# An Evaluation of the State Black Spot Program in Western Australia, 2003-2004

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**Abstract**
This report presents the results of an evaluation of projects that were treated as part of the State Black Spot Program during 2003 to 2004 in Western Australia. The purpose of this report is to evaluate the effectiveness of the State 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 ninety-five hazardous locations were treated throughout Western Australia at a cost of $14.4 million (excluding maintenance and operating costs). These treated sites consisted of 138 intersections and 57 road sections and non-intersection sites. Of the total of 195 treated sites, 24 were State roads.

The results showed the State Program has been effective overall, reducing all reported crash frequencies by 11% and casualty crash frequencies by 29%. The estimated crash cost savings over the expected life of the treated sites were $43.3 million for all reported crashes of which 92% was attributable to the reduction in casualty crashes. This will result in an overall net cost savings to the community of $27.6 million ($24.1 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 2.8. 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, the relatively short post treatment crash exposure period (average 45 months) or the treatment may genuinely have had no effect on road safety.

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

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

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The report evaluated the effectiveness of the State 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. It is anticipated that the results will provide Main Roads Western Australia and other road safety organisations 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 11% and casualty crash frequencies by 29%. The reduction in the number of reported crashes were estimated to reduce crash costs by $43.3 million over the expected life of the treated sites, with 92% of this reduction attributable to a reduction in casualty crashes. After accounting for program costs of $15.7 million (including maintenance and operating costs), the net cost savings to the community from the Black Spot Program were estimated at $27.6 million. Expressed as a benefit cost ratio (BCR), the net economic worth of the State Black Spot Program across all treatment sites was 2.8. Sites treated in rural areas had a better rate of return than those in the metropolitan area, with a BCR of 6.8 compared with 1.3 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** | 15 673 732 | 43 261 563 | 27 587 831 | 2.8 |
| **All Metro Sites** | 11 425 188 | 14 760 624 | 3 335 436 | 1.3 |
| **All Rural Sites** | 4 248 544 | 28 909 874 | 24 661 330 | 6.8 |

**Treatment Type**

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

- **Roundabouts** - a 21% reduction in all crashes ($p<0.001$) and 47% reduction in casualty crashes ($p<0.001$).
- **Traffic island on approach -** a 29% reduction in all crashes ($p<0.001$) and a 39% reduction in casualty crashes ($p<0.001$).
- **Non-skid treatments** - a 7% reduction in all crashes ($p<0.001$) and a 33% reduction in casualty crashes ($p<0.001$).
- **Left turn slip -** a 15% reduction in all crashes ($p<0.001$) and a 43% reduction in casualty crashes ($p<0.001$).
- **Improved route lighting -** a 12% reduction in all crashes ($p<0.001$) and a 61% reduction in casualty crashes ($p<0.001$).

There was very strong evidence that the following specific treatment type was successful in reducing *all* reported crashes. It was:

- **Remodel signal** - a 20% reduction in all crashes ($p<0.001$).

Due to small sample sizes and/or short post treatment crash exposure there was no statistical evidence that "*seagull islands*" ($p=0.162$), "*seal shoulder*" ($p=0.658$), "*new traffic signal*" ($p=0.136$) and "*remodel signal*" ($p=0.236$) significantly reduced the frequency of casualty crashes. Further monitoring of these treatments is required.

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

Treatment types varied in their estimated rate of return, with roundabouts, traffic islands on approach, non-skid treatments, seagull islands, remodelled signals and improved route lighting showing a positive rate of return. Some 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 higher cost of a small increase in more serious crashes (i.e. those involving a fatality or hospitalisation) dominating the cost savings generated from the greater decrease in less serious crashes.

Limitations of the study include the lack of a suitable control treatment site and the fact that some treatment types may not have been used often enough to produce statistically significant effects or the exposure period post treatment was not long enough (recommended three to five years post treatment). The average length of post crash data for treated sites was 45 months however some sites only had a minimum of 25 months. 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 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.
- Supply more detailed information about the treatment provided at the nominated Black Spot to ensure it is allocated to the correct treatment type.
- It is imperative that accurate recording of the date the treatment was actually done and the finish date should be recorded and verified on the Black Spot nomination form.
- Collect information on traffic volumes at individual Black Spot sites for any subsequent analysis to determine whether any change in crash frequency is due to the treatment or changes in traffic volume.
- The use of control sites in future evaluation would be extremely beneficial to producing valid results.
- A more detailed investigation of the multiple effects that may be derived with the implementation of more than one crash countermeasure.
- Further in-depth monitoring of treatments such as "*remodel signal*", "*new traffic signal*" and "*seal shoulders*" that did not significantly reduce crash frequency due to small number of sites and/or short post treatment exposure period.
- Re-evaluate the 2003 to 2004 State Black Spot Program when five years of follow up post treatment crash data is available.

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

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# 1. INTRODUCTION

## 1.1 Aim

The aim of this study is to evaluate the effectiveness of projects treated under the State Black Spot Program during 2003 to 2004 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 Western Australia 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 quasi-experimental "*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 2003 to 2004. 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). The 2003-04 State Black Spot Program provided funding of $14.4 million for road safety related works on State and Local Government roads. All road classifications were eligible for funding which included existing Black Spots, black lengths and also potentially hazardous locations. Black Spots could be at an intersection, mid block or a short section of road. Black lengths were lengths of road greater than three kilometres with a proven crash history. Potentially hazardous locations with no significant crash history were selected on the basis of formal road safety audits however these treatments have not been included in the analysis. 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 Western Australia 2003):

- the installation of roundabouts at various intersections;
- realignment and improvement of the road geometry at intersections and selected road sections;
- improvements to road surface treatments such as anti-skid treatments; and
- traffic calming treatments and improvements to street lighting.

### 2.3 Data Collection

Information on each treated site was obtained from the Road Safety Section at Main Roads Western Australia. 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 Western Australia.

### 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 crash data and at least six months post treatment crash data (up to December 31, 2007) which excluded the construction period. Crash data which was used in the analysis 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 State Black Spot Treatment Site Data

Main Roads Western Australia 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 C was assigned to each treatment for use in the analysis. These codes are based on tables obtained from Main Roads Western Australia 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 types of treatment. 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 individual types of treatment the increase in sample size for the overall evaluation improved the accuracy of the analysis.

## 2.5 Factors that may Affect the State 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 and 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 five-years of pre treatment crash data and at least six months of post treatment crash data. If there was not six months of post crash data after treatment, the site was not included in the analysis. 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 see 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 Western Australia 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 Western Australia.

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 economic worth of the program was the road crash, with unit road crash costs expressed in 2003/04 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 the rate of crashes "*before*" and "*after*" treatment periods based on the total program, broad treatment categories (i.e. intersection treatments and non-intersection/road section treatments), 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 generalised estimating equation (GEE) Poisson regression model was used to evaluate the State 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 before and after 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 Dupont (2002) and Twisk (2003).

Information on traffic volumes over time at individual Black Spot sites is useful to determine whether any changes in crash history are due to a treatment at the Black Spot site or whether changes in traffic flow give rise to the observed discrepancies before and after 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. Sites with zero crashes were also excluded from the analysis.

The model was fitted to the data using the Stata (Version 10) statistical package.

### 2.7.2 Economic Analysis

Two indicators of the 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 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 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 –

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

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

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 summarised 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 which include the number of sites, the number of crashes before and after treatment and the average follow-up exposure crash data post treatment are detailed in Appendix D and Appendix E with the main findings summarised below.

## 3.1 Statistical Analysis

There were a total of 211 sites nominated for treatment as a Black Spot from 2003 to 2004. For this analysis a total of 16 sites were eliminated from the assessment. This was due to inaccuracies in start and finish dates and/or SLK numbers. The final sample of 195 treated sites consisted of 138 intersections and 57 road section or non-intersection sites. Of the total of 195 treated sites, 24 were State roads. The average length of follow up exposure crash data post treatment for all treated sites was 45 months with a minimum of 25 months and a maximum of 58 months.

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, $\beta$ 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 $\beta$ indicates that all reported Police crash rate (includes fatality, hospitalisation and injury crashes and PDO) and casualty crash rate decreased following treatment, and vice versa for a positive value for $\beta$. 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 State Black Spot Treatment Effect on All Crash Reduction in Western Australia, 2003 – 2004**

| Area | Estimate (β) | Standard Error | Probability 0<p<1 | All Crash Reduction ** (%) |
|---|---|---|---|---|
| **Whole program** | -0.114 | 0.007 | 0.001 | 10.8 |
| **All Metropolitan Sites** | -0.092 | 0.007 | 0.001 | 8.8 |
| **All Rural Sites** | -0.392 | 0.022 | 0.001 | 32.5 |
| **Broad Categories** | | | | |
| Intersection Treatments | -0.085 | 0.009 | 0.001 | 8.2 |
| • Metro | -0.077 | 0.009 | 0.001 | 7.5 |
| • Rural | -0.231 | 0.084 | 0.006 | 20.7 |
| Road Section and Non Intersection Treatment | -0.145 | 0.010 | 0.001 | 13.5 |
| • Metro | -0.110 | 0.012 | 0.001 | 10.4 |
| • Rural | -0.604 | 0.035 | 0.001 | 45.3 |
| **Treatment Types** | | | | |
| All Roundabouts | -0.235 | 0.040 | 0.001 | 20.9 |
| • Metro | -0.202 | 0.042 | 0.001 | 18.4 |
| • Rural | -0.489 | 0.157 | 0.002 | 38.7 |
| New traffic signal | -0.127 | 0.117 | 0.277 | 11.9* |
| Non-skid treatment | -0.078 | 0.022 | 0.001 | 7.5 |
| Traffic island on approach | -0.034 | 0.050 | 0.001 | 29.1 |
| Seagull island | -0.178 | 0.053 | 0.001 | 16.3 |
| Left turn slip | -0.166 | 0.036 | 0.001 | 15.3 |
| Remodel signal | -0.216 | 0.048 | 0.001 | 19.5 |
| Seal shoulder | 0.139 | 0.003 | 0.001 | -15.0 |
| Improved route lighting | -0.124 | 0.033 | 0.001 | 11.7 |
| All State Roads | -0.024 | 0.013 | 0.070 | 2.5 |

**Crash increase/reduction is not statistically significant*

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

**Table 3.2 State Black Spot Treatment Effect on Casualty Crash Reduction in Western Australia, 2003-2004**

| Area | Estimate (β) | Standard Error | Probability 0<p<1 | Casualty Crash Reduction** (%) |
|---|---|---|---|---|
| **Whole program** | -0.342 | 0.022 | 0.001 | 28.9 |
| **All Metropolitan Sites** | -0.309 | 0.025 | 0.001 | 26.6 |
| **All Rural Sites** | -0.547 | 0.050 | 0.001 | 42.2 |
| **Broad Categories** | | | | |
| Intersection Treatments | -0.359 | 0.025 | 0.001 | 30.1 |
| • Metro | -0.354 | 0.031 | 0.001 | 29.9 |
| • Rural | -0.421 | 0.050 | 0.001 | 34.3 |
| Road Section and Non Intersection Treatment | -0.320 | 0.039 | 0.001 | 27.4 |
| • Metro | -0.236 | 0.043 | 0.001 | 21.1 |
| • Rural | -0.837 | 0.096 | 0.001 | 56.7 |
| **Treatment Types** | | | | |
| All Roundabouts | -0.638 | 0.141 | 0.001 | 47.2 |
| • Metro | -0.606 | 0.148 | 0.001 | 45.5 |
| • Rural | -0.960 | 0.692 | 0.165 | 61.7* |
| Traffic island on approach | -0.499 | 0.144 | 0.001 | 39.3 |
| Non-skid treatment | -0.394 | 0.069 | 0.001 | 32.6 |
| Seagull island | -0.247 | 0.177 | 0.162 | 21.9* |
| Left turn slip | -0.566 | 0.124 | 0.001 | 43.3 |
| New traffic signal | -0.419 | 0.281 | 0.136 | 34.3* |
| Remodel signal | -0.225 | 0.190 | 0.236 | 20.2* |
| Seal shoulder | -0.147 | 0.332 | 0.658 | 13.7* |
| Improved route lighting | -0.951 | 0.165 | 0.001 | 61.4 |
| All State Roads | -0.240 | 0.039 | 0.001 | 21.4 |

**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 11% ($p<0.001$) for all crashes (see Table 3.1) and a very strong reduction of 29% ($p<0.001$) 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 138 sites which received a treatment at an **intersection**. There was very strong evidence of an 8% reduction in the number for all crashes ($p<0.001$) and a 30% reduction in casualty crashes ($p<0.001$). The most frequently used treatments at an intersection for this evaluation were: roundabouts (n=33), traffic island on approach (n=31), left turn slip (n=15), seagull island (n=12), and non-skid treatments (n=11).

There was very strong evidence of a 14% reduction ($p<0.001$) in all crashes for the fifty-seven **road section treatment and non-intersection sites** and very strong evidence of a 27% reduction ($p<0.001$) for casualty crashes. The most frequently used treatments at road sections and non-intersection sites were: seal shoulder (n=5) and improved route lighting (n=3).

### 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. They were:

- **Roundabouts** - a 21% reduction in all crashes ($p<0.001$) and 47% reduction in casualty crashes ($p<0.001$).
- **Traffic island on approach -** a 29% reduction in all crashes ($p<0.001$) and a 39% reduction in casualty crashes ($p<0.001$).
- **Non-skid treatments** - a 7% reduction in all crashes ($p<0.001$) and a 33% reduction in casualty crashes ($p<0.001$).

- **Left turn slip -** a 15% reduction in all crashes ($p<0.001$) and a 43% reduction in casualty crashes ($p<0.001$).
- **Improved route lighting -** a 12% reduction in all crashes ($p<0.001$) and a 61% reduction in casualty crashes ($p<0.001$).

There was very strong evidence that the following specific treatment type was successful in reducing all reported crashes. It was:

- **Remodel signal** - a 20% reduction in all crashes ($p<0.001$)

There was no statistical evidence that "*seagull islands*" ($p=0.162$), "*seal shoulder*" ($p=0.658$), "*new traffic signal*" ($p=0.136$) and "*remodel signal*" ($p=0.236$) could affect the frequency of casualty crashes (see Table 3.1 and Table 3.2). However, "*seal shoulder*" ($p<0.001$) significantly increased the frequency of all crashes (see Table 3.1 and Table 3.2).

### 3.1.3 Analysis by Location

There were a total of 155 treatment sites in the metropolitan area. Overall, these treatments showed a very significant 9% ($p<0.001$) reduction for all reported crashes and a 27% ($p<0.001$) reduction for casualty crashes.

There were a total of 40 sites treated in rural areas. There was strong evidence of a 33% reduction ($p<0.001$) for all reported crashes and a 42% reduction ($p<0.001$) for casualty crashes.

A breakdown of broad treatment categories by location found:

- an 8% reduction ($p<0.001$) for all reported crashes and a reduction of 30% ($p<0.001$) for casualty crashes in the **metropolitan area** for **intersection** treatments.
- a 21% reduction for all reported crashes ($p<0.001$) and a 34% reduction for casualty crashes ($p<0.001$) in **rural areas** for **intersection** treatments.
- an 11% reduction ($p<0.001$) for all crashes and a 21% reduction for casualty crashes ($p<0.001$) in the **metropolitan area** for **road section and non-intersection** treatments.

- a 45% reduction ($p<0.001$) for all crashes and a 57% reduction for casualty crashes ($p<0.001$) for **road section and non-intersection** treatments 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 18% for all crashes ($p<0.001$) and a 46% reduction for casualty crashes ($p<0.001$) were reported in metropolitan Perth. In the rural areas a significant reduction of 39% for all crashes ($p<0.01$) and a 62% reduction for casualty crashes albeit statistically insignificance ($p=0.165$) was noted.

**State roads** also showed a very significant reduction of 3% for all crashes and a 21% reduction for casualty crashes ($p<0.001$).

## 3.2 Economic Evaluation of the State Black Spot Program

Table 3.3 presents the results of the economic evaluation of the Black Spot Program in terms of its reduction in all reported crashes. Appendix F shows the economic worth of the Program in terms of the reduction in casualty crashes only. The estimated crash cost savings over the expected life of the treatments were $43.3 million for all reported crashes, of which 92% were attributable to a reduction in casualty crashes. This will result in an overall net cost saving to the community over the expected life of the treated sites of $27.6 million ($24.1 million attributable to casualty crashes) after subtracting the capital costs of installing treatments and the maintenance and operating costs. The BCR across all treatment sites was estimated to be 2.8, which indicates benefits in the form of cost savings to the community of $2.80 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 6.8 compared with 1.3 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, traffic islands on approach, non-skid treatments, seagull islands, remodelled signals and improved route lighting. 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 sometimes increasing. With only relatively few sites for some treatment types, the occurrence of a fatality or hospitalisations tends to dominate post-treatment crash costs.

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 $32.9 million and the BCR to 3.1. An expected treatment life of 20 years increased the NPV to $36.2 million and the BCR to 3.3.

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

| Area | PV of Total Costs ($) | PV of Crash Cost Savings ($) | NPV ($) | BCR |
|---|---|---|---|---|
| **Whole program** | 15 673 732 | 43 261 563 | 27 587 831 | 2.8 |
| **All Metropolitan Sites** | 11 425 188 | 14 760 624 | 3 335 436 | 1.3 |
| **All Rural Sites** | 4 248 544 | 28 909 874 | 24 661 330 | 6.8 |
| **Broad Categories** | | | | |
| Intersection Treatments | 12 280 495 | 23 728 378 | 11 447 883 | 1.9 |
| Road Section and Non Intersection Treatment | 3 393 238 | 22 461 438 | 19 068 200 | 6.6 |
| **Treatment Types** | | | | |
| All Roundabouts | 3 384 343 | 13 266 286 | 9 881 943 | 3.9 |
| Traffic island on approach | 661 611 | 10 485 444 | 9 823 833 | 15.8 |
| Non-skid treatment | 613 586 | 1 084 019 | 470 433 | 1.8 |
| Seagull island | 321 944 | 5 557 832 | 5 235 888 | 17.3 |
| Left turn slip | 892 026 | -1 833 018 | -2 725 044 | -2.1 |
| New traffic signal | 1 448 163 | -6 885 249 | -8 333 412 | -4.8 |
| Remodel signal | 284 999 | 946 380 | 661 381 | 3.3 |
| Seal shoulder | 415 002 | -7 684 303 | -8 099 305 | -18.5 |
| Improved route lighting | 32 460 | 6 506 055 | 6 473 595 | 200.4 |
| All State Roads | 5 496 363 | -2 243 609 | -7 739 972 | -0.4 |

Note that figures do not add up due to rounding.

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

| Area | PV of Total Costs ($) | PV of Crash Cost Savings ($) | NPV ($) | BCR |
|---|---|---|---|---|
| **Base case**<br>Discount rate 5%<br>Treatment life 15 yrs | 15 673 732 | 43 261 563 | 27 587 831 | 2.8 |
| **Sensitivity analysis** | | | | |
| **Discount rate** | | | | |
| • 3% (15 years) | 15 867 777 | 48 809 332 | 32 941 555 | 3.1 |
| • 8% (15 years) | 15 447 362 | 36 694 824 | 21 247 462 | 2.4 |
| **Treatment life** | | | | |
| • 10 years (5%) | 15 342 831 | 32 183 491 | 16 840 660 | 2.1 |
| • 20 years (5%) | 15 746 840 | 51 941 265 | 36 194 425 | 3.3 |

# 4. DISCUSSION

This report presented the preliminary results of the evaluation of State Black Spot projects treated in Western Australia from 2003 to 2004 in terms of its effectiveness in reducing the frequency for all reported crashes, casualty crashes and costs. The analysis found the program to be effective overall in reducing the frequency of all reported crashes (11%) and casualty crashes (29%) at all treated sites under the Black Spot Program.

In designing the evaluation a number of decisions were made regarding the analysis. It was decided to examine the effects of Black Spot treatments on all crashes (including PDO) and also on casualty crashes only. The alternative to this would be to study treatment effect on 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 Western Australia's threshold criteria which enabled application of funds to a wider range of projects at hazardous situations based on the total number of crashes at a particular site which varied between locations, region and road type.

The evaluation of the Program identified specific treatment types such as roundabouts that were highly successful in reducing **all reported** 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 island on approach*", "*non-skid treatments*", "*left turn slip*", and "*improved route lighting*". However, the analysis yielded inconclusive results in terms of **casualty** crash reduction for treatment such as "*new traffic signal*", "*seagull islands*" "*remode*l *signal*" and "*seal shoulder*". 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

say. Second, traffic flow may have changed at some of the treated sites over the study period; however it was not possible to measure this effect in the evaluation. It is well known that traffic volume has risen at least 16% from 2001 to 2006 (Meuleners, 2006). This increase in traffic volume could have impacted on the number of before and after crashes if it had been controlled for in the analysis. Third, some treatment types may not have been used often enough to produce statistically significant effects in the short time available such as "*seal shoulder*" (n=5), "*remodel signal*" (n=5) and "*new traffic signals*" (n=6). The exposure period post treatment for these sites was 35 months, 45 months and 41 months respectively. Small sample sizes or inadequate exposure time post treatment may produce statistically insignificant or misleading results even if the treatments are working well. In the case of "*seagull islands*" the previous results of the 2000 to 2002 State Black Spot evaluation also found that seagull islands did not significantly reduce all crash or casualty crash frequency. This is despite an adequate sample size of 18 sites from the 2000 to 2002 evaluation and 12 sites from the 2003 to 2004 evaluation. In fact, seagull islands increased both types of crashes, though these results were insignificant for casualty crashes.

It must also be noted that this evaluation demonstrated the Black Spot Program was effective for reducing the frequency of crashes at intersection sites as well as road section and non-intersection sites even though the treatments 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 $27.6 million and 2.8 respectively. Treatment types varied in their estimated rate of return, with roundabouts, traffic islands on approach, non-skid treatments, seagull islands, remodelled signals and improved route lighting showing a positive rate of return. Some 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 higher cost of a small increase in more serious crashes dominating the cost savings generated from the greater decrease in 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 11% and is estimated to reduce crash costs by $43.3 million over the expected life of the treated sites. After accounting for project costs of $15.7 million (including maintenance and operating costs), the net cost savings to the community from the Black Spot Program were estimated as $27.6 million. This is the equivalent of a BCR of 2.8.

Obtaining accurate information related to treated sites, particularly in relation to costs of treatments and accurate treatment start and finish dates 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 nor the after treatment period overlaps the construction period otherwise the analysis is invalid. Uncertainties about dates meant that some potentially useful data was not used. Also poor definitions of road environment countermeasures made it difficult to determine what was actually done at the treated site. Given some of the difficulties experienced in the current study particularly in relation to accurate treatment start and finish dates it is recommended that a comprehensive and systematic method of data collection be introduced and maintained with regular rigorous quality control checks to facilitate future Black Spot Program evaluations.

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.
- Supply more detailed information about the treatment provided at the nominated Black Spot to ensure it is allocated to the correct treatment type.
- It is imperative that accurate recording of the date the treatment was actually done and the finish date should be recorded and verified on the Black Spot nomination form.

- Collect information on traffic volumes at individual Black Spot sites for any subsequent analysis to determine whether any change in crash frequency is due to the treatment or changes in traffic volume.
- The use of control sites in future evaluation would be extremely beneficial to producing valid results.
- A more detailed investigation of the multiple effects that may be derived with the implementation of more than one crash countermeasure.
- Further in-depth monitoring of treatments such as "*remodel signal*", "*new traffic signal*" and "*seal shoulders*" that did not significantly reduce crash frequency due to small number of sites and/or short post treatment exposure period.
- Re-evaluate the 2003 to 2004 State Black Spot Program when five years of follow up post treatment crash data is available.

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<br>***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<br>***Allocation*** | $ 4.982 annually | $ 7.5M annually | $11.25M annually (Including LGs contribution) |
| Distribution<br>***Metro***<br>***Rural*** | 50%<br>50% | 50%<br>50% | 50%<br>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***<br>***Project Max Cost*** | ≥ $ 2 000<br>≤ $ 750 000 | ≥ $ 2 000<br>≤ $ 1 000 000 | ≥ $ 2 000<br>≤ $ 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.<br><br>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,<br><br>or<br><br>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<br>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 STATE BLACK SPOT TREATMENT SITES

| PROGRAM YEAR | PROJECT OWNER / LG | PROJECT |
|---|---|---|
| 2002 | ALBANY | Lockyer Avenue/ Prior Street/ Minna Street Intersection - install roundabout and splitter islands with pedestrian access |
| 2002 | ESPERANCE | Esperance Road/ Dempster Road/ Norseman Road Intersections -lengthen existing left turn pocket/install signs and pavement markings and intersection lighting |
| 2002 | ESPERANCE | Norseman Road/ Goldfields Road Intersection - Install slip lanes |
| 2002 | ARMADALE | Westfield Road - Upgrade existing street lighting |
| 2002 | BAYSWATER | Broun Avenue/ Drake Street Intersection - Install high skid resistant asphalt surface |
| 2002 | BELMONT | Belmont Avenue/ Keane Street Intersection - Install roundabout |
| 2002 | CAMBRIDGE | Grantham Street/ Nanson Street Intersection - Install median |
| 2002 | CAMBRIDGE | Oceanic Drive/ Alderbury Street Intersection - Realign intersection to "T" junction |
| 2002 | CANNING | Rostrata Avenue/ Glenmoy Avenue Intersection - Install median and install bike lane |
| 2002 | CANNING | High Road/Y ampi Way Intersection - Install traffic island |
| 2002 | CANNING | High Road/ Meadowbrook Drive Intersection - Install traffic island |
| 2002 | CANNING | High Road/ Duff Road Intersection - Install seagull island |
| 2002 | CANNING | Manning Road/ Dumond Street/Ellis Street Intersection - Install traffic island |
| 2002 | CANNING | Manning Road/ Braibrise Road Intersection - Install traffic island |
| 2002 | CANNING | Nicholson Road/ Lynwood Avenue Intersection - Install traffic island |
| 2002 | GOSNELLS | Eileen Street/ Eudoria Street Intersection - Install roundabout |
| 2002 | GOSNELLS | Ranford Road / Southern River Road Intersection - Install left turn slip lane |
| 2002 | KWINANA | Gilmore Avenue/ Fielman Drive Intersection - Install left turn slip lane and passing lane |
| 2002 | KWINANA | Gilmore Avenue/ Sloan Drive Intersection - Install left turn slip lane and passing lane |
| 2002 | MELVILLE | Preston Point Road/ Waddell Road Intersection - Install traffic island |
| 2002 | MELVILLE | Sommerville Boulevard/ Prescott Drive Intersection - Install roundabout |
| 2002 | MUNDARING | Old Northam Road/ Ash Road Intersection - Install roundabout |
| 2002 | NEDLANDS | Selby / Lemnos Turn Pockets Install Left Slip Lane |
| 2002 | ROCKINGHAM | Rae Road/ Acapulco Road Intersection - Install channelisation and formalise overtaking lane |
| 2002 | ROCKINGHAM | Penguin Road/ Waimea Road Intersection - Channelise intersection |

| | | |
|---|---|---|
| 2002 | ROCKINGHAM | Read street/ Investigator Drive Intersection - Install median seagull island |
| 2002 | SOUTH PERTH | Mill Point Road/ Coode Street Intersection - Modify traffic control signals and add right turn arrow |
| 2002 | SWAN | Clayton Street/ Robinson Road/ Clayton Street Off Ramp Intersection - Reduce left turn radius, relocate signs restricting sight lines, improve alignment and reduce width of roadway |
| 2002 | SWAN | Beach Road/ Bonner Drive Intersection - Install seagull island and relocate left turn slip lane |
| 2002 | VICTORIA PARK | Berwick Street/ Mackie Street Intersection - Install seagull island to restrict right turn |
| 2002 | PERTH | Adelaide Terrace/ Hill Street Intersection - Modify traffic control signals and include pedestrian facilities |
| 2002 | ROCKINGHAM | Parkin Street/ Bell Street Intersection -Install channelisation |
| 2002 | VICTORIA PARK | Albany Highway/ Mackie Street Intersection - Install parking nibs |
| 2002 | VICTORIA PARK | Hordern St / McMillan St Intersection - Install Traffic Calming Devices |
| 2002 | MELVILLE | Murdoch Dr / Grave Pass Intersection - Install Seagull Island |
| 2002 | SWAN | Meadow St / Swan St Intersection - Improve Roundabout Angles and Resurface intersection |
| 2002 | VICTORIA PARK | Oats Street/ Swansea Street Intersection - Install right turn pocket and anti skid treatment |
| 2003 | ALBANY | North Rd/ Barnesby Drive Intersection - Install side seagull, extend median and install stop sign |
| 2003 | ALBANY | Angrove Rd / Hardie Rd Intersection - Install slip lane |
| 2003 | BRIDGETOWN-GREENBUSHES | Winnijup Rd - Widen the pavement, remove trees, prune vegetation and seal the shoulders |
| 2003 | BUNBURY | Blair St/ Rose St Intersection - Construct left turn slip lane and a median seagull island. Relocate power pole |
| 2003 | BUNBURY | Sandridge Rd/ Denning Rd Intersection - Install median seagull island and centre island |
| 2003 | BUNBURY | Hayes St - Improve street lighting, pedestrian treatment and parking embayment |
| 2003 | BUNBURY | Bussell Hwy / Timperley Rd Intersection - Widen pavement, painted lane marking |
| 2003 | BUSSELTON | Queen St / Duchess St Intersection - Install roundabout |
| 2003 | BUSSELTON | Kent St / Cammilleri St Intersection - Install Roundabout |
| 2003 | BUSSELTON | West St/ Duchess St Intersection - Install Roundabout |
| 2003 | COLLIE | Atkinson St - Non skid treatment |
| 2003 | DARDANUP | Harris Rd - Construct and seal shoulders, remove/prune trees and reinforce advisory signs |
| 2003 | DARDANUP | Pratt Rd - Construct and seal shoulders |
| 2003 | DONNYBROOK-BALINGUP | Upper Capel Rd - Cut crest, widen seal widen gravel shoulders |
| 2003 | HARVEY | Mornington Rd – Reseal road |
| 2003 | MANDURAH | Lakes Rd / Minilya Parkway Intersection - Install traffic islands, right turn lane, widen pavement, left turn lane |
| 2003 | MANDURAH | Pinjarra Rd / Randell St Intersection - Install upgraded and extra street lighting |
| 2003 | MANDURAH | Pinjarra Rd / France St Intersection - Install and upgrade street lighting |

| | | |
|---|---|---|
| 2003 | MANJIMUP | Perup Rd - Construct and seal shoulders, clear road side vegetation and install advisory signs |
| 2003 | MURRAY | North Yunderup Rd - Pavement improvements, advanced warning and line marking |
| 2003 | MURRAY | South Yunderup Rd - Pavement improvements-alignment, widen realign bridge, line marking and improve street lighting |
| 2003 | GERALDTON | Phelps St / George Rd Intersection - Increase the turning radius in the corner of the intersection |
| 2003 | KALGOORLIE-BOULDER | Roberts St / Lane St Intersection - Improve sight lines, nibs, median islands |
| 2003 | KALGOORLIE-BOULDER | Johnson St/ Lionel St Intersection - Install Roundabouts |
| 2003 | KALGOORLIE-BOULDER | Boulder Rd / Cheetham St Intersection - Improve sight lines, nibs, median islands |
| 2003 | BROOME | Wallcott St / Saville St Intersection - Install traffic islands, improve signage, line marking |
| 2003 | BROOME | Herbert St/ Robert St Intersection – Install traffic islands, Improve signage, line marking |
| 2003 | ARMADALE | Church Avenue / Seventh Rd / Avonlee Rd Intersections - Install roundabout |
| 2003 | ARMADALE | Eleventh Rd / Rowley Rd Intersection - Install roundabout |
| 2003 | ARMADALE | Holden Rd / Raeburn Rd Intersection - Install a roundabout |
| 2003 | ARMADALE | Lake Rd/ Cammillo Rd Intersection - Install a roundabout |
| 2003 | BELMONT | Abernethy Rd/ Alexander Rd Intersection - Modify traffic signals |
| 2003 | BELMONT | Abernethy Rd / Wright St Intersection – Modify traffic signals |
| 2003 | BELMONT | Alexander Rd / Belmont Avenue Intersection - Modify traffic signals |
| 2003 | CAMBRIDGE | Cambridge St / Birkdale St Intersection - Installation of centre median and narrowing the road to one lane |
| 2003 | CAMBRIDGE | Cambridge St / Marlow St Intersection - Installation of a median |
| 2003 | CAMBRIDGE | Grantham St and Lake Monger Drive/ Gregory St Intersection - Installation of median |
| 2003 | CANNING | Chapman Rd/ Walpole St Intersection - Install Roundabout |
| 2003 | CANNING | Chapman Rd/ Queen St Intersection - Install traffic island, reinforce priority signs |
| 2003 | CANNING | Vahland Avenue/ Lynton Rd Intersection - Construct left turn pocket and install seagull island |
| 2003 | CANNING | Collins Rd / Rostrata Avenue Intersection - Install roundabout |
| 2003 | CANNING | Grose Avenue/ Carousel Rd Intersection - Install roundabout |
| 2003 | CANNING | Pinetree Gully Rd / Apsley Rd to South St - Install medians along road |
| 2003 | CANNING | Pinetree Gully Rd / Agincourt Drive Intersection - Install traffic island, reinforce priority signs |
| 2003 | CLAREMONT | Stirling Rd / Shenton Rd Intersection - Removal of large rock, installation of approach islands |
| 2003 | CLAREMONT | Princess Rd / Goldsworthy Rd Intersection - Reinforcement of stop signs with id islands and anti skid colour treatment |
| 2003 | CLAREMONT | Shenton Rd / Servetus St Intersection - Improvement of existing island and anti-skid treatment. |
| 2003 | CLAREMONT | Shenton Rd / Davies Rd Intersection - Installation of approach islands |

| | | |
|---|---|---|
| 2003 | CLAREMONT | Shenton Rd / Graylands Rd Intersection - Install approach islands |
| 2003 | COCKBURN | North Lake Rd / Berrigan Drive Intersection - Realigning intersection, install islands and non skid treatment |
| 2003 | COCKBURN | Rockingham Rd / Newton St Intersection - Install islands and stop line |
| 2003 | COCKBURN | Rockingham Rd / Barrington St Intersection - Install traffic signals |
| 2003 | FREMANTLE | South Terrace / Lefroy Rd Intersection - Kerb extensions to improve sight lines |
| 2003 | FREMANTLE | Parry St / Ellen St Intersection - Krab and median extensions and improve alignment |
| 2003 | GOSNELLS | Nicholson Rd / Langford Avenue Intersection - Install left turn slip lane |
| 2003 | GOSNELLS | Spencer Rd / Burslem Drive Intersection - Extend right turn lanes and non skid treatment |
| 2003 | GOSNELLS | Spencer Rd / Langford Avenue Intersection - Extend left turn slip lane |
| 2003 | GOSNELLS | Spencer Rd - Install pedestrian refuge island, improvements to cycle path, upgrade street lighting |
| 2003 | GOSNELLS | Belmont Rd / Davison St Intersection - Left turn slip lane |
| 2003 | GOSNELLS | Albany Hwy / Gosnells Rd West Intersection - Install spilter island |
| 2003 | GOSNELLS | Warton Rd / Moss St Intersection - Left turn lane and ban U turns |
| 2003 | GOSNELLS | Warton Rd / Amherst Rd Intersection - Install traffic signals |
| 2003 | GOSNELLS | Warton Rd - Install sealed shoulders with delineation and apply non skid treatment |
| 2003 | JOONDALUP | Warick Rd / Davallia Rd Intersection - Install left turn slip lane (Davallia Road) and modify median seagull |
| 2003 | JOONDALUP | Ocean Reef Rd / Poseidon Rd Intersection - Modify existing left turn slip lane and install median seagull |
| 2003 | JOONDALUP | Moore Drive / Candlewood Boulevard Intersection - Install intended (protected) right turn and modify left turn slip lane |
| 2003 | ARMADALE | Nicholson Rd/ Warton Rd Intersection - Install roundabout |
| 2003 | BAYSWATER | Broun Avenue / Johnsmith St Intersection - Provide high skid resistance asphalt surface |
| 2003 | KALAMUNDA | Kalamunda Rd / Newburn Rd Intersection - Install a roundabout |
| 2003 | KALAMUNDA | Hale Rd / Dawson Avenue Intersection - Install Roundabout |
| 2003 | KALAMUNDA | Lesmurdie Rd - Rectify cross fall and superelevation problems, install central median, install painted edge lines, install raised pavement markers, improve drainage and install SMA |
| 2003 | CANNING | Metcalfe Rd / Nicholson Rd to High Rd - Install median, bike line and non skid treatment |
| 2003 | MELVILLE | Riseley St / Macleod St Intersection - Install median islands on approach |
| 2003 | MELVILLE | North Lake Rd / Davey St Intersection - Install traffic island on approach with stop sign |
| 2003 | MELVILLE | Marmion St / Redwood Crescent Intersection - Install traffic island on approach with stop sign |
| 2003 | MELVILLE | Carrington Rd / Elvira St Intersection - Install traffic island on approach with stop sign |
| 2003 | GOSNELLS | Kelvin Rd / Bickley Rd Intersection - Install Roundabout |
| 2003 | MELVILLE | Preston Point Rd / Fifth St Intersection - Install median islands on approach |
| 2003 | MELVILLE | Winthorp Drive / Aitken Drive Intersection - Install a roundabout |

| | | |
|---|---|---|
| 2003 | MELVILLE | Justinian St / Solomon St Intersection - Install median islands on approach |
| 2003 | MELVILLE | Baal St / Elvira St Intersection - Install median islands on approach |
| 2003 | ROCKINGHAM | Warnbro Sound Avenue / The Avenue Intersection - Install traffic island and double up regulatory signage |
| 2003 | MELVILLE | Parry Avenue / Camm Avenue Intersection - Upgrade existing lighting |
| 2003 | MUNDARING | Helena Valley Rd / Scott St Intersection - Install intended right turn island and install left turn slip lane |
| 2003 | SOUTH PERTH | Mill Point Rd / Douglas Avenue Intersection - Install traffic control signals |
| 2003 | NEDLANDS | Alfred Rd / Ashton Avenue Intersection - Install Medians and provide nibs |
| 2003 | NEDLANDS | Vincent St / Melvista Avenue Intersection - Install roundabout |
| 2003 | WANNEROO | Mirrabooka Avenue / Montrose Avenue and Koondoola Avenue Intersection - Provide a two lane approach with splitter islands. Modify the central rotary island to provide for a circular travel path. |
| 2003 | NEDLANDS | EdwaRd St / Florence Rd Intersection - Install two median islands |
| 2003 | MELVILLE | Cranford Avenue/ Moolyeen Rd Intersection - Install roundabout |
| 2003 | MELVILLE | Camm Avenue / Ewing Avenue Intersection - Install a roundabout at the intersection |
| 2003 | PERTH | Bennett St / Goderich St Intersection - Installation of new traffic signals |
| 2003 | ROCKINGHAM | Council Avenue / Hefron St Intersection - Realign and install traffic signals |
| 2003 | SOUTH PERTH | Manning Rd / Canavan Cresent Intersection - Install seagull island |
| 2003 | SOUTH PERTH | Manning Rd / Davilak St Intersection - Extend median island through intersection |
| 2003 | SOUTH PERTH | Henley St / Bruce St Intersection - Install a roundabout |
| 2003 | STIRLING | Jon Sanders Drive / Selby St Intersection - Indented left turn and install non skid treatment for northern approach. Clear vegetation |
| 2003 | STIRLING | Mirrabooka Avenue / Yirrigan Drive Intersection - Install non skid treatment |
| 2003 | STIRLING | Yirrigan Drive / Northwood Drive Intersection - Install non skid treatment. Modify the left slip lane |
| 2003 | SUBIACO | Heytesbury Rd/ Hensman Rd Intersection - 4 way islands |
| 2003 | MELVILLE | Bull Creek Drive/ Fyfe Circle Intersection - Install median islands on approach |
| 2003 | SUBIACO | Salvado Rd/ Old Jacaranda Way Intersection - Reduce width of incoming eastern leg |
| 2003 | SWAN | Morley Drive East / Altone Rd Intersection - Install seagull and left turn slip lane |
| 2003 | SWAN | Illawarra Cresent/ Shearwater Terrace Intersection - Install a roundabout |
| 2003 | VICTORIA PARK | Basinghall St / Moorgate St Intersection - Install kerb extension |
| 2003 | VICTORIA PARK | Albany Hwy / Welshpool Rd and Alday St - Reduce the lane width |
| 2003 | VICTORIA PARK | Albany Hwy / Oats St to Somerset St - Reduce the lane width |
| 2003 | VICTORIA PARK | Albany Hwy / Westminister St to Basingal St - Construct nibs |

| | | |
|---|---|---|
| 2003 | VINCENT | Walcott St / Curtis Parade Intersection - Install half seagull |
| 2003 | WANNEROO | Lenore Rd / Elliot Rd Intersection - The installation of a roundabout |
| 2003 | WANNEROO | Prindiville Drive - install a red asphalt |
| 2003 | WANNEROO | Wanneroo Rd / Prindiville Drive Intersection - Installation of anti-skid surface and a right turn lane |
| 2003 | WANNEROO | Ocean Reef Rd / Lenore Rd Intersection - The provision of the right turn slip lane and a left turn slip lane |
| 2003 | WANNEROO | Marangaroo Drive / Girrawheen Avenue Intersection - Installation of a left turn lane |
| 2004 | COOLGARDIE | CoolgaRdie North Rd - Widen and construct drainage protection and floodways, erect warning signs. |
| 2004 | KALGOORLIE-BOULDER | Gatacre St / Great Eastern Hwy Intersection - Install traffic signals |
| 2004 | HALLS CREEK | Hall St / Thomas St Intersection - Construct retaining wall, sealed bus bays, dual use footpath, pedestrian nibs, linemarking. |
| 2004 | CAMBRIDGE | The Boulevard / Birddale St/ Bourniville St Intersection - Partial closure of northern leg of intersection |
| 2004 | COCKBURN | Miguel Rd / Barrington St Intersection - Install roundabout and non-skid treatment. |
| 2004 | COTTESLOE | Curtin Ave / Forrest St Intersection - Close driveway to railway station, upgrade central island |
| 2004 | FREMANTLE | South Tce / Wray Ave Intersection - Kerb extensions |
| 2004 | CANNING | Riverton Drive / Bull Creek Rd - Park Beach Close Intersection - Install edgeline and construct parking embayment |
| 2004 | JOONDALUP | Hepburn Ave / Kingsley Dr Intersection - Non-skid treatment. |
| 2004 | KWINANA | Gilmore Ave / Chisham Av Intersection - Modify signals, skid resistant asphalt, modifying right turn pockets |
| 2004 | KWINANA | Bertram/ Mortimer / Johnson Rd Intersection - Improve sight lines, install skid resistant material, improve delineation of roundabout, installation of solar powered raised pavement markers, improvement of street lighting |
| 2004 | MELVILLE | Rome Rd / Kitchener Rd Intersection - Improve lighting |
| 2004 | MELVILLE | Reynolds Rd / Bombard St Intersection - Reinforce priority and traffic islands |
| 2004 | MELVILLE | Macleod Rd / Macrae Rd Intersection - Install roundabout |
| 2004 | MELVILLE | Karel Avenue / Beasley Rd Intersection - Install seagull island and reduce radius on left turn slip |
| 2004 | MELVILLE | Somerville Boulevard / Jackson Avenue Intersection - Roundabout |
| 2004 | MELVILLE | Winthrop Drive / Jackson Avenue Intersection - Non-skid treatment |
| 2004 | NEDLANDS | Smyth RD / Aberdare Rd Intersection - Installation of a roundabout |
| 2004 | NEDLANDS | Bruce St / Melvista Avenue Intersection - Installation of a roundabout |
| 2002 | STATE ROAD | Wanneroo Rd/ Green St/ Walcott St Intersection - install anti skid surface |
| 2002 | STATE ROAD | Perth to Bunbury Hwy - Install audible edge lines |
| 2002 | STATE ROAD | Great Eastern Hwy/ Throssell St Intersection - Install traffic control signals |
| 2002 | STATE ROAD | Goldfields Hwy - Upgrade and widening |
| 2002 | STATE ROAD | Karrinyup Rd/ Huntriss Rd Intersection - Modify traffic control signals and islands and install pedestrian facilities |

| | | |
|---|---|---|
| 2002 | STATE ROAD | Leach Hwy - Install street lighting |
| 2002 | STATE ROAD | Bunbury Hwy/ Dampier Dr Intersection- Install traffic control signals and construct acceleration lane for right turn traffic |
| 2002 | STATE ROAD | Great Eastern Hwy/ Brealey Avenue/ Tonkin Hwy Southbound Off Ramp - Install additional left turn lane, improve pedestrian facilities, convert existing through lane to right turn |
| 2002 | STATE ROAD | Leach Hwy/ Norma Rd Intersection - Modify geometric layout including a splitter island under Give Way control; Modify layout of right turn; Extend the right turn pocket |
| 2002 | STATE ROAD | Leach Hwy/ Welshpool Rd Intersection - Modify swept path for heavy vehicles and extend island |
| 2002 | STATE ROAD | Mitchell Freeway Southbound Off Ramp/ Warwick Rd Intersection - Modify left turn slip and incorporate into signals |
| 2002 | STATE ROAD | Wanneroo Rd / Prindiville Dr Intersection - Reduce the cross fall between the crown and median |
| 2002 | STATE ROAD | South Western Hwy/ Boodjidup Rd Intersection - Construct Roundabout |
| 2003 | STATE ROAD | Albany Hwy - Install audible edge lines and RPPM's |
| 2003 | STATE ROAD | Shepperton Rd / Miller St Intersection - Install new traffic control signals with turning arrows |
| 2003 | STATE ROAD | Albany Hwy / Leige St Intersection - Install anti-skid treatment, install mast arm signals |
| 2003 | STATE ROAD | Tonkin Hwy / Benara Rd Intersection - Modify existing low entry to a high angle entry 70 degree left slip lane on all four corners of the intersection. |
| 2003 | STATE ROAD | Armadale Rd/ Warton Rd Intersection – Install high entry island at left slip lane |
| 2003 | STATE ROAD | Tonkin Hwy / Welshpool Rd Intersection - Modify left turn pockets |
| 2003 | STATE ROAD | Bunbury Hwy (H2) / Thomas Rd Intersection - Reduce radius on left turn |
| 2003 | STATE ROAD | Brookton Hwy/ Croyden Rd, Peet Rd Intersection – Provide lighting, ramps, handrails to bus shelter, signs and markings |
| 2004 | STATE ROAD | South Western Hwy - Improve channelisation, formalise parking, Install nibs and right turn pocket |
| 2004 | STATE ROAD | Broome Hwy / Cable Beach Rd East, Reid Rd Intersections - Install left slip lane and acceleration lane, reinforce signs. |
| 2004 | STATE ROAD | Stirling Hwy / Glyde St Intersection - Upgrade pedestrian traffic signals and upgrade pedestrian ramps |
| 2004 | STATE ROAD | Brookton Hwy - Provide lighting, ramps, handrails to bus shelter and signing and marking |

## 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 (months) | Estimate (β) | Standard Error | Probability 0<p<1 | 95% CI-Lower | 95% CI Upper | Casualty Crash Reduction (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Whole program** | 195 | 1291 | 687 | 60 | 44.5 | -0.342 | 0.022 | 0.001 | -0.385 | -0.298 | 28.9 |
| **All Metropolitan Sites** | 155 | 1097 | 602 | 60 | 44.7 | -0.309 | 0.025 | 0.001 | -0.359 | -0.260 | 26.6 |
| **All Rural Sites** | 40 | 194 | 85 | 60 | 44.0 | -0.547 | 0.050 | 0.001 | -0.645 | -0.449 | 42.2 |
| **Broad Categories** | | | | | | | | | | | |
| | | | | | | | | | | | |
| Intersection Treatments | 138 | 1130 | 613 | 60 | 45.0 | -0.359 | 0.025 | 0.001 | -0.409 | -0.308 | 30.1 |
| • Metro | 115 | 1058 | 584 | 60 | 45.2 | -0.354 | 0.031 | 0.001 | -0.416 | -0.292 | 29.9 |
| • Rural | 23 | 72 | 29 | 60 | 44.2 | -0.421 | 0.050 | 0.001 | -0.519 | -0.322 | 34.3 |
| Road Section and Non Intersection Treatment | 57 | 161 | 74 | 60 | 44.2 | -0.320 | 0.039 | 0.001 | -0.398 | -0.243 | 27.4 |
| • Metro | 40 | 39 | 18 | 60 | 43.7 | -0.236 | 0.043 | 0.001 | -0.322 | -0.150 | 21.1 |
| • Rural | 17 | 122 | 56 | 60 | 45.7 | -0.837 | 0.096 | 0.001 | -1.026 | -0.648 | 56.7 |
| • | | | | | | | | | | | |
| **Treatment Types** | | | | | | | | | | | |
| | | | | | | | | | | | |
| **All Roundabouts** | 33 | 108 | 42 | 60 | 43.6 | -0.638 | 0.141 | 0.001 | -0.916 | -0.360 | 47.2 |
| • Metro | 28 | 98 | 39 | 60 | 43.1 | -0.606 | 0.148 | 0.001 | -0.896 | -0.315 | 45.5 |
| • Rural | 5 | 10 | 3 | 60 | 46.4 | -0.960 | 0.692 | 0.165 | -2.316 | 0.396 | 61.7* |
| | | | | | | | | | | | |
| Traffic island on approach | 31 | 86 | 40 | 60 | 45.6 | -0.499 | 0.144 | 0.001 | -0.781 | -0.216 | 39.3 |
| Non-skid treatment | 11 | 137 | 76 | 60 | 44.9 | -0.394 | 0.069 | 0.001 | -0.531 | -0.257 | 32.6 |
| Seagull island | 12 | 47 | 23 | 60 | 47.5 | -0.247 | 0.177 | 0.162 | -0.594 | 0.099 | 21.9* |
| Left turn slip | 15 | 82 | 37 | 60 | 47.0 | -0.566 | 0.124 | 0.001 | -0.809 | -0.323 | 43.3 |
| New traffic signal | 6 | 28 | 13 | 60 | 41.3 | -0.419 | 0.281 | 0.136 | -0.970 | 0.131 | 34.3* |
| Remodel signal | 5 | 42 | 31 | 60 | 45.0 | -0.225 | 0.190 | 0.236 | -0.598 | 0.147 | 20.2* |

| 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* (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Seal shoulder | 5 | 9 | 5 | 60 | 35.2 | -0.147 | 0.332 | 0.658 | -0.798 | 0.503 | 13.7* |
| Improved route lighting | 3 | 35 | 12 | 60 | 47.9 | -0.951 | 0.165 | 0.001 | -1.275 | -0.628 | 61.4 |
| | | | | | | | | | | | |
| All State Road Treatments | 24 | 489 | 289 | 60 | 45.6 | -0.24 | 0.039 | 0.001 | -1.151 | -0.977 | 21.4 |

- Negative casualty crash reductions indicates an increase
- Some treatment codes are a combination of several codes. The treatment 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** | 195 | 4846 | 3226 | 60 | 44.5 | -0.114 | 0.007 | 0.001 | -0.128 | -0.100 | 10.8 |
| **All Metropolitan Sites** | 155 | 4256 | 2888 | 60 | 44.7 | -0.092 | 0.007 | 0.001 | -0.108 | -0.077 | 8.8 |
| **All Rural Sites** | 40 | 590 | 338 | 60 | 44.0 | -0.392 | 0.022 | 0.001 | -0.436 | -0.349 | 32.5 |
| **Broad Categories** | | | | | | | | | | | |
| Intersection Treatments | 138 | 4374 | 2936 | 60 | 45.0 | -0.085 | 0.009 | 0.001 | -0.105 | -0.67 | 8.2 |
| • Metro | 115 | 4121 | 2798 | 60 | 45.2 | -0.077 | 0.009 | 0.001 | -0.096 | -0.057 | 7.5 |
| • Rural | 23 | 253 | 138 | 60 | 44.2 | -0.231 | 0.084 | 0.006 | -0.397 | -0.065 | 20.7 |
| Road Section and Non Intersection Treatment | 57 | 472 | 290 | 60 | 44.2 | -0.145 | 0.010 | 0.001 | -0.166 | -0.124 | 13.5 |
| • Metro | 40 | 135 | 90 | 60 | 43.7 | -0.110 | 0.012 | 0.001 | -0.135 | -0.086 | 10.4 |
| • Rural | 17 | 337 | 200 | 60 | 45.7 | -0.604 | 0.035 | 0.001 | -0.673 | -0.534 | 45.3 |
| | | | | | | | | | | | |
| **Treatment Types** | | | | | | | | | | | |
| **All Roundabouts** | 33 | 433 | 253 | 60 | 43.6 | -0.235 | 0.040 | 0.001 | -0.315 | -0.156 | 20.9 |
| • Metro | 28 | 383 | 229 | 60 | 43.1 | -0.202 | 0.042 | 0.001 | -0.286 | -0.120 | 18.4 |
| • Rural | 5 | 50 | 24 | 60 | 46.4 | -0.489 | 0.157 | 0.002 | -0.799 | -0.181 | 38.7 |
| | | | | | | | | | | | |
| New traffic signal | 6 | 99 | 60 | 60 | 41.3 | -0.127 | 0.117 | 0.277 | -0.358 | 0.103 | 11.9* |
| Non-skid treatment | 11 | 516 | 370 | 60 | 44.9 | -0.078 | 0.022 | 0.001 | -0.121 | -0.035 | 7.5 |
| Traffic island on approach | 31 | 289 | 158 | 60 | 45.6 | -0.034 | 0.050 | 0.001 | -0.443 | -0.245 | 29.1 |
| Seagull island | 12 | 143 | 79 | 60 | 47.5 | -0.178 | 0.053 | 0.001 | -0.284 | -0.074 | 16.3 |
| Left turn slip | 15 | 293 | 194 | 60 | 47.0 | -0.166 | 0.036 | 0.001 | -0.238 | -0.094 | 15.3 |
| Remodel signal | 5 | 199 | 119 | 60 | 45.0 | -0.216 | 0.048 | 0.001 | -0.312 | -0.121 | 19.5 |
| Seal shoulder | 5 | 32 | 22 | 60 | 35.2 | 0.139 | 0.003 | 0.001 | 0.133 | 0.147 | -15.0 |
| | | | | | | | | | | | |

| **Treatment Types** | **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** (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Improved route lighting (road section) | 3 | 97 | 74 | 60 | 47.9 | -0.124 | 0.033 | 0.001 | -0.191 | -0.058 | 11.7 |
| | | | | | | | | | | | |
| All State Road Treatments | 24 | 1836 | 1351 | 60 | 45.6 | -0.024 | 0.013 | 0.070 | -0.052 | 0.002 | 2.5 |

- Negative crash reductions indicates an increase
- Some treatment codes are a combination of several codes. The treatment 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 | PV of Total Costs ($) | PV of Crash Cost Savings ($) | NPV ($) | BCR |
|---|---|---|---|---|
| **Whole program** | 15 673 732 | 39 814 552 | 24 140 820 | 2.5 |
| **All Metropolitan Sites** | 11 425 188 | 12 958 927 | 1 533 739 | 1.1 |
| **All Rural Sites** | 4 248 544 | 27 558 056 | 23 309 512 | 6.5 |
| **Broad Categories** | | | | |
| Intersection Treatments | 12 280 495 | 19 893 370 | 7 612 875 | 1.6 |
| Road Section and Non Intersection Treatment | 3 393 238 | 21 995 843 | 18 602 605 | 6.5 |
| **Treatment Types** | | | | |
| All Roundabouts | 3 384 343 | 12 358 484 | 8 974 141 | 3.7 |
| Traffic island on approach | 661 611 | 9 002 913 | 8 341 302 | 13.6 |
| Non-skid treatment | 613 586 | 1 701 517 | 1 087 931 | 2.8 |
| Seagull island | 321 944 | 4 904 357 | 4 582 413 | 15.2 |
| Left turn slip | 892 026 | -2 106 549 | -2 998 575 | -2.4 |
| New traffic signal | 1 448 163 | -6 476 202 | -7 924 325 | -4.5 |
| Remodel signal | 284 999 | 25 058 | -259 941 | 0.1 |
| Seal shoulder | 415 002 | -7 529 697 | -7 944 699 | -18.1 |
| Improved route lighting | 32 460 | 6 992 455 | 6 959 995 | 215.4 |
| All State Roads | 5 496 363 | -940 759 | -6 437 122 | -0.2 |

Note that figures do not add up due to rounding.

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

| Area | PV of Total Costs ($) | PV of Crash Cost Savings ($) | NPV ($) | BCR |
|---|---|---|---|---|
| **Base case**<br>Discount rate 5%<br>Treatment life 15 yrs | 15 673 732 | 39 814 552 | 24 140 820 | 2.5 |
| **Sensitivity analysis** | | | | |
| **Discount rate** | | | | |
| • 3% (15 years) | 15 867 777 | 44 920 276 | 29 052 490 | 2.8 |
| • 8% (15 years) | 15 447 362 | 33 771 034 | 18 323 672 | 2.2 |
| **Treatment life** | | | | |
| • 10 years (5%) | 15 342 831 | 29 619 157 | 14 276 326 | 1.9 |
| • 20 years (5%) | 15 746 840 | 47 303 527 | 31 556 687 | 3.0 |