An Evaluation of the Effectiveness of the State Black Spot Programs on Motorcycle Crashes in Western Australia

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Title

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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 2000 to 2006 in Western Australia in terms of a reduction in motorcycle crashes.

The results showed the State Program has been effective overall, in reducing all reported motorcycle crash frequencies by 12%. The cost savings from this reduction in motorcycle crashes were $24.6 million using recent official estimates of average road crash costs and $32.1 million using earlier official estimates. Cost savings were largely due to the reduction in motorcycle crashes in rural areas. The results provide Main Roads WA and other road safety organisations with reliable, objective information for enhancing strategies for improving safety for motorcyclists

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Keywords
Black spot treatment, motorcycles, crash reduction, cost savings analysis

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EXECUTIVE SUMMARY

This report presents the results of an evaluation of the effectiveness of the State Black Spot treatments which were undertaken during 2000 to 2006 in reducing motorcycle crashes and its associated cost savings in Western Australia.

The analysis compared the frequency of motorcycle crashes "*before*" and "*after*" treatment periods based on Black Spot treatments from 2000 to 2006 as well as an examination by specific treatment types, by location (metropolitan Perth and the rural areas), and treatment year. A generalised estimating equation (GEE) Poisson regression model was used to evaluate the crash reduction.

There were a total of 2000 sites treated under the Black Spot Program during the study period. The number of treated sites where a motorcycle crash occurred was 327 over the study period. The average length of follow up exposure crash data post treatment for all treated sites was 60 months.

The economic assessment of the effect of treated sites on motorcycle crashes was a partial evaluation that calculated the cost savings from fewer crashes involving motorcyclists at treated sites. The reason for not conducting a full economic evaluation in which benefit cost ratios or net present values were calculated was that the WA Black Spot Program does not differentiate between road users in the eligibility criteria for inclusion in the program. This meant that treatment costs of undertaking the projects during the period under review could only meaningfully be compared with benefits in the form of cost savings from fewer crashes involving all road users rather than just those involving motorcyclists.

Two sets of cost savings were calculated based on different road crash unit costs. The most recent road crash costs for Australia were produced for 2006 by the Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG), with different breakdowns of cost presented including unit crash costs by severity and jurisdiction (DITRDLG 2009). Previous evaluations of the State Black Sport Program have been based on the road crash costs for Australia for 1996 produced by the Bureau of Transport Economics (BTE) (2000), adjusted for price increases and state variations in costs (Willett, 2004). Both sets of average costs 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. In addition, the 2006 costs produced by DITRDLG included four costs not included in the 1996 cost calculations, namely the health costs of additional local air pollution, higher vehicle operating cost for vehicles due to crash-induced congestion, workplace and household losses due to imprisonment for culpable driving causing death, and a (non-pecuniary) value for pain, grief and suffering for friends and relatives (DITRDLG 2009). Cost savings were calculated based on both sets of road crash unit costs as the DITRDLG's estimates are the current official figures of road crash costs, while using the 1996 estimates adjusted for price increases and state variations in costs enables comparisons to be made with cost savings presented in previous evaluations of Black Spot Programs.

The results of the evaluation of the WA Black Spot Programs 2000 to 2002, 2003 to 2004 and 2005 to 2006 found that overall, the Programs have been effective in reducing all reported motorcycle crashes by 12%. Moreover, this 12% reduction in motorcycle crashes is comparable to overall crash reductions reported in previous Black Spot Program evaluations (Meuleners et al. 2008). This evaluation also found that the Black Spot Program 2005 to 2006 appears to be more effective in reducing motorcycle crashes than the earlier programs (2000 to 2002 and 2003 to 2004). A significant 25% reduction in the number of motorcycle crashes in rural areas was also found during the study period.

In relation to the economic analysis of the Black Spot programs during 2000 to 2006, cost savings from fewer crashes involving motorcyclists at treated sites amounted to $24.6 million using recent official estimates of average road crash costs and $32.1 million using earlier official estimates for 1996 adjusted for price increases and state variations in costs. These cost savings were largely due to the reduction in motorcycle crashes in rural areas.

This provides preliminary evidence that generic black spot programs can provide equivalent benefits for motorcyclists as well as all road users.

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1 INTRODUCTION

The identification, analysis and treatment of road accident black spots is widely regarded as one of the most effective approaches to road accident prevention (Elvik, 1997). The WA State Black Spot Program was first introduced in 2000 with the objective of reducing the frequency and severity of crashes at locations experiencing a poor crash record. A recent analysis of 195 locations treated under the WA State Black Spot Program from 2003 to 2004 showed that the Program has been effective overall, reducing all reported crash frequencies by 11% and casualty crash frequencies by 29% (Meuleners et al. 2008). In addition, the benefit cost ratio (BCR) across all treatment sites was 2.8.

The WA State Black Spot Program does not differentiate between road users in its eligibility criteria for inclusion in the Program (Main Roads/ WALGA 2004). Also, to date no analysis has examined the Program's effectiveness for different road user groups separately.

Motorcyclists have a much greater risk of being killed or seriously injured in the event of a crash than drivers of other motor vehicles (Candappa et al. 2006). Motorcycles are less stable and their riders far more vulnerable than four-wheeled motor vehicles, meaning they have different needs and risk factors in the road environment (Motorcycle Council of NSW 2007). The road infrastructure can play a significant role in the motorcyclist's risk of crashing, ability to recover and avoid the crash and injury severity in the event of a crash (VicRoads 2009). Road environment characteristics of particular significance to motorcycles include fixed roadside objects, curves or bends in the road, uneven road surfaces, signage and roadside safety barriers.

In recognition of the specific road safety needs of motorcyclists, VicRoads introduced a specific Motorcycle Blackspot Program in the State of Victoria, Australia in 2002. This Program allows the implementation of road treatment/ improvement projects at locations that are specifically high risk for motorcyclists. Preliminary analyses of the Victorian Motorcycle Blackspot Program are very promising reporting an overall 24% reduction in casualty motorcycle crashes and a BCR of 15.1 for 85 black spot locations treated under the Program (VicRoads 2009). However, the Victorian Motorcycle Blackspot Program utilises a wide variety of road engineering treatments and the effects of each of these specific treatments on motorcycle crashes are currently unknown.

The treatments implemented under the Victorian Motorcycle Blackspot Program are similar to those shown to be successful in treating general black spots under the Federal and State black spot programs around Australia. Treatments include removal of roadside hazards, street lighting, installation of signs, sealing road shoulders, edge lines and improved delineation of the road for example (VicRoads 2009). It is therefore possible that treatments implemented under the general WA State Black Spot Program may provide road safety benefits for motorcyclists specifically.

Since very little evidence currently exists on the effectiveness of specific road infrastructure treatments for reducing motorcycle crashes and injury severity at black spots or black lengths, it would be extremely worthwhile to examine the effectiveness of the WA State Black Spot Program for this road user group specifically.

1.1 Aim

The aim of this study is to evaluate the effectiveness of projects treated under the State Black Spot Programs during 2000 to 2006 in terms of the net reduction in motorcycle crash frequency and crash costs at treated sites in WA.

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 motorcycle road safety strategies. The economic analysis should also enable road authorities to manage future resources so that injury from motorcycle road trauma is minimised.

2 METHODS

2.1 Study Design

The study adopted a quasi-experimental "*before*" and "*after*" comparison of motorcycle crash frequencies (including fatality, hospitalisation and PDO crashes) at sites treated under the State Black Spot Program for the years 2000 to 2006. The analysis also included an estimation of the net economic worth of the Program for motorcycles.

2.2 Selection of Sites for Funding

Black spots are locations noted for a high incidence of crashes involving death and injury (Elvik et al., 2009). All road classifications were eligible for funding including 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.

Typical major road safety improvements included:

- 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.
  (Main Roads Western Australia 2003)

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.

The data used to complete the evaluation on motorcycle crashes was the same data that was used to evaluate the effect of the program on all crashes. However since the current evaluation only looks at before and after counts of motorcycle crashes, all crashes that did not involve a motorcycle were removed from the crash data that was to be analysed.

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" (Hill, Marchant & Gant 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 treatment crash data and at least six months post treatment crash data (up to December 31, 2009) 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 Local Government area;
- 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 treatment code 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.

2.3.3 Categorisation of Treatment Types

An aim of the study was also to estimate the effectiveness of specific treatment types on motorcycle crashes. 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.

2.4 Factors that may Affect the State Black Spot Evaluation

All known factors that have the potential to affect the Black Spot Program 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.

2.4.1 Site Specific Factors

Specific events other than treatment could account for some of the observed changes 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 of these may lead to an increase in driver or rider 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 Economics, 2001). However, it may have an effect on the analysis at a particular site (Bureau of Transport Economics, 2001).

2.4.2 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 the 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. However, most sites did have five years of crash data post treatment available. The statistical methodology used in this report also recognised the level and distribution of random variation in the data and provided appropriate confidence intervals and significance levels.

2.4.3 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).

2.5 Cost Data

The economic assessment of the effect of treated sites on motorcycle crashes was a partial evaluation that calculated the cost savings from fewer crashes involving motorcyclists at treated sites. The reason for not conducting a full economic evaluation in which benefit cost ratios or net present values were calculated was that the WA Black Spot Program does not differentiate between road users in the eligibility criteria for inclusion in the program. This meant that treatment costs of undertaking the projects during the period under review could only meaningfully be compared with benefits in the form of cost savings from fewer crashes involving all road users rather than just those involving motorcyclists.

Two sets of cost savings were calculated based on different road crash unit costs. The most recent road crash costs for Australia were produced for 2006 by the Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG), with different breakdowns of cost presented including unit crash costs by severity and jurisdiction (DITRDLG 2009). Previous evaluations of the State Black Sport Program have been based on the road crash costs for Australia for 1996 produced by the Bureau of Transport Economics (BTE) (2000), adjusted for price increases and state variations in costs (Willett, 2004). Both sets of average costs 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. In addition, the 2006 costs produced by DITRDLG included four costs not included in the 1996 cost calculations, namely the health costs of additional local air pollution, higher vehicle operating cost for vehicles due to crash-induced congestion, workplace and household losses due to imprisonment for culpable driving causing death, and a (non-pecuniary) value for pain, grief and suffering for friends and relatives (DITRDLG 2009). Cost savings were calculated based on both sets of road crash unit costs as the DITRDLG's estimates are the current official figures of road crash costs while using the 1996 estimates adjusted for price increases and state variations in costs enables comparisons to be made with cost savings presented in previous evaluations of Black Spot Programs.

The two sets of average road crash costs for Western Australia are shown below, with the most notable difference being the lower unit costs for non-fatal crashes involving a hospitalised casualty and to a lesser extent a non-fatal crash involving non-hospitalised injury.

Crash severity	**DITRLG (2006)**	**BTE (updated to 2006)**
Fatal	$2,660,398	$2,532,018
Hospital admission	$266,815	$562,768
Medical Treatment	$14,784	$34,065
Property Damage Only	$9,632	$13,498

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).

2.6 Statistical Analysis

2.6.1 Effectiveness of the Program

The analysis compared the frequency of motorcycle crashes "*before*" and "*after*" treatment periods based Black Spot treatments undertaken from 2000 to 2006. Wherever possible an examination by specific treatment types or by location (metropolitan Perth and the rural areas) was undertaken.

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 for 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 took into account the correlated nature of the repeated measures taken before and after black spot treatment.

It is also worth noting for this evaluation that if the aggregated frequency of motorcycle crashes for a treated site was zero in either or both the before and after period, these sites were omitted from the analysis.

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.

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

2.6.2 Economic Analysis

Cost savings were calculated by multiplying the reduction in the number of motorcycle crashes by crash severity as estimated from the GEE Poisson regression model by the corresponding unit crash costs. These cost savings were calculated for crashes of all severity levels and for casualty crashes only (i.e., excluding property damage only crashes). In the base case analysis, cost savings were calculated based on an average treatment life of 15 years, which was varied between 10 and 20 years in the sensitivity analysis. Future cost

savings were discounted using a 5% discount rate in the base case as recommended by Main Roads WA, with 3% and 8% used in the sensitivity analysis.

The formula for calculating cost savings was as follows –

$$\text{Cost savings} = \sum_{i=0}^{n} (C_i / (1+r)^i)$$

where C_i = total cost savings in year i resulting from a reduction in the number of motorcyclist crashes

r= discount rate

n=the expected life of the treatment

3 RESULTS

This section summarises the results of the effectiveness of the Black Spot Program in reducing all-reported motorcycle crash frequency in Western Australia from 2000 to 2006. The analysis was stratified by metropolitan and rural Western Australia, specific treatment types as well as by Black Spot Program year.

3.1 Statistical Analysis

There were a total of 2000 sites treated under the Black Spot Program during the study period. The number of treated sites where a motorcycle crash occurred was 327 over the study period. The average length of follow up exposure crash data post treatment for all treated sites was 60 months.

Table 3.1 shows the effect of black spot treatments on all-reported motorcycle crashes stratified by location and treatment type and Table 3.2 shows the effect on all-reported motorcycle crashes stratified by Black Spot Program year. 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 that all-reported crash rate (including fatal, hospitalisation/ injury and PDO crashes) decreased following treatment, and vice versa for a positive value for β. The incidence rate ratio (IRR) is shown in the last column of Table 3.1 and Table 3.2. The percentage reduction in the number of all reported crashes was obtained from the IRR.

3.1.1 All-Reported Motorcycle Crash Reduction for All Crash Types

Based on the estimated incidence rate ratio, a significant overall reduction of 12 % ($p<0.001$) was found when all severities of motorcycle crashes were included (see Table 3.1 and Figure 3.1). When examined by specific treatment types there was no significant difference for any of the treatments examined. These included roundabouts, new traffic signal (no turn arrows), seagull islands, left turn slip and traffic islands on approach. However, there was a significant 25% reduction ($p=0.011$) in the number of motorcycle crashes in the rural areas during the study period.

Table 3.1 Black Spot treatment effect on all-reported motorcycle crashes stratified by location and specific treatment types, 2000 – 2006**

	Estimate (β)	Standard Error	Probability 0<p<1	IRR***
All treated sites (n=327)				
Treatment	-0.123	0.050	0.015	0.884*
Program year	0.131	0.056	0.020	1.140*
Location				
Metropolitan (n=258)				
Treatment	-0.084	0.056	0.133	0.918
Program year	0.152	0.061	0.013	1.165*
Rural (n=69)				
Treatment	-0.287	0.112	0.011	0.750*
Program year	0.028	0.138	0.210	1.029
Specific Treatments				
Roundabouts (n=53)	-0.017	0.152	0.909	0.982
New traffic signal (n=18) (no turn arrows)	-0.422	0.262	0.108	0.655
Traffic island on approach (n=19)	-0.597	0.383	0.119	0.550
Seagull island (n=23)	0.213	0.353	0.545	1.238
Left turn slip (n=21)	-0.328	0.294	0.264	0.720

**Significant at 0.05 level*
***Includes all crashes-fatality, hospitalisation, injury and property damage- major and minor*
**** Incidence rate ratio*

An examination of the effectiveness of the Black Spot Program in reducing motorcycle crashes was also undertaken by Black Spot Program year (see Table 3.2). There was no significant reduction in motorcycle crashes for the Black Spot Program from 2000 to 2002 and 2003 to 2004. However there was a marginal 14% reduction in motorcycle crashes for treatments undertaken in 2005 to 2006.

Table 3.2 Black Spot treatment effect on all-reported motorcycle crashes stratified by Black Spot Program year**

	Estimate (β)	Standard Error	Probability 0<p<1	IRR***
Black Spot Program 2000-2002 (n=79)	-0.242	0.137	0.078	0.784
Black Spot Program 2003-2004 (n=144)	-0.051	0.072	0.476	0.949
Black Spot Program 2005-2006 (n=104)	-0.150	0.076	0.049*	0.859

**Significant at 0.05 level*
***Includes all crashes-fatality, hospitalisation, injury and property damage major and minor crashes*
**** Incidence rate ratio*

3.2 Economic Evaluation of the State Black Spot Program

Table 3.3 presents the cost savings from fewer crashes involving motorcyclists at treated sites. Separate analyses are presented based on the unit road crash costs produced by the DITRDLG and the BTE.

In the base case analysis of crashes of all severity levels in all regions, cost savings from fewer crashes involving motorcyclists were $24.6 million using DITRDLG's costs and $32.1 million using BTE's costs. Similar cost savings were found for the reduction in casualty crashes only. The reason for the latter being slightly above those for all crashes was that the number of property damage crashes increased in the post treatment period.

Cost savings from fewer motorcycle crashes in rural areas accounted for the greatest share of overall cost savings. The apparent anomaly in the lower cost savings for the metropolitan region using BTE's unit costs is explained by an increase being recorded in the number of non-fatal crashes involving a hospitalised casualty in the post treatment period. With BTE's unit costs being considerably higher for non-fatal crashes involving a hospitalised casualty, the increase in costs for these crashes offset the reduction in costs for crashes of other severity levels.

Varying the assumptions relating to the discount rate and treatment life of the project showed cost savings based on DITRDLG's unit costs dropping to approximately $18 million and $20 million based on a treatment life of 10 years and a discount rate of 8% respectively. If a lower discount rate of 3% was used or the treatment life was extended to 20 years, then cost savings increased to approximately $27 million and $29 million respectively. If BTE's unit costs were used in the sensitivity analysis, costs savings under the different assumptions relating to parameter values showed a similar pattern and were approximately 30% above those using DITRDLG's costs.

Table 3.3 Crash cost savings from the reduction in motorcycle crashes as a consequence of black spot treatment

Type of analysis	Region	DITRDLG costs 2006		BTE's updated costs 2006	
		All crashes ($)	Casualty crashes ($)	All crashes ($)	Casualty crashes ($)
Base case					
5% discount rate; 15 yrs treatment life	All regions	24,570,168	24,759,168	32,123,046	32,387,846
	Metro	8,042,221	-	3,809,538	-
	Rural	16,527,967	-	28,313,497	-
Sensitivity analysis					
3% discount rate; 15 yrs treatment life	All regions	27,721,036	27,934,221	36,242,440	36,541,191
8% discount rate; 15 yrs treatment life	All regions	20,840,657	21,000,929	27,247,043	27,471,644
5% discount rate; 10 yrs treatment life	All regions	18,278,466	18,419,034	23,897,238	24,094,226
5% discount rate; 20 yrs treatment life	All regions	29,499,803	29,726,667	38,567,997	38,885,918

4 DISCUSSION

Evaluation of the WA Black Spot Programs 2000 to 2002, 2003 to 2004 and 2005 to 2006 indicates that overall, the Programs have been effective in reducing all reported motorcycle crashes by 12%. Moreover, this 12% reduction in motorcycle crashes is comparable to overall crash reductions reported in previous Black Spot Program evaluations (Meuleners et al. 2008). This provides preliminary evidence that generic black spot programs can provide equivalent benefits for motorcyclists as well as all road users. This is an interesting finding because it has been reported that motorcycle black spots may differ from general black spots and that road environment factors including road surfaces, potholes, limited sight distances and sharp curves pose a greater safety risk for motorcyclists than other motor vehicles (Brennan & Beer 2007). While this may be the case, it is positive to find that the treatments implemented by the Black Spot Program nevertheless, still have benefits for motorcyclists.

This evaluation also found that the Black Spot Program 2005 to 2006 appears to be more effective in reducing motorcycle crashes than the earlier programs (2000 to 2002 and 2003 to 2004). A significant 25% reduction in the number of motorcycle crashes in rural areas was found during the study period. This is an extremely positive finding because motorcycle crashes in rural areas are more likely to result in serious injury (Meuleners, Lee & Haworth 2007). However, there was no significant reduction in the number of motorcycle crashes in the metropolitan area during the study period. It is possible that Black Spot Program treatments may be more effective in rural areas because of the poorer quality of roads and road surfaces in these areas and because the road environment may play a greater role in rural motorcycle crashes.

The majority of multi-vehicle motorcycle crashes occur at intersections, especially intersections with no traffic controls (Motorcycle Council of NSW 2007). In a NSW-based motorcycle study, 80% of crashes at uncontrolled intersections were due to the other driver failing to give way to the motorcyclist (Motorcycle Council of NSW 2007). There was a non-statistically significant 2% reduction in the number of motorcycle roundabout crashes. Of interest, seagull islands actually increased the number of all reported motorcycle crashes by 24%, although this increase was not significant. Similarly, previous evaluations of the 2000 to 2002 and 2003 to 2004 Black Spot Programs also found that seagull islands in fact,

increased all crashes and casualty crashes when all road user type crashes were examined, though this increase was not significant for casualty crashes (Meuleners et al. 2005; Meuleners et al. 2008).

It was not the original objective of the Black Spot Program to determine the most effective road treatments for reducing motorcycle crashes, so it difficult to recommend specific treatments from this evaluation. However, it may be beneficial for future funding to specifically target areas of concern for motorcycle safety. Due to the lower numbers of motorcycles on the road than other vehicles, many sites that are black spots for motorcycles experience too few crashes to meet the eligibility criteria for funding and are less likely to be prioritised for treatment under Black Spot Program. For this reason, VicRoads has been investigating ways to improve road design for motorcyclists and implement road treatments for motorcycle black spots since 2002 and the Victorian Motorcycle Blackspot Program is thought to be the first of its kind in the world (VicRoads 2009). Under this Program, areas where there are high rates of motorcycle crashes are identified and motorcycle experts, road safety experts and engineers are engaged to review the locations. Road treatments are then developed specifically to address the factors that have contributed to motorcycle crashes at the location. Preliminary analyses of the Victorian Motorcycle Blackspot Program are very promising, reporting a 24% reduction in casualty motorcycle crashes and a BCR of 15.1 for 85 black spot locations treated under the Program (VicRoads 2009). The Victorian Motorcycle Blackspot Program utilises a wide variety of road engineering treatments, including those shown to be successful in treating general black spots but the effects of each of these specific treatments on motorcycle crashes are currently unknown.

Around the world, other unique road engineering treatments have shown promise for reducing motorcycle crashes. In Malaysia, where motorcycle use is high, almost 60% of fatal crashes involve motorcyclists (Umar, Mackay & Hills 1995). An exclusive motorcycle lane was introduced on a 14 kilometre stretch of a main urban expressway in Malaysia and preliminary analysis showed significant reductions in motorcycle crashes of approximately 34% and a BCR of about 3 to 5 (Umar, Mackay & Hills 1995). This exclusive carriageway separates motorcycles from other vehicles in order to minimise conflicts and research suggests that these may be highly effective. Other research suggests that motorcycle lanes may reduce crashes by 25% to 40% (Elvik et al., 2009). Due to the relatively low rates of

motorcycle use in WA however, it is not likely that this road treatment would be cost effective.

In relation to the economic analysis of the Black Spot programs during 2000 to 2006, cost savings from fewer crashes involving motor cyclists at treated sites amounted to $24.6 million using recent official estimates of average road crash costs and $32.1 million using earlier official estimates for 1996 adjusted for price increases and state variations in costs. These cost savings were largely due to the reduction in motorcycle crashes in rural areas.

A strength of the current evaluation is the inclusion of all severities of motorcycle crashes in the analysis. It has been reported in previous investigations that while some black spot treatments may reduce casualty crashes, lower severity crashes are actually increased. This evaluation took into account all possible beneficial and detrimental effects of the treatments (Newstead and Corben, 2001). In addition, the long follow-up of post treatment crash data led to more definitive and reliable conclusions being made concerning treatment effectiveness in reducing motorcycle crashes.

Limitations of this evaluation include the lack of suitable control sites which did not undergo black spot treatments. It is therefore difficult to conclusively determine that motorcycle crash reductions observed were a direct effect of the road treatments. A further limitation is the lack of data available to examine any possible “crash migration” effects for motorcyclists. “Crash migration” is where crashes prevented by road engineering treatments delivered under the Black Spot Program on one section of road may occur further along the road on untreated sections. Finally, exposure data was not included in the analysis and it was not possible to account for other possible confounding factors including weather conditions and road lighting.

5 CONCLUSION AND RECOMMENDATIONS

This evaluation has highlighted that generic black spot programs can be effective in reducing motorcycle crashes. However, very little evidence exists on the efficacy of specific road safety treatments for motorcycle safety. Past research indicates that motorcyclists are vulnerable to different risk factors in the road environment than other road users. Early results from the Victorian Motorcycle Blackspot Program indicate that a systematic program specifically targeting motorcyclists can be very cost-effective and such a program may be necessary in WA to bring about further significant reductions in motorcycle casualty crashes. Road engineering treatments implemented under the Victorian Motorcycle Blackspot Program are relatively modest and cost effective treatments, similar to those shown to be successful in treating black spots for other road users. This indicates that the introduction of a systematic motorcycle black spot program would most likely bring about benefits for all types of road users as well as motorcyclists. In light of this information we recommend the following areas are worth further investigation.

5.1 Recommendations

The effect of different road treatments on motorcycle crashes and injury is an area requiring further research. Specific recommendations include to:

- Analyse WA motorcycle crash data to identify black spots with above average crashes, high risk routes and road environment factors that feature in motorcycle crashes.
- Map locations of motorcycle crashes in WA to assist in the identification of black spots.
- Include a suitably experienced motorcycle user on motorcycle crash investigations and road safety audits to ensure the perspective of the motorcyclists is fully understood.
- Investigate the feasibility of introducing a separate motorcycle black spot program in WA or of formulating separate criteria for motorcycle crashes that would allow motorcycle black spots to be included and funded under the existing WA State Black Spot Program.

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