TOPIC 3
SAFETY ANALYSIS
AND POLICY (SIG)

AN ECONOMIC EVALUATION OF THE AUSTRALIAN FEDERAL 'BLACK SPOT' ROAD SAFETY PROGRAM

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Abstract

This paper evaluates benefits of the black spot program. Estimates of engineering treatment benefits are provided using the crash-severity and crash-type methods of costing crashes. The program is estimated to have generated a net present value of one billion dollars and benefits of around four dollars per dollar of expenditure.

INTRODUCTION

Nature of the Black Spot Program

In December 1989 the Australian Federal Government announced a two-pronged initiative aimed at reducing the incidence and severity of road crashes. The initiative, known as the Black Spot Program, involved a total allocation of $270 million over the period 1 July 1990 to 30 June 1993 to ameliorate black spots, tied to a requirement that Australian states and territories (referred to in this paper as 'jurisdictions') adopt a 10-point package of various road safety measures including a 0.05 per cent blood alcohol concentration limit and nationally uniform speed limits.

The Black Spot Program was directed at improving the physical condition or management of hazardous locations with a history of crashes involving death or serious injury by implementing appropriate treatments at these locations. The Program was intended to effectively prioritise funds to meet greatest road safety needs and to obtain the highest economic returns in terms of avoided crashes.

The Program was administered by the Federal Office of Road Safety (FORS), who retained the Australian Road Research Board (ARRB) to identify and categorise traffic engineering treatments with relatively high potential benefits. Consequently, a 'Schedule of Acceptable Treatments' (Appendix 1) was drawn up to provide a convenient basis for jurisdictions to submit applications for funding the treatment of hazardous sites. Provided a site met the criterion of having had a history of injury crashes, a remedial project involving any treatment in the Schedule was considered to have a potential benefit-cost ratio of at least 2. Apart from the funding of Schedule treatments, a proportion of funds (about $30 million) was spent on other road safety projects. Black spot projects numbering 3,176 were approved under the Program. The mean cost per project was $85,000.

This study provides an assessment of the economic performance of the Black Spot Program based on a cost-benefit analysis of a sample of completed projects.

EVALUATION METHODOLOGY

General methodology

The methodology adopted involves the application of cost-benefit analysis to the difference in crashes before and after treatment. The analysis was carried out using a sample of 254 projects. As the study was conducted in 1993-94 and at least one full year's post treatment data were essential for meaningful analysis, only projects completed during the first half of the Program could be included in the sample.

Nearly all the projects in the sample were implemented in 1991. The 'before' period chosen was 1988-90 and the 'after' period was 1992.

In attempting to determine the true effect of treatments and to assess the benefits due to the Program, there are several potentially confounding effects to be considered. These include site-specific factors, crash trends over time, regression-to-mean effect, changes in the reporting of crashes over time, publicity effects, statistical instability and crash migration. Controlling all these factors was beyond the scope of the study but the effects considered most influential were taken into account.

The methodology incorporated an adjustment to reflect the extent to which reductions in crashes after treatment could be attributed to general crash trends in each jurisdiction. The adjustment was carried out using urban and rural areas within each jurisdiction as controls. The procedure involved estimating the difference between the expected number of crashes at groups of sites had there been no treatment (based only on general community crash trends) and the number of crashes that actually occurred after treatment.

The sample was chosen using a detailed procedure which took account of the relative numbers of projects involving various treatments and their costs, and the geographical spread of sites in jurisdictions. In using control areas, it is expected that general community trends in crashes will affect both the sites to be treated and the control areas of which such sites form a part, in a similar manner. Sites selected for evaluation were spread around urban and rural areas in such a manner as to increase the likelihood that they would, in the absence of treatment, have experienced crash trends similar to the overall experience of these areas.

The expected number of crashes at a group of treated sites during the period after treatment (had there been no treatment) is equal to the actual number of crashes at the sites in the period before treatment multiplied by the 'control ratio'. The control ratio is the ratio of the number of crashes in the control area in the period after treatment to the number in the period before treatment. A control ratio based on aggregate urban crash data in each jurisdiction was used for urban sites, and a similar ratio based on rural crash data was used for rural sites.

The reduction in crashes attributable to the treatment (other things being equal) is the expected number of crashes in the period after treatment minus the number that occur, subject to the reduction being statistically significant. The methodology proposed by Tanner (1958) was used to test whether changes in crash numbers after treatment were statistically significant and to estimate crash-reduction factors. The reductions in crashes during the first year after treatment were assumed to continue undiminished over the economic lifetimes of treatments. These lifetimes were estimated from data provided by the jurisdictions.

To estimate the net benefits of the Schedule treatments implemented under the Black Spot Program, the results obtained for the sample of treated sites were expanded to the population of treated sites on the basis of four capital expenditure categories. The approach assumes that the projects sampled for evaluation are representative of those carried out during the entire Program and that the benefits of the treatments in each expenditure category of the sample are representative of the benefits in the corresponding category for the whole Program. However, it must be noted that the projects selected for evaluation were those completed during the first half of the Program and did not include all treatments undertaken during the Program.

In evaluating the effectiveness of black spot treatments, crash reduction benefits were estimated in terms of crash costs avoided. There are two methodological approaches available in Australia to assess road crash costs: crash-type and crash-severity. In estimating the human costs of crashes in both methods, the conceptual basis used was the human capital approach where the 'value of life' (more correctly, livelihood or productive capacity) of crash victims is measured in terms of the discounted present value of their expected future earnings lost due to premature death or injury.

Crash-type method of costing crashes

In this context, 'type' refers to vehicle movements just before impact and is commonly based on the recording of crashes in collision diagrams and subsequent coding. The general technique used to cost crashes by type adopted in this study is based on the work of ARRB. Total crash costs comprise personal injury costs and incident costs for each crash type.

Comprehensive crash data for 1992, relating to fifteen different crash types and an 'other' category, were obtained from all jurisdictions. From these data, the injury profiles for a typical or average urban and rural crash of each type were obtained by dividing the total numbers of casualties (killed, hospitalised etc) by the number of associated crashes. The injury profiles for each crash type were multiplied by ARRB's standardised costs of casualties (fatality, hospitalisation etc) (ARRB 1992) to estimate the total personal injury cost for each crash type.

In calculating injury profiles, two-vehicle and multiple-vehicle crashes of the same type were examined separately to determine whether there were differences in underlying injury patterns.

Where there were several hundred multiple-vehicle crashes, the injury profile was often noticeably worse than for two-vehicle crashes of the same type.

Incident costs, including property damage, were also derived from ARRB (1992). ARRB's calculations were based on one-vehicle and two-vehicle crashes. However, aggregate data obtained for this study indicated that for some crash types (for example, rear-end crashes) the mean number of vehicles per crash was somewhat greater than two. The technique adopted in this study therefore differed from ARRB's in one respect: all coded crashes of a particular type were considered as belonging to that type, irrespective of the number of vehicles involved in each crash. An adjustment was made to ARRB's incident cost estimates to take account of the differences in the mean number of vehicles involved in some crash types.

Estimated standardised crash costs by crash type for urban 'two-vehicle' crashes used in the evaluation are presented in Appendix 2. Costs of urban crashes normally involving one vehicle, and costs of one- and two-vehicle rural crashes were also estimated and used in the analysis.

Crash-severity method of costing crashes

In the crash-severity method, crashes are categorised on the basis of the highest degree of injury of the victims involved, and an average cost for each category of crash is calculated. For example, a fatal injury crash is one in which at least one person involved in the crash dies, while there may or may not be others who sustain less severe injuries. Four categories of injury were used: fatal injury, hospitalisation, medical treatment and nil injury (property damage only).

The total costs in 1992 dollars of the four classes of crashes based on injury severity, derived from BTCE (1992) are: fatal injury crash $780,416; hospital injury crash $111,419; medical injury crash $11,707; and nil injury crash $4,847.

One of the disadvantages of using costs based on crash severity is that the results of an analysis using these costs can be heavily influenced by the relatively high cost of serious injury crashes. Crashes in general are random, infrequent events and fatal injury crashes are even less common. In an economic analysis of the effects of a black spot treatment, the occurrence of a single fatal injury crash either before or after the implementation of the treatment can substantially influence the results of the analysis if the change in crash experience is projected constantly over the lifetime of the treatment. This possibility tends to increase the uncertainty in estimates derived using costs based on crash severity. In this study, the effect of fatal injury crashes has been moderated by using a weighted combination of fatal injury and hospital injury crash costs ($170,000) for all crashes where the most serious injury was a fatality or one which required hospitalisation.

EVALUATION RESULTS

Overview of crash and injury experience at sample sites

The following analysis compares the mean number of crashes at sample sites over the period 1988 to 1990 (before treatment) with those that occurred in 1992 (after treatment). The analysis of property damage only (PDO) crashes excludes data for the state of Victoria, as recording of PDO crashes was discontinued in Victoria after December 1990.

Table 1 shows that injury crashes declined by 46 per cent after treatment, and PDO crashes by 30 per cent. The number of persons killed fell by 33 per cent, those hospitalised by 64 per cent, and those requiring medical treatment by almost half.

At the treated sample sites, no fatalities occurred in 1992 in the Northern Territory, Australian Capital Territory, Tasmania and Western Australia, and neither did any of the sample sites in the two territories have a crash resulting in a hospitalisation injury. Among the jurisdictions, the reductions in the number of serious injuries ranged from just under 50 per cent in South Australia and New South Wales, through to 75 per cent in Victoria and 90 per cent in Tasmania.

The 46 per cent fall in injury crashes in the sample compares with reductions over the same period of 15-30 per cent in the numbers of hospitalisation crashes in five of the jurisdictions (including New South Wales and Victoria), 10 per cent in another, and a situation of very little change in the other two.

Decreases in the numbers of less severe injury crashes (those involving medical and first aid injuries) throughout the relevant control areas were around 30 per cent in New South Wales and Victoria. The decreases were generally around 10 per cent elsewhere, except in the Australian Capital Territory where they remained steady, and in Queensland where they rose by 20 per cent.

Table 1 Crashes and injuries at all sample sites before and after treatment (mean number per year, rounded to nearest integer)

	Before (1988-90)	After (1992)	Per cent reduction
Injury crashes	1,004	543	46%
PDO crashes[a]	2,276	1,600	30%
Persons seriously injured	317[b]	122	61%
Killed	25	17	33%
Hospitalised	291	105	64%
Persons medically treated	881	447	49%

Notes:

a. Excludes Victorian experience.
b. Persons killed and hospitalised do not add to persons seriously injured because of rounding.

Source: Estimates based on data provided by Australian states and territories.

Overall, the decrease in injury crashes at the sample sites was more than two and a half times what could have been expected on the basis of general comparable crash trends in the various jurisdictions over the relevant period (the mean number of crashes between 1988 and 1990 compared with the number in 1992).

The experience of this sample of treated sites suggests that the Black Spot Program achieved considerable success in reducing the incidence of crashes involving death and hospitalisation. The treatments appear to have also moderated the level of injury within the much smaller numbers of crashes which occurred after treatment. Table 2 shows the overall reductions in crashes and injuries for selected treatments.

Table 2 Percentage reductions[a] in crashes and injuries[b] for selected treatments (per cent)

Treatment	Injury crashes	PDO crashes[c]	Serious Injuries[d]	Medical Injuries
New traffic signals	42	36	66	57
Modified traffic signals	50	31	71	56
Roundabouts	88	52	100	88
Intersection channelisation	42	33	57	40
Provision of medians	39	25	53	33
Protected turning bays	30	49	42	26

Notes:

a. The difference between mean numbers of crashes or injuries in 1988-90 relative to the numbers in 1992, rounded to the nearest integer.
b. Percentage reductions in the number of persons injured.
c. PDO crashes exclude Victorian experience.
d. Serious injuries comprise persons killed and hospitalised.

Source: Estimates based on data provided by Australian states and territories.

Crash-type analysis

A detailed analysis was carried out on eight of the more common treatments implemented during the Program. These eight treatments were associated with a total of 214 sample projects (out of a total of 254 originally selected for analysis) having a combined capital cost of $22.4 million. The number of sample projects per treatment ranged from 6 for protected right-turns to 59 for traffic signal modification. Based on data provided by the jurisdictions, the estimated lifetimes of these treatments ranged from 12 years for traffic signals to 20 years for treatments such as roundabouts and shoulder sealing.

Table 3 sets out the net present values (NPVs) and benefit-cost ratios (BCRs) for five of the eight treatments estimated using a benchmark discount rate of 8 per cent. This rate, which is broadly consistent with empirical estimates of before-tax rates of return in the Australian corporate sector, is recommended by the Department of Finance for use in evaluating public sector investment projects (Department of Finance 1991). The table also has estimates using discount rates of 6 per cent and 10 per cent. Measures of performance for the other three treatments are not reported because, as it turned out, the sample projects relating to these treatments had numbers of crashes in the periods before and after treatment which were too small for meaningful analysis.

The total NPV of 184 projects involving 5 treatments was $92.7 million at an 8 per cent discount rate. The highest BCR estimated was 13.4 for provision of medians. Roundabouts and channelisation had BCRs of 5.6 and 4.9 respectively. New traffic signals and modified traffic signals had BCRs of 2.6 and 6.8 respectively.

Table 3 Cost-benefit analysis[a] of sample projects by treatment: crash-type method (per cent)

Treatments	Capital cost ($m)[b]	No. of projects	Life-time (yrs)	8 per cent discount rate		6 per cent discount rate		10 per cent discount rate	
				NPV ($m)[b]	BCR	NPV ($m)[b]	BCR	NPV ($m)[b]	BCR
New traffic signals	5.8	50	12	12.0	2.6	14.0	2.8	10.3	2.4
Traffic signal modification	5.7	59	12	35.3	6.8	39.9	7.5	31.3	6.2
Channelisation	2.7	32	15	11.0	4.9	12.8	5.6	9.4	4.4
Provision of median	1.1	12	15	14.7	13.4	16.9	15.2	13.0	12.0
Roundabouts	4.1	31	20	19.8	5.6	23.8	6.4	16.6	4.9
Protected turning bays[c]	0.7	9	15						
Shoulder sealing[c]	1.5	15	20						
Protected right turns[c]	0.9	6	20						
Total[d]	22.4	214		92.7		107.3		80.6	

Notes:

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance.
b. 1992 dollars.
c. Insufficient crash numbers in the before and after periods to make estimates.
d. Numbers may not add to totals due to rounding.

Source: Estimates based on data provided by Australian states and territories.

Table 4 sets out statistically significant crash reduction effects of treatments based on the methodology of Tanner (1958). Testing was undertaken on the basis that the natural logarithm of the ratio of observed crashes after treatment, to those expected on the basis of control ratios calculated for the jurisdictions, was approximately normally distributed. A level of significance of 90 per cent was adopted for the one-sided t-test.

Table 4 Statistically significant crash reduction effects of treatments: crash-type method

Treatment	Crash type with significant effect[a]	Crash reduction factor (1-κ)[b]	90 percent confidence interval	
			Lower limit	Upper limit
New traffic signals	Right-angle	74	57	85
	Rear-end	25	0[c]	47
Traffic signal modification	Right-angle	30	0[c]	54
	Right-turn	56	0[c]	84
	Rear-end	21	0[c]	41
Channelisation	Right-angle	37	3	59
	Rear-end	31	12	46
Provision of medians	Right-turn	48	0[d]	74
	Rear-end	27	0[c]	47
Roundabouts	Right-angle	72	21	90
	Right-turn	88	20	98

Notes:

a. Testing was undertaken on the basis that the natural logarithm of the ratio of the number of observed crashes after treatment to the number expected, based on the various state and territory control ratios, was approximately normally distributed. A 90 per cent level of significance was used for the one-sided t-test arising from the use of sample values to estimate population parameters.

b. The value represents the ratio of crashes after treatment to the expected number calculated using the relevant control ratios. Therefore, the value (1-κ) is the crash reduction factor: here it represents the percentage amount by which the actual number of crashes after treatment should be below the number expected on the basis of control ratios. For example, in the case of right-angle crashes associated with new traffic signals (κ=0.26), the best estimate of the actual number of crashes that occur after treatment will be 26 per cent of the number expected on the basis of the relevant control ratios. The crash reduction factor (1-κ) is therefore 0.74, that is the number of right-angle crashes after the installation of new traffic signals should be 74 per cent less than what would be expected if the treatment was not implemented.

c. The effect was not significant at the 95 per cent level.

d. Occasionally it was found that after statistical significance at the 90 per cent level had been established, revision of the estimate for the variance of log κ produced a confidence interval including the value of zero.

Source: Estimates based on the methodology of Tanner (1958) and data provided by Australian states and territories.

The quantity 1-κ presented in Table 4 can be interpreted as the percentage crash reduction factor attributable to treatments after allowance has been made for general community trends. It effectively represents the amount by which the actual number of crashes after treatment was less than the number that would have been expected had the treatment not been implemented (see note in Table 4). The crash reduction factors provide estimates of the crash reduction potential of various treatments when cost-benefit evaluations of such treatments are conducted.

Of particular note in Table 4 are the substantial reductions in right-angle crashes at sites with new traffic signals and in right-angle and right-turn crashes at roundabouts. There was also a relatively large decrease in right-turn crashes at sites with modified traffic signals, which often involved the installation of a separate right-turn phase.

For the purpose of estimating overall Program benefits, sample projects were categorised on the basis of capital expenditure. This was also one of the techniques used to select sample projects from the population of projects. Four expenditure categories were defined: major ($100,000 or more), medium ($50,000-$100,000), small ($20,000-$50,000) and minor (less than $20,000). Mean project lifetimes in each category were used in the analysis.

The 254 projects in the sample had a total capital cost of $25.5 million. The sample of projects comprised 95 major projects (totalling $18.4 million), 62 medium ($4.5 million), 63 small ($2.2

million) and 34 minor (0.4 million). The total NPV for the 254 projects was $83.2 million at an 8 per cent discount rate, made up of $50.2 million for major projects, $30.3 million for medium, $2.0 million for small, and $0.6 million for minor.

The highest BCR was for the medium category (6.8), indicating that projects in the expenditure range $50,000-$100,000 produced the highest returns per dollar of expenditure. The lowest BCR was for the small category (1.8). The major and minor project categories had BCRs of 3.5 and 2.1 respectively.

Overall estimates for the Black Spot Program were obtained by expanding the estimates for the four sample capital expenditure categories to obtain estimates for equivalent categories in the total population of black spot projects undertaken during the Program. These four individual estimates were then combined to generate an estimate of overall Program benefits.

The expansion process resulted in an estimate of $791.8 million as the net present value of benefits from the Black Spot Program at an 8 per cent discount rate. The overall BCR for the Black Spot Program was estimated at 3.9.

Crash-severity analysis

In this section, results based on the crash-severity method of costing crashes are presented. These results correspond to those obtained using the crash-type method.

Table 5 sets out NPVs and BCRs for five treatments at discount rates of 6, 8 and 10 per cent. The total NPV of 184 projects involving 5 treatments was $89.2 million at an 8 per cent discount rate. The highest BCR obtained was 9.2 for roundabouts. Traffic signal modification, channelisation and provision of medians had BCRs of 7.7, 6.5 and 5.0 respectively. New traffic signals had a relatively low BCR of 0.1 as the reductions in serious injuries were not statistically significant. In regard to protected turning bays, shoulder sealing and protected right-turns, it turned out that the crash numbers associated with the sample projects were too small to make a definite assessment of the effectiveness of these treatments.

Table 6 sets out statistically significant crash reduction effects of treatments using the methodology of Tanner (1958).

Table 5 Cost-benefit analysis[a] of sample projects by treatment: crash-severity method (per cent)

Treatments	Capital cost ($m)[b]	No. of projects	Life-time (yrs)	8 per cent discount rate		6 per cent discount rate		10 per cent discount rate	
				NPV ($m)[b]	BCR	NPV ($m)[b]	BCR	NPV ($m)[b]	BCR
New traffic signals	5.8	50	12	-7.2	0.1	-7.4	0.1	-7.1	0.1
Traffic signal modification	5.7	59	12	40.9	7.7	46.1	8.5	36.4	7.0
Channelisation	2.7	32	15	15.3	6.5	17.7	7.3	13.3	5.8
Provision of medians	1.1	12	15	4.7	5.0	5.5	5.6	4.1	4.4
Roundabouts	4.1	31	20	35.6	9.2	42.3	10.7	30.3	8.1
Protected turning bays[c]	0.7	9	15						
Shoulder sealing[c]	1.5	15	20						
Protected right turns[c]	0.7	6	20						
Total[d]	22.4	214		89.2		104.2		76.9	

Notes:

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance.
b. 1992 dollars.
c. Insufficient crashes in the before and after periods to make an assessment.
d. Numbers may not add to totals due to rounding.

Source: Estimates based on data provided by Australian states and territories.

Table 6 Statistically significant crash reduction effects of treatments: crash-severity method

Treatment	Crash severity with significant effect[a]	Crash reduction factor (1-κ)[c]	90 per cent confidence interval[b]	
			Lower bound	Upper bound
New traffic signals	First aid injury	158[c]	100[d]	510
	Medical injury	30	0[d]	61
Traffic signal modification	Nil injury	21	6	33
	Medical injury	39	17	55
	Serious injury	60	17	81
Channelisation	Nil injury	30	14	43
	First aid injury	38	0[f]	74
	Medical Injury	20	0[d]	48
	Serious injury	40	0[f]	75
Provision of medians	Nil injury	20	0[d]	45
Roundabouts	Nil injury	47	8	69
	First aid injury	82	0[f]	99
	Medical injury	80	47	92
	Serious injury	100	e	e

Notes:

a. Testing was undertaken on the basis that the natural logarithm of the ratio of observed crashes after treatment to those expected, based on the various state and territory control ratios, was approximately normally distributed. A 90 per cent level of significance was used for the one-sided t-test arising from the use of sample values to estimate population parameters.

b. For an explanation of κ see Table 4, note b.

c. Increase

d. The effect was not significant at the 95 per cent level.

e. No serious injury crashes were observed after treatment, so it is not possible to obtain a confidence interval for the precise effect of the treatment.

f. Occasionally it was found that after statistical significance at the 90 per cent level had been established, revision of the estimate for the variance of log κ produced a confidence interval including the value of zero.

Source: Estimates based on the methodology of Tanner (1958) and data provided by Australian states and territories.

The total NPV for the 254 projects was estimated at $132.7 million at an 8 per cent discount rate. This amount was made up of $92.3 million for major projects, $26.8 million for medium, $-0.5 million for small, and $14.0 million for minor. The highest BCR was for the minor projects (26.9) while the lowest was for small projects (0.8). The relatively low BCR for the small projects was due to the reduction in fatal and hospitalisation crashes not being statistically significant. The medium and major project categories had BCRs of 6.1 and 5.6 respectively.

The net present value of benefits from the Black Spot Program using the crash-severity method was estimated at $1,338.7 million at an 8 per cent discount rate. The overall BCR for the Black Spot Program was estimated at 5.9.

Comparison of crash-type and crash-severity estimates

The NPVs and BCRs based on the crash-type and crash-severity methods show some significant differences, indicating that these values are quite sensitive to the method used to obtain estimates of first-year crash-reduction benefits. For individual treatments, the range of BCRs using the crash-severity method (0.1 to 9.2) was less than that for the crash-type method (2.6 to 13.4). The opposite applied for projects classified by level of expenditure: crash-severity BCRs ranged from 0.8 for small projects costing between $20,000 and $50,000 to 26.9 for minor projects costing less than $20,000, while crash-type BCRs ranged from 1.8 for small projects to 6.8 for medium projects costing between $50,000 and $100,000.

Projects involving the construction of medians had a crash-severity BCR of 5.0 while the crash-type BCR was 13.4, and for new traffic signals the crash-type BCR (2.6) also greatly exceeded that from the crash-severity method (0.1). However, for roundabouts the crash-severity BCR (9.2) was much greater than the crash-type BCR (5.6). The BCRs obtained using the two methods were reasonably close for traffic signal modification (7.7 and 6.8) and channelisation (6.5 and 4.9). The impressive reductions in both crashes and injuries, particularly serious injuries (Tables 1 and 2), explains why most of these treatments have generated substantial benefit-cost ratios with both crash costing methods.

One reason for the differences in BCRs obtained using the two crash costing methods is that the nature of these methods substantially influences the results when a small number of crashes are evaluated. In the crash-severity method there are only four classifications of crashes, and if significant crash reductions were found for serious injury crashes, the unit cost applied was $170,000. In the analysis by crash type, many more crash classifications tend to reduce the potential for establishing significant effects among small numbers, and the unit costs applied for individual crash types are typically in the region of $20,000 to $60,000 (Appendix 1).

In comparing the effectiveness of different treatments, the interplay between the relative numbers of crashes before treatment, crash reduction factors, and expenditure on treatment work, affect the economic assessment. An example is the case of modified traffic signals and roundabouts. Sites where traffic signals were modified had on average nearly three times as many crashes per site prior to treatment than did sites where roundabouts were constructed. Mean expenditure at these traffic signal sites was about one-quarter less than that for roundabouts. Even though crash reduction factors at roundabouts were much higher, their BCR was lower than for modified traffic signals under the crash-type method, and higher under the crash-severity method.

Some studies (for example, BTCE 1993; Andreassen 1992) have obtained BCRs based on the crash-type method which are substantially higher than those based on the crash-severity method. However, in this study, the converse was generally found to be the case. The main reason for the atypical result is the marked drop in serious injury crashes and associated serious injuries, particularly hospitalisation injuries, at many treated sites. The relatively greater sensitivity of the crash-severity method to the effects of serious injuries caused the crash-severity BCRs to increase relative to the crash-type BCRs.

Because of the wide variety of circumstances in which crashes can occur, there is a substantial element of chance effects and situation-dependent variability to be expected in injury outcomes. When crashes are classified and costed on the basis of injury severity levels, the extent to which relatively infrequent fatalities and hospitalisations arise is critical, and may change over different sets of observations.

On the other hand, when crashes are classified by type, there should not be such great variations in the nature of vehicle movements prior to crashes at particular sites. The relevant unit cost estimates are therefore not likely to fluctuate nearly as much.

CONCLUDING ASSESSMENT

This study provides some illuminating perspectives on the results of an extensive black spot remedial program. Although data constraints did not permit the full range of factors that could potentially affect the evaluation to be controlled, the methodology took account of the most influential factors.

One of the difficulties encountered was the instability associated with small crash numbers. The reliability of statistical tests generally tends to be affected by the use of small crash numbers and in such cases the results have to be interpreted with caution. The effects of some treatments could not be reliably determined because of the small crash numbers involved.

Two methods of estimating crash costs were used. For several treatments, the crash-severity BCRs were found to be greater than the corresponding crash-type BCRs, contrary to the findings of some previous research. These atypical results reflect the fact that BCRs generated using the crash-severity method are more sensitive to changes in high-cost serious-injury crashes.

The nature of the crash-type method suggests that the crash-type BCRs obtained in this study would display greater stability and consistency than crash-severity BCRs if future evaluations were made of the effectiveness of black spot treatments.

The Black Spot Program was intended to improve locations with a history of crashes involving death or serious injury. The comparative crash experience before and after treatment in the sample of sites studied, and the results of the economic evaluation, suggest that this objective has been achieved.

Spin-off benefits of the Black Spot Program included employment generation and the multiplier effects of an injection of $270 million into the Australian economy during a recessionary period.

The economic evaluation of the Black Spot Program using two methods of costing crashes indicates that the Program has delivered net benefits to the Australian community of at least $800 million, generating benefits of around $4 for each dollar of expenditure.

The estimated safety benefits of the treatments have been somewhat moderated by the use of the valuation of lost output due to injury and premature death by discounting future earnings (human capital approach). The use of a value of statistical life and values of injury prevention using a willingness to pay approach would have produced substantially higher benefits. In this context, estimates of benefits of individual treatments as well as estimates of overall Program benefits should be regarded as conservative.

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APPENDIX 1: SCHEDULE OF ACCEPTABLE TREATMENTS

High-potential urban

UH1	New traffic signal installations
UH2	Traffic signal modification
UH3	Intersection channelisation
UH4	Provision of medians (with turn protection)
UH5	Median closures
UH6	Pedestrian refuges
UH7	Roundabout installation
UH8	Selective roadside hazard modification
UH9	Improved lighting at pedestrian facilities

High potential rural

RH1	Shoulder sealing
RH2	Lighting at isolated intersections
RH3	Site specific edgelining
RH4	Selective roadside hazard modification
RH5	Curve delineation
RH6	Provision of pavement markers, guide posts, corner cube reflectors
RH7	Staggering of cross intersections
RH8	Warning and direction signs (2 lane 2 way roads)
RH9	Protected right turns

Medium potential urban

UM1	Improved skid resistance
UM2	Protected turning bays
UM3	Local area traffic management (including street closures)
UM4	Clearway provisions/parking controls
UM5	Median barriers
UM6	Red light cameras

Medium potential rural

RM1	Superelevation on isolated curves
RM2	Median barriers
RM3	Improved sight distance
RM4	Overtaking lanes
RM5	Improvements to divided highways
RM6	Acceleration and deceleration lanes

Source: FORS (1990)

APPENDIX 2: URBAN CRASH COSTS BY CRASH-TYPE

Table 7 Costs of urban crashes for selected crash-types by jurisdiction[a] (two-vehicle crashes), $

Crash-type (two vehicle)	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
Person cost								
Right-angle	8,949	11,945	21,389	22,033	5,132	9,637[b]	48,032	11,852
Head-on	7,641	37,243	95,142	122,086	20,859	28,915	108,871	51,174
Right-turn	6,642	11,017	16,855	29,469	6,341	9,637[b]	47,689	14,647
Rear-end	527	6,080	7,012	13,186	1,214	6,220	19,056	5,145
Side-swipe	705	10,865	9,238	15,522	1,665	3,406	32,210	3,689
U-turn	na	9,394	6,079	11,701	3,312	na	41,191	10,641
Overtaking	na	36,568	13,797	38,561	3,069	na	110,361	4,814
Incident cost[c]								
Right-angle	11,967	12,172	12,001	12,069	12,138	12,704[b]	12,240	12,001
Head-on	14,836	14,787	14,787	14,787	15,175	15,272	15,563	15,272
Right-turn	12,856	13,047	12,895	12,895	13,009	12,704[b]	13,123	12,895
Rear-end	9,839	10,753	9,976	10,433	10,182	10,090	10,525	10,045
Side-swipe	8,953	9,165	8,992	9,165	9,050	9,050	9,146	9,011
U-turn	na	10,644	10,562	10,726	10,672	na	10,781	10,589
Overtaking	na	8,885	8,885	8,885	8,980	na	9,075	8,904
Standardised total cost[d]								
Right-angle	20,916	24,117	33,390	34,103	17,270	22,341[b]	60,272	23,854
Head-on	22,476	52,030	109,929	136,873	36,134	44,187	124,434	66,446
Right-turn	19,498	24,064	29,749	42,363	19,350	22,341[b]	60,812	27,542
Rear-end	10,366	16,833	16,988	23,619	11,396	16,310	29,581	15,190
Side-swipe	9,658	20,030	18,230	24,687	10,715	12,455	41,356	12,700
U-turn	na	20,038	16,641	22,427	13,984	na	51,972	21,231
Overtaking	na	45,453	22,682	47,446	12,049	na	119,436	13,718

Notes:

na=not available. It was not possible to obtain estimates for some crash types from the data provided by jurisdictions.

a. The calculation of standardised costs was based on the recorded crashes in each jurisdiction. Caution must be exercised when comparing cost figures among jurisdictions because crash recording arrangements and coding systems vary considerably among jurisdictions.

b. Tasmania's coding system treats both right-angle and right-turn crashes as part of an 'angle' crash category.

c. The incident costs incorporate an adjustment for greater average vehicle numbers in crashes classified as involving two vehicles.

d. Numbers may not add to total due to rounding.

Source: Estimates based on data provided by Australian states and territories and ARRB (1992).