the entire route or
    - o maintaining edge marker posts only around curves
- Modifying the volume thresholds at which various devices are installed.

In many cases those proposing such strategies quote studies showing the removal of lines or other delineation devices results in a reduction of travel speed (e.g. Burdett and Nicholson 2010) and given the strong link between speed and crashes (Elvik et al 2004; Kloden et al 2001) the proposers conclude removing markings reduces speed and thereby increases safety.

2. Context and Purpose

It is a fact that Burdett and Nicholson (2010) found the absence of line markings was associated with lower recorded speeds. There is also a body of research that supports a strong link between speed and crash risk. However, users of research need to take into account the research context, the type of study undertaken and the situations studied. It is also important to relate the context of any research to the purpose or characteristics of what is being considered, as well as ensuring a range of studies are considered, not simply those that justify a desired position.

While continuing with the delineation example, which is quite topical, it is important to point out the aim of this paper is NOT to criticise the research undertaken by Burdett and Nicholson. The aim is to raise industry awareness of some of the subtleties of applying research findings, and by using delineation as an example, address some of the more commonly voiced misperceptions regarding delineation devices.

The role of delineation devices such as centrelines, edgelines and edge marker posts are to aid lateral control, curve negotiation, and pre-view and long–range information for [curve] navigation (FHWA 1998), respectively and by doing so to reduce the likelihood of crashes.

The Burdett and Nicholson study is a cross sectional study (the before and after data was not reported), that is it essentially pairs of similar sites with and without any markings, or with a centreline but no edgeline. The sites were all on straight, flat sections of road, not within 500m of any vertical or horizontal curve, had edge marker posts at variable spacing (Figure 1) and the dependant variable was speed.

Figure 1Sites 1A (Whitikahu Road, left) and 1B (Boyd Road) taken from Burdett and Nicholson (2010)

So why would we expect the result of the Burdett and Nicholson study to be applicable to other lower volume rural such as that shown in Figure 2 ? The study did not consider the key elements that delineation seeks to address and uses speed as a proxy measure of safety rather than crashes or crash rate.

Figure 2 A section of low volume rural road

Looking at Figure 2 is it possible to determine the forward direction of the carriageway ? Does it curve to the left go straight ahead or curve to the right, if so and would you really be going slowly enough at this point ?

2.1. Role of Delineation

The role of roadside delineation is discussed with reference to Figure 2 through to Figure 5 together with some discussion taken from Baas et al (2004) who reviewed 24 key reports (citing more than 500 source documents).

2.1.1. Edgelines

Edgelines aid drivers curve negotiation, particularly on left hand curves, impact on lateral position, and reduce potentially hazardous shoulder encroachments. Baas et al (2004) report edgeline on roads with narrow shoulders (Figure 3) tend to move drivers away from the shoulder, although this is dependent on the associated vista with drivers travelling closer to the edgeline when the vista is constrained; conversely when edgelines are added to wide shoulders with open vistas drivers move closer to the shoulder.

Figure 3 Edgeline added

While the addition of edgelines has been found to increase speed, some combinations of edge and centrelines reduces speeds.

The associated crash reductions, of 0% to 80%, appears to depend on the type of crashes considered in analysis of crashes although a reliable reduction of 25% of loss of control crashes appears to be commonly reported (Baas et al, 2004). More importantly the provision of edge and centre lines has been found to reduce driver workload and such delineation is generally preferred by road users, our customers.

2.1.2. Centrelines

In many cases the available literature considers the combination of centrelines and edgelines. Centrelines are particularly important in situations such as Figure 4, where given the forward sight distance it is important that drivers do not encroach into the opposing traffic lane. Bass et al report that adding a centreline to a road will generally increase speeds but moves drivers toward the centre of their own lane and reduces the variability in lateral position.

In terms of expected crash reductions Bass et al report estimates form a 1% crash reduction through to 65% with an average of 30%.

Importantly wider edgelines and centrelines appear to produce fairly consistent improvements in lane keeping by drivers, particularly for intoxicated drivers, young drivers, and the elderly (Baas et al 2004). This is a particularly important finding when we consider removing these lines from low volume rural roads where the crash problem is often associated with “locals” and alcohol.

Figure 4 Edgeline and centreline

Turner and Tate (2009) have established that drivers make their curve negotiation speed choices based on the curve radius not the design speed. When visible, the provision of edge and centre line markings helps drivers determine curve radii and reduces the likelihood of drivers making curve negotiation speed errors.

2.1.3. Edge Marker Posts

With the move to brighter edge and centreline treatments, edgeline reflectorised raised pavement markers (RRPMs) and ATP on higher volume roads, numerous road asset managers have questioned the need for edge marker posts.

It must be remembered the vast majority of low volume, and even medium volume, rural roads in New Zealand have evolved, rather than being specifically designed. As a result situations such as that shown in Figure 5, are all too common.

Figure 5 Edgeline, centreline and edge marker posts

Looking at Figure 5, it is not until edge marker posts are added that the forward alignment can be determined, even at this point some 20m before the curve. At 70km/h the pre-view, without edge marker posts is 1 second, and 2 seconds at 36km/h.

Even on “new” designed roads, the typical design criteria, safe stopping sight distance, is calculated to an object 200mm high and not to the road surface. So without raised edge marker posts or some other raised feature it may be very difficult for drivers to identify the forward alignment when combinations of horizontal and vertical curves are present.

2.1.4. Delineation Hierarchy

The above discussion suggests there is a hierarchy of delineation devices. Although possibly dependant on the specific context, this hierarchy would, from most to least important, be:

Edge Marker Posts	- to define the forwards alignment
Edgelines	- to aid curve negotiation and reduce unintended shoulder encroachment and potential over correction and loss of control
Centrelines	- to aid curve negotiation and to position vehicle on the correct side of the carriageway

This hierarchy can then be supplemented with wider and brighter markings, reflectorised raised pavement markers, and audio tactile profiled markings, where traffic volumes are higher and crashes are more likely and curve chevrons to address specific curves are needed to reduce crashes.

2.2. Crash Reductions

2.2.1. Data Sources

As noted above, the crash reduction benefits associated with delineation devices or indeed any safety initiatives can vary greatly depending on the type of study and the context.

For example, before and after studies of road safety initiatives are typically implemented at locations where it is expected the specific initiative will address a particular road safety issue. As a consequence there is a significant likelihood of selection bias. Even if other issues such as regression to the mean or an underlying downwards trend associated with education, Policing or vehicle improvements, are accounted for, such studies are more likely to indicate higher crash reductions compared to cross sectional studies. Particularly when the cross sectional studies consider apply the treatment of interest over large areas of network which may or may not include sections where the crash problem the treatment targets may not be an issue.

It is therefore important to consider a range of studies, giving particular emphasis to those studies which clearly relate to the situation under consideration.

There are a number of really good sources, which provide expected crash reductions or crash modification factors (CMFs). Examples include:

- Federal Highways Administration Crash Modification Factor Clearinghouse (FHWA 2012)
- Austroad Road Safety Engineering Toolkit (Austroads, 2012a)
- Effectiveness of Road Safety Engineering Treatments, (Austroads, 2012b),
- The Handbook of Road Safety Measures (Elvik et al, 2009)

2.2.2. Crash Modification Factors

The table below contains some examples of the various crash reductions that have been documented in the above sources (Table 1). Those selected apply to all crash types (unless otherwise stated) on rural roads.

Table 1 Selected crash modification factors

Device and context	Crash reduction[1]	Source[2]
Post Mounted delineators in general	-4%	Elvik et al and FHWA[3]
	7%	Elvik et al
Particularly on vertical and horizontal curves	25%	FHWA[4]
	30%	Austroads
Edgelines on curves	26% to 33%	FHWA
Edgelines on straights	6%	FHWA
Edgelines on curves and straights	3%	Elvik et al and FHWA[2]
	8%	FHWA
	30%	Austroads
Centrelines	1%	Elvik et al and FHWA[3]
	33%	FHWA[4]
	30% to 35%	Austroads
Edgeline and centreline markings	24%	Elvik et al and FHWA[3]
at higher crash locations	14%	FHWA
Edgelines centreline and post mounted delineators	45%	Elvik et al and FHWA[3]

[1] negative value is a crash increase [2] Austroads 2012b not included in table as final publication was notified after paper was drafted [3]FHWA citing Elvik et al [4] study not quality rated

While the range of the crash reduction estimates in Table 1 above, appear confusing, closer inspection confirms that in general, installing a device in a higher risk location such as on curves, typically provides a higher crash reduction than when the device is installed in a lower risk situation such as on a straight. As a consequence estimates of network-wide performance are likely to be in between these values and depend on the ratio of high risk to low risk situations, i.e. additional delineation is more important on winding low volume rural roads. Alternatively removing delineation on straights may not result in a major increase in crashes.

A second issue arises, how to deal with the impact of multiple treatments which may have similar impacts. In the above we are provided with an estimate of the crash reductions for edgelines, centrelines and post mounted delineators of 45%, as well as separate estimates for edgelines and centrelines of 24%, as well as a range of estimates for the separate components.

When combining the impact of multiple treatments it is unrealistic to simply add the various components e.g.

Post mounted delineators (on curves)	25%	
Edgelines on curves	30%	(range 26% to 33%)
Centrelines	33%	
Total	88%	

Research by ARRB (2011) suggests the better approach is to apply the results sequentially beginning with the initiative with the largest impact first.

$$CRF_t = 1-(1-CRF_1)(1-CRF_2)(1-CRF_3)......(1-CRF_n)$$

Where

CRF_t = total crash reduction

CRF_n = individual crash reductions

So

$$CRF_t = 1-(1-0.33)(1-0.30)(1-0.25)$$

$$= 0.65$$

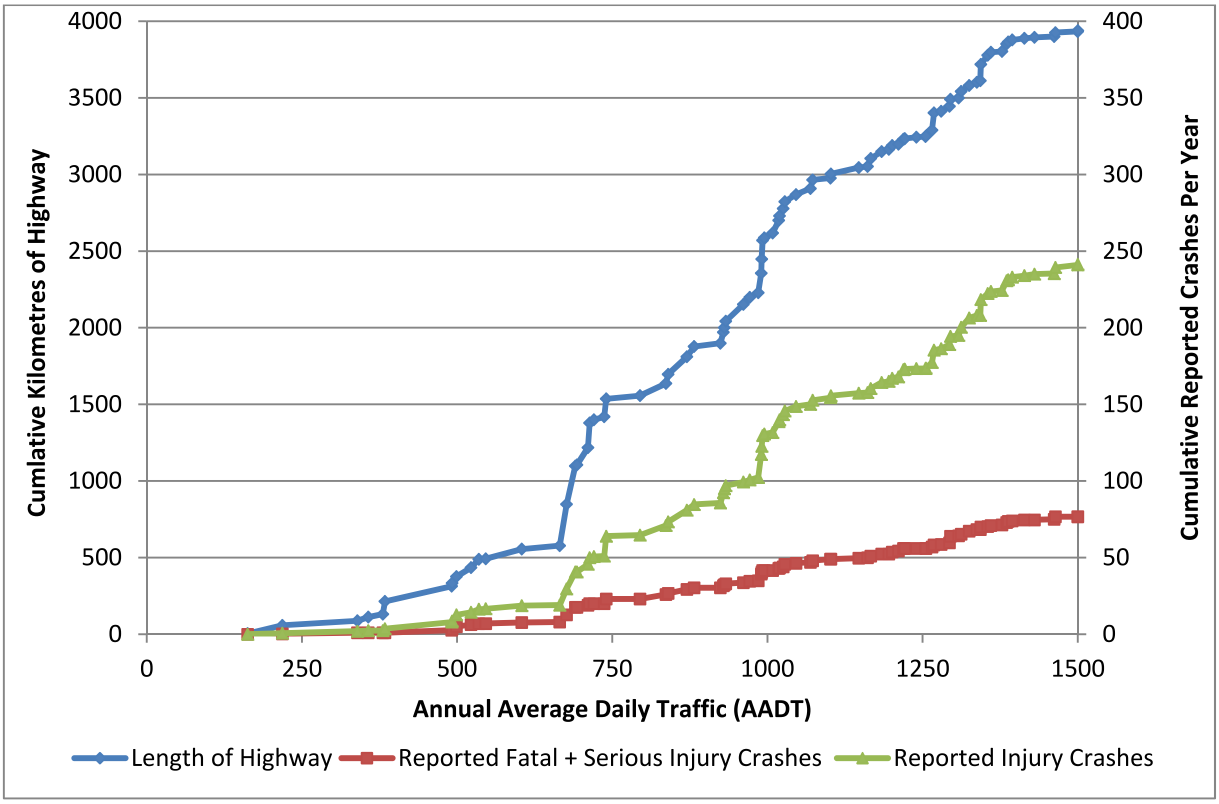
ARRB (2011) then recommends the resulting crash reduction is then tempered by taking two thirds of the result. i.e. 0.65*0.67 = 0.43.

3. Application

Continuing with the delineation example, how do we establish the likely crash increases associated with changing the level of delineation. RTS 5 Guidelines for rural road marking and delineation (LTSA 2002) set out the expected delineation for roads carrying less than 1500 vehicles per day.

All state highway lengths, greater than 1 km and carrying more 1500 vehicle per day have been identified, in this case using the KiwiRAP analysis tool, KAT. The almost 4000km of rural state highway carrying less than 1500 vehicles per day represents around 38% of the rural state highway network. Over the five year period 2006 to 2010, there were on average 271 reported injury crashes per year of which approximately 86 resulted in death or serious injury. Almost 90% of all injury crashes and 76% of the fatal and serious injury crashes were either Run-Off-Road or Head-On crashes, the types of crash typically addressed by improvements to marking and delineation.

The length of highway together with the average number of fatal + serious and all injury Run-Off-Road + Head-On crashes per annum is plotted against traffic volume in Figure 6.



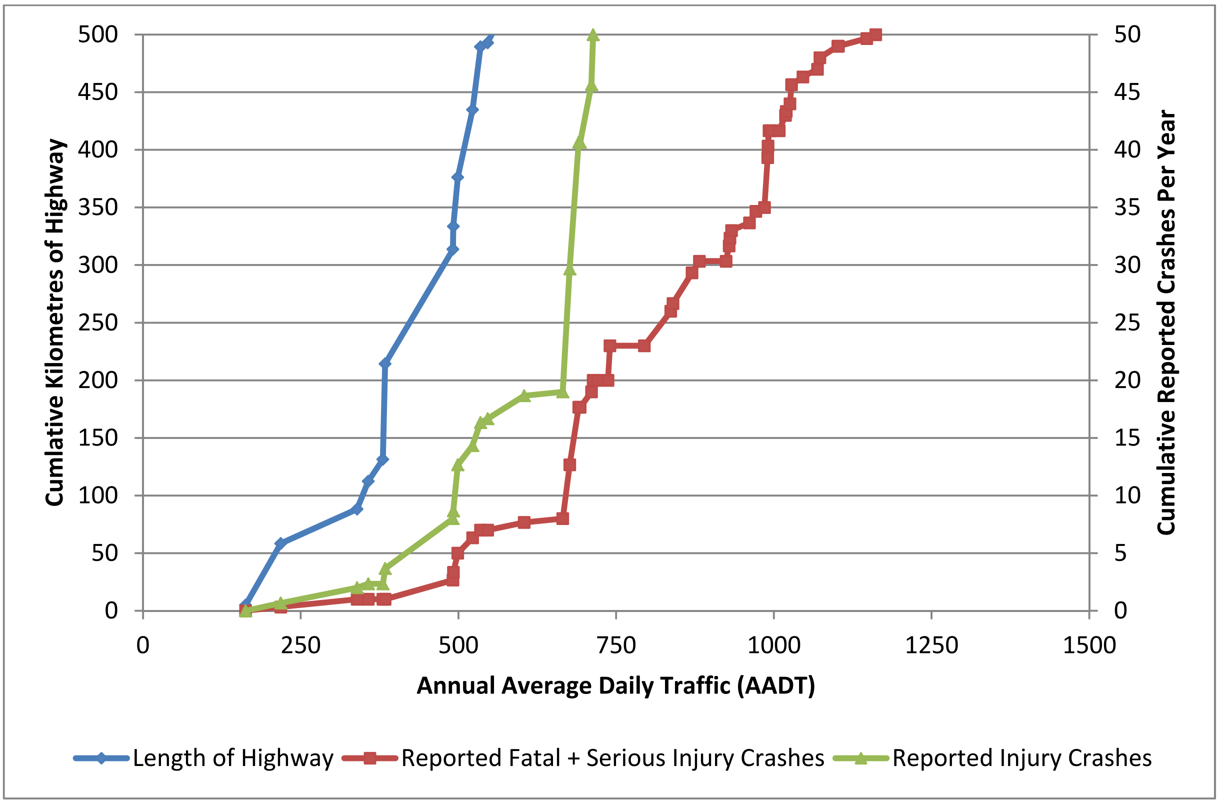


Figure 6 Length of Highway, Average number of Fatal+Serious and All Injury, Run-Off-Road and Head-On Crashes per year versus AADT

Using the data in Figure 6, it is then possible to create a table such as that below (Table 2) where the expected number of additional crashes is predicted against the length of highway.

In Table 2 the crash increase for removing each of centreline, edgeline and marker posts are 1/(1-Crash reduction factor) with crash reduction factors of 0.3, 0.25 and 0.3 respectively and 0.45 for removal of all three. These values are taken from Table 1and the curve values have been used, because in general the highway sections being considered are 2 star roads with a high run off road protection score in KiwiRAP indicating these roads have more winding alignments and numerous roadside hazards. A quick look at the highway video suggested that a policy of only maintaining these devices on curves would result in only very limited savings as the majority of the route examined had either horizontal or vertical curves, or both, and maintenance crews would still need to drive the entire route and maintain the vast majority of the length.

Table 2 Expected increases in Run-Off-Road and Head-On crashes per annum

AADT	Cumulative length With AADT less than	Run-Off-Road and Head-On Crashes/yr All Injury (Fatal + Serious)	Additional Crashes per year as a result of removing the following delineation devices			
			Centreline Only	Edgeline Only	Marker Posts	All three
250	58	0.7 (0.3)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.6 (0.2)
500	376	16.7 (7.0)	7.2 (3.0)	5.6 (2.3)	7.2 (3.0)	13.7 (5.7)
750	1536	30.0 (13.0)	12.9 (5.6)	10.0 (4.3)	12.9 (5.6)	24.5 (10.6)
1000	2587	64.0 (23.0)	27.4 (9.9)	21.3 (7.7)	27.4 (9.9)	52.4 (18.8)
1250	2343	173.3 (56.0)	74.3 (24.0)	57.8 (18.7)	74.3 (24.0)	141.8 (45.8)
1500	3938	241.3 (76.7)	103.4 (32.9)	80.4 (25.6)	103.4 (32.9)	197.4 (62.8)

A complete Table 2 would also include the cost saving associated with removing or no longer maintaining each item and possibly the social cost of the consequences. Although the costs of various line markings varies throughout New Zealand, it is likely that line markings on these low volume roads would be painted annually using 180 microns of water borne paint at an indicative cost of around $180/km for the centreline and $220/km for each edgeline.

It is important to note that the above analysis still requires some further review in terms of practicalities. For example there are only 2 sections of highway with volumes less than 250 vehicles per day. The first is a 5 kilometre section of SH 38 and the second a 53 kilometre section of SH43. However, a further 30km of SH38 carries between 250 and 500 vehicles per day, while on SH 43 there is 83km of also carrying between 250 and 500 vehicles per day. As drivers are unaware of such subtleties as AADT it is unlikely delineation would suddenly be reduced over the 58 km of state highway carrying less than 250 AADT. Furthermore, when looking at a sample of crashes on some of the longer lengths, we find a large proportion of the drivers involved in these crashes are foreign drivers, which is only be expected for state highways, and as such drivers are less familiar with New Zealand roads.

Even more importantly, the above analysis is looking at policy as proposed for multiple lengths of highway, not individual sections. While the crash rates on these low volume roads are typically high, the actual number of crashes is generally low and subject to significant fluctuations. It is quite possible that when looking at shorter sections of road over short timeframes, crashes may drop below those recorded following treatment. While this might be viewed as justifying the works, crashes may also increase simply as a result of the statistical fluctuations associated with a small sample.

Finally, such a strategy is unlikely to align with the longer term view of Safer Journeys (Ministry of Transport, 2010) and the NZ Transport Agency's High Risk Rural Roads Guide (NZTA 2011). The latter in particular, identifies that for rural roads with high personal crash risk but low collective crash risk, the available safety benefits are limited and insufficient to justify even moderate capital expenditure. As a result the optimum safety strategy is Safety Management with a focus on marking and delineation, signage, road surface friction and speed management.

4. Summary

Using highway delineation as an example, this paper looks at how the need for and the impact associated with removing safety related delineation devices. However, those undertaking such analysis must:

- Understand the role or function of the devices
- Understand, the type, quality and context of research reporting crash reductions (or expected increases) associated with these devices
- Ensure a range of research is consulted
- Not focus on individual sections of highway

This methodology can be applied to a wide range of similar analysis.

5. References

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