EVALUATION OF WIDE CENTRELINE EFFECTIVENESS

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ABSTRACT

Head-on and cross centreline crashes are among the most severe crash types occurring on the Bruce Highway in Queensland. Wide centrelines increase separation of opposing traffic with painted lines up to 1 metre wide, often accompanied by audio-tactile linemarking. The Queensland Department of Transport and Main Roads implemented this treatment on selected sections of the Bruce Highway in 2011. This paper presents the findings of a before-and-after study investigating the safety benefit and effectiveness of these wide centrelines.

The robust method of Empirical Bayes was employed to assess the treatment's effectiveness. Safety performance functions were developed using 8 years of control and treatment site data, to estimate the crashes that would have occurred without wide centrelines. These estimates were augmented with accident modification factors (AMFs) derived from an updated Nilsson's Power Model to account for posted speed limit changes. The approach eliminated regression-to-the-mean bias, and delivered an unbiased estimate of safety-effectiveness.

From the crash reduction estimates it was also possible to determine the benefit cost ratio. Knowledge of both the crash reductions and projected savings gives a more complete picture of wide centreline safety effectiveness. The research findings greatly expand the existing knowledge base about wide centreline treatment.

INTRODUCTION

Queensland Department of Transport and Main Roads (TMR) has progressively introduced improvements on the Bruce Highway over the past 10 years to improve its overall safety performance. A wide range of treatments have been installed, including wide centreline treatments (WCLT).

WCLT refers to the installation of line markings to increase the separation between opposing traffic by two lines up to 1 metre apart. The general layout is shown in Figure 1. Most installations aim to maintain lane widths of at least 3.25 metres; in most cases this involves a reduction in shoulder width. However, the lane widths in the sites analysed were slightly narrower, approximately 3 metres.

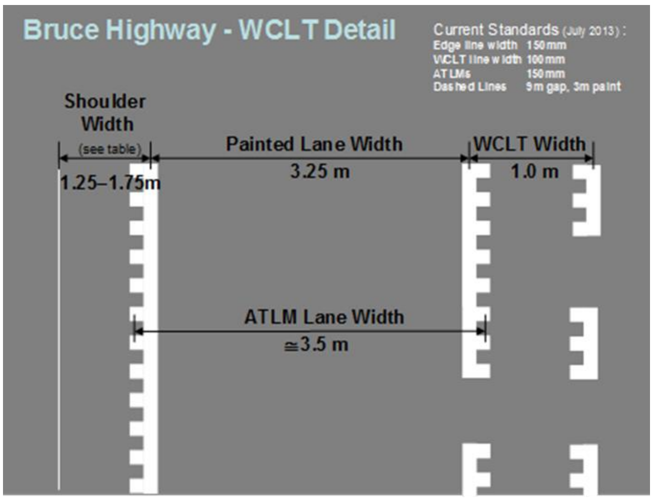

Figure 1: General layout of WCLT

WCLT was installed over a 35.2 km long section of the Bruce Highway from Cooroy to Curra in June 2011 (TMR roads with ID 10A and 10B). Sites which had no additional safety treatments after WCLT were selected for analysis, leaving a remaining total of 25.3 km. Before-and-after analysis was conducted with data collected from:

- January 2007 to January 2011 (four years) as the 'before' period
- July 2011 to June 2015 (four years) as the 'after' period.

The main objective of the study was to determine the effectiveness of WCLT for reducing fatal and serious injury (FSI) crashes, all injury crashes, targeted crash types, and the resulting financial savings from its implementation.

METHOD

Target Crash Types Considered

TMR supplied FSI and all injury crash data from 1 January 2007 to 31 August 2016. The full dataset was filtered according to crash severity, year, road ID, and Definitions for Coding Accidents (DCA) codes to obtain the relevant crashes for the analysis. Average Annual Daily Traffic (AADT) data for the selected sites for each year was also supplied by the Department.

The main crash types that may be impacted by WCLT are head-on and cross-centreline crashes (HOCL), and run-off-road-left crashes (RORL). The effectiveness of WCLT was assessed for these crash types along with all injury crash types (Total). The DCA codes were:

- 201, 702, and 704 for HOCL
- 701 and 703 for RORL
- All codes for Total injury crashes.

The main reason for investigating crashes coded as 'off carriageway to right' (DCA code 702) and 'right off carriageway into object' (DCA code 704) is that movements on a two-lane highway that resulted in those types of crashes are similar to movements that could result in a head-on crash.

Crashes on curves were not included because the coding for run-off-road crashes on curves does not differentiate between running off the road to the left or right. There were some crashes on curves within the selected sites, but these could not be categorically deemed to be either HOCL or RORL crashes, so they were excluded from the analysis to avoid having to make assumptions. Therefore, the findings of this study can be only directly applied to straight road sections.

Assessment of Treatment Effectiveness

Treatment effectiveness for any road section can be expressed as:

$$B - A$$

where B is the number of crashes that would have occurred without treatment, and A is the actual number of crashes with treatment.

The evaluation consisted of two approaches:

- descriptive statistics
- the Empirical Bayes (EB) method.

Descriptive Statistics

The percentage changes in FSI and all injury crashes before and after treatment were determined for the treatment sections on roads 10A and 10B, for each of the crash types.

Empirical Bayes Method

Analysing roads with a high accident count history is prone to regression-to-the-mean bias. As a result, accident counts on those roads alone will not give a complete picture of the road's safety. The EB method is an established and recommended method for determining the safety effect of road treatments (Elvik 2008). It controls for regression-to-the-mean bias in before-and-after studies, which must be done to maintain the validity of developed models (Persaud & Lyon 2007). Controlling this bias also increases the precision of crash estimates when the available accident history is short (Hauer et al. 2002). The safety of similar roads on the network (in terms of volume, horizontal and vertical geometry, cross-section, etc.) must be used in conjunction with the high-accident-count roads as a control, to yield more accurate crash estimates.

The perceived reduction in crashes after a treatment has been installed may not be solely attributable to the treatment itself. Other factors such as changes in posted speed limit and traffic volumes will have an impact on the resulting crash counts after treatment. These are accounted for in the EB method. The analysis presented in this report followed the method used by Persaud, Retting & Lyon (2004) to investigate the crash reduction effect of centreline rumble strips on two-lane roads.

The steps of the EB method taken in this evaluation are shown in Figure 2.

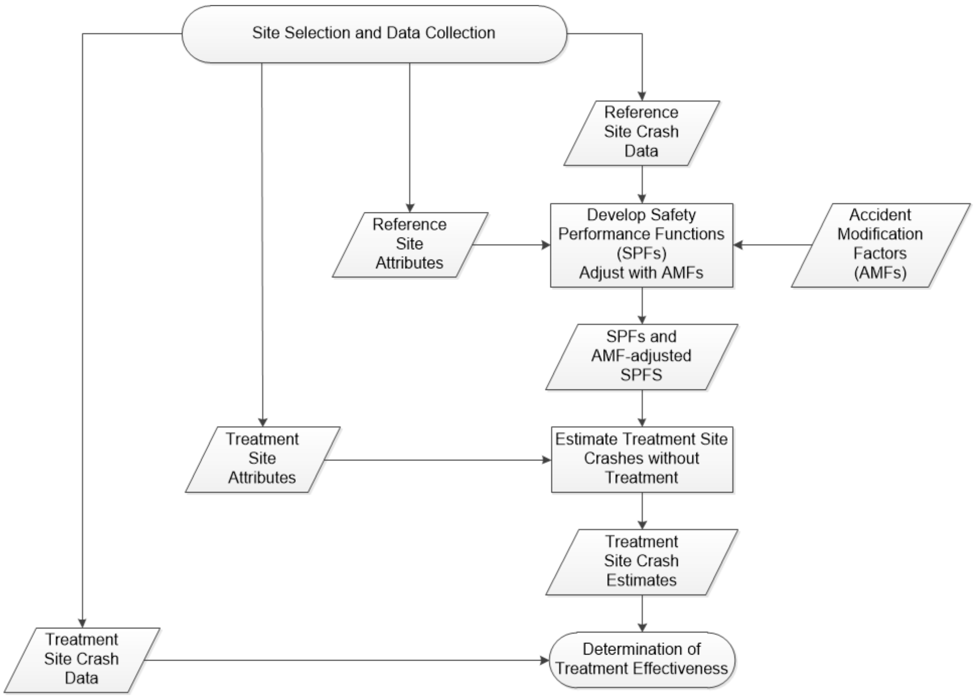

Figure 2: Process diagram of the EB Method for this evaluation

Site selection and data collection

Two types of sites were used in the EB analysis – treatment and reference sites. Treatment sites were sections of the Bruce Highway with WCLT. Reference sites were road sections with similar horizontal and vertical geometry, geographical location, and cross-section to the treatment sites, but without WCLT.

The treatment sites included 15 sections, ranging in length from 0.31 to 6.03 km, with AADT between 9 000 and 17 300. FSI and injury crashes were filtered for those occurring between 1 January 2007 to 31 December 2010 (before period), and 1 July 2011 to 30 June 2015 (after period).

The reference sites included 60 road sections on 10A and 10B as well as on other highways (17B, 18B, 22B, 40A, 42A), ranging in length from 0.13 to 19.25 km, with AADT between 3 200 and 17 300. FSI and injury crashes were filtered for those occurring between 2007 and 2013. A brief review of video data of the reference sites confirmed there was no installation of safety improvements at the sites during the analysis period.

Certain sites in the initial study by Whittaker (2012) were upgraded from WCLT to divided carriageways in 2012. These were excluded from the treatment sites in the EB analysis following a check of the video data. Their crash data from 2007–2010 which predated the upgrade was included in the reference site data.

Safety performance functions (SPFs)

A SPF is a mathematical model that relates the expected crash frequency to specific road characteristics, based on collected data. It averages the safety of similar road entities, and when combined with the accident counts from the treatment sites corrects for regression-to-the-mean bias (Hauer et al. 2002). Details of the data periods for the reference and treatment sites used are shown in Table 1. The crash data collected at the treatment sites during the before period was also used in the reference crash data for SPF development, because no WCLT had yet been applied.

Table 1: Data periods for reference and treatment site data

Site	Site type	Reference data set period (with no WCLT)	Treatment data set periods (before, after)
10A	Reference /treatment	2007 – 2010	2007 – 2010, mid 2011 – mid 2015
10B	Reference /treatment	2007 – 2010	2007 – 2010, mid 2011 – mid 2015
17B	Reference	2007 - 2013	-
18B	Reference	2007 - 2013	-
22B	Reference	2007 - 2013	-
40A	Reference	2007 - 2013	-
42A	Reference	2007 - 2013	-

Generalised Linear Models (GLM) were used to model the data with a negative binomial distribution. It consisted of three components: a random component, a linear function of regressors, and a linearizing link function (Fox 2008). The link function used in this project was a log link, which inverts to become an exponential function with the exponent being a linear function of the regressors. This takes the form:

$$Crashes\ per\ year = e^{(\alpha+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_n x_n)}$$

where α is a constant and β_1 to β_n are the coefficients of the regressors x_1 to x_n. These coefficients were estimated by using the reference site data only. The main regressors were AADT and length of the road section, with crash frequency as the response variable. The model should return 0 expected crashes when there is no traffic, and so *AADT* must sit outside the exponential function. By regressing the crashes per year with the natural logarithm of the AADT data, the SPF model can be manipulated as follows:

$$Crashes\ per\ year = e^{(\alpha+\beta_1\times ln(AADT)+\beta_2\times Length)}$$

$$= e^{\alpha}\times e^{\beta_1\times ln(AADT)}\times e^{\beta_2\times Length}$$

$$= e^{\alpha}\times e^{ln(AADT^{\beta_1})}\times e^{\beta_2\times Length}$$

$$= e^{\alpha} \times AADT^{\beta_1} \times e^{\beta_2 \times Length}$$

$$= AADT^{\beta_1} \times e^{(\alpha + \beta_2 \times Length)}$$

SPF models of similar form with AADT raised to an estimated power, with the other explanatory variables in the linear function have been used in EB evaluations by Patel, Council & Griffith (2007). The negative binomial distribution of the data was fitted using the Maximum Likelihood Estimation (MLE) method in SPSS Statistics version 22. This distribution has been shown to fit accident counts more accurately than Poisson distributions (Hauer et al. 2002). The Poisson distribution relies on the assumption that the data variance equals the mean. When this is not the case the data is said to be 'over-dispersed', and an over-dispersion parameter, *k*, is estimated. The over-dispersion parameter was estimated for several of the models. Other explored model types included non-linear models with exponential terms, and multivariate linear models.

Accident modification factors

The posted speed limit on sections 10A and 10B of the Bruce Highway was reduced from 100 km/h to 90 km/h in December 2008. The data for the reference SPFs came mostly from highways with a 100 km/h speed limit. Thus, the SPF estimates for the years after 2008 were adjusted with accident modifications factors (AMFs) to allow for the expected effect. Lower posted speed limits have been shown to reduce the number of crashes on a road, and this should be accounted for in the SPF estimates.

Nilsson (1981) suggested power relationships between traffic speed and road trauma. The powers proposed by Nilsson were refined by Elvik et al. (2004) through meta-analysis of 98 evaluation studies relating road trauma to speed changes.

The power model relating FSI and injury crashes to changes in mean speed is:

$$Y_1 = \left(\frac{V_1}{V_0}\right)^{Exponent} Y_0$$

where Y_0 and Y_1 are the number of crashes before and after the change in mean speed respectively. The exponent in the model is dependent on the severity of the crashes considered. V_0 and V_1 are the mean speeds before and after the change (Cameron & Elvik 2008). The resulting coefficient in front of Y_0 is taken as the AMF.

Elvik et al. (2004) developed the following relationship between changes in posted speed limit and vehicle mean speed:

$$y = 0.2525x - 1.2204$$

where x is the change in posted speed limit, and y is the change in mean speed. The values from this equation are used to calculate V_0 and V_1 in the power model.

Estimating crash numbers at treatment sites

Solely using treatment site crash counts may give higher than average estimates of reduction (Hauer et al. 2002). This is due to the regression-to-the-mean effect, where treatment sites show increased crash counts due to chance, not the actual high risk. This problem is particularly evident when dealing with small crash numbers. The before period treatment crash counts were combined with the SPF estimates of crashes at those sites using weighting factors.

The overall unfactored estimate, m, which uses both crash counts and SPF estimates is given by:

$$m = w_1 x + w_2 P_B$$

where P_B is the sum of the SPF estimated crashes at all the treatment sites in the before period, and x is the sum of the actual crashes at those sites in the before period. Weights w_1 and w_2 are given by:

$$w_1 = \frac{P_B}{P_B + \frac{1}{k}}$$

and

$$w_2 = \frac{1}{k\left(P_B + \frac{1}{k}\right)}$$

where k is the over-dispersion factor from the SPF. B, the expected after period crashes at treatment sites had no treatment been applied, is given by:

$$B = m \times Reduction\ Factor$$

The reduction factor accounts for the changes in AADT between before and after periods, as well as any difference in duration of the data analysed. Only small changes in AADT were observed between the periods. The reduction factor is given by:

$$Reduction\ Factor = \frac{P_A}{P_B}$$

where P_A is the sum of SPF estimates at the treatment sites in the after period.

Effectiveness of treatment

An estimate of the safety effectiveness, λ, could be obtained by:

$$\lambda = \frac{A}{B}$$

which is simply a ratio of the actual number of crashes at a site, A, to the estimated crashes had no treatment been applied, B (Patel et al. 2007). This ratio, even with unbiased estimators A and B, is biased as discussed by Hauer in 1997 (Patel et al. 2007). In contrast, an unbiased measure is the index of effectiveness, θ, given by:

$$\theta = \frac{\frac{A}{B}}{1+\left(\frac{Var(\tau)}{B^2}\right)}$$

where $Var(\tau)$ is the sum of variances of after period estimates at all treatment sites (Patel et al. 2007). The standard deviation of θ is given by:

$$SD.\theta = \left\{\frac{\theta^2\left[\left(\frac{Var(A)}{A^2}\right)+\left(\frac{Var(B)}{B^2}\right)\right]}{\left[1+\left(\frac{Var(B)}{B^2}\right)\right]^2}\right\}^{0.5}$$

The variances of A and B are given by the square of their standard deviations. The percentage reduction in crashes is related to θ, and is given by:

$$Percentage\ Reduction\ (\%) = 100 \times (1-\theta)$$

Limitations of Analysis

The number of reference sites with similar characteristics to the treatment sites was limited. AADT was a major attribute that restricted the number of available sites, along with location, sufficient data, and having no safety treatments installed. The selection of the reference sites has a significant impact on the treatment effectiveness determined by the EB method. It was important therefore to select appropriate reference sites and not relax the criteria to include sites which were too dissimilar. Future research should aim to find even more reference sites to give added robustness to the information regarding similar entities.

The coding for crashes on curves does not differentiate between those running off the road to the left, or to the right. These were therefore excluded from the analysis, as they could have been HOCL or RORL crashes. Only crashes on straight highway sections were included in the analysis.

The earliest data used in the analysis dated back to 2007. Many changes may have been made to the roadside condition at the reference and treatment sites. Roadside condition and hazards would be a large determining factor in the severity of run-off-road crashes. The findings determined for the reduction in RORL crashes in this analysis should be interpreted with this in mind.

SAFETY BENEFIT OF WIDE CENTRELINES

Descriptive Statistics

The numbers and percentage changes in FSI and all injury crashes at the treatment sites are shown in Table 2. The Table shows the results not adjusted for the effect of the speed limit reduction, changes in AADT, and may be subject to regression-to-the-mean. After the implementation of WCLT there were reductions in FSI and all injury crashes of 9% and 24% respectively.

Table 2: FSI and all injury crash changes for treatment sections (10A and 10B)

Crash type	FSI crashes			All injury crashes		
	Before	After	Percent change	Before	After	Percent change
HOCL	9	7	–22.2%	15	10	–33.3%
RORL	7	4	–42.9%	14	7	–50.0%
Total	33	30	–9.1%	72	55	–23.6%

Empirical Bayes

SPF Models

Several SPFs were generated for HOCL, RORL, and Total FSI and all injury crashes, shown in Tables 3 and 4. The SPFs were compared and selected based on the following criteria:

- The SPF should return 0 expected crashes when there is no traffic (*AADT* = 0)
- The over-dispersion parameter, *k*, should be estimated by the MLE method in the negative binomial distributions
- Both *AADT* and *Length* were regressors in the model, and ideally statistically significant
- Bayesian Information Criteria (BIC) score
- R^2 – for linear models – is a measure of how close the regression approximates the data.

Table 3: SPFs selected for HOCL, RORL, and Total FSI crashes

SPF	Significant variables
$\text{HOCL FSI crashes} = e^{-12.320+0.153\times Length} \times AADT^{1.080}$	All
$\text{RORL FSI crashes} = e^{-12.991+0.145\times Length} \times AADT^{1.051}$	Length
$\text{Total FSI crashes} = e^{-8.809+0.197\times Length} \times AADT^{0.817}$	All

Table 4: SPFs selected for HOCL, RORL, and Total injury crashes

SPF	Significant variables
$\text{HOCL injury crashes} = e^{-11.751+0.157\times Length} \times AADT^{1.057}$	All
$\text{RORL injury crashes} = e^{-12.609+0.156\times Length} \times AADT^{1.097}$	All
$\text{Total injury crashes} = e^{-8.633+0.178\times Length} \times AADT^{0.874}$	All

AMF Adjusted Models

AMFs were calculated using the power model suggested by Nilsson (1981) with updated power values from Cameron and Elvik (2008). For FSI crashes, the meta-analysis revised power estimate was 2.592. For all injury crashes, the power estimate was 2.495 (Cameron & Elvik 2008). The power models used were:

$$\text{FSI crashes: } Y_1 = \left(\frac{V_1}{V_0}\right)^{2.592} Y_0$$

$$\text{All injury crashes: } Y_1 = \left(\frac{V_1}{V_0}\right)^{2.495} Y_0$$

The coefficient in front of Y_0 describes the estimated proportion of the original crashes that would be expected to occur after a change in posted speed limit, which is the AMF. Cameron and Elvik (2008) assumed that the posted speed limit was an appropriate estimator of the mean speed before the change, V_0. The change in posted speed limit was –10 km/h on roads 10A and 10B, so the change in mean speed was estimated to be –3.75 km/h. The ratio V_1/V_0, based on an initial posted speed of 100 km/h was 0.96, giving an AMF of 0.90579 for FSI crashes and 0.90915 for all injury crashes. These factors were applied to their respective SPF models for the years after 2008, as shown in Tables 5 and 6.

Table 5: AMF-adjusted SPFs selected for HOCL, RORL, and Total FSI crashes

SPF	Significant variables
$\text{HOCL FSI crashes} = 0.90579 \times e^{-12.320+0.153\times Length} \times AADT^{1.080}$	All
$\text{RORL FSI crashes} = 0.90579 \times e^{-12.991+0.145\times Length} \times AADT^{1.051}$	Length
$\text{Total FSI crashes} = 0.90579 \times e^{-8.809+0.197\times Length} \times AADT^{0.817}$	All

Table 6: AMF-adjusted SPFs selected for HOCL, RORL, and Total injury crashes

SPF	Significant variables
$HOCL\ injury\ crashes = 0.90915 \times e^{-11.751+0.157\times Length} \times AADT^{1.057}$	All
$RORL\ injury\ crashes = 0.90915 \times e^{-12.609+0.156\times Length} \times AADT^{1.097}$	All
$Total\ injury\ crashes = 0.90915 \times e^{-8.633+0.178\times Length} \times AADT^{0.874}$	All

Model Parameters and Effectiveness of WCLT

Table 7 shows the calculated parameters for HOCL, RORL, and Total FSI crashes used to estimate the treatment effectiveness.

Table 7: Calculated parameters for HOCL, RORL, and Total FSI crashes

Parameter	HOCL FSI crashes	RORL FSI crashes	Total FSI crashes
Overdispersion (k)	1.093E-07	0.234	0.523
SPF estimated crashes (P_B)	9.961	3.792	30.280
Actual crashes during before period (x)	9	7	33
Weight (w_1)	1.089E-06	0.470	0.941
Weight (w_2)	1.000	0.530	0.059
Unfactored crash estimate (m)	9.961	5.300	32.838
Standard deviation (*std dev. m*)	0.068	0.157	0.862
Reduction factor	1.000	0.998	0.988
Factored crash estimate (B)	9.959	5.290	32.458
Variance ($Var(B)$)	0.005	0.025	0.726
Actual crashes during after period (A)	7	4	30
Variance ($Var(A)$)	0.113	0.051	0.622
Variance ($Var(\tau)$)	0.036	0.005	0.348

The index of effectiveness, percent reductions and standard deviations are shown in Table 8.

Table 8: Treatment effectiveness in HOCL, RORL, and Total FSI crashes

Measure	HOCL FSI crashes	RORL FSI crashes	Total FSI crashes
Index of effectiveness (θ)	0.703	0.756	0.924
Standard deviation (θ)	0.034	0.048	0.034
Reduction	30%	24%	8%
Standard error	3%	5%	3%

The calculated parameters for HOCL, RORL, and Total injury crashes used to estimate the treatment effectiveness are shown in Table 9.

Table 9: Calculated parameters for HOCL, RORL, and Total injury crashes

Parameter	HOCL injury crashes	RORL injury crashes	Total injury crashes
Over-dispersion (k)	0.312	1.626E-04	0.092
SPF estimated crashes (P_B)	14.292	8.850	59.422
Actual crashes during before period (x)	15	14	72
Weight (w_1)	0.817	0.001	0.845
Weight (w_2)	0.183	0.999	0.155
Unfactored crash estimate (m)	14.870	8.857	70.055
Standard deviation (*std dev. m*)	0.475	0.062	1.311
Reduction factor	1.001	1.003	0.993
Factored crash estimate (B)	14.881	8.881	69.530
Variance ($Var(B)$)	0.226	0.004	1.694
Actual crashes during after period (A)	10	7	55
Variance ($Var(A)$)	0.171	0.086	1.387
Variance ($Var(\tau)$)	0.075	0.029	1.304

The index of effectiveness, percent reductions and standard deviations are shown in Table 10.

Table 10: Treatment effectiveness of HOCL, RORL, and Total injury crashes

Measure	HOCL injury crashes	RORL injury crashes	Total injury crashes
Index of effectiveness (θ)	0.672	0.788	0.791
Standard deviation (θ)	0.035	0.033	0.022
Reduction	33%	21%	21%
Standard error	4%	3%	2%

Cost Benefit Analysis

The cost-benefit analysis compared the cost of crashes that were expected to occur without WCLT in the after period (B) to the cost of crashes that actually occurred with WCLT (A). The difference was the cost savings attributable to WCLT. The proportions used to divide the expected crashes into severity categories were taken from those observed in the before period. Willingness-to-pay crash cost values determined by TMR in 2015 were used.

The average cost of WCLT was $33,000 per km. The cost of procurement (low end) provided by TMR was $27,400 per km of WCLT (only painting and ATLM installation, without road widening). An upper, conservative estimate of the cost provided by TMR was $40,000 per km for WCLT. Using this upper estimate, the total implementation cost of the WCLT was $1.1 million in 2011-dollar terms. A life of five years before replacement/significant maintenance was considered appropriate for WCLT. The installation would have cost $1.2 million in 2015 using a discount rate of 4% typically adopted by TMR.

For all injury crashes, the total cost savings amounted to $7.6 million. This yielded a BCR of 6.4 for all injury crashes due to installation of the WCLT treatment. The actual project BCR would be higher if the benefits and costs of speed limit reductions were to be included.

DISCUSSION

The reduction in crashes associated with WCLT determined in this study was 21% for total injury crashes. This was comparable to a report by the Land Transport Safety Authority (1995) stating a 19% reduction in crashes after installing flush medians on New Zealand roads. Austroads (2010) compiled international research on painted medians and proposed a conservative crash reduction factor for this treatment in the range of 15–20%.

In this study, 60 reference sites and 15 treatment sites were used, giving a control to case ratio of 4:1. This was statistically sufficient to reduce bias. Linden and Samuels (2013) conducted a study on the preferred matching ratio (control:cases) and stated that, generally, a ratio of 4:1 elicits the lowest bias, but control to case ratios of up to 100:1 could be used. A study by Hennessey et al. (1999) showed that little statistical power is gained by using more than four or five controls per case.

A few sites had no counts of certain types of crashes, resulting in several zeros in the analysed data. The use of zero-inflated negative binomial regressions was considered, but they are more appropriate for data in which the excess zeros are generated by a separate process to the count values (UCLA: Statistical Consulting Group 2011). As there was no second zero-generating process in the crash count data, the general negative binomial model was elected.

Finding appropriate sites with similar characteristics to allow the safety benefits of WCLT for the wider road network to be estimated was a critical factor. Ensuring that the selected reference sites had an AADT between 3 000 and 17 300 encapsulated roads with AADT volumes as high as the treatment sites. These SPFs may be useful in future investigations of the safety on rural highways in Queensland, using the EB method. Roads with similar AADT's and cross-sections can be used to determine if the safety is worse than expected. Further data could be included to boost the predictive power of the models, including data for crashes on curves.

The SPFs have been developed to fit the reference sites' data and give indication about the safety of road sections typified by the ones selected in this evaluation. The maximum length of reference sites used for SPF development was 19.25 km. The SPFs should therefore not be extrapolated to make assumptions of safety for road sections greater than 20 km. A caveat to be placed on the models is to limit their appropriate use to road sections 20 km or shorter.

The effect of WCLT on reducing all FSIs (8%) was lower than for HOCL (30%) and RORL crashes (24%). The layout of WCLT lends itself to treating certain types of crashes; it could be combined with other road environment treatments to elicit a greater reduction on FSI crashes, to work towards a Safe System environment on rural highways.

The computed coefficients for the HOCL, RORL and Total crash SPF models were all statistically significant, for all injury crashes. The findings for injury crash reductions and the cost-benefit ratio were therefore supported statistically. The HOCL and Total crash SPF models had significant variables. The AADT variable and the constant in the RORL SPF model for FSI crashes were not significant. The FSI crash reduction of 24% reported for RORL crashes should therefore be considered with this in mind.

Possible avenues for further research include the effectiveness of the treatment based on heavy vehicle type composition, peak volumes, combination with other treatments on rural highways, and comparing routes with higher percentages of heavy vehicles with lower ones.

CONCLUSIONS

The key findings in the WCLT evaluation for rural highway sections were reductions of 33% in HOCL injury crashes and 21% for all injury crashes, providing positive economic returns with a BCR of 6.4. Effectiveness by crash types are as follows:

Crash type	FSI crash reduction	All injury crash reduction
HOCL	30%	33%
RORL	24%	21%
Total crashes	8%	21%

Further investigation with more sites may refine the estimates determined in this project. The SPFs may be used in future projects to estimate safety on rural highways with similar characteristics. The effect of WCLT on heavy vehicles could be examined in future studies when the data becomes available.

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Michael has been with ARRB since 2014, after completing an internship in his final year. He graduated from the University of Queensland with a Bachelor of Engineering (Civil - Hons), and Bachelor of Commerce (Finance). His work has largely involved the analysis of severe crash types on Queensland roads, the national AusRAP assessment, NetRisk, contributing to the ANRAM framework, and researching new innovative treatments such as wide centrelines, and the reflectivity of new road linemarking products.

Michael also completed a summer research scholarship project at the University of Queensland in his penultimate year, working with Dr Mahmud Mesbah. His work, 'Investigating the lagged effect of weather parameters on travel time reliability' studied the effect of weather on Melbourne Tram travel time delay, as well as the go-card network of buses in Brisbane. The study was published as a conference paper.

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Sam is an experienced engineer and holds a Bachelor of Civil Engineering, a Master of Road and Transport Engineering and a Master of Applied Science by research. He has held lead design engineering, traffic and transport engineering and senior engineering positions since 2000. After immigrating to Australia Sam has worked for CARRS-Q and two councils. Sam is currently providing engineering services within the Safer Roads unit of the Queensland Department of Transport and Main Roads.

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Joseph joined ARRB in February 2005. Joseph holds a Ph.D degree from the University of South Australia. Prior to joining ARRB Group, Joseph was employed for eight years by Griffith University, as a Research Fellow / Lecturer at the School of Environmental Planning.

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