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THE GENERAL EFFECTIVENESS OF COUNTERMEASURES FOR CRASHES INTO FIXED ROADSIDE OBJECTS

by

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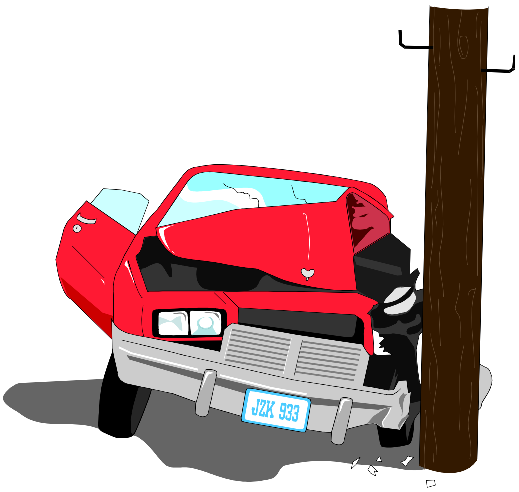

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The General Effectiveness of Countermeasures for Crashes into Fixed Roadside Objects

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Abstract:
Vehicles crashing into fixed roadside objects, such as trees, poles and embankments, continue to create substantial trauma and costs for individuals and society. These crashes tend to be severe in nature, accounting for about one-quarter of all serious road casualties in Victoria. This study aimed to evaluate treatments implemented to address the problem of crashes into fixed roadside objects, in terms of casualty crash occurrence, costs, and economic worth. The results may help set priorities to further improve the return on future road safety investments.

Over 250 countermeasures for crashes into fixed roadside objects, undertaken in Victoria since 1989, were evaluated. Analyses were divided into several distinct levels to provide a comprehensive evaluation of various treatment types, both individually and when aggregated.

For the sample of treatments evaluated, casualty crashes and costs were reduced by 9% and 16%, respectively, and a Benefit/Cost Ratio of 4.1 was achieved. Changes to horizontal road geometry reduced casualty crashes by 44%, while large-scale shoulder sealing reduced casualty crashes and costs by 32% and 37%, respectively. Several other results *approached* statistical reliability and should therefore be considered indicative only at this stage.

This results have both immediate and medium-term implications for existing strategies for roadside safety. They suggest existing strategies should give increased emphasis to the highly effective treatments, such as shoulder sealing, improved horizontal road alignment and skid resistant pavements. Further critical assessment of selected other treatments is recommended before they form a significant part of future roadside safety strategies. A number of opportunities for further strategic improvements are also recommended.

Key Words:
(IRRD except when marked*)
Accident, roadside hazard, road design, evaluation

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EXECUTIVE SUMMARY

Single vehicles crashing into fixed roadside objects continue to create substantial trauma and costs for individuals and society. Of the 5,184 serious casualty crashes in Victoria during 1994, 1,175 involved a single vehicle striking a fixed roadside object. These crashes tended to be severe in nature. For example, they accounted for 23% of all serious casualties on Victoria's roads, with 1,454 people either seriously injured or killed. The most common objects struck were trees, poles and embankments.

Although evaluations of programs of black-spot treatments have been undertaken, there is a need to better understand the effects of specific treatments which are targeted at various accident types. The aim of this study was to evaluate treatments which have been implemented to address the problem of single vehicles crashing into fixed roadside objects, in terms of casualty crash occurrence, crash costs, and economic worth. This evaluation may help set priorities to further improve the return on road safety investments.

Treatment and Data Sources

A list of 410 road engineering treatments undertaken in Victoria since 1989 to address crashes into fixed roadside objects was supplied by VicRoads. Of those, 254 were retained for evaluation, and the balance excluded due to incomplete records on location, type of treatment, or start and end dates. Treatments were drawn from federally funded programs from 1990/91 to 1993/94, the Transport Accident Commission's Black-Spot Program covering 1992/1993 and 1993/1994, and state funded programs from 1989/1990 to 1993/1994.

Results

The analyses were divided into several distinct levels to provide the most comprehensive evaluation of the various treatment types, both individually and when aggregated. Wherever numbers are given, the reductions were statistically reliable. In considering these results, it is important that account be taken of a number of key qualifiers, also summarised below.

Major Findings:

For the sample of treatments evaluated:

Casualty crash frequencies and costs were reduced by **9%** and **16%**, respectively.

A **Benefit-to-Cost Ratio (BCR) of 4.1** was achieved**.**

Road/roadside geometry improvements reduced casualty crash frequencies by **23%.** A subset of these treatments, **changes to horizontal road geometry,** reduced casualty crashes by **44%.**

Road surface improvements reduced casualty crashes and costs by **30%** and **36%,** respectively, and achieved a **BCR of 5.6.** A subset of these treatments, **large-scale shoulder sealing,** reduced casualty crashes and costs by **32%** and **37%,** respectively.

Several treatment types yielded an increase in casualty crash frequency, cost, or both. However, some estimates were not statistically reliable and require monitoring and further critical assessment.

Qualifiers - At each level of analysis, several results approached statistical reliability at the 5% or 10% probability level and **should therefore be considered indicative only** at this stage. These treatments may have been unsuccessful at reducing road trauma or, alternatively, the relatively low number of crashes available for some analyses may have reduced their statistical power. These results highlight the need to include more treatments and longer after-treatment periods for some treatment types to provide more robust support for these findings.

Recommended Actions:

This evaluation has **both immediate and medium-term implications** for existing strategies for roadside safety. The results suggest that:

Existing strategies should:

- **Give increased emphasis** to the highly effective treatments designed to improve the road surface and road geometry, such as **large-scale shoulder sealing, improved horizontal road alignment and skid resistant pavements**.
- **Include further critical assessment of guard end rails, street lighting and pavement widening** before they form a significant part of future roadside safety strategies.
- Given that the program of treatments in **rural areas was found to be less effective than that in metropolitan Melbourne,** more strenuous efforts should be made to enhance the rural program, probably through an increased emphasis on the most effective treatments, such as improvements to the road surface and horizontal alignment.

Opportunities for further strategic improvements include:

- **Extending current evaluations** to determine conclusively the effectiveness of treatments whose effectiveness is currently unclear, as well as improving the systems for recording treatment details in future and **monitoring and further assessing** those treatments showing an increase in casualty crash frequency, costs, or both.

1. INTRODUCTION

1.1 BACKGROUND

Single vehicles crashing into fixed roadside objects continue to create substantial trauma and cost for individuals and society. Of the 5,184 serious casualty crashes in Victoria during 1994, 1,175 involved a single vehicle striking a fixed roadside object (Natalizio, 1995). These crashes tended to be severe in nature. For example, they accounted for 23% of all serious casualties on Victoria's roads, with 1,454 people either seriously injured or killed. The most common objects struck were trees, poles and embankments.

Over the last decade or so, *accident black-spot* programs have been implemented in Australia to reduce the incidence and severity of crashes at sites with poor crash records, including sites where vehicles striking fixed roadside objects are prevalent. These programs usually include relatively low cost, highly effective road engineering treatments (Corben, Ambrose & Wai, 1990). They are often undertaken on a broad scale at multiple locations, resulting in a large investment of road safety resources. For example, the treatments implemented as part of the Transport Accident Commission's (TAC) Black-Spot Program between 1992/1993 and 1993/1994 included capital costs of around $75 million (Corben, Newstead, Diamantopoulou & Cameron, 1996).

Previous evaluations of black-spot programs yielded positive results, particularly in terms of showing overall program benefits (e.g. Corben et al., 1996; Corben et al., 1990; Richardson, 1987). However, specific categories and types of treatments have been shown to be more effective than others. For example, in an evaluation of the TAC's Accident Black-Spot Program (covering 457 treatments), Corben et al. (1996) reported a 17% reduction in casualty crash frequency and an 18% reduction in casualty crash costs to the community for the entire program. However, only some categories of treatments, such as those targeting intersections (e.g. roundabouts, new signals and fully controlled right-turn phases) and routes (e.g. shoulder sealing), yielded statistically reliable reductions in casualty crashes, costs, or both.

Corben et al. (1990) evaluated black-spot treatments undertaken in Victoria between 1979 and 1986. They found that, across 116 treated intersections, casualty crash occurrence was reduced by 33%, with a Benefit-to-Cost ratio (BCR) of 9. In particular, roundabouts, new intersection signals and fully-controlled right-turn phases at signals resulted in substantial reductions in casualty crashes. While treatments undertaken mid-block were unsuccessful in reducing these crashes, a later study of mid-block treatments by Tziotis (1993) found similar levels as Corben et al. (1990). Furthermore, intersections treated in rural areas lead to greater casualty crash reductions than those undertaken in metropolitan Melbourne.

Although previous evaluations of accident black-spot programs have shown overall program benefits and have begun to highlight the most effective treatments, there is a need to better understand the effects of program components which targeted specific accident types, such as single vehicles crashing into fixed road side objects. In other words, a better understanding of the relative effectiveness of various types of treatments can help set priorities to further improve the return on road safety investments. Therefore, this study set out to evaluate the effectiveness of treatments that have been implemented to address the problem of single vehicles crashing into fixed roadside objects.

1.2 OBJECTIVES

The specific objectives of this study were to:

1. Determine the change in casualty crash frequency and costs at sites where treatments targeted at single vehicle crashes with fixed roadside objects have been implemented;

2. Determine the economic worth of treatments targeted at single vehicle crashes with fixed roadside objects.

2. STUDY METHOD

2.1 THE EVALUATION DESIGN AND METHODOLOGY

2.1.1 Evaluation Design

This evaluation adopted a quasi-experimental design with control groups. With this design, the treatment success is determined by comparing the crash frequencies (and costs) before and after the treatment is undertaken to those during the same periods at the control sites. Before-periods consisted of five full years of crash data, while after-periods comprised the maximum number of full years of crash data available. In the context of this evaluation, the control group allows adjustments to be made for factors (other than countermeasures for fixed road side object crashes) that may affect road trauma. For example, during the period covered by this evaluation, several road safety initiatives have been implemented in Victoria that may have affected casualty crash rates (e.g. Cameron, Newstead & Vulcan, 1994). Indeed, this design has been used successfully to evaluate the effectiveness of accident black-spot treatments (Corben et al., 1990; BTCE, 1993) and other road safety countermeasures (Newstead & Mullan, 1996).

2.1.2 The Evaluation System

The evaluation system used here is based on that originally developed to evaluate the TAC's Accident Black-Spot Program (Corben, Newstead, Cameron, Diamantopoulou & Ryan, 1994) and later used successfully to evaluate speed zone changes in Victoria (Newstead & Mullan, 1996). A key feature of the system is its applicability to crash-based evaluations of various road safety countermeasures. While the system was described in detail by Corben et al. (1993 and 1994), a brief overview follows, focusing on the collection and management of the various data sources.

2.2 DATA SOURCES

2.2.1 Site and Treatment Data

Available lists of black-spot treatments undertaken over the past ten years were supplied by the VicRoads' regions. From this list, a spreadsheet containing the known details of projects considered relevant to this study was constructed. Relevant projects were defined as those designed to reduce, at least in part, the incidence and severity of crashes into fixed roadside objects. A fixed roadside object includes a tree, pole, embankment, cutting, mound, boulder, traffic signal, bridge, culvert, barrier, building, wall, fence, or other structure that, if struck by a vehicle, may lead to a rapid transfer of energy.

The lists of projects from black-spots programs comprised federally funded programs for the years 1990/1991 to 1993/1994, the TAC's program covering the financial years 1992/1993 and 1993/1994, and state funded programs for the years 1989/1990 to 1993/1994.

The fields in the spreadsheet of treatments included the program administration code, location and municipality, and start and end dates. To enable identification and extraction of the relevant crash data from Victoria's crash database, Road Reference Point (RRP) and Road Segment (RS) codes were also included. RRP refers to the intersection at which a crash occurs; RS describes the location of a crash occurring away from an intersection. Information on other characteristics of the treated locations was also included to enable comparable control sites to be selected. These characteristics included intersection geometry, road hierarchy and road characteristics. Finally, where available, the capital cost of the treatments and annual maintenance and operating costs were provided by the VicRoads' regions, as these costs were required in the evaluation of the economic worth of the treatments.

Initially, the spreadsheets contained 410 projects or black-spot treatments. Of those, 254 were retained in the final evaluation. Treatments were excluded because of insufficient information about location (i.e. to enable identification of RRP or RS codes), type of treatment, or start and end dates. The treatments were categorised into one of seven broad categories: hazard removal, hazard delineation, road and roadside geometry, roadway delineation, road surface improvements, traffic operations and other/miscellaneous. Within each category, several treatment types were included. These are listed in Table 1.

2.2.2 Crash Data

Crash data were obtained from VicRoads' database for the period 1984 to 1995. This database contains information on all police-reported casualty crashes in Victoria and includes details on the date of the crash, RRP and RS codes. For each crash, injury information is also recorded, including the severity level (fatal, serious injury, other injury) of each person injured. In order to extract the relevant crash data for the treated sites, RRP and RS codes from the spreadsheet describing the treatments were merged onto the casualty crash database. Crashes at the treated sites were extracted and allocated to either the before or after period, according to when they occurred in relation to the installation of the treatment. To control for possible seasonal effects, whole years were used to define the period of data extracted for the before and after periods. There were 9,253 crashes at the 254 treatment sites for the period 1984 to 1995, comprising 6,989 in the before and 2,264 in the after period.

2.2.3 Control Data

After the crash data at the treated sites were extracted, the remaining casualty crashes in the database represented the potential source of control data. The initially proposed approach of closely matching treatment and control groups (Corben et al., 1993) was trialed but proved impractical due to excessively low crash frequencies at the few suitable control sites. Therefore, control groups were formed as in the original MUARC evaluation of black spot treatments (Corben et al., 1990), using the remaining reported casualty crash data (excluding all treatment sites) for the entire Local Government Area (LGA). Where more than one treatment had been carried out in a given LGA, control crashes were randomly and equally assigned to each treatment. This method was used to ensure that important assumptions of the analysis method (i.e. independence of cell frequencies) were met.

2.2.4 Crash Costs

In order to evaluate the economic worth of the treatments, capital and maintenance costs were obtained from the VicRoads' regions where available (see Section 2.2.1). Also required for the economic evaluation were estimates of the costs to society of road crashes. In line with previous accident black-spot evaluations (Newstead, Corben, Diamantopoulou, & Cameron 1995), the social costs of crashes proposed by Andreassen (1992) were used as a basis. The actual values used are shown in Table 2. The approach adopted in estimating these casualty crash costs is described in some detail in Corben et al. (1994) and Corben et al. (1996).

Table 1 Summary of the type of treatments and number of sites included in this evaluation

Treatment Type	No. of Sites
Hazard Removal	
Pole Removal	5
Pole Relocation	14
Frangible Poles	4
Tree Removal	2
Guard Rail	19
Guard Rail End	3
Bridge End Post Guard Rail	8
Other Safety Barriers	1
Miscellaneous	7
Hazard Delineation	
Delineation of Other Hazards	4
Road and Roadside Geometry	
Horizontal Geometry	8
Pavement Widening	5
Improved Cross-fall	4
Culvert Widening	2
Bridge Widening	3
Bridge Pavement Widening	1
Miscellaneous	1
Roadway Delineation	
Tactile Edge lining	10
Edge lining	35
Raised Pavement Markers	2
Raised Reflective Pavement Markers (RRPMs)	2
Curve Delineation Signs	1
Guideposts	1
Street Lighting	11
General Delineation	5
Edge lining and Curve Delineation.	9
RRPMs and Curve Delineation	4
Miscellaneous	2
Road Surface Improvements	
Skid Resistance	3
Large-scale Shoulder Sealing	42
Shoulder Sealing on Bridge	8
Shoulder Sealing with Tactile Edgelining	9
Miscellaneous	1
Traffic Operations	1
Miscellaneous	17
TOTAL	**254**

Table 2 Estimated Average Social Costs Per Casualty Crash ($1993)

Fatal Crash	***Serious Injury Crash***	***Other Injury Crash***

Urban	*Rural*	*Urban*	*Rural*	*Urban*	*Rural*
742,930	799,508	113,159	117,648	6,936	7,255

The economic evaluation did not include benefits other than those due to crash savings (i.e. changes in travel time, congestion, etc., were ignored).

2.3 DATA ANALYSIS

2.3.1 Levels of Analysis

The analyses were undertaken in two steps. Initially, an analysis was run using all crash types (i.e. single and multiple vehicle crashes) to enable comparisons to be made with previous black-spot evaluations. Second, an analysis was undertaken based on single vehicle casualty crashes into fixed road side objects only. Because single vehicle crashes represent a subset of all crashes, these analyses were not independent. In other words, the results of one analysis can help predict the results of the other.

Within each of the crash categories (single vehicle and all crashes), the analyses were divided into several distinct levels to provide the most comprehensive evaluation of the various types of treatments, both individually and when aggregated.

1. *Entire sample*. The overall effect of the sample of treatments, irrespective of treatment type.
2. *Rural and metropolitan.* The effects of the sample of treatments in rural and metropolitan areas, regardless of treatment type. In these analyses, the rural and metropolitan areas represented the aggregate of the rural and metropolitan VicRoads' regions respectively.
3. *Treatment category*. The combined effect of the treatments classified into one of seven broad categories: hazard removal, hazard delineation, road and roadside geometry, roadway delineation, road surface improvements, traffic operations and miscellaneous.
4. *Treatment type.* The effect of each treatment type (see Table 1).

3. RESULTS

3.1 STATISTICAL ANALYSIS

The assumptions and rationale underlying the statistical analyses undertaken in this evaluation will not be described here in detail (see Corben et al., 1993). It will suffice to say that the method employed follows the early work of Tanner (1958) and the more recent approach of Bruhning and Ernst (1985). Furthermore, it has been used successfully in previous evaluations of road safety countermeasures, including accident black-spot treatments (e.g. Newstead et al., 1995; Newstead & Mullan, 1996). This method assumes that the crashes at the treated site in the before and after period follow a binomial distribution. Under the null hypothesis of no treatment effect, the ratio of crashes in the before and after period should be the same in the treatment and control groups. On the basis of Generalised Linear Models, a log-linear model with Poisson error structure is then applied to the data. In this model, the magnitude of the treatment effect and relevant confidence limits can be calculated. In line with statistical conventions (Tabachnick & Fidell, 1989), a criterion for statistical reliability of 5% was adopted, that is, a change in crash frequency (or costs) is said to be statistically reliable when the probability is less than 5% that it is due to chance alone.

In the context of this evaluation, confidence limits provide an interval (bound by upper and lower values) for which there is a 95% probability of including the true change in casualty crash frequency (or costs) due to the treatment being evaluated. Thus, upper and lower confidence limits both less than zero indicate a statistically reliable 97.5% probability that the treatment reduced casualty crash frequency (or costs), whereas upper and lower confidence limits both greater than zero indicate a statistically reliable 97.5% probability that the measure increased crash frequencies (or costs). Furthermore, the *chi-square* statistic was used to evaluate the reliability of the size of the treatment effect estimated by the log-linear model. This statistic, which is highly related to the confidence limits, indicates the goodness-of-fit between the model's estimate of the size of the treatment effect and the actual data.

The results of the analyses are presented in section 3.2. In general, attention is paid to those results that are statistically reliable at the 5% probability level. However, the results for those treatments that are statistically reliable given a less stringent criterion are also reported, as they are still likely to provide substantial road safety benefits. In particular, the results are reported where the probability of chi-square is less than 10%. A chi-square value at this level of significance provides strong evidence that, if 90% confidence intervals were calculated, a statistically reliable treatment effect would also be observed.

3.1.1 Regression-To-the-Mean

Regression-To-the-Mean (RTM) analysis was not regarded as an important practical consideration in this study and, therefore, was not undertaken. The main reasons for this view were that the before-period for all treatments evaluated spanned a full five year period and this is considered sufficient (Nicholson, 1986(a) and 1986(b)) to smooth out any abnormally high annual crash frequencies. Furthermore, abnormal variations in annual crash frequencies tend to be reflected in wider confidence intervals about the estimated change in crash frequencies, resulting in a reduced chance of observing statistically reliable changes. Finally, these views were supported by the results of recent RTM analyses on the TAC Accident Black-Spot Program (which included many of these treatments), where the effect of RTM on estimates of treatment effectiveness was found to be negligible.

3.2 CASUALTY CRASH OCCURRENCE - ALL CRASHES

3.2.1 Overall Sample

The results for the entire sample of treatments indicate that the treatments were successful in reducing casualty crash frequency, with a statistically reliable 8.6% reduction.

3.2.2 Rural and Metropolitan Treatments

A statistically reliable reduction in casualty crashes of 14.5% was found for the sample of treatments undertaken in metropolitan Melbourne. A 4% reduction in casualty crashes was estimated in the rural regions, but this reduction was not statistically reliable ($p = 0.29$).

3.2.3 Treatment Category

Table 3 summarises the results by treatment category. A statistically reliable reduction in casualty crash frequency was observed for road and roadside geometry improvements (22.9%) and road surface improvements (29.6%). A category defined as “miscellaneous”, because of insufficient information to determine treatment type, showed a statistically reliable 28.1% reduction in casualty crash frequency.

3.2.4 Treatment Type

The results for the individual treatment types are summarised in Appendix A. Changes to horizontal road geometry resulted in a statistically reliable 43.6% reduction in casualty crash occurrence. Improvements to the road surface also yielded statistically reliable reductions, with large-scale shoulder sealing reducing casualty crashes by 31.8%. A 28.4% reduction due to shoulder sealing with tactile edge markings was also found, although this reduction was just outside the 5% criterion for statistical reliability ($p = 0.08$) and thus would be reliable at the less stringent 10% level. Skid resistant pavements resulted in a large 75.2% reduction in crash frequency. However, because of the low numbers of crashes at the sites where this treatment was undertaken (i.e. 13 in the before period), this reduction was not statistically reliable ($p = 0.18$) and should be considered indicative only at this stage.

An increase in casualty crashes was found for some treatment types. For example, the addition of guard rail end treatments resulted in a 42.7% increase in crash frequency, although only three treatments of this type could be evaluated. Furthermore, the increase in casualty crashes following the installation of street lighting (24.9%) was statistically reliable at the 10% level ($p = 0.0502$), and the increase following pavement widening at five sites (47.5%) was just outside this criterion for statistical reliability ($p = 0.11$). These results are discussed in some detail in Section 4.

3.3 CASUALTY CRASH COSTS - ALL CRASHES

3.3.1 Overall Sample

The **entire sample** of treatments was successful in reducing the cost of **all** casualty crashes, with a statistically reliable 15.5% reduction for the treatments evaluated. This reduction is around twice that observed for casualty crash frequencies, suggesting that the sample of treatments was particularly successful in reducing the severity of casualty crashes.

Table 3 Results of the casualty crash frequency analyses by treatment category

Treatment Category		Treatment crashes		Control crashes			95% confidence limits		
	No. of sites	Before	After	Before	After	% change	Lower	Upper	Pr>Chi
Hazard removal/reduction	63	1025	381	21825	8397	4.2	-8.5%	18.6%	.532
Hazard delineation	4	28	8	1339	499	-19.9	-67.1%	95.1%	.625
Road & roadside geometry	24	378	134	6859	3149	-22.9	-38.3%	-3.7%	.022
Roadway delineation	82	3893	1273	13841	5385	0.9	-7.2%	9.6%	.836
Road surface improvements	63	1377	332	7213	2432	-29.6	-39.2%	-18.5%	.000
Traffic operations	1	1	0	49	11	-100.0	-100.0%	n/a	1.000
Miscellaneous	17	287	136	9433	6392	-28.1	-41.7%	-11.4%	.002

▨ Shaded areas indicate statistically reliable results with 95% confidence

Table 4 Results of the casualty crash cost analyses by treatment category

Treatment Category		Treatment costs ($000’s)		Control costs ($000’s)			95% confidence limits		
	No. of sites	Before	After	Before	After	% change	Lower	Upper	Pr>Chi
Hazard removal/reduction	63	76,280	25,704	1,394,001	519,762	-6.1	-26.1%	19.5%	0.610
Hazard delineation	4	4,107	802	72,899	25,423	-70.0	-93.8%	45.3%	0.135
Road & roadside geometry	24	26,862	9,779	450,629	204,565	-25.7	-50.4%	11.4%	0.151
Roadway delineation	82	377,030	111,277	1,160,111	410,928	-5.3	-19.3%	11.1%	0.502
Road surface improvements	63	153,185	33,349	552,181	185,767	-36.2	-48.3%	-21.2%	0.000
Traffic operations	1	17	n/a	4,344	647	-100.0	-100.0%	n/a	1.000
Miscellaneous	17	17,752	7,105	8,498,922	3,486,573	-35.2	-57.9%	-0.1%	0.049

▨ Shaded areas indicate statistically reliable results with 95% confidence

3.3.2 Rural and Metropolitan Treatments

A statistically reliable reduction in crash costs of 25.4% was observed for the sample of treatments implemented in metropolitan Melbourne. A reduction in crash costs of 10.3% was found for the sample of treatments undertaken in rural areas. This reduction was just outside the criterion for statistically reliability at the 5% level ($p = 0.09$).

3.3.3 Treatment Category

Table 4 summarises the results of analysing crash costs by treatment category. A statistically reliable 36.2% reduction in crash costs was observed for road surface improvements, while for hazard delineation (70.0%), and improvements to road and roadside geometry (25.7%), the results approached statistical reliability at the 10% level ($p = 0.13$ and 0.15, respectively). The “miscellaneous” treatment category (i.e. specific treatment types unknown) reduced casualty crashes by an estimated 35.2%, also statistically reliable.

3.3.4 Treatment Type

The results for the individual treatment types are summarised in Appendix B. The addition of guideposts (one location only) lead to an 84.9% reduction in crash costs, improved cross-fall resulted in a 76.2% reduction and raised reflective pavement markers in combination with curve delineation resulted in a 54.3% reduction in casualty crashes. Crash costs tended to be reduced by all road surface improvements, with statistically reliable reductions observed for skid resistant pavements (92.7%) and large-scale shoulder sealing (36.5%). Reductions of 43.7% and 33.3% in crash costs were also observed for shoulder sealing on bridges and shoulder sealing with tactile edge markings respectively, although these reductions were just outside the 10% criterion for statistical reliability ($p = 0.13$ for both). The reduction associated with several other treatments also approached this criterion for statistical reliability, including 58.0% for raised pavement markers ($p = 0.13$) and 65.7% for raised reflective pavement markers ($p = 0.15$).

The addition of bridge end guard rails and pavement widening resulted in increases in casualty crash costs of 161.4% and 75.6% respectively, with the former statistically reliable at the 10% level and the latter just outside this criterion for statistical reliability. While these results are discussed further in Section 4, it is important to note that some estimates were based on small numbers of treatments and should therefore be regarded as indicative only.

3.4 ECONOMIC WORTH OF THE TREATMENTS

3.4.1 Introduction

In examining the economic worth of the treatments, only those that resulted in a statistically reliable reduction at the 5% level in crash frequency, costs, or both, were considered. This is because it would be of doubtful practical utility to have treatments that are economically worthwhile but do not reduce the frequency or cost of road trauma. Capital and maintenance costs were not available for 94 of the 254 treated sites, leaving 160 sites suitable for economic analysis. The total capital cost of these 160 treatments was $16.1m.

3.4.2 Benefit-to-Cost Ratios

Statistically reliable estimates of economic worth, found at several levels of analysis, are summarised in Table 5. The entire sample of treatments yielded a BCR of 4.1 indicating that it was economically worthwhile. Statistically reliable BCR's were also found for the treatments undertaken in metropolitan Melbourne (BCR = 5.6).

At the treatment category level, a statistically reliable BCR of 5.6 was found for road surface improvements. Positive outcomes were evident for several treatment types. In particular, statistically reliable BCR's were observed for improved cross-fall (29.2), skid resistant pavements (4.5), and large-scale shoulder sealing (6.5).

Table 5 Estimated economic worth of the treatments by level of analysis

Level of Analysis	No. of Sites	BCR
1. Entire sample	160	4.1
2. Rural/Metropolitan		
Metropolitan Melbourne	4	5.6
3. Treatment Category		
Road surface improvements	53	5.6
4. Treatment Type		
Improved cross-fall	3	29.2
Skid resistance	1	4.5
Large-scale shoulder sealing	36	6.5

Note: BCR = Benefit/Cost Ratio

3.5 SINGLE VEHICLE CRASHES INTO FIXED ROADSIDE OBJECTS

The results of the analyses based on single vehicle crashes into fixed roadside objects only are summarised in Appendix C. These analyses were based on 202 treatments (the other 52 treatments that were included in the analysis of all casualty crashes were excluded from this analysis due to zero crashes in the before and after period). These analyses failed to reveal statistically reliable reductions in casualty crash frequencies at each level of analysis. A reduction in casualty crash costs was found for hazard delineation; however, because this result is based on only five crashes in the before- and four crashes in the after-period, it should be interpreted with caution. Analyses at the *treatment type* level were not undertaken due to low statistical power resulting from insufficient crash data.

3.6 TREATMENT TYPES WITH ZERO CRASHES IN THE AFTER-PERIOD

Tables A1, B1 and C1 show that there was a small number of treatment types for which zero casualty crashes were recorded in the after-periods, indicating a notional 100% level of effectiveness. The statistical methods used here (Bruhning and Ernst, 1985), while estimating a 100% reduction in casualty crash frequency and costs, do not allow for the calculation of any reliable estimates of 95% confidence intervals to be made in regard to the estimate of effectiveness. In such cases, the number of crashes in the before-period tended to be small and the after-period too short for this result to be regarded as anything more than indicative of a positive outcome. Notwithstanding this important qualification, it is worth noting that the following treatment types were found to have zero crashes in the after-period, even though no statistically reliable estimate of treatment effectiveness can be given:

- bridge pavement widening - one treatment only and only one crash in the before-period;
- curve delineation signs - one treatment only and six crashes in the before-period;
- traffic operations (miscellaneous) - one treatment only and only one crash in the before-period;

The possibility of continuing to monitor such treatments (e.g. low cost measures such as curve delineation signs) to obtain better estimates of their true effect, before committing significant road safety resources to their implementation, is discussed in section 4.

4. DISCUSSION

The results of this evaluation suggest that the **entire sample** of treatments undertaken to address the problem of crashes into fixed roadside objects was successful, with a 9% reduction in **all** casualty crashes and a 16% reduction in casualty crash costs (wherever numbers are given in this section, the changes were statistically reliable at the 95% level of confidence, unless otherwise stated). Furthermore, a BCR of 4.1 was observed for the entire sample of treatments, indicating that the treatments were economically worthwhile and further supporting the road safety benefits. The fact that the reduction in casualty crash cost was almost double that observed for casualty crash frequencies suggests that the sample of treatments was particularly successful at reducing the severity of these crashes.

The program of treatments undertaken in Melbourne's metropolitan area reduced casualty crash frequency by 14.5%, crash costs by 25.4% and yielded a BCR of 5.6. However, for rural areas, the analysis indicated only a small reduction which was not statistically reliable. These results contrast with those of an earlier evaluation of accident black spot programs by Corben et al. (1990), who found greater reductions in casualty crashes in rural areas. Several reasons may account for these contrasting findings. First, research project resources dictated that a relatively unrefined approach was adopted to define the rural and metropolitan areas based on the aggregation of VicRoads' regions. Second, in the previous evaluation by Corben et al. (1990), the effects of specific treatment types (e.g. intersections, routes) were examined within rural and metropolitan regions. These interactions were not examined here. Nonetheless, these results suggest that more strenuous efforts should be made to enhance the rural program. This could be achieved, for example, through an increased emphasis on those treatments that were shown to be effective, such as improvements to the road surface and horizontal road alignment.

The results also indicated that some categories of treatments in general and individual treatments specifically were more effective than others at reducing trauma. For example, improvements to the road and roadside geometry (22.9%) and the road surface (29.6%) yielded reductions in casualty crash frequency. A 36.2% reduction in crash costs and a BCR of 5.6 were also observed from road surface improvements. The reductions in casualty crash occurrence were underlined by changes to horizontal road geometry (43.6%) and large-scale shoulder sealing (31.8%), whereas reductions in crash costs were observed for large-scale shoulder sealing (36.5%), skid resistant pavements (92.7%) and the installation of guideposts (84.9%). Results for the latter two treatments should be regarded with caution as they are based on small sample sizes.

An increase in casualty crashes was found for some treatment types. For example, the addition of guard rail ends resulted in a 42.7% increase in crash frequency. Furthermore, the increase in casualty crashes following the installation of street lighting (24.9%) was statistically reliable at the 10% level. One possible explanation for these results is that improved street lighting may have been attained by the installation of additional poles that increased the number of fixed roadside objects. Better street lighting may also have attracted more traffic and thus increased exposure at the treated sites. These issues require further site-specific assessment.

Increases in casualty crash frequency (47.5%) and cost (75.6%) were observed following pavement widening, although these increases were just outside the 10% criterion for statistical reliability and should be considered indicative only at this stage. Nonetheless, crashes at sites where this treatment type was installed need to be monitored closely in the future. It may be, for example, the wider pavements place drivers closer to fixed roadside objects or attract higher traffic volumes and thus increased exposure to crash risk where constructed. Further, consideration should be given to extending the evaluation to include more treatments of the types whose effectiveness is unclear due, perhaps, to small sample sizes or treatments where no crashes have been recorded in the after-period (refer to section 3.3.5). More robust information on treatment effectiveness is needed before committing significant road safety resources to such countermeasures.

When the analyses were undertaken focusing only on single vehicle crashes into fixed roadside objects, little evidence was found of beneficial treatment effects. Several explanations may account for these particular results. First, it may be that the treatments evaluated here were in fact unsuccessful in reducing road trauma resulting from these crashes. Alternatively, and more logically, there was much less data available for use in these analyses (around 25% of all crashes at the treated sites were single vehicle crashes), thereby reducing the power of the analyses and thus the likelihood of being able to demonstrate statistically reliable treatment effects.

In this regard, additional data were potentially available for use in this evaluation but could not be identified because records were unavailable for some treated sites. For example, of the 400 or so sites identified by the VicRoads' regions, around 150 could not be included in the evaluation because of missing information, such as location and start and end dates.

Given that a number of important indications have arisen from this evaluation, continuing this type of research seems warranted. In other words, these results highlight the potential of including additional crash data and more treatments in future evaluations as they become available in order to provide more robust strategic guidance. The option exists for like treatments, carried out in similar circumstances in other Australian states, to be included in future evaluations to increase sample sizes for selected treatment types. Moreover, greater attention is required to document treatment details by some VicRoads' regions to enable maximum use of the available crash data.

Finally, this evaluation has been confined to a broad-level analysis of treatment and crash records and has not involved detailed, on-site examination of treatment features. Consequently, it has not been possible to present more telling insights into some results which may be regarded as surprising, i.e. where safety appears not to have been improved.

5. CONCLUSIONS AND RECOMMENDATIONS

This section presents **the two main conclusions** of an evaluation of 254 road engineering treatments undertaken in Victoria since 1989 to address single vehicle crashes into fixed roadside objects. These conclusions take the form of **major findings** of the evaluation and **recommended actions**. In considering these conclusions, it is important that account be taken of a number of key qualifiers, also summarised below.

5.1 MAJOR FINDINGS

For the sample of treatments evaluated:

1. **Casualty crash frequencies and costs** were reduced by **9%** and **16%**, respectively.

2. A **BCR of 4.1** was achieved.

3. **Road/roadside geometry improvements** reduced casualty crash frequencies by **23%**. A subset of these treatments, **changes to horizontal road geometry,** reduced casualty crash frequencies by **44%**.

4. **Road surface improvements** reduced casualty crash frequencies and costs by **30%** and **36%**, respectively, and achieved a **BCR of 5.6**. A subset of these treatments, l**arge-scale shoulder sealing,** reduced casualty crash frequencies and costs by **32%** and **37%**, respectively.

5. **Several treatment types yielded an increase in casualty crash frequency, cost, or both** (e.g. the addition of guard rail ends, street lighting and pavement widening). However, some of those treatments were not statistically reliable at the 5% level and require monitoring and further critical assessment in the future.

Qualifiers - At each level of analysis, several results approached statistical reliability at the 5% or 10% probability level and **should therefore be considered indicative only at this stage**. These treatments may have been unsuccessful at reducing road trauma or, alternatively, the relatively low number of crashes available for some analyses may have reduced their statistical power. These results highlight the need to include more treatments and longer after-treatment periods for some treatment types to provide more robust support for these findings.

5.2 RECOMMENDED ACTIONS

This evaluation has **both immediate and medium-term implications** for existing strategies for roadside safety. The results suggest that:

Existing strategies should:

8. **Give increased emphasis** to the highly effective treatments designed to improve the road surface and road geometry, such as **large-scale shoulder sealing, improved horizontal road alignment and skid resistant pavements**.

9. **Include further critical assessment of guard end rails, street lighting and pavement widening** before they form a significant part of future roadside safety strategies.

10. Given that the program of treatments in **rural areas was found to be less effective than that in metropolitan Melbourne,** more strenuous efforts should be made to enhance the rural program, probably through an increased emphasis on the most effective treatments, such as improvements to the road surface and horizontal alignment.

Opportunities for further strategic improvements include:

11. **Extending current evaluations** to determine conclusively the effectiveness of treatments whose effectiveness is currently unclear. This could also include:

- **more strenuous efforts to obtain details of treatments** that had to be excluded from this evaluation because of missing data; and

- **greater attention by some VicRoads' regions to documenting future treatment details** to enable maximum use of available crash data.

12. **Monitoring and further assessing** those treatments showing an increase in casualty crash frequency, costs, or both. The issues to be considered may address:

- **appropriateness of site and countermeasure selection**; and

- **the possibility of increased exposure to crash risk** due, perhaps, to higher traffic volumes, more roadside objects and/or reduced lateral offsets of roadside features following implementation of some types of treatments.

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APPENDIX A: SUMMARY OF CASUALTY CRASH FREQUENCY ANALYSES BY TREATMENT TYPE

Table A.1 Summary of casualty crash frequency analyses by treatment type

	No. of	Treatment Crashes		Control Crashes			95% Confid. Limits			
Treatment Type	Sites	Before	After	Before	After	% Change	Lower	Upper	Chi Square	*p*
Hazard Removal										
Pole Removal	5	278	76	3315	962	-1.9%	-24.8%	28.1%	0.02	0.888
Pole Relocation	14	112	50	6069	2197	12.7%	-20.3%	59.3%	0.46	0.498
Frangible Poles	4	200	50	3447	1080	-13.9%	-37.8%	19.2%	0.81	0.367
Tree Removal	2	11	5	257	57	102.8%	-32.6%	510.3%	1.58	0.209
Guard Rail	19	212	68	4026	2175	-21.0%	-42.0%	7.8%	2.21	0.137
Guard Rail End	3	122	86	561	258	42.7%	3.7%	96.3%	4.76	0.029
Bridge End Post Guard Rail	8	32	17	523	216	41.6%	-26.8%	174.0%	1.07	0.301
Other Safety Barriers	1	0	1	43	7				.	.
Miscellaneous	7	58	28	3584	1445	27.7%	-25.8%	119.9%	0.78	0.377
Hazard Delineation										
Delineation of Other Hazards	4	28	8	1339	499	-19.9%	-67.1%	95.1%	0.24	0.626
Road & Roadside Geometry										
Horizontal Geometry	8	135	44	1242	703	-43.6%	-61.4%	-17.6%	8.77	0.003
Pavement Widening	5	67	29	434	128	47.5%	-8.9%	138.8%	2.50	0.114
Improved Cross-fall	4	46	12	2047	974	-38.3%	-68.4%	20.7%	1.99	0.159
Culvert Widening	2	33	25	97	67	-5.7%	-53.9%	92.7%	0.03	0.872
Bridge Widening	3	67	16	1955	832	-18.2%	-53.5%	43.9%	0.49	0.486
Bridge Pavement Widening	1	1	0	70	21	-100.0%	-100.0%	n/a	0.00	1.000
Miscellaneous	1	29	8	1014	424	-34.0%	-70.1%	45.5%	1.06	0.303

(*continued*)

(**Table A.1.** *continued*)

	No. of	**Treatment Crashes**		**Control Crashes**			**95% Confid. Limits**			
Treatment Type	**Sites**	**Before**	**After**	**Before**	**After**	**% Change**	**Lower**	**Upper**	**Chi Square**	***p***
Roadway Delineation										
Tactile Edge lining	10	463	151	1778	572	2.4%	-17.3%	26.8%	0.05	0.827
Edge Lining	35	2562	812	3932	1271	-1.4%	-11.7%	10.1%	0.07	0.797
Raised Pavement Markings	2	23	10	77	33	-3.1%	-59.5%	131.9%	0.01	0.943
RRPMs	2	98	44	144	65	-11.6%	-47.3%	48.3%	0.22	0.641
Curve Delineation Signs	1	6	0	151	30	-100.0%	-100.0%	n/a	0.00	1.000
Guideposts	1	6	2	33	15	-26.7%	-86.8%	306.6%	0.13	0.723
Street Lighting	11	353	133	3469	1435	24.9%	-0.0%	56.1%	3.84	0.050
General Delineation	5	81	20	693	220	9.1%	-39.2%	95.7%	0.09	0.770
Edge Lining and Curve Delin.	9	205	51	1799	582	-18.6%	-44.4%	19.2%	1.12	0.291
RRPMs and Curve Delin	4	49	34	1500	1063	-6.2%	-42.4%	52.6%	0.07	0.796
Miscellaneous	2	47	16	265	99	-2.7%	-49.5%	87.6%	0.01	0.936
Road Surface Improvements										
Skid Resistance	3	13	1	1685	526	-75.2%	-96.8%	90.9%	1.79	0.181
Large-scale Shoulder Sealing	42	964	260	4159	1462	-31.8%	-42.4%	-19.2%	19.64	0.000
Shoulder Sealing on Bridge	8	63	22	547	205	-7.14%	-46.9%	62.3%	0.07	0.795
Shoulder Sealing with Tactile	9	334	45	629	128	-28.4%	-50.7%	4.1%	3.06	0.081
Miscellaneous	1	3	4	193	111	131.8%	-49.1%	954.7%	1.18	0.277
Traffic Operations										
Miscellaneous	1	1	0	49	11	-100.0%	-100.0%	n/a	0.00	1.000
Miscellaneous	17	287	136	9433	6392	-28.1%	-41.7%	-11.36%	9.55	0.002

▨ Shaded areas indicate statistically reliable results with 95% confidence

APPENDIX B: SUMMARY OF CASUALTY CRASH COST ANALYSES BY TREATMENT TYPE

Table B.1 Summary of casualty crash cost analyses by treatment type

	No. of	Treatment Costs ($000's)		Control Costs ($000's)			95% Confid. Limits			
Treatment Type	**Sites**	**Before**	**After**	**Before**	**After**	**% Change**	**Lower**	**Upper**	**Chi Square**	***p***
Hazard Removal										
Pole Removal	5	21,015	5,044	196,347	66,773	-28.2%	-67.5%	58.5%	0.67	0.413
Pole Relocation	14	7,622	2,339	372,989	129,232	-18.0%	-51.4%	38.4%	0.55	0.457
Frangible Poles	4	10,426	2,892	202,119	61,009	-12.2%	-47.5%	46.9%	0.25	0.621
Tree Removal	2	2,232	986	19,822	3,195	171.6%	-24.1%	871.9%	2.36	0.124
Guard Rail	19	16,030	5,108	300,714	144,543	-17.7%	-55.7%	53.0%	0.38	0.538
Guard Rail End	3	11,837	5,745	36,885	15,783	5.1%	-46.4%	106.1%	0.02	0.885
Bridge End Post Guard Rail	8	3,053	1,883	40,253	16,586	161.4%	-6.6%	631.5%	3.35	0.067
Other Safety Barriers	1	0	18	5,586	567	n/a	-100.0%	n/a	0.00	1.000
Miscellaneous	7	4,064	1,691	219,286	82,074	31.3%	-36.4%	171.0%	0.54	0.461
Hazard Delineation										
Delineation of Other Hazards	4	4,107	802	72,899	25,423	-70.0%	-93.8%	45.3%	2.24	0.135
Road & Roadside Geometry										
Horizontal Geometry	8	7,841	3,045	89,885	45,504	-23.0%	-60.1%	48.6%	0.61	0.436
Pavement Widening	5	5,768	2,074	31,519	8,417	75.6%	-21.4%	292.4%	1.88	0.170
Improved Cross-fall	4	3,930	559	124,126	54,839	-76.2%	-93.8%	-8.9%	4.39	0.036
Culvert Widening	2	3,161	3,007	9,861	7,494	-19.1%	-76.5%	178.1%	0.11	0.737
Bridge Widening	3	4,346	835	123,810	52,278	-25.6%	-73.9%	111.9%	0.31	0.580
Bridge Pavement Widening	1	20	0	7,084	3,539	-100.0%	-100.0%	n/a	0.00	1.000
Miscellaneous	1	1,796	259	64,343	32,494	-71.5%	-71.6%	-71.3%	> 100.0	0.000

(*continued*)

(Table B.1. *continued*)

	No. of	Treatment Costs ($000's)		Control Costs ($000's)			95% Confid. Limits			
Treatment Type	**Sites**	**Before**	**After**	**Before**	**After**	**% Change**	**Lower**	**Upper**	**Chi Square**	***p***
Roadway Delineation										
Tactile Edge lining	10	55,386	21,001	183,675	63,042	14.0%	-30.2%	86.0%	0.27	0.601
Edge Lining	35	249,121	68,651	434,385	132,915	-9.9%	-27.6%	12.3%	0.86	0.353
Raised Pavement Markings	2	2,528	516	7,973	3,173	-58.0%	-86.3%	28.1%	2.33	0.127
RRPMs	2	12,845	6,779	10,717	3,413	65.7%	-16.1%	227.2%	2.12	0.146
Curve Delineation Signs	1	328	0	8,992	2,643	-100.0%	-100.0%	n/a	0.00	1.000
Guideposts	1	1,116	145	2,120,	1,825	-84.9%	-85.0%	-84.8%	> 100.0	0.000
Street Lighting	11	23,696	6,065	226,222	91,116	-6.7%	-38.2%	40.8%	0.11	0.741
General Delineation	5	6,321	1,136	49,956	14,067	-25.6%	-60.6%	40.6%	0.83	0.363
Edge lining and Curve Delin.	9	19,050	4,603	131,449	33,649	-9.4%	-57.8%	94.5%	0.06	0.801
RRPMs and Curve Delin.	4	4,505	1,041	84,770	58,213	-54.3%	-79.8%	2.1%	3.64	0.056
Miscellaneous	2	2,135	1,339	19,851	6,871	127.4%	-63.4%	1312.8%	0.78	0.378
Road Surface Improvements										
Skid Resistance	3	663	14	103,449	30,089	-92.7%	-99.2%	-34.6%	5.48	0.019
Large-scale Shoulder Sealing	42	100,428	26,421	324,805	118,589	-36.5%	-50.9%	-17.9%	11.98	0.000
Shoulder Sealing on Bridge	8	8,039	1,295	46,007	17,024	-43.7%	-72.7%	16.2%	2.41	0.120
Shoulder Sealing with Tactile	9	44,002	5,438	62,967	12,196	-33.3%	-60.3%	12.1%	2.34	0.126
Miscellaneous	1	52	180	14,953	7,870	556.5%	550.1%	562.9%	> 100.0	0.000
Traffic Operations										
Miscellaneous	1	17	0	4,344	647	-100.0%	-100.0%	n/a	0.00	1.000
Miscellaneous	17	17,752	7,105	615,297	396,195	-35.2%	-57.9%	-0.1%	3.86	0.049

▨ Shaded areas indicate statistically reliable results with 95% confidence

APPENDIX C: SUMMARY OF ANALYSES BASED ON SINGLE VEHICLE CRASHES INTO FIXED ROADSIDE OBJECTS ONLY

Table C.1. Summary of casualty crash frequency analyses of single vehicle crashes into fixed road side objects

	No. of	**Treatment Crashes**		**Control Crashes**			**95% Confid. Limits**			
Level of Analysis	**Sites**	**Before**	**After**	**Before**	**After**	**% Change**	**Lower**	**Upper**	**Chi Square**	***p***
WHOLE SAMPLE	202	1501	470	6717	2774	-3.4%	-15.5%	10.3%	0.39	0.533
TREATMENT CATEGORY										
Hazard Removal/Reduction	48	142	60	1771	728	-5.9%	-34.2%	34.6%	0.11	0.739
Hazard Delineation	3	5	4	80	29	122.7%	-61.4%	1183.7%	0.80	0.370
Road and Roadside Geometry	17	52	29	761	373	35.8%	-21.6%	135.2%	1.20	0.274
Roadway Delineation	68	860	270	2314	832	0.0%	-16.2%	19.2%	0.00	0.995
Road Surface Improvements	55	432	101	1255	404	-19.8%	-40.3%	7.8%	2.14	0.144
Traffic Operations	1	1	0	9	4	-100.0%	-100.0%	n/a	0.00	1.000
Miscellaneous	10	9	6	527	404	-8.4%	-68.0%	162.0%	0.03	0.870
METROPOLITAN/RURAL										
Metropolitan	62	310	106	3316	1540	3.9%	-19.2%	33.8%	0.09	0.764
Rural	140	1191	364	3401	1234	-6.1%	-19.8%	9.8%	0.62	0.430

▨ Shaded areas indicate statistically reliable results with 95% confidence

Table C.2 Summary of casualty crash cost analyses of single vehicle crashes into fixed road side objects

	No. of	**Treatment Costs ($000’s)**		**Control Costs ($000’s)**			**95% Confid. Limits**			
Level of Analysis	**Sites**	**Before**	**After**	**Before**	**After**	**% Change**	**Lower**	**Upper**	**Chi Square**	***p***
WHOLE SAMPLE	202	183,566	56,916	704,140,	270,075	-6.7%	-24.0%	14.6%	0.44	0.510
TREATMENT CATEGORY										
Hazard Removal/Reduction	48	15,592	4,452	163,188	64,384	-29.0%	-56.8%	16.7%	1.82	0.177
Hazard Delineation	3	1,211	401	7,306	3,305	-77.3%	-81.1%	-72.8%	>1008	0.000
Road and Roadside Geometry	17	4,698	2,287	75,072	36,703	-21.9%	-63.4%	66.6%	0.41	0.522
Roadway Delineation	68	117,025	35,354	288,062	94,419	-0.4%	-28.8%	39.1%	0.00	0.979
Road Surface Improvements	55	44,222	13,365	120,582	38,786	-9.2%	-39.1%	35.3%	0.23	0.635
Traffic Operations	1	17	0	598	401	-100.0%	-100.0%	n/a	0.01	1.000
Miscellaneous	10	801	1,058	49,331	32,076	114.3%	-45.9%	749.1%	1.18	0.278
METROPOLITAN/RURAL										
Metropolitan	62	33,593	11,140	301,690	134,140	-14.8%	-44.1%	29.9%	0.55	0.458
Rural	140	149,973	45,776	402,449	135,935	-4.0%	-24.1%	21.5%	0.11	0.736

▨ Shaded areas indicate statistically reliable results with 95% confidence