Evaluation and Review of the Western Australian Black Spot Program

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Abstract

The purpose of this paper was twofold. First, it compared the criteria used by the different authorities in Australia to fund black spot treatments in their jurisdictions. Second, it presented the results of an evaluation of the effectiveness and cost-effectiveness of the Black Spot Program in WA. The findings presented in the paper form part of a wider review of the Black Spot Program in WA, which includes also a review of international black spot programs and a qualitative study of the views of stakeholders of the WA State Black Spot Program. The paper reports that different black spot programs within Australia have different eligibility criteria for funding and distribute varied proportions of funding to projects located on metropolitan, non-metropolitan, state and local roads. The WA Black Spot Program was found to be effective and cost-effective, with an overall crash reduction of 20% pre- and post-treatment and a BCR of 4.0. Factors that might have affected the evaluation of the effectiveness of the program were the lack of control sites and no account being taken of crash migration. It is difficult to identify what the best criteria for funding are in order to achieve an optimal reduction in crashes, with different stakeholders disagreeing on how funding should be distributed across road types and between metropolitan and non-metropolitan regions. A recent international investigation on state-of-the-art black spot approaches suggested an alternative approach, the empirical Bayesian method, as best practice for identifying black spots. Empirical Bayesian methods, however, require comprehensive and connected crash, road and traffic data and may be currently unrealistic for Australian black spot programs. It also stated that reactive crash analysis was still considered the best indicator of black spots rather than proactive methods based on road safety audits. However, proactive identification of black spots through road safety audits is still likely to be highly relevant to several Australian states due to their large area and long stretches of remote roads where crashes are more dispersed.

Keywords

Black spot treatment, crash reduction, cost-effectiveness

Introduction

Black spot programs have been used by all leading road safety countries of the world to effectively reduce road crashes. Due to the success of black spot programs, several of these countries have been able to redirect their focus from treating 'spots' to implementing mass action, area-wide or network treatments or adopting the 'safe systems' approach to road safety (1). Black spots can be described as locations noted for a high incidence of road crashes involving death and injury (2), and the identification, analysis and treatment of these black spots are widely regarded as one of the most effective approaches to preventing road crashes (3). Within Australia, the vast road network and comparatively low population result in black spots remaining a problem, with black spot programs still being widely used.

A national black spot program was first implemented in Australia in mid-1990, and many states and territories introduced their own programs in subsequent years. Currently, AusLink runs a Federal Black Spot Program, and Western Australia (WA), South Australia (SA), Tasmania and Victoria run specific State Black Spot Programs. In other states and territories, black spot treatment is undertaken as part of broader road safety programs.

The purpose of this paper was twofold. First, it compared the criteria used by the different authorities in Australia to fund black spot treatments in their jurisdictions. Second, it presented the results of an evaluation of the effectiveness and cost-effectiveness of the Black Spot Program in WA. The findings presented in this paper form part of a wider review of the Black Spot Program in WA, which includes also a review of international black spot programs and a qualitative study of the views of stakeholders of the WA State Black Spot Program.

Objective 1 - Comparison of the criteria used to fund black spot treatments

Method

Each Australian State and Territory road authority's website was searched for information on black spot programs and activities. The Medline and ScienceDirect databases were also searched for Australian publications on black spot programs using the keywords of 'road' in combination with 'black spot' or 'hazard elimination'. Publication reference lists were also scanned for relevant articles.

Results

Funding distribution

Different black spot programs within Australia distribute varied proportions of their funding to projects located on metropolitan, non-metropolitan, state or local roads (Table 1).

Both the AusLink and the WA Black Spot Program stipulate that approximately 50% of funding is to be spent on non-metropolitan roads and 50% on metropolitan roads (4). In Tasmania, no allocation is specified (5) but in SA where 61% of road fatalities occurred on non-metropolitan roads in 2007, 60% of funding is designated to non-metropolitan roads (6). In the past, Victoria allocated large amounts of funding to eliminating black spots but due to the success of these programs, much less is now spent treating black spots (7). Victoria currently runs a Grey Spot Program that specifically targets outer-metropolitan and rural intersections (8).

The AusLink Program does not designate specific proportions of funding to state and local government controlled roads (4), whereas Tasmania allocates all its state-based black spot funding to local roads (5). In WA, where local roads make up 88% of the road network and 65% of serious crashes occur on these roads, 50% of black spot funding is allocated to these roads (10). SA only designates one third of its black spot funding to local roads (6).

Each black spot program also allocates funding for reactive and proactive black spot projects. Reactive projects are identified on the basis of crash data and proactive projects target potentially hazardous locations identified on the basis of a road safety audit so do not necessarily have a crash history. While the AusLink and SA State Black Spot Programs only allocate 20% and 30% of their budgets to proactive projects (4, 6), WA can allocate up to 100% (10). This method of identification is highly relevant to WA due to its large area and long stretches of remote roads. The Tasmanian Black Spot Program only funds reactive projects identified on the basis of crash history (5).

Table 1 Comparison of Black Spot Funding Distributions

	AusLink	**WA**	**SA**	**Tasmania**
% funding to metro vs. non-metro roads	50% metro 50% non-metro	50% metro 50% non-metro	40% metro 60% non-metro	Not specified
% funding to state and local roads	Not specified	50% state roads 50% local roads	2/3 state roads 1/3 local roads	100% local roads
% proactive and reactive projects	Up to 20% proactive	50% proactive but can be increased to 100%	30% proactive 70% reactive	100% reactive

Identification of black spots and crash criteria

The AusLink and various state black spot programs in Australia receive nominations from the State road authority, local governments and the community to identify black spots for funding. All black spot programs use non-model based methods to establish the eligibility of nominated reactive black spot projects on road sections < 3km or road lengths ≥ 3km. The two methods used are 'crash number' and 'crash frequency' (crashes per km). However, the WA Program is the only one to set different crash criteria for state, local, metropolitan or non-metropolitan roads (Table 2). The number and frequency of crashes required for eligibility is higher in WA than other programs since police reported property-damage-only (PDO) crashes are included as well as casualty crashes (4, 5, 6, 10).

Table 2 Crash Criteria for Australian Black Spot Programs

Criteria	WA Black Spot Program				AusLink	SA Black Spot Program	Tasmanian Black Spot Program
	State metro roads	**State rural roads**	**Local metro roads**	**Local rural roads**			
Crash criteria for intersection, mid-block or short road section (< 3 km)	10 crashes over 5 years	3 crashes over 5 years	5 crashes over 5 years	3 crashes over 5 years	3 casualty crashes over a five-year period	3 casualty crashes over a five-year period	3 casualty crashes over a five-year period
Crash criteria for road length ($\geq$ 3km)	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	Average of 0.2 casualty crashes per km per annum over a 5 year period or top 10% of sites which have a demonstrably higher crash rate than other roads in a region	Average of 0.2 casualty crashes per km per annum over a 5 year period or top 10% of sites which have a demonstrably higher crash rate than other roads in a region	At least 1 reported crash per km within the last 5 years
BCR	≥ 1				≥ 2	≥ 1	Not stated
Maximum project cost	$1 000 000				$750 000	$1000 000	$250 000

All black spot programs use the benefit-cost ratio (BCR) formula to prioritise black spot projects for funding. This formula identifies whether the site is amenable to treatment and if the location exhibits significant correctable crashes for the treatment and cost to be worthwhile (2). The AusLink Program requires a BCR of greater than or equal to 2 for funding but the WA and SA State Programs require a BCR of greater than or equal to 1 thus allowing a greater scope of projects to be funded. The Tasmanian program does not specify a minimum BCR (5). The different programs also stipulate different maximum project costs ranging from $250,000 in Tasmania to $1.0 million in WA and SA for Federal black spot funding (4, 5, 6, 10).

With the exception of Tasmania, the other black spot programs allow for proactive funding of projects that do not meet the specified crash criteria but rather are identified and prioritised on the basis of a road safety audit.

Black spot programs targeting specific road users

Two states have programs targeting specific, vulnerable road users. The South Australian Black Spot Program directs 10% of all black spot funding to cycling-related improvements (DTEI 2007) and Victoria has initiated the world's first Motorcycle Black Spot Program targeting locations with a history of motorcycle crashes. Projects must meet specific crash criteria and treatments specifically address the factors contributing to these crashes (11).

Discussion

Black spot programs within Australia have different criteria relating to the identification and funding of black spot treatments. There are no correct or incorrect criteria, and all programs share a common goal of reducing road crashes at locations noted for a high incidence of road crashes. The WA State Program has devised different crash criteria for state, local, metropolitan and non-metropolitan roads that take into account road volumes and total funding available. However, these criteria do not account for variations in traffic volume within regions. The second part of this paper presents the results of an evaluation of the effectiveness and cost-effectiveness of the Black Spot Program in WA.

Evaluation of the effectiveness and cost-effectiveness of the WA Black Spot Program

Methods

The study design was a before and after comparison of reported crash frequencies (including fatalities, hospitalisation and PDO crashes) at sites treated under the State Black Spot Program for the years 2000 to 2002. Over this three-year period, the Black Spot Program allocated a total amount of $13 million for road safety related works on state and local government roads.

Information for each treatment site was obtained from the road safety section at Main Roads WA. The information that was provided included the treatment number, its location, a treatment description, start and finish dates and treatment costs. Information about the treatment life and annual maintenance and operating costs for each treatment type was obtained through consultation with a small group of experts at Main Roads. Based on the treatment description, a treatment code was assigned to each treatment site for use in the analysis. In cases where a black spot site had a combination of individual treatments, a 'dominant' treatment was selected.

Crash data was obtained from the Integrated Road Information System (IRIS) using police reported data, which is maintained by Main Roads. Data were obtained for each treatment site for a five-year pre- and post-treatment period. The data extracted included crash date, crash severity and crash location.

The effectiveness of the treatments in reducing crashes was estimated using a generalised estimating equation (GEE) Poisson regression model. The decision to use a GEE Poisson model was based on the need to take account of the correlated nature of the repeated measures taken pre- and post-treatment. Factors that were not taken into account due to data limitations but which might have affected the evaluation of the effectiveness of the treatments were crash migration and the lack of a control group. Using pre- and post -period time frames of five years is argued be sufficient to deal with regression to the mean effects.

The cost-effectiveness of the black spot program was assessed using benefit-cost analysis, with the benefit-cost ratio (BCR) calculated as 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. Two types of cost data were needed to calculate the BCRs, namely the cost of treating and maintaining the sites included in the program and the cost savings from a reduction in the number of road crashes resulting from treating the sites. 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 (13), adjusted for price increases and state variations in costs (14). 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 (15). 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 (15, 16).

The cost of treating black spot sites included the initial capital outlay as well as operating and maintenance costs and treatment life. 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 (17). 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.

Results

The evaluation of the effectiveness of the black spot program implemented from 2000 to 2002 covered 143 sites, with 11 sites eliminated due to poor quality of data. Of the included sites, 125 were intersection sites and the remaining 18 were non-intersection sites or road sections.

The effect of the black spot program across all treatment sites showed a strong positive result, with an overall crash reduction of 20% ($p<0.001$) (Table 3). The reduction in crashes at treated sites was greater for rural sites (33%) than metropolitan sites (17%). Crash reduction was similar for intersection sites (19%) and non-intersection sites and road sections (22%). Most treatment types showed positive crash reduction rates, with only two treatment types (seagull islands and high friction surfacing) not recording a significant crash reduction.

In terms of cost-effectiveness, the overall BCR across the Black Spot Program was 4.0, with BCRs of 2.1 and 9.6 for metropolitan and rural sites respectively (Table 4). Individual treatment types varied in their cost-effectiveness, with roundabouts, improved route lighting, traffic islands and non-skid treatments recording positive BCRs. The reason for some treatment types having a positive crash reduction but negative BCR was because of crash severity pre- and post-treatment, with a single serious or fatal crash at a site post-treatment impacting on its assessed cost-effectiveness. This resulted from having too few treatment sites to cancel out the effects of the costs of these more severe crashes on BCRs.

The sensitivity analysis showed the Black Spot Program to be cost-effective across all variations in assumptions, with lower discount rates and longer treatment lives of projects improving the rates of return and vice versa (Table 5).

Table 3 Effectiveness of Black Spot Treatments Implemented between 2000 and 2002 in Reducing Crashes in WA

Area/treatment	n	Estimate (β)[1]	Standard error	Probability 0<p<1	Crash reduction (%)
Whole program	143	-0.221	0.010	0.001	19.8
All metropolitan sites	115	-0.189	0.011	0.001	17.3
All rural sites	28	-0.400	0.036	0.001	32.9
Broad categories					
Intersection treatments	121	-0.214	0.013	0.001	19.3
• Metro	100	-0.198	0.013	0.001	17.9
• Rural	21	-0.378	0.081	0.001	31.5
Road section and non-intersection treatments	17	-0.245	0.018	0.001	21.8
• Metro	12	-0.137	0.145	0.001	12.8
• Rural	5	-0.419	0.083	0.001	34.3
Treatment types					
All roundabouts	44	-0.410	0.020	0.001	33.7
• Metro	32	-0.355	0.019	0.001	29.9
• Rural	12	-0.720	0.174	0.001	51.3
Traffic control signals	7	-0.427	0.783	0.001	34.7
Non-skid treatment	10	-0.386	0.030	0.001	32.1
Traffic island on approach	9	-0.249	0.090	0.006	22.1
Seagull island	18	0.132	0.024	0.001	-14.1
Left turn slip	9	-0.171	0.042	0.001	15.8
Median on existing road	5	-0.382	0.091	0.001	31.8
Nibs (pedestrian facilities)		-0.435	0.161	0.007	35.3
Improved route lighting	2	-0.127	0.005	0.001	11.9
All State roads	4	-0.094	0.023	0.001	9.0

1. β represents the regression coefficient in terms of the log-scale of the outcome variable. The crash reduction rate is given by $1 - e^{\beta}$.

Table 4 Economic Evaluation of the Black Spot Program Implemented in WA between 2000 and 2002

Area/treatment	Present value of total treatment costs ($)	Present value of crash cost savings ($)	Benefit cost ratio (BCR)
Whole program	10 822 034	43 744 083	4.0
All metro sites	8 013 829	16 805 760	2.1
All rural sites	2 808 204	26 938 335	9.6
Treatment types			
All roundabouts	5 341 262	40 327 207	7.6
• Metro	4 032 498	25 103 855	6.2
• Rural	1 308 764	15 223 341	11.6
Traffic control signals	949 779	- 3 847 420	-4.1
Non-skid treatment	624 237	4 275 133	6.8
Traffic island on approach	496 367	5 308 002	10.7
Seagull island	593 458	-4 835 970	-8.1
Left turn slip	442 089	-1 418 025	-3.2
Median on existing road	356 872	-1 221 965	-3.4
Nibs (pedestrian facilities)	116 911	-659 163	-5.6
Improved route lighting	399 218	7 146 678	17.9
All State roads	396 282	-3 157 840	-8.0

Table 5 Sensitivity Analysis for the Economic Evaluation of the Black Spot Program Implemented in WA between 2000 and 2002

	Present value of total treatment costs ($)	Present value of crash cost savings ($)	Benefit cost ratio (BCR)
Base case Discount rate, 5%; treatment life, 15 years	10 804 596	43 744 083	4.0
Sensitivity analysis			
Discount rate			
• 3% (15years)	11 024 616	49 353 727	4.5
• 8% (15years)	10 582 243	37 104 100	3.5
Treatment life			
• 10 years (5%)	10 417 507	28 470 833	2.8
• 20 years (5%)	10 891 755	45 674 705	4.2

Discussion

The Black Spot Program implemented in WA between 2000 and 2002 was found to be effective in reducing crashes at treated sites, with a reduction in the number of reported crashes of 20% pre- and post- treatment. Cost savings from the reduction in the number of crashes at the treated sites exceeded the costs of implementing and maintaining the sites, with an overall BCR across all treated sites of 4.0. Important limitations of the study that might have affected its effectiveness and cost-effectiveness were the lack of a control and no account being taken for regression to the mean.

Conclusion

The evaluation of WA's Black Spot Program provides evidence to support the argument that treating black spots remains an effective approach to preventing road crashes. Australia's vast road network and comparatively low population means it is likely that, in several states, black spots remain. However, as time progresses, the benefits of treating the remaining black spots will reduce so ongoing evaluations are required to determine the best criteria for sites to be eligible for funding and perhaps when such programs are no longer useful.

Selecting the best criteria for funding black spot sites is difficult, with different stakeholders disagreeing on how funding should be distributed across road types and between metropolitan and non-metropolitan regions. Some rural groups in Australia consider that the crash criteria for black spot programs have a built-in bias against non-metropolitan projects due to their low traffic volume and concentration of crashes, despite these roads having a more hazardous environment (18). In terms of the distribution of funding between state and local roads, SA only designates one third of its black spot funding to local roads despite these roads comprising 75% of its road network. Tasmania, on the other hand, allocates its whole state black spot funding to local roads, which make up 80% of its network. Further investigation into crash patterns and severity on metropolitan, non-metropolitan, state and local roads may assist in determining how funding should be distributed to produce optimum safety benefits.

A recent international investigation on state-of-the-art black spot approaches was recently funded by the European Commission (19). When identifying black spots based on crash criteria, the report rated model-based methods as best practice with the empirical Bayes method considered best, followed by a traditional model (including the Poisson method), then category analysis. Empirical Bayesian methods, however, require comprehensive and connected crash, road and traffic data and may be currently unrealistic for Australian black spot programs due to its vast road network and the difficulty of collecting the required data. The European Commission Report also stated that reactive crash analysis was still considered the best indicator of black spots because proactive methods have not yet been extensively researched and developed (19). However, a leading traffic safety consultancy estimated that 30% of hazards identified during a road safety audit on an existing road will lead to a crash within 5 years unless they are conclusively eradicated (20). For this reason, the WA Program for example, can allocate up to 100% of its funding to proactive projects, and the AusLink and SA programs also allocate funding to proactive projects. Proactive identification of black spots through road safety audits is highly relevant in Australia due to their large area and long stretches of remote roads where crashes are more dispersed.

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