An Evaluation of the State Black Spot Program in Western Australia, 2000-2002: Final Report

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Abstract
This report presents the final results of an evaluation of the Black Spot Program which was implemented during 2000 to 2002 in Western Australia. A preliminary evaluation of the Program was completed in December 2004. It was decided to re-evaluate the Program based on the recommendations of the initial report now that five year follow-up post treatment crash data was available. The purpose of this report is to evaluate the effectiveness of the Black Spot Program in terms of reduction in crash frequency (presented for all crashes including property damage only (PDO) and casualty crashes) at treated locations and the economic worth of these treatments.

One hundred and forty-three hazardous locations were treated throughout Western Australia at a cost of $9.2 million excluding operating and maintenance costs. The results showed the Program has been effective overall, reducing all reported crash frequencies by 20% and casualty crash frequencies by 36%. The estimated crash cost savings over the expected life of the treated sites were $43.7 million for all reported crashes of which 84% was attributable to the reduction in casualty crashes. This will result in an overall net cost savings to the community of $32.9 million ($25.7 million attributable to casualty crashes) after subtracting the capital costs of treating sites and maintenance and operating costs. The benefit cost ratio (BCRs) across all treatment sites was 4.0. Evaluation of the program has identified treatment types that were highly successful, while others have not been shown to be successful. This could be due to insufficient number of sites having undergone the treatment or the treatment may genuinely have had no effect on road safety.

The results provide Main Roads WA and other road safety organizations with reliable, objective information for enhancing strategies for future road safety investment.

Keywords
Black spot treatment, evaluation, cost-effectiveness, cost-benefit analysis

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EXECUTIVE SUMMARY

This report presents the final results of an evaluation of the Black Spot Program which was implemented during 2000 to 2002 in Western Australia. A preliminary evaluation of the Program was completed in December 2004. It was decided to re-evaluate the Program based on the recommendations of the initial report now that five year follow-up post treatment crash data was available.

The final report evaluated the effectiveness of the Black Spot Program in terms of reduction in crash frequency (presented for all crashes including property damage only (PDO) and casualty crashes) at treated locations and the economic worth of the treatments. Only BCR applications and not road safety audits were included in the evaluation. It is anticipated that the results will provide Main Roads WA and other road safety organizations with reliable, objective information for enhancing strategies for future road safety investment.

The major findings from the evaluation are summarised below.

Overall

The results showed the Program has been effective overall, reducing all reported crash frequencies by 20% and casualty crash frequencies by 36%. The reduction in the number of reported crashes were estimated to reduce crash costs by $43.7 million over the expected life of the treated sites, with 84% of this reduction attributable to a reduction in casualty crashes. After accounting for program costs of $10.8 million, the net cost savings to the community from the Black Spot Program were estimated as $32.9 million. Expressed as a benefit cost ratio (BCR), the net economic worth of the State Black Spot Program across all treatment sites was 4.0. Sites treated in rural areas had a better rate of return than those in the metropolitan area, with a BCR of 9.6 compared with 2.1 in the metropolitan area.

Summary of the Results of the Economic Evaluation of the State Black Spot Program in Relation to Total Crash Reduction in Western Australia

Area	Present Value of Treatment Costs and Operating/ Maintenance Costs ($)	Present Value of Crash Cost Savings	Net Present Value	Benefit Cost Ratio
Whole program	10 822 034	43 744 083	32 922 049	4.0
All Metro Sites	8 013 829	16 805 760	8 791 931	2.1
All Rural Sites	2 808 204	26 938 335	24 130 131	9.6

Broad and Specific Treatment Type

A number of broad categories and specific treatment types and location were highly effective in reducing the frequency of both all reported crashes and casualty crashes. These included:

Black Spot Treatment Effect on All Crash and Casualty Crash Reduction in Western Australia, 2000 – 2002

Area	All Crash Reduction** (%)	Probability	Casualty Crash Reduction (%)	Probability
All Metropolitan Sites	17.3	0.001	34.6	0.001
All Rural Sites	32.9	0.001	46.7	0.001
Broad Categories				
Intersection Treatments	19.3	0.001	36.4	0.001
• Metro	17.9	0.001	35.1	0.001
• Rural	31.5	0.001	50.9	0.001
Road Section and Non Intersection Treatment	21.8	0.001		0.001
• Metro	12.8	0.001	30.8	0.001
• Rural	34.3	0.001	42.3	0.001
Treatment Types				
All Roundabouts	33.7	0.001	62.4	0.001
• Metro	29.9	0.001	62.2	0.001
• Rural	51.3	0.001	63.6	0.053
Traffic control signals	34.7	0.001	43.2	0.001
Non-skid treatment	32.1	0.001	45.4	0.001
Traffic island on approach	22.1	0.006	53.6	0.002
Seagull island	-14.1	0.001	-8.0*	0.365
Left turn slip	15.8	0.001	39.1	0.001
Median on existing road	31.8	0.001	33.3*	0.159
Nibs (pedestrian facilities)	35.3	0.007	62.5	0.021
Improved route lighting	11.9	0.001	41.0	0.025
All State Roads	9.0	0.001	25.0	0.001

** Crash increase/reduction is not statistically significant*
***Includes all crashes-fatality, hospitalisation, injury and property damage major and minor crashes*

There was no statistical evidence that seagull islands and median on existing road significantly affected the frequency of casualty crashes.

It must also be noted that this evaluation demonstrated that the Black Spot Program was effective for reducing the frequency of all reported and casualty crashes at intersection sites as well as road section and non-intersection sites even though BCR projects analysed were heavily weighted towards intersection treatments.

Treatment types varied in their estimated rate of return, with roundabouts, improved route lighting, the installation of traffic islands and non-skid treatments showing a positive rate of return. Several treatment types had a negative rate of return despite being effective in reducing the overall number of crashes. This resulted from the use of crash costs based on severity rather than type of crash as the basis for costing. Using crash costs based on severity resulted in the increased cost of one or a few more serious crashes dominating the cost savings from a greater decrease in less serious crashes.

Limitations to the study include the lack of a suitable control treatment site and the fact that some treatment types such as high friction surfacing may not have been used often enough to produce statistically significant effects. Consequently, the results were inconclusive for some treatment types. However, this does not necessarily mean that the treatment was ineffective. The treatment types that do not appear to have been as successful such as seagull islands and median on existing road require further monitoring and reassessment for their future use.

Recommendations and Conclusion

In conclusion, as traffic patterns and road use change over time, new Black Spots will emerge. Since road authorities tend to treat the worst sites first, the benefits from treating remaining sites will reduce. This means that ongoing evaluations are necessary to help governments determine if the benefits from further treatment justify the treatment costs.

Recommendations include:

- Maintaining accurate and timely recording of details of treatments, including location, treatment types, costs, start and completion dates and any other details relevant to future evaluations.
- Maintaining accurate information relating to the precise cost of treatments, including maintenance and operating costs.
- LGs supply more detailed information about the treatment implemented at the nominated Black Spot to ensure the treatment can be correctly allocated to the appropriate treatment type.
- Collect information on traffic volumes at individual Black Spot sites and include in any subsequent analysis as it is necessary to determine whether any change in crash history is due to the treatment or changes in traffic volume.
- A more detailed investigation of the multiple effects that may be derived with the implementation of more than one crash countermeasure.
- Further in-depth evaluation of treatments that did not significantly reduce or increase crash frequency such as seagull islands and medians on existing roads.
- Further in-depth evaluation of treatments such as high friction surfacing that were not used often enough to produce valid results.
- Future evaluations of the State Black Spot Program should include an analysis of cost savings based on type of crash as well as crash severity to take account of the impact of the high crash costs of fatalities and serious crashes on the calculations of program cost-effectiveness.

In conclusion, as more Black Spot sites are treated the effectiveness of the countermeasures implemented should be monitored. This will enable a more accurate evaluation of treatments to be developed.

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1. INTRODUCTION

The identification, analysis and treatment of road accident Black Spots are widely regarded as one of the most effective approaches to road accident prevention (Elvik, 1997). In WA, the implementation of the State Black Spot program was first introduced in 2000. The program's objective was to reduce the frequency and severity of crashes at locations experiencing a poor accident record. This program was complementary to the existing Auslink Black Spot program which commenced on July 1, 1996. However the State Black Spot Program criteria enabled application of funds to a wider range of projects at hazardous situations through the use of different thresholds – for example using data for all crashes rather than casualty crashes only (Main Roads, 2003). In WA, there are 17,735 kilometres of highways and main roads which lie under the responsibility of Main Roads, WA and 127,069 km of local roads which are the responsibility of Local Governments.

In September 2004 the Injury Research Centre at The University of Western Australia completed an interim evaluation of the State Black Spot Program from 2000 to 2002 (Meuleners et al., 2004). This report evaluated 150 sites for which treatment had been completed to the end of 2002. It found the Program was effective overall, reducing all reported crash frequencies by 15% and casualty crash frequencies by 28%. Now that adequate post-treatment crash data was available to enable more accurate estimates of the effects to be made for both the Program as a whole and specific treatment types, it was appropriate to undertake a comprehensive evaluation of the Program.

1.1 Aim

The aim of this study was to evaluate the effectiveness of the State Black Spot Program in terms of the net reduction in crash frequency and crash costs at treated sites in WA. The evaluation also examined the effectiveness of the program by treatment category at both broad and specific levels of categorisation.

1.2 Significance

The results of this analysis will provide Main Roads, WA and other responsible agencies with reliable and objective information for future investments in developing road safety strategies. The economic analysis should also enable road authorities to manage future resources so that injury from road trauma is minimised.

2. METHODS

2.1 Study Design

The study adopted a before and after comparison of casualty crash and all reported crash frequencies (include fatalities, hospitalisation and PDO crashes) at sites treated under the State Black Spot Program for the years 2000 to 2002. The analysis also included the estimation of the net economic worth of the Program.

2.2 Selection of Sites for Funding

Black spots are locations noted for a high incidence of crashes involving death and injury (Australian National Audit Office, 2007). In WA, the 2000-02 State Black Spot Program provided funding of $13 million for road safety related works on State and Local Government roads. All road classifications were eligible for funding. The program targeted existing Black Spots, black lengths and also potential hazardous locations. Black Spots could be at an intersection, mid block or short sections of road and black lengths were lengths of road greater than three kilometres with a proven crash history. Potentially hazardous locations were selected on the basis of formal road safety audits. Fifty percent of funding was spent on roads in the Perth metropolitan region and 50% on roads outside the Perth metropolitan region. For a more detailed list of the criteria used for the selection of sites please see Appendix A.

Typical major road safety improvements included (Main Roads, 2003):

- the installation of roundabouts at various intersections;
- realignment and improvement of the road geometry at intersections and selected road sections;
- provision of pedestrian refuges and facilities for cyclists;
- improvements to road surface treatments such as anti-skid treatments;

- traffic calming treatments and improvements to street lighting.

2.3 Data Collection

Information on each treatment site was obtained from the road safety section at Main Roads WA. Only BCR applications and not road safety audits were included in the evaluation. Crash data was obtained from the Integrated Road Information System (IRIS) using police reported data which is maintained by Main Roads WA

2.3.1 Integrated Road Information System (IRIS)

The IRIS database contains detailed information on the characteristics of the vehicles involved in road crashes, crash circumstances, Police reported injury and road information related to the crash location. Crash data for the evaluation was obtained up to and including December 31, 2007.

The definition of a crash used throughout this report is the definition used by the Road Safety Council in its annual publication "Reported Road Crashes in Western Australia" (2005). A crash is "*any apparently unpremeditated collision reported to the police which resulted from the movement of at least one road vehicle on a road open to and used by the public and involving death or injury to any person, or property damages*". In WA, it is mandatory to report a crash to the police if a person is injured or if property damage exceeds $1,000.

Critical data retrieved for use in the study were:

- Crash date;
- Crash severity;
- Local government area of crash;
- Specific crash location.

The approach adopted in this study was to use five years pre and five years post treatment available crash data excluding the construction period in the analysis. This included all fatality, injury and property damage only (PDO) crashes. This was consistent with Main Roads' intention to ensure application of funds to a wider range of projects at hazardous situations using different thresholds such as all crashes

rather than casualty crashes only. However, a separate analysis by casualty crashes only was also undertaken.

2.3.2 Black Spot Treatment Site Data

Main Roads WA provided details about each Black Spot treatment. This included information related to Black Spot location and municipality, treatment description, and precise treatment start and finish dates (to within one week).

Information provided included:

- treatment number;
- Black Spot location and LG;
- treatment description;
- treatment start and finish dates;
- treatment cost;
- estimated annual maintenance and operating costs of each treatment;
- estimated treatment life.

Using information obtained from the treatment description, one of the treatment codes described in Appendix B was assigned to each treatment for use in the analysis. These codes are based on tables obtained from MRWA Road Safety Branch.

2.4 Categorisation of Treatment Types

An aim of the study was also to estimate the effectiveness of specific treatment types. However some of the Black Spots sites had a combination of individual treatments which made it difficult to analyse by specific treatment types. Therefore only the "dominant" treatment was chosen to be included in the analysis. While this resulted in a loss of accuracy in what could be concluded about some individual treatment types the increase in the sample size for the evaluation improved the accuracy of the analysis.

2.5 Factors that Affect the Black Spot Evaluation

All known factors that have the potential to affect the Black Spot evaluation should be accounted for when estimating the treatment effect. However, as found by Elvik

(1997) the more factors that are accounted for, the less effective the treatment appears to be.

Some of the factors that may affect the evaluation of the effectiveness of Black Spot treatments are described below. These include site-specific factors, regression- to-the mean, and crash migration.

2.5.1 Site Specific Factors

Specific events other than treatment could account for some of the observed change in the number and severity of crashes at a site. These can include weather conditions and increased publicity about the safety of the site. Both these may lead to an increase in driver caution which could lead to a reduction in crashes that has little to do with the treatment at the site. While it was not possible to assess these effects in this report it does appear unlikely that site specific factors would have a significant effect on the evaluation of the Black Spot program as a whole (Bureau of Transport, 2001). However it may have an effect on the analysis at a particular site (Bureau of Transport, 2001).

2.5.2 Regression to the Mean

It is possible that high crash rates at some sites may be due to chance or a combination of both chance and a moderately hazardous site. These sites are likely to have fewer crashes in subsequent period even if no treatment is carried out because the number of crashes will tend to gravitate to the long-term mean. Under these conditions the effect of any treatment is likely to be over-estimated. Failing to allow for the regression to the mean effect can result in statistically significant results for treatments that are in fact ineffective.

On the basis of work reported by Nicholson (1986) at least three, and preferably five years of data is the preferred before/after time period to smooth out any random fluctuations as well as providing sufficient evidence of any trend or change in an established pattern of crashes. All sites evaluated in this study used a five-year time span of pre and post treatment crash data. The statistical methodology also used in this report recognised the level and distribution of random variation in the data and provided appropriate confidence intervals and significance levels.

2.5.3 Crash (accident) Migration

The term crash migration (also referred as accident migration) describes an increase in crashes at sites in the vicinity of a Black Spot following the treatment of that Black Spot away from the treated site to the surrounding area. Whether crash migration is a real effect in a Black Spot treatment remains a controversial topic, which has not been adequately resolved by road safety experts. Therefore the analysis has not attempted to deal with crash migration. For the purpose of this report the assumption was made that no treatment could be associated with crash migration resulting from traffic migration away from the treated site.

For a more in-depth discussion of crash migration sees Elvik (1997).

2.6 Cost Data

Two types of cost data were used in the evaluation of the economic worth of the State Black Spot Program: the costs of implementing the program and the cost savings from a reduction in the number of road crashes as a result of the program being implemented.

The costs of treating black spots include both the initial capital outlay as well as operating and maintenance costs. As discussed previously (section 2.3.2), Main Roads WA provided these details for each black spot treatment included in the study. The initial capital outlay was obtained from recorded expenditure, and operating and maintenance costs and expected treatment life were estimated by treatment type by Main Roads WA.

The cost savings from fewer road crashes at treated sites were calculated based on the road crash severity costs for Australia in 1996 produced by the Bureau of Transport Economics (2000), adjusted for price increases and state variations in costs (Willett, 2004). These are the most recent road crash costs available for Australia and include the human costs of treating injuries plus any associated productivity losses and loss of functioning, vehicle repair and related costs, and general crash costs. Excluded are road user costs such as vehicle operating costs and travel time. Applying certain treatments may change the travel time on particular routes as well as vehicle operating costs and maintenance costs. However, to include this type of

analysis in calculating the benefits and costs of treated sites requires extensive data and for this reason studies evaluating the cost-effectiveness of black spot programs tend to exclude these costs (Bureau of Transport Economics, 2001). The unit of costing used in calculating the net economic worth of the program was the road crash, with unit road crash costs expressed in 2003 Australian dollars shown below.

Crash severity	**$**
Fatal	2,226,100
Hospital admission	494,800
Medical Treatment	29,900
Property Damage Only	11,900

The use of crash costs based on crash severity rather than type of crash (e.g. head on, right angle turn) has the disadvantage that a single serious crash at a site can potentially have a considerable impact on the calculation of the cost-effectiveness of a site. However, if the number of treatment sites being assessed is sufficiently large, this effect should cancel out. Recent Australian studies evaluating the cost-effectiveness of black spot programs have used crash costs based on severity rather than crash type (Bureau of Transport Economics, 2001; Newstead & Corben, 2001).

2.7 Statistical Analysis

2.7.1 Effectiveness of the Program

The analysis compared before and after treatment periods based on the total program, broad treatment categories (i.e. intersection treatments and non-intersection/road sections treatment), and specific treatment types (e.g. non-skid treatment). The analysis was also stratified by metropolitan Perth and non-metropolitan Perth (rural) to assess differential program effectiveness between Perth and the rest of WA.

A generalized estimating equation (GEE) Poisson regression model was used to evaluate the Black Spot Program. The number of crashes in one year is a discrete "count" variable and is assumed to follow a Poisson distribution. However, the longitudinal nature of the observations render the application of standard Poisson regression analysis inappropriate, and methods such as the GEE should be used to

accommodate the inherent correlation of the longitudinal data. While a Poisson regression model was used in the National Black Spot Program the decision to use the GEE Poisson model was to take account of the correlated nature of the repeated measures taken pre- and post- Black Spot treatment

The GEE Poisson regression model was also capable of estimating the correct effect of each treatment, as robust standard errors were generated to provide valid statistical inferences The model was used to estimate the overall treatment effects, broad category treatment and specific treatment effects. Similar treatment types were grouped together to attain a higher statistical power. For example, all treatments involved in the provision of a roundabout were grouped together regardless of the size of the roundabout installed. Details about the GEE technique can be found in Twisk (2003).

Information on traffic volumes over time at individual Black Spot sites is useful to determine whether any changes in crash history is due to a treatment at the Black Spot site or whether changes in traffic flow give rise to the observed discrepancies pre- and post- treatment. Unfortunately, it was not possible to obtain before and after treatment traffic volumes for all treated sites. For the purpose of this analysis it was thus assumed that before and after traffic volumes remained constant.

The model was fitted to the data using the Stata (version 9) statistical package.

2.7.2 Economic Analysis

Two indicators of the net economic worth of the program were calculated: the net present value (NPV) and the benefit cost ratio (BCR).

NPV is the difference between the present value of the time stream of cost savings from a reduction in road crashes and the present value of the time stream of costs incurred to achieve these savings. In the case of the Black Spot Program, the latter include the capital costs of installing the treatments and maintenance and operating costs. NPV is expressed in monetary terms, with a NPV significantly greater than zero indicating a project is worthwhile. If the net economic worth of two or more

projects is being compared then the project with the highest NPV is the most worthwhile.

The BCR is the ratio of the present value of the time stream of cost savings from a reduction in road crashes to the present value of the time stream of costs incurred to achieve these savings. It has no units, since it is a ratio of monetary values. A BCR significantly greater than one indicates a project is worthwhile, or if the net economic worth of two or more projects are being compared then the project with the highest BCR is the most worthwhile.

The formulas for calculating the NPV and BCR are as follows –

$$NPV = \sum_{i=0}^{n} (B_i/(1+r)^i) - \sum_{i=0}^{n} (C_i/(1+r)^i)$$

$$BCR = \left[\sum_{i=0}^{n} (B_i/(1+r)^i) \right] / \left[\sum (C_i/(1+r)^i) \right]$$

where Bi = benefits in year i resulting from savings in road crash costs
Ci = costs of installing Black Spot treatments in year 0 and the operating and maintenance costs in subsequent years
r= discount rate (5% used in the base case analysis)
n=the expected life of the project (10 years assumed for all treatments)

NPVs and BCRs were calculated using the following sources of data: (i) the capital costs of initial treatment of the sites (ii) the maintenance and operating costs of treatments (iii) the expected treatment life (iv) the effectiveness of treatments in reducing the number of road crashes and (v) the unit road crash cost data. The capital costs of installing treatment were adjusted to 2003 Australian dollars using the road and bridge construction price index for output of the construction industry (Australian Bureau of Statistics, 2004). The treatment life of projects varied between 10 and 20 years, with an average treatment life of 15 years. This latter was varied to 10 years and 20 years in the sensitivity analysis. Maintenance and operating costs were estimated on an annual basis and assumed to remain constant throughout the expected life of the treatment. Likewise savings from a reduction in road crash costs achieved since installing the treatments were assumed to be maintained over the entire expected life of the treatments. Future costs and cost savings were discounted

using a 5% discount rate in the base case, with 3% and 8% used in the sensitivity analysis. Again 5% was the discount rate suggested by Main Roads, WA. NPVs and BCRs were calculated for the whole Black Spot Program, components of the program, and specific treatment types. The sensitivity analysis was only conducted for the whole Black Spot Program. NPV and BCR calculations were made on the basis of all reported crash data and casualty crashes only.

3. RESULTS

This section summarized the results of the analyses for all reported crash frequency and casualty crash frequency. The sample of treated sites for which sufficient data was obtained were evaluated by broad categories (intersection and road section/non-intersection), by specific treatment type and by geographic area (metropolitan Perth and rural WA). The full results of the analysis are detailed in Appendix B, Appendix C and Appendix H with the main findings summarised below.

3.1 Statistical Analysis

There were a total of 154 sites nominated for treatment as a Black Spot. In the initial evaluation four sites were eliminated from the assessment of treatment effectiveness due to quality of the data at those sites. For this analysis a total of seven sites were eliminated from the assessment. This was due to changes in the road network which meant it was not possible to extract the crash data from the same location as the previous evaluation. The final sample of 143 treated sites consisted of 125 intersections and 18 road sections or non-intersection sites.

Table 3.1 shows the effect of the Black Spot Program on road safety for all crashes and Table 3.2 shows the effect for casualty crashes only. In both tables, β represents the regression coefficient in terms of the log-scale of the outcome variable so that the reduction rate is given by $1-e^{\beta}$. A negative value for β indicates a percentage reduction in all Police reported crashes (includes fatality, hospitalization and injury crashes and PDO) and casualty crashes decreased following treatment, and vice versa for a positive value for β. The statistical significance of treatment is given by p. For example, $p<0.001$ means that the probability of obtaining such a result by chance is less than one in a thousand. The percentage reduction in the number of all reported crashes and casualty crashes is shown in the last column of Table 3.1 and Table 3.2.

In this analysis very strong evidence meant that the probability of an event occurring by chance is less than one in one thousand ($p <0.001$); strong evidence meant that the probability is less than one in one hundred ($p<0.01$); moderate evidence meant that the probability is less than one in fifty ($p<0.02$); weak evidence meant that the probability is less than one in ten ($p<0.1$) and not significant was indicated by $p>0.1$.

This was consistent with the criteria adopted by the National Black Spot Program evaluation.

Table 3.1 Black Spot Treatment Effect on All Crash Reduction in Western Australia, 2000 – 2002

Area	Estimate (β)	Standard Error	Probability 0<p<1	All Crash Reduction** (%)
Whole program	-0.221	0.010	0.001	19.8
All Metropolitan Sites	-0.189	0.011	0.001	17.3
All Rural Sites	-0.400	0.036	0.001	32.9
Broad Categories				
Intersection Treatments	-0.214	0.013	0.001	19.3
• Metro	-0.198	0.013	0.001	17.9
• Rural	-0.378	0.081	0.001	31.5
Road Section and Non Intersection Treatment	-0.245	0.018	0.001	21.8
• Metro	-0.137	0.145	0.001	12.8
• Rural	-0.419	0.083	0.001	34.3
Treatment Types				
All Roundabouts	-0.410	0.020	0.001	33.7
• Metro	-0.355	0.019	0.001	29.9
• Rural	-0.720	0.174	0.001	51.3
Traffic control signals	-0.427	0.783	0.001	34.7
Non-skid treatment	-0.386	0.030	0.001	32.1
Traffic island on approach	-0.249	0.090	0.006	22.1
Seagull island	0.132	0.024	0.001	-14.1
Left turn slip	-0.171	0.042	0.001	15.8
Median on existing road	-0.382	0.091	0.001	31.8
Nibs (pedestrian facilities)	-0.435	0.161	0.007	35.3
Improved route lighting	-0.127	0.005	0.001	11.9
All State Roads	-0.094	0.023	0.001	9.0

***Includes all crashes-fatality, hospitalisation, injury and property damage major and minor crashes*

Table 3.2 Black Spot Treatment Effect on Casualty Crash Reduction in Western Australia, 2000-2002

Area	Estimate (β)	Standard Error	Probability 0<p<1	Casualty Crash Reduction** (%)
Whole program	-0.449	0.031	0.001	36.2
All Metropolitan Sites	-0.425	0.033	0.001	34.6
All Rural Sites	-0.628	0.084	0.001	46.7
Broad Categories				
Intersection Treatments	-0.452	0.036	0.001	36.4
• Metro	-0.432	0.038	0.001	35.1
• Rural	-0.712	0.185	0.001	50.9
Road Section and Non Intersection Treatment	-0.436	0.042	0.001	35.4
• Metro	-0.367	0.041	0.001	30.8
• Rural	-0.550	0.131	0.001	42.3
Treatment Types				
All Roundabouts	-0.977	0.078	0.001	62.4
• Metro	-0.972	0.080	0.001	62.2
• Rural	-1.011	0.523	0.053	63.6
Traffic island on approach	-0.767	0.247	0.002	53.6
Non-skid treatment	-0.604	0.088	0.001	45.4
Traffic control signals	-0.565	0.174	0.001	43.2
Seagull island	0.077	0.085	0.365	-8.0*
Left turn slip	-0.496	0.115	0.001	39.1
Median on existing road	-0.405	0.288	0.159	33.3*
Nibs (pedestrian facility)	-0.980	0.423	0.021	62.5
Improved route lighting	-0.528	0.236	0.025	41.0
All State Roads	-0.287	0.083	0.001	25.0

**Crash increase/reduction is not statistically significant*
***Includes fatal, hospitalisation, and injury crashes*

The overall effect of the Black Spot Program for all crash types showed a very strong reduction of 20% ($p<0.001$) for all crashes (see Table 3.1) and a very strong reduction of 36% ($p<0.001$) for casualty crashes (see Table 3.2).

3.1.1 Analysis by Broad Treatment Categories

Reported crash data by **broad treatment categories** (intersection and road section/non-intersection treatment) were also analysed. There were a total of 125 sites which received a treatment at an **intersection**. There was very strong evidence of a 19% reduction in the number for all crashes ($p<0.001$) and a 36% reduction in casualty crashes ($p<0.001$). The most frequently used treatments at an intersection for this evaluation were: seagull island (n=18), non-skid treatment (n=10), left turn slip (n=9), traffic island on approach (n=9), and traffic control signals (n=7).

There was very strong evidence of a 22% reduction ($p<0.001$) in all crashes for the eighteen **road section and non-intersection treatment sites** and very strong evidence of a 35% reduction ($p<0.001$) for casualty crashes. The most frequently used treatments at road sections and non-intersection sites were: median on existing road (n=4), pedestrian refuge (n=1), improved route lighting (n=1) and indented right turn island (n=1).

3.1.2 Analysis by Specific Treatment Type

As evident from Table 3.1 and Table 3.2 the study was able to identify different treatment types which were successful in reducing both all reported crash and casualty crash frequencies at treated Black Spots.

There was very strong evidence that the following specific treatment types were successful in reducing both casualty crashes and all reported crashes:

- **Traffic island on approach -** a 22% reduction in all crashes ($p<0.001$) and a 54% reduction in casualty crashes ($p<0.001$).
- **Nibs -** a 35% reduction in all crashes ($p<0.01$) and a 63% reduction in casualty crashes ($p<0.05$).
- **Median on existing road** - a 32% reduction in all crashes ($p<0.001$)

- **Non-skid treatments** - a 32% reduction in all crashes ($p<0.001$) and a 45% reduction in casualty crashes ($p<0.001$).
- **Traffic control signals** - a 35% reduction in all crashes ($p<0.001$) and a 43% reduction in casualty crashes ($p<0.001$).
- **Left turn slip -** a 16% reduction in all crashes ($p<0.001$) and a 39% reduction in casualty crashes ($p<0.001$).
- **Improved route lighting -** a 12% reduction in all crashes ($p<0.001$) and a 41 reduction in casualty crashes ($p<0.05$).

Installation of "seagull islands" appeared to be associated with an increase in all reported crashes (14%), however there was no statistical evidence that "seagull islands" and "median on existing road" affected the frequency of casualty crashes (see Table 3.1 and Table 3.2).

3.1.3 Analysis by Location

There were a total of 115 treatment sites in the metropolitan area. Overall, these treatments showed a very significant 17% ($p<0.001$) reduction for all reported crashes and a 35% ($p<0.001$) reduction was reported for casualty crashes within the metropolitan area.

There were a total of 28 sites treated in rural areas. There was strong evidence of a 33% reduction ($p<0.001$) for all reported crashes and a 47% reduction ($p<0.001$) for casualty crashes.

A breakdown of broad treatment categories by location found:

- a 18% reduction ($p<0.001$) for all reported crashes and a reduction of 35% ($p<0.001$) for casualty crashes in the metropolitan area for **intersection** treatments.
- a 32% reduction for all reported crashes ($p<0.001$)and a 51% reduction for casualty crashes ($p<0.001$) in rural areas for **intersection** treatments.
- a 13% reduction ($p<0.001$) for all crashes and a 31% reduction for casualty crashes ($p<0.001$) in the metropolitan area for **road section and non-intersection treatment**.

- a 34% reduction ($p<0.001$) for all crashes and a 42% reduction for casualty crashes ($p<0.001$) for **road section and non-intersection treatment** in rural areas.

An analysis of the differential effect of **roundabout** treatments for both the metropolitan and rural area was also undertaken. A very significant reduction of 30% for all crashes ($p<0.001$) and a 62% reduction for casualty crashes ($p<0.001$) were reported in metropolitan Perth. In the rural areas a very significant reduction of 51% for all crashes ($p<0.001$) and a 64% reduction for casualty crashes albeit statistically weak significance ($p=0.053$) was noted.

3.2 Economic Evaluation of the State Black Spot Programs

Table 3.3 presents the results of the economic evaluation of the State Black Spot Program in terms of its cost reduction of all reported crashes. Appendix F shows the net economic worth of the Program in terms of the cost reduction of casualty crashes only. The estimated crash cost savings over the expected life of the treatments were $43.7 million for all reported crashes, of which 84% were attributable to a reduction in casualty crashes. This resulted in an overall net cost saving to the community over the expected life of the treated sites of $32.9 million ($25.7 million attributable to casualty crashes) after subtracting the capital costs of installing treatments and the maintenance and operating costs of $10.8 million. The BCR across all treatment sites was estimated to be 4.0, which indicates benefits in the form of cost savings to the community of $4 for each $1 invested in the program. Sites treated in rural areas had a better rate of return than those in the metropolitan area, with a BCR of 9.6 compared with 2.1 in the metropolitan area.

Treatment types varied in their estimated rates of return. Treatment types that were found to be good public investments in terms of having positive NPVs or BCRs greater than one were roundabouts in both metropolitan and rural regions, improved route lighting, the installation of traffic islands and non-skid treatments. While the majority of the other treatment types were effective in reducing the number of crashes overall, this reduction was predominantly of crashes of lower severity levels with higher severity crashes often increasing. With relatively few sites for some treatment types, the high costs of the more severe crashes tended to dominate post-

treatment crash costs, thus resulting in negative NPVs and BCRs for these treatment types despite recording an overall reduction in the number of crashes.

Table 3.4 shows the effect of varying the assumptions relating to the discount rate and treatment life of projects on the estimated rate of return of the Black Spot Program. The Program was found to be cost-effective across all variations in assumptions, with lower discount rates and longer treatment lives of projects improving rates of return and vice versa. A discount rate of 3% increased the NPV of the Black Spot Programs to $38.3 million and the BCR to 4.5. An expected treatment life of 20 years increased the NPV to $34.8 million and the BCR to 4.2.

Table 3.3 Economic Evaluation of the State Black Spot Programs in Relation to Total Crash Reduction in Western Australia

Area	Present Value of Treatment Costs and Operating/ Maintenance Costs ($)	Present Value of Crash Cost Savings	Net Present Value	Benefit Cost Ratio*
Whole program	10 822 034	43 744 083	32 922 049	4.0
All Metro Sites	8 013 829	16 805 760	8 791 931	2.1
All Rural Sites	2 808 204	26 938 335	24 130 131	9.6
Treatment Types				
All Roundabouts	5 341 262	40 327 207	34 985 945	7.6
• Metro	4 032 498	25 103 855	21 071 357	6.2
• Rural	1 308 764	15 223 341	13 914 577	11.6
Improved route lighting	399 218	7 146 678	6 747 460	17.9
Traffic island on approach	496 367	5 308 002	4 811 635	10.7
Non-skid treatment	624 237	4 275 133	3 650 896	6.8
Left turn slip	442 089	-1 418 025	-1 860 114	-3.2
Median on existing road	356 872	-1 221 965	-1 578 837	-3.4
Traffic control signals	949 779	-3 847 420	- 4 797 199	-4.1
Nibs (pedestrian facilities)	116 911	-659 163	-776 074	-5.6
State roads -all treatments	396 282	-3 157 840	-3 554 122	-8.0
Seagull island	593 458	-4 835 970	-5 429 428	-8.1

** Negative BCRs are due to the small number of sites and more severe crashes post treatment*

Table 3.4 Sensitivity Analysis for the Economic Evaluation of the Overall State Black Spot Programs in Relation to All Crash Reduction in Western Australia

Area,	Present Value of Treatment Costs and Operating/ Maintenance Costs	Present Value of Crash Cost Savings	Net Present Value	Benefit Cost Ratio
ALL CRASHES				
Base Case Discount rate, 5%; treatment life, 15 years	10 822 034	43 744 083	32 922 049	4.0
Sensitivity Analysis				
Discount Rate				
• 3% (15years)	11 024 616	49 353 727	38 329 111	4.5
• 8% (15years)	10 582 243	37 104 100	26 521 857	3.5
Treatment Life				
• 10 years (5%)	10 417 507	28 470 833	18 388 365	2.8
• 20 years (5%)	10 891 755	45 674 705	34 7822 950	4.2

4. DISCUSSION

This report presented the results of the final evaluation of Black Spot treatments conducted in the period 2000 to 2002 in Western Australia in terms of its effectiveness in reducing the frequency for all reported crashes, casualty crashes and crash costs. The evaluation is comprehensive in a number of respects in that, 143 individual treatments were evaluated, represented by 9 separate treatment types using five years of pre and post treatment crash data. The analysis found the overall program to be effective in reducing the frequency of all reported crashes and casualty crashes.

In designing the evaluation a number of decisions were made regarding the analysis. It was decided to separately examine the effects of the Black Spot treatments on all severity of crashes (including PDO) and casualty crashes only. The alternative to this would be to study treatment effect on only crash types most likely to be affected by the particular treatment being examined. However an evaluation of specific crash types only may have the potential to miss all possible benefits of a treatment as well as potential detrimental effects. According to Newstead & Corben (2001) an evaluation that includes all crash types is more relevant when examining Black Spot treatment effectiveness which was the aim of the present study. This was also in keeping with Main Roads WA threshold criteria, which enabled application of funds to a wider range of projects at hazardous locations based on the total number of crashes at the sites which varied between locations, regions and road types.

The evaluation of the Program identified specific treatment types such as roundabouts that were highly successful in reducing crash frequency in both the metropolitan and rural areas. Other types of treatment that showed statistically significant reductions in the number of all reported crashes and casualty crashes included traffic control signals, non-skid treatments, left turn slip, and nibs. The analysis yielded inconclusive results in terms of casualty crash reduction for treatments such as median on existing road and seagull islands. However seagull islands significantly increased crash frequency for all reported crashes and warrants further investigation.

It must be noted that a failure to reject the null hypothesis of no difference does not necessarily mean that the treatment countermeasure was ineffective. There are several possible reasons why the treatment did not have an effect on treated sites. The first is that the treatment may genuinely have had no effect on road safety contrary to what the literature may suggest. Second, traffic flow may have changed at some of the treated sites that was not controlled for in this evaluation. Third, some treatment types such as high friction surfacing may not have been used often enough to achieve minimum sample size requirements in order to estimate statistically significant results associated with the treatment type. Small sample sizes may produce statistically insignificant results even if the treatments were proven to work well.

It must also be noted that this evaluation demonstrated that the Black Spot Program was effective for reducing the frequency of cashes at intersection sites as well as road section and non-intersection sites even though the projects analysed were heavily weighted towards intersection treatments.

In relation to the net economic worth of the State Black Spot Program, the NPV and the BCR across all treatment sites were estimated to be $32.9 million and 4.0 respectively. Treatment types varied in their estimated rate of return, with roundabouts, improved route lighting, the installation of traffic islands and non-skid treatments showing a positive rate of return. Several treatment types had a negative rate of return despite being effective in reducing the overall number of crashes. This resulted from the use of crash costs based on severity rather than type of crash as the basis for costing. Using crash costs based on severity resulted in the increased overall cost of crashes due to an increase in one or more serious crashes at the treatment sites compared to the number of less serious crashes.

5. CONCLUSIONS AND RECOMMENDATIONS

The results found the Program to be effective producing positive outcomes for the community in terms of road safety. The Program has reduced all reported crash numbers by 20% and is estimated to reduce crash costs by $43.7 million over the expected life of the treated sites. After accounting for project costs of $10.8 million,

the net cost savings to the community from the 2000 to 2002 State Black Spot Program were estimated at $32.9 million.

Obtaining accurate information related to treated sites, particularly in relation to costs of treatments was difficult at times and needs to be properly documented for any future evaluation to ensure the validity of the results. It is crucial that neither the before treatment period nor the after treatment period overlaps the construction period in which case estimates of the treatment effect could result in bias towards the lesser or greater magnitude compared to the true value. Uncertainties about dates meant that some potentially useful data was not used. Also poor definitions of road environment countermeasures from some LGs made it difficult to determine what was actually done at the treated site. For example: the description of one treatment was "adjustment" only. Given some of the difficulties experienced in the current study it is recommended that a comprehensive and systematic method of data collection be introduced and maintained to facilitate future Black Spot Program evaluations.

Recommendations include:

- Maintaining accurate and timely recording of details of treatments, including location, treatment types, changes to road geometry and traffic costs, start and completion dates and any other details relevant to future evaluations by LGs.
- LGs supply more detailed information about the treatment implemented at the nominated Black Spot to ensure the treatment can be correctly allocated to the appropriate treatment type.
- Collect information on traffic volumes at various points in time over the evaluation period at individual Black Spot sites that could be used in subsequent analysis to determine whether any change in crash frequency is due to the treatment or changes in traffic volume.
- A more detailed investigation of the multiple effects that may be derived with the implementation of more than one crash countermeasure.
- Further in-depth evaluation of treatments that did not significantly reduce or increase crash frequency such as seagull islands and medians on existing roads.

- Further in-depth evaluation of treatments such as high friction surfacing that were not used often enough to produce valid results.
- Future evaluations of the State Black Spot Program should include an analysis of cost savings based on type of crash as well as crash severity to take account of the impact of the high crash costs of fatalities and serious crashes on the calculations of program cost-effectiveness.

In conclusion, as traffic patterns and road use change over time, new Black Spots will emerge. Since road authorities tend to treat the worst sites first, the benefits from treating remaining sites will reduce. This means that ongoing evaluations are necessary to help governments determine if the benefits from further treatment justify the treatment costs.

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APPENDIX A

BLACK SPOT PROGRAM – PROJECT CRITERIA

Criteria	National Black Spot State and Local Roads	State Black Spot Highways and Main Roads	State Black Spot Local Roads
General ***Owner***	DOTARS	WA State Government	WA State Government and Local Government
Co-ordination	MRWA Road Network Services Program Co-ordinator (RNSPC)	MRWA State Black Spot Program Manager	MRWA Regional Managers and Regional Road Group
State Panel Meeting	Yes – Senator Alan Eggleston (November)	N/A	N/A
Recommendation	WA Black Spot State Consultative Panel	MRWA - EDRNS	Regional Road Groups
Approval	Federal Minister for Transport	Commissioner of Main Roads	State Road Funds to Local Government Advisory Committee
Period	4 years, 2002/2003 to 2005/2006	2005/06 onwards	2005/06 onwards
Funding ***Allocation***	$ 4.982 annually	$ 7.5M annually	$11.25M annually (Including LGs contribution)
Distribution ***Metro*** ***Rural***	50% 50%	50% 50%	50% 50% (Based on 25% four way proportional formula for regional allocations)
Contributions	Yes – encouraged	Yes (eg. Developers – service roads)	Yes 2:1 mandatory (State and Local Govt)
Over fund	Yes up to 25%	Yes (decided at the programming stage)	Yes (based on merit)
Variations	No, fully allocated program	Fully allocated - Managed by MRWA	Fully allocated -Managed by RRG
Project Min Cost ***Project Max Cost***	≥ $ 2 000 ≤ $ 750 000	≥ $ 2 000 ≤ $ 1 000 000	≥ $ 2 000 ≤ $ 1 000 000

Criteria	National Black Spot State and Local Roads	State Black Spot Highways and Main Roads		State Black Spot Local Roads	
Funding Cont. Components paid for successful projects					
Administration Overheads	No, paid by MRWA	No, paid by MRWA		No, paid by local govt.	
Road Safety Audit	Yes	Yes		Yes	
Design/Land/Services and Design Audit (Where Required)	Yes	Yes		Yes	
Capital Costs	Yes	Yes		Yes	
Specific & Routine Maintenance	No	No		No	
Roads					
National Highways	No	Yes		Optional	
Road of National Importance	No	Yes		Optional	
State Roads	Yes	Yes		Optional	
Local Roads	Yes	Yes (for intersection treatments only)		Yes	
Crash criteria (see note 2)		**Metro**	**Rural**	**Metro**	**Rural**
Intersection or Mid-block or Short road section (< 3 km)	3 casualty crashes over a five-year period	10 crashes over 5 years	3 crashes over 5 years	5 crashes over 5 years	3 crashes over 5 years
Road length (≥ 3km)	1 casualty crashes per kilometre over 5 years, or top 10% of sites which have a demonstrably higher crash rate than other roads in a region.	Average of 3 crashes per km over 5 years	Average of 1 crash per km over 5 years	Average of 2 crashes per km over 5 years	Average of 1 crash per km over 5 years
Crash Period	5 years (eg.1999 to 2003 for 2005/2006 program)	5 years (eg. 1999 to 2003 for 2005/2006 program)		5 years (eg.1999 to 2003 for 2005/2006 program)	

Criteria	National Black Spot State and Local Roads	State Black Spot Highways and Main Roads	State Black Spot Local Roads
BCR			
Minimum	≥ 2.0	≥ 1.0	≥ 1.0
Discount rate	5%	5%	5%
Crash Reduction % Factors	DOTARS and MRWA	DOTARS and MRWA	DOTARS and MRWA
Costs for calculating BCR	Includes capital costs, contributions by others, routine maintenance and specific maintenance	Includes capital costs, contributions by others, routine maintenance and specific maintenance.	Includes capital costs, contributions by others, routine maintenance and specific maintenance.
Projects based on Road Safety Audit (see note 2)			
Projects	Yes up to 20% of program	Yes up to 50% of program. RM may apply to Executive Director to vary percentage up to a higher level.	Yes up to 50% of program. RRG's may apply to Advisory Committee to vary percentage up to a higher level.
Ranking of Audit Projects	Yes - ARRB Risk Cost Ratio	Yes	Yes
Project Completion	Project should be completed within the time frame of the program	June 30 of funding year	June 30 of funding year
Staged construction	Not normally	Yes	Yes
Recognition			
Signing during construction	≤ $100,000 during construction only.	$50,000 - $100,000 during construction only.	$50,000 - $100,000 during construction only.
Signing post construction	≥ $100,000, + permanent signing for 2 years Any other signposting relating to the project must be endorsed by the Minister.	Over $100,000 - permanent signing for 1 year.	Over $100,000 - permanent signing for 1 year.

Criteria	National Black Spot State and Local Roads	State Black Spot Highways and Main Roads	State Black Spot Local Roads
Environment, Heritage, Aboriginal clearances	Yes	Yes	Yes
Design and technical clearances	Yes	Yes	Yes
Roundabouts and pedestrian facilities	Ensures needs of cyclists and pedestrians are properly catered for.	Ensures needs of cyclists and pedestrians are properly catered for.	Ensures needs of cyclists and pedestrians are properly catered for.
Traffic Control Signals	MRWA approval required	MRWA approval required	MRWA approval required
Design Audits	May be required	Yes over $150,000	Yes over $150,000
Evaluation of completed projects/programs	BTRE (Canberra)	Independent Research Consultant eg ARRB Transport Research, BTE	Independent Research Consultant eg ARRB Transport Research, BTE

Notes:

1. Crash data is provided by Main Roads to assist Local Governments identify sites meeting the crash criteria or other hazardous locations.

2. A Road Safety Audit is encouraged for all projects not based on crash criteria. A formal Road Safety Audit is MANDATORY for projects over $40 000. Generally a project shall not consist solely of a Road Safety Audit; however, where agreed by the Regional Road Group, a small proportion of projects on rural local roads may consist of only a road safety audit.

APPENDIX B BLACK SPOT TREATMENT SITES

PROGRAM YEAR	PROJECT OWNER / LG	PROJECT
2001/02	Esperance	Andrew Street/Dempster Street Intersection - Install roundabout
2001/02	Kalgoorlie - Boulder	Lane Street/Brockman Street/Hay Street Intersection - Install roundabout
2001/02	Kalgoorlie - Boulder	Lionel Street (Burt Street to Johnston Street) - Upgrade street lighting
2000/01	Kalgoorlie-Boulder	Lionel Street (Hampden Street to Johnson Street) – Install channelisation including central median and protected right turn pockets
2001/02	Albany	Sanford Road/Stead Street Intersection - Install roundabout
2001/02	Geraldton	Waldeck Street/Brede Street Intersection - Construct roundabout
2001/02	Geraldton	Shenton Street/Francis Street Intersection - Install roundabout
2000/01	Roebourne	Balmoral Road/Welcome Road Intersection - Install roundabout
2000/01	Goomalling	Yarramony Road - Widen and improve approaches to old railway crossing
2001/02	Bunbury	Strickland Street/Blair Street Intersection - Install left turn slip lane
2001/02	Bunbury	Spencer Road/Beach Road/ Forrest Road Intersection - Install non skid treatment
2001/02	Bunbury	Strickland Street(Albert Street - King Road) - Widening
2001/02	Bunbury	Ecclestone Street/Wiseby Street - Install roundabout
2001/02	Busselton	Thomas Street/High Street Intersection - Install roundabout
2001/02	Busselton	Cammilleri Street/Harris Road Intersection - Install roundabout
2001/02	Busselton	Queen Street/Kent Street Intersection - Install roundabout
2001/02	Busselton	Marine Terrace/Ford Road Intersection - Install roundabout
2001/02	Collie	Prinsep Street North - Install non skid treatment
2001/02	Collie	Prinsep Street North/Medic Street Intersection - Install roundabout
2001/02	Harvey	Paris Road/Travers Drive Intersection - Upgrade left turn slip lane

2001/02	Mandurah	Arnold Street/Pinjarra Road - Install left turn lane
2001/02	Manjimup	Leman Street/Arnott Street Intersection - Improve intersection definition
2001/02	Manjimup	Sommerville Street/Ipsen Street - Install splitter islands
2000/01	Augusta-Margaret River	Elva Street/Georgette Drive/Forest Street Intersection - Extend median island and kerbing and upgrade school bus parking
2000/01	Bunbury	Sandridge Road/Hennesy Road Intersection - Reconstruct service road and alterations to median island
2000/01	Bunbury	Old Coast Road - Install path under Collie River Bridge and dual use paths
2000/01	Bunbury	Sandridge Road - Install new drainage line with large entry capacity
2000/01	Bunbury	Washington Avenue/Bussell Highway Intersection - Resurface road, install line marking and construct bus embayment
2000/01	Harvey	Old Coast Road / Marine Drive Intersection - Install slip lanes, improve road markings, signage and lighting.
2000/01	Mandurah	Coolibah Avenue / Third Avenue Intersection - Remove dangerously located power pole and underground power.
2001/02	Armadale	Albany Highway/Davis Road Intersection - Modify intersection to restrict turning movements
2001/02	Armadale	Railway Avenue/Lowanna Way Intersection - Install right turn facility along Railway Avenue
2001/02	Armadale	Jarrah Road/Wygonda Road Intersection - Install roundabout
2001/02	Armadale	Pearson Street/Streich Avenue Intersection - Install passing lane at Streitch Avenue
2001/02	Armadale	Ranford Road/Wright Road Intersection - Install left turn slip and channelise intersection
2000/01	Armadale	Lowanna Street/Tate Street Intersection - Install traffic islands, channelisation and signs
2000/01	Armadale	Railway Avenue/Champion Drive Intersection - Install roundabout
2000/01	Armadale	Seville Drive - Install channelisation and intersection treatments
2000/01	Armadale	Admiral Road (School Access) - Widen access to school
2000/01	Armadale	Railway Avenue/Westfield Road Intersection - Install roundabout
2000/01	Armadale	Nicholson Road/Rowley Road Intersection - Install channelisation, improve lighting and signs
2000/01	Bayswater	Broun Ave/Russell Road Intersection - Install high skid asphalt layer
2000/01	Bayswater	Walter Road West/Coode Street Intersection - Install high skid asphalt layer
2000/01	Bayswater	Walter Road West/Birkett Street Intersection - Install high skid asphalt layer
2000/01	Belmont	Wright Street/Kooyong Road Intersection - Install roundabout
2000/01	Belmont	Belgravia Street/Keane Street Intersection - Install roundabout
2000/01	Belmont	Abernethy Road/Kewdale Road Intersection - Construct left turn slip lane

2001/02	Belmont	Abernethy Road/Barker Street Intersection - Install central islands on all approaches
2001/02	Belmont	Brearley Avenue/Second Street Intersection - Install seagull island and right turn pocket
2001/02	Cambridge	The Boulevard/Durston Road Intersection - Reduce slip lane to 70 degree island
2001/02	Cambridge	Oceanic Drive/Perry Lakes Drive Intersection - Install seagull island
2000/01	Cambridge	Grantham Road/Seymour Avenue Intersection -Modify intersection
2000/01	Cambridge	The Boulevard/Seymour Avenue Intersection - Modify intersection
2001/02	Canning	Agincourt Drive - Install traffic and pedestrian refuge islands
2001/02	Canning	Riley Rd / Riverton Rd Median on Existing Carriageway (LG $7,000)
2001/02	Canning	Vahland Ave West C'Way / Querrin Ave Seagull Treatment (LG $7,000)
2001/02	Canning	Centre St / George St Construct Roundabout (LG $19,000)
2001/02	Canning	Portcullis Dr 2M Wide Median & Signs (LG $15,000)
2001/02	Canning	At the intersection of High Rd South C'Way / Vellgrove Ave Traffic Islands on Approach (LG $6,000)
2000/01	Canning	Cecil Avenue (Albany Highway to Carousel Road) - Install roundabout, right turn pockets and traffic island
2000/01	Canning	Webb Street/Bull Creek Drive Intersection - Modify intersection
2001/02	Cockburn	Carrington Street/Winterfold Road Intersection - Modify traffic control signals and provide non skid treatment
2001/02	Cockburn	North Lake Road/Gwillam Drive/Forrest Road Intersection - Modify traffic control signals and provide non skid treatment
2001/02	Cockburn	Farrington Street/Bibra Drive Intersection - Modify traffic control signals and provide non skid treatment
2001/02	Cockburn	Rockingham Road/Spearwood Avenue Intersection - Non skid treatment
2001/02	Cockburn	Spearwood Avenue/Gerald Street Intersection - Intersection improvements and reinforce priority signs
2001/02	Cockburn	Rockingham Road/Carrington Road Intersection - Non skid treatment and install larger aspects to traffic control signals
2001/02	Cockburn	Carrington Road/Forrest Road Intersection - Non skid treatment
2001/02	Cockburn	Beeliar Drive/Dunraven Drive Intersection - Install slip lane and seagull island
2001/02	East Fremantle	St Peters Road/Silas Street Intersection -Install roundabout
2001/02	Fremantle	Marine Terrace/South Street Intersection- Install nibs
2000/01	Fremantle	Peel Road/Ladner Street Intersection - Upgrade lines and signs
2000/01	Fremantle	High Street/Amherst Street Intersection - Install traffic islands
2000/01	Fremantle	Forsyth Street/Hines Road Intersection - Upgrade lines and signs

2001/02	Gosnells	Spencer Rd / Berehaven Ave Install Street Lighting & Advance Warning Signs (LG $6,950)
2001/02	Gosnells	Albany Hwy / Burslem Dr Construct a 70 Degree Splitter Island (LG $6,667)
2001/02	Gosnells	Attfield Street/Burslem Drive Intersection - Install roundabout
2000/01	Gosnells	Berehaven Avenue/Storey Road Intersection - Install Roundabout (NB: Was originally submitted as Construct pedestrian refuge islands)
2000/01	Gosnells	Gosnells Road West/Westfield Street Intersection - Install roundabout and improve lighting
2000/01	Gosnells	Eudoria Street/Harry Street Intersection - Install roundabout and improve lighting
2001/02	Joondalup	Warwick Rd / Dorchester Ave - Install Traffic signals
2001/02	Joondalup	Whitfords Ave / Kingsley Dr - Install traffic signals
2001/02	Joondalup	Ocean Reef Road/Dampier Avenue Intersection - Install indented right turn island
2001/02	Joondalup	Mullaloo Drive/Dampier Avenue Intersection - Modify roundabout entry widths and circulating radius and provide non skid treatment
2001/02	Joondalup	Hepburn Avenue/Gibson Avenue Intersection - Reduce radius left turn slip lane and install segull island
2001/02	Joondalup	Marmion Avenue/Giles Avenue Intersection - Reduce radius left turn slip lane and median segull island
2000/01	Joondalup	Ocean Reef Road/Oceanside Promenade Intersection - Install roundabout
2000/01	Joondalup	Davallia Road - Lane narrowing, and install turning pockets
2001/02	Kalamunda	Hawtin Road/Berkshire Road Intersection - Install roundabout
2000/01	Kalamunda	Gooseberry Hill Road/Watsonia Road Intersection - Install roundabout
2001/02	Melville	North Lake Road/Somerville Boulevard Intersection - Install traffic control signals
2001/02	Melville	Murdoch Drive/Somerville Boulevard Intersection - Install traffic control signals
2001/02	Melville	North Lake Rd/Winterfold intersection - Install seagull island
2001/02	Melville	Leach Highway/Marcus Avenue Intersection - Install seagull island
2001/02	Melville	Farrington Road/Casserley Drive Intersection - Install seagull islands
2001/02	Melville	Karel Avenue/Gracechurch Circle Intersection - Install seagull island
2001/02	Melville	Karel Avenue/Bernera Drive Intersection - Install seagull island
2001/02	Melville	Karel Avenue/Hurley Road Intersection - Install seagull island
2001/02	Melville	Matheson Road/Dee Road Intersection - Install roundabout
2001/02	Melville	Carrington Street/Zenobia Street Intersection - Install roundabout
2000/01	Melville	South Street-Beasley Road Intersection - Install seagull island

2000/01	Melville	Leach Highway-Rome Road Intersection - Install seagull island
2000/01	Melville	Stock Road-Davis Road Intersection - Install roundabout
2000/01	Melville	Reynolds Road-Queens Road Intersection - Install roundabout and improve lighting
2000/01	Melville	Rome Road-McCoy Street Intersection - Install roundabout
2000/01	Melville	Canning Highway-Hislop Road Intersection - Install seagull island, relocate bus embayment
2000/01	Melville	North Lake Road-Garling Street Intersection - Install seagull island
2001/02	Mosman Park	Manning Street/Victoria Street Intersection - Install roundabout
2001/02	Nedlands	Brookdale St Construct 2.0M wide painted median with planted and paved median island (LG $20,000)
2001/02	Nedlands	Montgomery Ave Construct 2.0M wide painted median with planted and paved median island (LG $15,000)
2000/01	Nedlands	Smyth Road/Stirling Highway Intersection - Construct islands and install signs, no right turn
2001/02	Peppermint Grove	Johnson Street - Modify intersections and install median islands
2001/02	Perth	Adelaide Terrace/Hill Street Intersection - Modify traffic control signals and include pedestrian facilities
2001/02	Rockingham	Grange Drive/Gascoyne Way Intersection - Install roundabout
2001/02	South Perth	Manning Rd / Challenger Ave Install seagull island (LG $3,500)
2001/02	Stirling	Lawley Crescent/Beaufort Street Intersection - Install seagull island in Lawley Crescent
2001/02	Stirling	Weaponess / Ewen Modify roundabout approaches to reduce speed and improve intersection definition (LG - $30000)
2001/02	Stirling	Howe St / O'Malley St Install Traffic islands & double up Stop signs (LG - $30000)
2001/02	Subiaco	Rokeby Road/Heytsbury Road Intersection - Install nibs
2001/02	Swan	Bushmead / Wingate Construct Roundabout (LG - $26;667)
2001/02	Swan	Illawarra Crescent/Kingfisher Avenue - Install roundabout
2000/01	Swan	Bushmead Road/Stirling Cresent Intersection - Overlay with skid resistant material
2001/02	Victoria Park	Berwick Street/Basingall Street Intersection - Install right turn pockets and narrow Berwick Street to single lane in each direction
2001/02	Victoria Park	Forward St / Swansea St - adjustment
2001/02	Victoria Park	Burswood Road/Howick Street Drive Intersection - Install nibs and relocate holding line
2001/02	Victoria Park	Albany Highway/Gresham Street Intersection - Install nibs

2001/02	Victoria Park	Albany Highway/Temple Street Intersection - Install nibs
2001/02	Vincent	Stirling Street/Brisbane Street Intersection - Install roundabout
2001/02	Vincent	Oxford Street/Richmond Street Intersection - Install median islands and upgrade signs
2001/02	Vincent	Bulwer Street/Bulwer Avenue Intersection - Install traffic island
2001/02	Vincent	Egina Street/Berryman Street Intersection - Install roundabout and improve signage
2001/02	Vincent	Scarborough Beach Road/Egina Street Intersection - Realign intersection and install traffic islands
2001/02	Vincent	Lord Street/Windsor Street Intersection - Install median islands and improve signage
2001/02	Wanneroo	Evandale Road/Berkley Road Intersection - Install roundabout
2001/02	Wanneroo	Hainsworth Ave Install Seagull Island; LT lane; Roundabout; Skid Res (LG - $100000)
2001/02	Wanneroo	Beach Rd / Butterworth Ave Install LT Slip lanes (LG - $27333)
2001/02	Wanneroo	Butterworth Avenue - Install roundabout, traffic calming and non skid treatment
2001/02	Wanneroo	Marangaroo Drive/Highclere Boulevard Intersection - Install traffic control signals with ped phases
2001/02	Wanneroo	Quarkum Street/Elliot Road Intersection - Install roundabout and non skid treatment
2000/01	Wanneroo	Koondoola Avenue - Install roundabout, pedestrian refuge and traffic islands and painted medians
2000/01	Wanneroo	Blackmore Avenue - Install traffic islands, painted medians and signs
2000/01	Wanneroo	Mirrabooka Avenue/Aristos Way Intersection - Install left turn lane, signs and line marking
2000/01	Wanneroo	Marangaroo Drive/Giralt Road Intersection - Install left turn lane, upgrade signs and provide new skid-resistant surface
2000/01	Wanneroo	Amberton Road - Install traffic and pedestrian refuge islands and a roundabout
2000/01	Wanneroo	Church Road - Install traffic islands, pedestrian refuges, parking embayments and painted medians
2001/02	State road	Perth-Bunbury Highway-Construct slip lane
2001/02	State Road	Bunbury Highway/Phoenix Road Intersection –Replace existing heavy vehicle apron and install street lighting
2001/02	State Road	Bunbury Highway –Install street lighting at various intersections
2001/02	State Road	Tonkin Highway/Mills Road East Intersection-Remove right turn filter
2001/02	State Road	Leach Highway-Install street lighting
2001/02	State Road	Bunbury Highway/Winterfold Road Intersection –Replace existing Signal Ahead warning signs with Signal Ahead prepare to Stop warning signs and flashing amber signals

APPENDIX C Intersection Treatment Codes

Code	Treatment Type
K1	Roundabout
K2	New traffic signal (no turn arrows)
K3	New signal with turn arrows
K4	Remodel signal
K5	Grade separation
K6	Improve sight lines
K7	Street closure (one leg of cross)
K8	Street closure (close stem of Tee)
K9	Non-skid treatment
K10	Stagger cross intersection (right hand)
K11	Improve/reinforce priority signs (e.g. STOP)
K12	Ban right turns
K13	Ban left or U turns
K14	Improve lighting
K15	Traffic islands on approach
K16	Indented right island
K17	Painted turn lane
K18	Ban parking adjacent to intersection
K19	Extend median through intersection
K20	Reduce radius on left turn slip lane
K21	Protected left turn lane in crossing street
K22	Nibs
MR 1	Larger signal aspects
MR 2	Seagull island
MR 3	Left turn slip
MR 4	Mini roundabout
MR 5	Advanced warning flashing lights
MR 6	Acceleration lane
MR 11	High friction surfacing

Note: Table taken from MRWA Road Safety Section (Traffic and Safety Branch), June 2003

Road Section and Non-Intersection Treatment Codes

Code	Treatment Type
S1	Median on existing road
S2	Pedestrian refuge
S3	Pedestrian crossing
S4	Pedestrian overpass
S5	Pedestrian signals
S6	Pedestrian crossing lighting
S7	Improved route lighting
S8	Clearway, parking bans
S9	Indented RT island
S10	Painted turn lanes
S11	Roadside hazards-remove
S12	Roadside hazards-guard rail
S13	Non-skid surface
S14	Seal shoulder
S15	Advisory speed sign on curves
S16	Delineation
S17	Edgelines
S18	Reconstruct superelevation on curve
S19	Climbing lane (overtaking lane)
S20	Signs (rail crossing)
S21	Flashing lights (rail crossing)
S22	Barriers/gates (rail crossing)
S23	Bridge/overpass (rail crossing)
S24	Frangible posts, poles
MR 7	Shared path (new)
MR 8	Shared path (upgrade existing path)
MR 9	Tactile edgelines
MR 10	Raised pavement markers
MR11	High friction surfacing

Note: Table taken from MRWA Road Safety Section (Traffic and Safety Branch), June 2003

APPENDIX D CASUALTY CRASH REDUCTIONS

Area	No. of Sites	No. of Crashes before treatment	No. of Crashes after treatment	Pre – exposure data (months)	Post-exposure data	Estimate (β)	Standard Error	Probability 0<p<1	95% CI-Lower	95% CI Upper	Casualty Crash Reduction (%)**
Whole program	143	809	516	60	60	-0.449	0.031	0.001	-0.510	-0.389	36.2
All Metropolitan Sites	115	704	460	60	60	-0.425	0.033	0.001	-0.490	-0.360	34.6
All Rural Sites	28	105	56	60	60	-0.628	0.084	0.001	-0.793	-0.463	46.7
Broad Categories					60						
Intersection Treatments	121	679	432	60	60	-0.452	0.036	0.001	-0.524	-0.380	36.4
• Metro	100	626	406	60	60	-0.432	0.038	0.001	-0.508	-0.357	35.1
• Rural	21	53	26	60	60	-0.712	0.185	0.001	-1.076	-0.348	50.9
Road Section and Non Intersection Treatment	17	130	84	60	60	-0.436	0.042	0.001	-0.520	-0.353	35.4
• Metro	12	78	54	60	60	-0.367	0.041	0.001	-0.448	-0.287	30.8
• Rural	5	52	30	60	60	-0.550	0.131	0.001	-0.808	-0.291	42.3
					60						
All Roundabouts	44	186	70	60	60	-0.977	0.078	0.001	-1.130	-0.823	62.4
• Metro	32	164	62	60	60	-0.972	0.080	0.001	-1.130	-0.814	62.2
• Rural	12	22	8	60	60	-1.011	0.523	0.053	-2.037	0.014	63.6
Treatment Types					60						
Traffic control signals	7	88	50	60	60	-0.565	0.174	0.001	-0.906	-0.224	43.2
Non-skid treatment	10	108	59	60	60	-0.604	0.088	0.001	-0.777	-0.431	45.4
Traffic island on approach	9	28	13	60	60	-0.767	0.247	0.002	-1.252	-0.282	53.6
Seagull island	18	97	104	60	60	0.077	0.085	0.365	-0.090	0.245	-8.0*
Left turn slip	9	48	31	60	60	-0.496	0.115	0.001	-0.723	-0.269	39.1
Median on existing road	5	12	8	60	60	-0.405	0.288	0.159	-0.970	0.159	33.3*

Improved route lighting	3	77	30	60	22.33	-0.147	0.135	0.277	-0.412	0.118	13.7*
Area	**No. of Sites**	**No. of Crashes before treatment**	**No. of Crashes after treatment**	**Pre – exposure data**	**Post-exposure data**	**Estimate (β)**	**Standard Error**	**Probability 0<p<1**	**95% CI - Lower**	**95% CI Upper**	**Casualty Crash Reduction* (%)**
Treatment Types											
Nibs	6	24	9	60	60	-0.980	0.423	0.021	-1.811	-0.149	62.5
Improved route lighting	2	39	23	60	60	-0.528	0.236	0.025	-0.991	-0.064	41.0
All State Road Treatments	4	64	48	60	60	-0.287	0.083	0.001	-0.451	-0.123	25.0

- Negative casualty crash reductions indicates an increase
- Some T codes are a combination of several T codes. The T code used is based on the dominant treatment given at the site
- Reductions that are not statistically significant are indicated with an asterisk
- * *Includes fatality, hospitalisation, and injury crashes

APPENDIX E ALL CRASH REDUCTIONS

Area	No. of Sites	No. of Crashes before treatment	No. of Crashes after treatment	Pre exposure (months)	Mean post exposure (months)	Estimate (β)	Standard Error	Probability 0<p<1	95% CI - Lower	95% CI Upper	All Crash Reduction** (%)
Whole program	143	2888	2316	60	60	-0.221	0.010	0.001	-0.241	-0.199	19.8
All Metropolitan Sites	115	2418	2001	60	60	-0.189	0.011	0.001	-0.210	-0.167	17.3
All Rural Sites	28	470	315	60	60	-0.400	0.036	0.001	-0.470	-0.329	32.9
Broad Categories											
Intersection Treatments	125	2287	1846	60	60	-0.214	0.013	0.001	-0.239	-0.188	19.3
• Metro	102	2068	1696	60	60	-0.198	0.013	0.001	-0.224	-0.172	17.9
• Rural	23	219	150	60	60	-0.378	0.081	0.001	-0.537	-0.219	31.5
Road Section and Non Intersection Treatment	18	601	470	60	60	-0.245	0.018	0.001	-0.281	-0.209	21.8
• Metro	13	350	305	60	60	-0.137	0.145	0.001	-0.166	-0.109	12.8
• Rural	5	251	165	60	60	-0.419	0.083	0.001	-0.582	-0.256	34.3
All Roundabouts	44	648	430	60	60	-0.410	0.020	0.001	-0.450	-0.369	33.7
• Metro	32	535	375	60	60	-0.355	0.019	0.001	-0.392	-0.318	29.9
• Rural	12	113	55	60	60	-0.720	0.174	0.001	-1.061	-0.378	51.3
Treatment Types											
Traffic control signals	7	325	212	60	60	-0.427	0.783	0.001	-0.580	-0.273	34.7
Non-skid treatment	10	371	252	60	60	-0.386	0.030	0.001	-0.446	-0.327	32.1
Traffic island on approach	9	77	60	60	60	-0.249	0.090	0.006	-0.426	-0.072	22.1
Seagull island	18	334	382	60	60	0.132	0.024	0.001	0.085	0.179	-14.1
Left turn slip	9	183	157	60	60	-0.171	0.042	0.001	-0.255	-0.088	15.8
Median on existing road	5	85	58	60	60	-0.382	0.091	0.001	-0.560	-0.203	31.8

Area	No. of Sites	No. of Crashes before treatment	No. of Crashes after treatment	Pre exposure (months	Mean post exposure (months)	Estimate (β)	Standard Error	Probability 0<p<1	95% CI - Lower	95% CI Upper	All Crash Reduction** (%)
Treatment Types											
Nibs	6	85	55	60	60	-0.435	0.161	0.007	-0.752	-0.118	35.3
Improved route lighting	2	134	118	60	60	-0.127	0.005	0.001	-0.138	-0.115	11.9
All State Road Treatments	4	233	212	60	60	-0.094	0.023	0.001	-0.140	-0.047	9.0

- Negative crash reductions indicates an increase
- Some T codes are a combination of several T codes. The T code used is based on the dominant treatment given at the site

* Reductions that are not statistically significant are indicated with an asterisk

* *Includes all crashes –fatalities, hospitalisation, injuries and property damage only crashes

APPENDIX F ECONOMIC EVALUATION OF THE STATE BLACK SPOT PROGRAMS IN RELATION TO CASUALTY CRASH REDUCTION IN WESTERN AUSTRALIA

Area	Present Value of Treatment Costs and Operating/ Maintenance Costs	Present Value of Crash Cost Savings	Net Present Value	Benefit Cost Ratio
Whole program	10 822 034	36 527 326	25 705 292	3.4
All Metropolitan Sites	8 013 829	12 330 846	4 317 017	1.5
All Rural Sites	2 808 204	24 196 490	21 388 286	8.6
Treatment Types				
All Roundabouts	5 341 262	37 688 822	32 347 560	7.1
• Metro	4 032 496	23 603 601	19 571 103	5.9
• Rural	1 308 764	14 085 222	12 776 458	10 8
Improved route lighting	399 218	7 146 678	6 747 460	17.9
Traffic island on approach	496 367	5 253 986	4 757 619	10.6
Non-skid treatment	624 237	2 464 478	1 840 241	3.9
Left turn slip	442 089	-1 650 818	-2 092 907	-3.7
Median on existing road	356 872	-1 843 149	-2 200 021	-5.4
Traffic control signals	949 779	-4 722 779	-5 672 558	-5.0
Nibs (pedestrian facilities)	116 911	-1 047 156	-1 164 067	-9.0
State roads -all treatments	396 282	-3 287 184	-3 683 466	-8.3
Seagull island	593 458	-3 775 477	-4 368 905	-6.4

APPENDIX G SENSITIVITY ANALYSIS FOR THE ECONOMIC EVALUATION OF THE STATE BLACK SPOT PROGRAM IN RELATION TO CASUALTY CRASH REDUCTION ON WESTERN AUSTRALIA

Area	Present Value of Treatment Costs and Operating/ Maintenance Costs	Present Value of Crash Cost Savings	Net Present Value	Benefit Cost Ratio
CASUALTY CRASHES				
Base Case Discount rate, 5%; treatment life, 15years	10 822 034	36 527 326	25 705 292	3.4
Sensitivity Analysis				
Discount Rate				
• 3%	11 024 616	41 211 513	30 186 897	3.7
• 8	10 582 243	30 982 789	20 400 546	2.9
Treatment Life				
• 10 years	10 417 507	27 173 704	16 756 197	2.6
• 20 years	10 891 755	38 139 443	27 247 689	3.5

APPENDIX H CRASH REDUCTIONS BY SEVERITY

Area	Crash severity	No. of crashes before treatment	No. of crashes after treatment
Whole Program	Fatal	5	2
	Hospitalised	135	132
	Injured	669	382
	PDO major	1590	1392
	PDO minor	489	408
	Total	**2888**	**2316**
All Metropolitan Sites	Fatal	4	2
	Hospitalised	102	115
	Injured	598	343
	PDO major	1305	1189
	PDO minor	409	352
	Total	**2418**	**2001**
All Rural Sites	Fatal	1	0
	Hospitalised	33	17
	Injured	71	39
	PDO major	285	203
	PDO minor	80	56
	Total	**470**	**315**
Broad Categories			
Intersection Treatments	Fatal	3	2
	Hospitalised	110	103
	Injured	566	327
	PDO major	1242	1101
	PDO minor	366	313
	Total	**2287**	**1846**
• Metro	Fatal	3	2
	Hospitalised	90	98
	Injured	533	306
	PDO major	1110	1005
	PDO minor	332	285
	Total	**2068**	**1696**
• Rural	Fatal	0	0
	Hospitalised	20	5
	Injured	33	21
	PDO major	132	96
	PDO minor	34	28
	Total	**219**	**150**
Road Section and Non-Intersection Treatments	Fatal	2	0
	Hospitalised	25	29
	Injured	103	55
	PDO major	348	291
	PDO minor	123	95
	Total	**601**	**470**
• Metro	Fatal	1	0

	Hospitalised	12	17
	Injured	65	37
	PDO major	195	184
	PDO minor	77	67
	Total	**350**	**305**
• Rural	Fatal	1	0
	Hospitalised	13	12
	Injured	38	18
	PDO major	153	107
	PDO minor	46	28
	Total	**251**	**165**
All Roundabouts	Fatal	1	0
	Hospitalised	44	19
	Injured	141	51
	PDO major	362	261
	PDO minor	100	99
	Total	**648**	**430**
• Metro	Fatal	1	0
	Hospitalised	30	18
	Injured	133	44
	PDO major	287	227
	PDO minor	84	86
	Total	**535**	**375**
• Rural	Fatal	0	0
	Hospitalised	14	1
	Injured	8	7
	PDO major	75	34
	PDO minor	16	13
	Total	**113**	**55**
Treatment Types			
Traffic control signals	Fatal	0	0
	Hospitalised	11	19
	Injured	77	31
	PDO major	187	128
	PDO minor	50	34
	Total	**325**	**212**
Non-skid treatment	Fatal	0	1
	Hospitalised	16	12
	Injured	92	46
	PDO major	186	155
	PDO minor	77	38
	Total	**371**	**252**
Traffic island on approach	Fatal	0	0
	Hospitalised	7	3
	Injured	21	10
	PDO major	35	38
	PDO minor	14	9
	Total	**77**	**60**
Seagull island	Fatal	1	0

	Hospitalised	15	23
	Injured	81	81
	PDO major	182	225
	PDO minor	55	53
	Total	**334**	**382**
Left turn slip	Fatal	0	1
	Hospitalised	8	6
	Injured	40	24
	PDO major	100	91
	PDO minor	35	35
	Total	**183**	**157**
Median on existing road	Fatal	0	0
	Hospitalised	2	4
	Injured	10	4
	PDO major	58	38
	PDO minor	15	12
	Total	**85**	**58**
Nibs	Fatal	0	0
	Hospitalised	2	4
	Injured	22	5
	PDO major	50	37
	PDO minor	11	9
	Total	**85**	**55**
High friction surfacing	Fatal	0	0
	Hospitalised	8	10
	Injured	26	37
	PDO major	64	95
	PDO minor	20	19
	Total	**118**	**161**
Improved route lighting	Fatal	1	0
	Hospitalised	6	5
	Injured	32	18
	PDO major	70	65
	PDO minor	25	30
	Total	**134**	**118**
All State Road Treatments	Fatal	1	0
	Hospitalised	4	13
	Injured	59	35
	PDO major	121	125
	PDO minor	48	39
	Total	**233**	**212**