Effectiveness of combined treatments: shoulder sealing and guard fence

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Abstract

Department for Transport, Energy and Infrastructure, South Australia, has been implementing intensive road and roadside safety treatments to address crashes; most notably 1.0 metre wide shoulder sealing and roadside safety barrier installation, under different programs. The aim is to reduce the frequency and severity of "single vehicle run off road" and "head on" crashes. This observational study looked at patterns of crashes before and after implementation of the two general treatments that were identified on the same road sections.

A difficult part of the study was site selection. The authors first concentrated on identifying sites in typical locations that had extensive roadside safety barrier installed rather than short treatments shielding individual roadside hazards. The study therefore focused on arterial roads in hilly terrain that are generally winding and narrow. These roads typically have embankments on one or both sides and are also lined with trees. The roads were investigated to identify sections that had been retrofitted with both subject treatments either in the same financial year, or over two consecutive years. After the screening process, seven sites were selected for evaluation.

The evaluation of combined treatments was based on a before/after comparison of casualty crashes and crash cost. The key finding has been that considering geographic location, the combined treatments have reduced numbers of casualty crashes by 61%: fatal by approximately 69%, serious injury by about 59% and minor injury by nearly 61%. Casualty crash costs amounted to $6.24 million per year before treatment, reducing to $2.11 million per year after treatment, leading to a benefit-cost ratio of 6.7 across all treatment sites. Due to an insufficient number of suitable control sites, no statistical model was used. Instead, a comparison group in similar terrain, where no work was undertaken, was used to account for any general trends. The comparison group experienced a casualty crash increase of 1.6% p.a. over the study period, while traffic increased by an average of 1.5% p.a.. Future research could include control sites to increase confidence in results.

To assist evaluations towards optimising investments and outcomes, the maintenance of timely and accurate treatment records, including treatment type and cost, exact location, start and completion dates and preferably in a single database is recommended.

Keywords: hilly terrain, type of crashes, shoulder sealing and guard fence, crash statistics, economic evaluation

Introduction

Department for Transport, Energy and Infrastructure (DTEI), South Australia, is responsible for identifying, analysing and prioritising crash locations and directing funds to road safety treatments that ensure the most cost-effective returns in crash and injury reductions. The majority of road safety investment has been directed towards the Metropolitan and Eastern Regions and generally hilly terrain. DTEI has been implementing intensive road and roadside safety treatments to address crashes, especially shoulder sealing[a] and roadside safety barrier (usually w-beam guard fence), and mostly under separate programs. The aim is to reduce the frequency and severity of "single vehicle run off road" crashes chiefly, being the most predominant type of crash in rural South Australia. This study attempts to look at patterns of crashes before and after implementation of two separate treatments, i.e. shoulder sealing and guard fence (w-beam), as a combined effect. Example views before and after the combined treatments are shown in Figure 1.

Figure 1: Example views before and after the combined treatments

Methodology

The primary objective was to measure the effectiveness of the combined treatments of shoulder sealing and guard fence in terms of numbers and cost of casualty crashes. The study focus was therefore on those sites that were most likely to have attracted extensive lengths of both treatments. The study consequently focussed on single carriageway arterial roads in winding topography, typically with embankments on one or both sides and trees lining the road. All selected sites were hence from the Adelaide Hills and lower Southern Ranges and are two-lane, two-way roads.

The site selection process was a difficult part of this study, as there was no common database holding all the information required for the study. The team had to gather information from different stakeholders. The step by step process in extracting potential sites for the study is explained below:

a) The previous Mass Action Program was designed to treat entire roads exhibiting high crash rates with multiple treatments such as shoulder sealing and roadside safety barrier. So the first step was to check the Mass Action Program to see if both treatments were carried out on the same road in the same financial year.
b) Due to few sites being treated and meeting the criteria under the Mass Action Program, this study then looked at other programs for the two general treatments within the same financial year.
c) As DTEI's road safety programs targeted sites with a speed limit ≥ 80kph, sites were screened out for speed limits less than that.

[a] Shoulder sealing – 1.0 m nominal added width both sides with edge lines marked

d) All treated sites were then selected where guard fence and shoulder sealing were installed either in the same financial year or over two consecutive years regardless of the funding programs in order to maximise potential candidate sites.
e) After numerous iterations, twenty road sections, located in hilly terrain, were identified and were further screened thoroughly by undertaking virtual tours using PMS and Hawkeye videos, and followed by site visit investigations to ascertain that all criteria were met. Due to the specific nature of the evaluation, seven sites were finalised for this study that were treated with substantial amounts of guard fence and extensive shoulder sealing.

Table 1 details the seven sites that were treated with sealed shoulders and guard fence under various funding programs. Shoulder sealing was generally done for the whole section (refer Appendix A for detail), whereas guard fence was installed at specific locations identified by safety auditors or regional traffic engineers. The length of guard fence installation is presented as a percentage of road length.

All seven sites had been selected for treatment based on casualty crash history. Five sites were treated under a black spot program (federal or state), meaning they had to satisfy the criteria of 0.2 casualty crashes/km/year over the previous five years. The two other sites were treated under two different programs, as indicated in Table 1.

Table 1: Site details, including proportion of road treated with guard fence

Site	Road name	Start RRD[b]	End RRD	Distance (km)	Speed limit (km/h)	Treated program	Proportion* of guard fence to road length %	Avg. AADT[c] (vehicles/day)	
								Before	After
1	Tea Tree Gully-Mannum	29.10	30.30	1.20	80	National Black spot	77	2629	2711
2	Cudlee Creek - Lobethal	0.589	7.791	7.20	80	National Black spot	74	1711	1900
3	Blackwood-Goolwa	34.00	44.53	10.53	100	Mass Action & Shoulder Sealing	79	850	950
4	Grants Gully	0.872	2.96	2.09	80	National Black spot	73	3171	3250
5	Tea Tree Gully-Mannum	49.60	62.13	12.53	100	Shoulder Sealing & Rural Road Safety	45	1624	1711
6	Stirling-Strathalbyn	30.17	36.70	6.53	100	Auslink Black spot	40	492	543
7	Yankalilla-Victor Harbor	6.418	9.941	3.52	100	State Black spot	53	688	706

* Some guard fence previously installed, however substantial lengths installed under these programs

Site 3 has the highest proportion of guard fence at 79%, whereas Site 6 has the lowest proportion at 40%. No minimum level for the proportion of guard fence treatment was set; as the proportion varies according to site requirements between the start and end road running points. The spatial locations of the treated sites are presented in Figure 2.

During the site investigation it was observed that some sites were treated with chevron markers (whether installed before or during the evaluation period) on some curves where hazards were not shielded or removed; however this treatment was in the minority.

[b] RRD – Road Running Distance
[c] AADT – Annual Average Daily Traffic

The study team went through the crash database available from the DTEI intranet website for the sites and extracted all relevant crashes for analysis. The study adopted a before-and-after comparison of all reported casualty crashes (by crash type and by severity) at the treated sites for the respective evaluation period. In our case, exact start and completion dates of treatments were unavailable. Therefore, the whole financial year was considered as the "treatment year(s)" and all crashes during that year(s) were excluded from analysis.

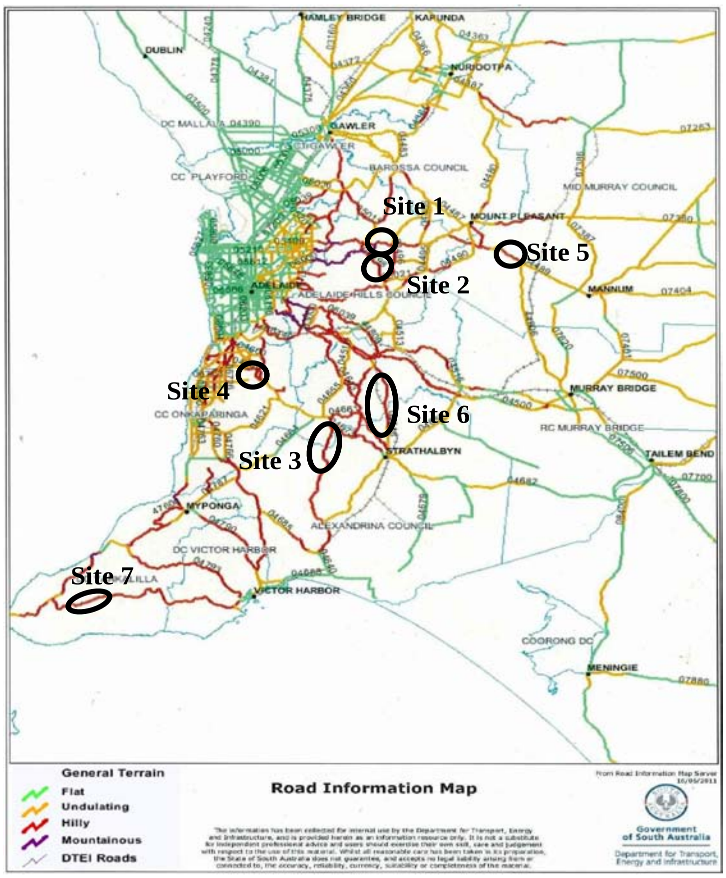

Figure 2: Approximate location of treated sites

Results

All selected sites were mid-block and the objective of the treatments was to reduce the frequency and severity of "single vehicle run off road" and "head on" crashes. So, the initial study included head on, hit fixed object, rollover, and left road-out of control types of crashes (SA crash coding and descriptions attached as Appendix B) and excluded intersection crashes (rear end, right turn and right angle) during the initial crash data analysis.

It is expected that sealed shoulder and guard fence would individually cut the aforementioned casualty crash types by up to 40% and 30% respectively (Austroads 2009), while the estimated combined effect, if both treatments are applied at the same location, is 58% (Austroads 2009 p.82). Results were extracted using three methods as below:

a) *Before and after casualty crash comparison*

The treatments were carried out at some of the sites in different financial years. Therefore, the evaluation periods for the sites differed as shown in Table 2. It shows five years *before* for all treated sites while the *after* period was the longest possible period, i.e. five years for Sites 1-3; four years for Site 4; and two years for Sites 5-7. All relevant casualty crashes for the nominated sites for the respective evaluation period were extracted and tabulated by severity i.e. fatal, serious injury and minor injury.

Table 2: Casualty crash data before and after treatment

Site	Road name & RRDs	Before				After			
		5 year				5 year			
		Fatal	Serious injury	Minor injury	Total	Fatal	Serious injury	Minor injury	Total
1	Tea Tree Gully-Mannum RRD:29.10-30.30		3	2	5			2	2
2	Cudlee Creek-Lobethal RRD: 0.59-7.79	3	5	10	18		7	4	11
3	Blackwood-Goolwa RRD: 34.00-44.53	1	5	10	16			1	1
	Sub total crashes/year	0.80	2.60	4.40	7.80	0.00	1.40	1.40	2.80
		5 year				4 year			
4	Grants Gully RRD: 0.87-2.96	1		4	5		1	1	2
	Sub total crashes/year	0.20	0.00	0.80	1.00	0.00	0.25	0.25	0.50
		5 year				2 year			
5	Tea Tree Gully-Mannum RRD:49.60-62.13	2	8	7	17				0
6	Stirling-Strathalbyn RRD: 30.17-36.70	1	4	6	11		1	3	4
7	Yankalilla-Victor Harbor RRD: 6.42-9.94		1	1	2	1			1
	Sub total crashes/year	0.60	2.60	2.80	6.00	0.50	0.50	1.50	2.50
	Total crashes/year	1.60	5.20	8.00	14.80	0.50	2.15	3.15	5.80
	% reduction					-68.8%	-58.7%	-60.6%	-60.8%

The casualty crash reduction performance appears most successful for Sites 3 and 5; and least successful for sites 6 and 7 (to date). The proportional reduction on the remaining roads appears reasonable in relation to the estimated combined effect (of 58%).

Likewise, Figure 3 displays the total number of crashes by severity p.a. (columns, left vertical axis) and casualty crash cost p.a. (line, right vertical axis), before/after treatment. The total fatal, serious injury and minor injury crashes per year were 1.6, 5.2, and 8.0 before treatment, reducing to 0.5, 2.15 and 3.15 crashes per year after treatment; indicating a reduction in fatal, serious and minor injury crashes of 68.8%, 58.7% and 60.6% respectively.

The social cost per year was also calculated based on the road crash severity costs for South Australia (BITRE 2006), where total costs per crash are adjusted to 2009 dollars. The reported casualty crashes amount to $6.24 million per year before treatment, reducing to $2.11million per year after treatment; meaning an overall saving of $4.13 million per year following treatment. This saving is based on the assumption that the same average number of casualty crashes would continue to appear in the after period as it was in the before period, without treatment. The total investment on these projects was $7.2 million. Considering a treatment life of 20 years (refer Austroads, pp. 6, 8) and a discount rate of 6%, the present value of the cost of treatment is $6.73 million and maintenance/repair is $0.4 million, leading to a benefit-cost ratio (BCR[d]) of 6.7. A BCR of 6.7 implies a net saving of $6.70 to the community for each dollar invested in these programs.

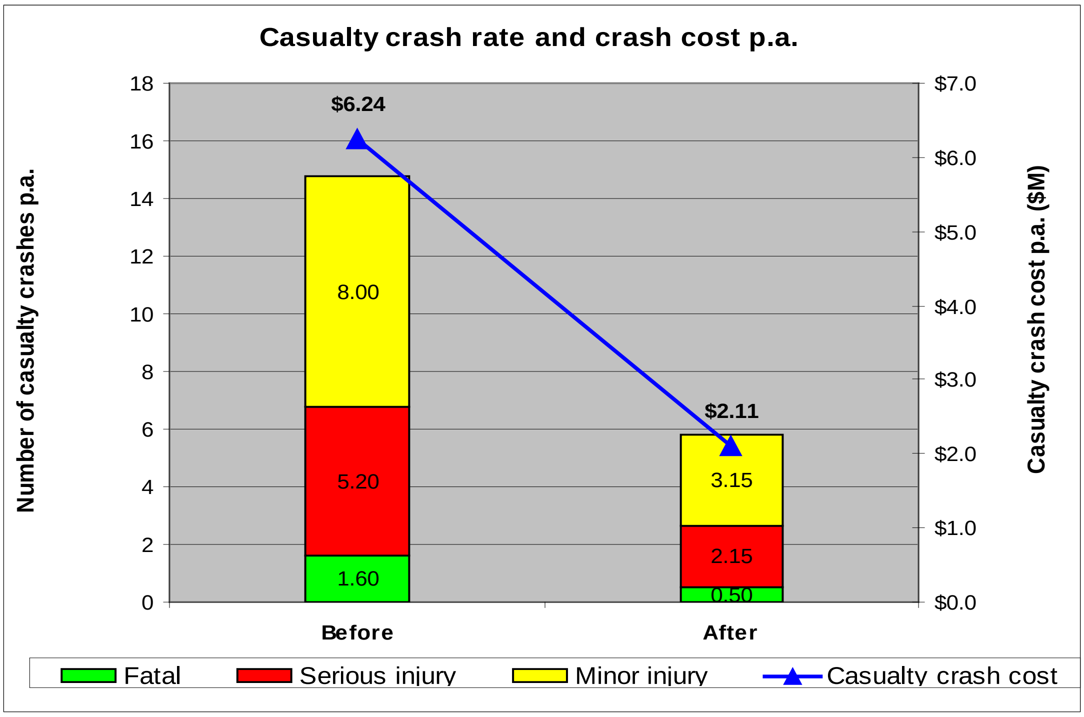

Figure 3: Graph of casualty crashes and crash cost p.a. before/after treatment

All sites were selected for treatment based on casualty crash history, so regression to the mean is likely to be an issue. In this regard, regression to the mean was not attempted to be corrected, however a longer evaluation period is considered to reduce its effect to some extent. In addition, due to a lack of suitable control sites, no model was used for a statistical test. However, an untreated comparison group selected from hilly terrain was used to account for any general trend.

The selected sites were further analysed for minor intersection crashes, as these also provide access to private property. However, crashes were found to be not distinctly different between before and after period at these locations.

b) Casualty crash comparison using MVKT [e]

The results presented in Table 2 and Figure 3 above show aggregated crashes per year for the seven sites but do not account for AADT changes or variations. It was therefore decided to also measure the performance using casualty crashes per 100 mvkt as an exposure unit. AADT data are not available for every year during the study period, and the year of available traffic data varied by site. Linear interpolation was used to fill in years for which counts were not available. The AADT increased at all of the sites over the study period by an average of 1.2% p.a..

[d] BCR – as per ATC National Guidelines for Transport System Management
[e] mvkt – million vehicle kilometres travelled

Large variation in AADT and road length and different speed limits between sites made an aggregated analysis complicated and problematic. Sites were therefore analysed separately and the outcomes presented in terms of individual performance. Table 3 shows the before-and-after fatal, serious and minor injury crashes per 100mvkt for the individual sites.

Table 3: Casualty crashes per 100mvkt data before and after treatment

	Before treatment Crashes/(year*100mvkt)				After treatment Crashes/(year*100mvkt)				
	Fatal	Serious injury	Minor injury	Total	Fatal	Serious injury	Minor injury	Total	% reduction
Site 1	0.00	52.21	34.65	86.86	0.00	0.00	33.77	33.77	-61.1%
Site 2	12.01	20.00	39.62	71.64	0.00	26.17	14.81	40.98	-42.8%
Site 3	5.55	28.84	57.93	92.33	0.00	0.00	5.12	5.12	-94.5%
Site 4	8.23	0.00	32.99	41.22	0.00	10.11	10.06	20.17	-51.1%
Site 5	5.83	22.89	20.21	48.93	0.00	0.00	0.00	0.00	-100.0%
Site 6	16.64	65.72	102.20	184.56	0.00	38.66	115.98	154.64	-16.2%
Site 7	0.00	22.50	22.37	44.86	55.28	0.00	0.00	55.28	23.2%

Sites 3 and 5 again appear the most successful sites, while Sites 6 and 7, shorter sections and with lower AADT, again appear the least successful (to date).

The speed limit has been changed from 100km/h to 80km/h on various roads in the Adelaide Hills over the past decade. So this study also checked all evaluated sites and found three sites (as identified in Table 1) were affected by a changed speed limit. The speed limit of Site 1 was changed in 2002, which influenced partly the before period and completely the after period of this evaluation. On the other hand, the speed limits for Sites 2 & 4 were changed almost in the same year of the shoulder sealing and guard fence construction, so any influence can be expected only in the after evaluation period for these sites.

The effect of the changed speed limit on casualty crash reduction could not be quantified separately; however, a study conducted by the Centre for Automotive Safety Research (CASR) on "Evaluation of the Adelaide Hills speed limit change from 100km/h to 80km/h" in 2009, shows that the changed speed limit has most likely led to a 15% reduction in casualty crashes.

c) Identification of general trend

This study was unable to find a sufficient number of suitable control sites that are identical in geometric and operational characteristics as the treated group, so no statistical model was used. Instead, a comparison group of arterial roads similar in terms of terrain and speed zones, where no work was undertaken, was used to identify whether there were any system-wide effects that should be accounted for.

The comparison group consisting of 12 arterial road sections (58 km in total) experienced a casualty crash increase of 1.6% p.a. over the study period based on a best-fit linear regression line. The AADT increased at these sites over the study period by an average of 1.5% p.a..

Discussion

The analysis confirmed that the combined effect of shoulder sealing and guard fence is effective in reducing overall casualty crashes and crash costs at the treated sites.

The evaluation identified that certain treated sites were very successful and some not so successful. For instance, the overall casualty crash reduction performance for Sites 3 and 5 were very successful, but not so successful for Sites 6 and 7. The proportion of reductions on the remaining roads appears reasonable relative to the estimated combined effect (of 58%).

Keeping other influences aside, the study team looked for road infrastructure features leading to differing results and went through a virtual tour again to look at the existing physical road environment of these more/less successful sites. All sites are similar in geographical terrain; however, the difference found was about roadside forgivingness and inconsistency in shoulder sealing application. The more successful sites were treated with shoulder sealing consistently on both sides with edge lines and sufficient gap to the guard fence, whereas the least successful sites generally appeared to have intermittent shoulder sealing, no edge lines and a typically small gap to the guard fence. For example, the typical road and roadside characteristics of the most and least successful sites are shown in Figure 4.

Figure 4: Comparison between the most and least successful sites' road environments

The funding programs for the treatments in this evaluation were different (refer Table 1). Five sites, but short sections, were selected from Black Spot programs under which both treatments were completed at once, whereas the other two sites were completed under more than one program, namely Shoulder Sealing Program, Rural Road Safety Program (roadside barrier protection) and Mass Action (for multiple treatments). The proportion of treatment length under Black Spot Programs to other programs is 20.54km to 23.06km respectively and the effectiveness of the combined treatments appears to be more successful on longer sections than short sections of road (as treated under Black Spot Programs).

There are three limitations in this evaluation. Firstly, particularly in this case the influence of the speed limit change from 100 km/h to 80 km/h on three treated sites was unavoidable; but in as much as possible the influence of such changes should not be included in future evaluations. Secondly, the after-period of three of the study sites is 2 years. Ideally 3-5 years of casualty crash data are more commonly used among road safety practitioners. As the crashes tend to occur randomly along a length of road, a short post treatment period may lead to inaccurate estimates and results could be different from a longer-term evaluation. Lastly, due to lack of suitable control sites, no statistical model was used. Instead, an untreated but similar comparison group selected from hilly terrain was used to account for any general trends. Future research could include control sites to increase confidence in results.

Conclusion and Recommendations

The assessment of the effect of combined treatments on reducing casualty crashes was successful and this finding should have important implications on resource allocations and in preparing strategies for future road safety investment plans.

Recommendations and issues identified during this study are:

1. Maintain accurate and timely recording of treatment details, including exact location, treatment types, cost, start and completion dates for monitoring and future evaluation, preferably in a single database.
2. There are indications that the target locations for the combined treatments (shoulder sealing and guard fence) should be longer sections, unlike Black Spot treatments that tend to treat short sections in most cases, in order to achieve more productive outcomes.
3. Instead of implementing several treatments under different funding programs spread over several years, it may be more appropriate to treat road sections with a consistent width of shoulder sealing and roadside safety barrier together under a single program; this would assist in monitoring and analysing the treated sites to support future investment: as a consequence this study could otherwise have included many other sections for evaluation.
4. Geographic terrain and road function are integral to this analysis. Funding programs could provide most benefit by targeting different terrain and roadside risks with specific treatments. For example, shoulder sealing and guard fence could be most appropriate on arterial roads in hilly terrain, whereas sealed shoulders and audio tactile line marking may be more appropriate for plain terrain with clear roadsides.
5. Due to a lack of suitable control sites for this study, no statistical model was used. Future research could include control sites to increase confidence in results.

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Appendix A: Detail of shoulder sealing width

Site	Road Name	Start RRD	End RRD	Dist. (km)	Avg. shoulder sealing width * (m)		Comments
					Left	Right	
1	Tea Tree Gully - Mannum	29.10	30.30	1.20	1.30	2.30	Shoulder sealing was done only where possible and not much shoulder width left in front of all guard fence
2	Cudlee Creek - Lobethal	0.589	7.79	7.20	0.80	1.17	
3	Blackwood-Goolwa	34.00	44.53	10.53	0.70	0.77	
4	Grants Gully	0.872	2.96	2.09	1.61	1.00	
5	Tea Tree Gully - Mannum	49.60	62.13	12.53	1.13	0.97	
6	Stirling-Strathalbyn	30.17	36.70	6.53	-	-	Intermittent shoulder sealing work with no edge line marking
7	Yankalilla-Victor Harbor	6.418	9.94	3.52	-	-	Intermittent shoulder sealing work with no edge line marking

***** outside marked edge line

Appendix B: SA Crash Type approximation to DCA coding

SA Crash Type	DCA code	DCA Description
Head on	201	Head on
Hit fixed object	703-704	On straight off road hit object
	803-804	On curve off road hit object
Roll over , Left road out of control	701-702	On straight off road
	801-802	On curve off road

Note: Where SA Crash Type relates to two or more DCA codes, crash description should be referred.