MONASH University
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EVALUATION OF MID-BLOCK ACCIDENT 'BLACK SPOT' TREATMENTS

by

Michael Tziotis

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TABLE OF CONTENTS

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
REPORT DOCUMENTATION PAGE

Report No.	Report Date	ISBN	Pages
48	March 1993	0 7326 0048 0	23

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TZIOTIS, M.

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Abstract:
The implementation of an Accident Black Spot Program was first introduced in Victoria in 1979. The program's objective was to reduce the frequency and severity of crashes at locations experiencing a poor accident record by applying cost effective accident countermeasures. The purpose of this study was to evaluate mid-block 'Black Spots' treatments, focusing on the resultant changes in casualty crash frequencies and the economic worth of these treatments following their implementation.

The major findings of the study were that the treatment of high accident 'Black Spot' mid-blocks (1980 - 1989), provided highly significant reductions in casualty crashes of 30.5% (compared to 33.4% for intersections, Corben & Foong, 1989), while also returning high economic benefits, Net Present Worth of approximately $19.8 million (1992), with a Benefit Cost Ratio of 7.59 (7.13 for intersections, Corben & Foong 1989).

Other key findings were that targeted **pedestrian treatments** were highly significant in reducing pedestrian casualty crashes by 52%, and all casualty crashes within pedestrian mid-block 'Black Spots' by 37.4%, with new pedestrian signals achieving a significant 49.5% reduction in pedestrian casualty crashes (41.5% overall). **Off-path/head-on treatments** were also highly significant in reducing those types of crashes by 52.1% (41.8% overall), with roadworks in this case the most successful treatment (ie., 57.4% in the targeted crash type and 55.8% overall). **Roadside hazard treatments** reduced pole accidents significantly by 68.4%, while the use of a **combination of treatments** for differing types of accidents reduced casualty crashes by a highly significant 29.1%.

Key Words:
Accident Black Spot, accident countermeasures, delineation, economic evaluation, pedestrian treatments, remedial treatments, roadworks, roadside hazards, road safety,

EXECUTIVE SUMMARY

The treatment of accident 'Black Spots' was commenced in Victoria in 1979 with the aim of reducing the incidence and severity of crashes at locations with a poor accident record. 'Black Spots' treatments were implemented at both intersections and along mid-block locations and in 1989 Monash University Accident Research Centre (MUARC) undertook a study (Corben & Foong 1989) to determine the effectiveness of these treatments. The effectiveness of the remedial works was measured in terms of the changes in casualty crash frequencies and the economic worth of the treatments implemented.

The report by Corben & Foong was able to conclude that remedial works at intersection 'Black Spots' were highly effective in reducing the incidence of casualty crashes and that these works delivered high economic returns. However insufficient data prevented any conclusions being made about the effectiveness of remedial works at mid-block locations. With the availability of additional mid-block 'Black Spot' site data this evaluation was able to proceed.

The evaluation was based on 69 mid-block 'Black Spot' locations that were almost exclusively located in the Melbourne Metropolitan Area. A 'before' and 'after ' method using control ratios was carried out to estimate the changes in casualty crash frequencies following the implementation of remedial treatments. A Chi-Square test was then used to assess the statistical significance in the changes to accident frequencies.

The analysis undertaken investigated:

* the effectiveness of mid-block 'Black Spot' treatments
* the effectiveness of specific treatments targeting particular crash categories and their effect on the remaining crash types that prevail
* the economic value of mid-block 'Black Spot' treatments in terms of Net Present Worth (NPW) and Benefit Cost Ratio (BCR).

Key Findings:

Effects on Casualty Crashes

The treatment of mid-block 'Black Spots' produced a highly significant reduction of 30.5% in casualty crashes. When considering targeted accident countermeasures, **pedestrian treatments** were highly significant in reducing pedestrian casualty crashes by 52%, and all casualty crashes within pedestrian mid-block 'Black Spots' by 37.4%. **New pedestrian signals** produced a significant reduction in pedestrian casualty crashes of 49.5% (41.5% overall), while **remodelled or relocated pedestrian signals** were not statistically significant in reducing pedestrian crashes. When considering all casualty mid-block crashes however, remodelled/ relocated pedestrian signals achieved a mildly significant reduction of 43.8% of all mid-block casualty crashes.

Non-signal pedestrian treatments (eg., pedestrian refuges, fencing, etc.,) reduced pedestrian casualty crashes by a significant 68.6%. Overall there was a reduction of 27.8% in all mid-block casualty crashes, this however was not statistically significant

Targeted treatments were also highly significant in reducing **off-path/head-on casualty crashes** by 52.1% (41.8% overall), with **roadworks** proving highly significant in reducing these types of casualty crashes by 57.4% (overall 55.8%). **Delineation** treatments were less effective, reducing off-path/head-on casualty crashes by 40.7% (only mildly significant) and overall 10.3% (not significant).

Roadside hazard treatments reduced casualty crashes involving utility poles by a significant 68.4%. **Pole removal/replacement** was mildly significant in reducing roadside hazard casualty crashes by 71.2%. Roadside hazard treatments however did not have a effect on other types of mid-block casualty crashes.

The treatment of mid-block 'Black Spot' sites experiencing **differing types of crashes** using a **combination of treatments** reduced casualty crashes by a highly significant 29.1%. **Delineation** works were less effective in reducing all types of casualty crashes by 19.8% (only mildly significant).

Economic Effects

When considering the economic worth of treating mid-block 'Black Spots', high economic returns were achieved. For **55 of the total 69 mid-block 'Black Spot' sites** with known cost or estimated cost data investigated (1980-1989), the NPW of the treatments that had accrued to the end of 1992 was approximately $19.8 million, with a BCR of 7.59 (compared to a BCR of 7.13 for 'Black Spot' intersections, Corben & Foong 1989) .

Pedestrian treatments (17 sites) produced a NPW of $5.89 million (BCR of 7.46), highlighted with the installation of **new pedestrian signals** (7 sites, NPW of $2.81 million and BCR of 6.31), and **remodelled or relocated pedestrian signals** (5 sites, NPW of $2.14 million and BCR of 7.61) as the of pedestrian treatments that provided the greatest economic returns.

High economic returns were also achieved with **off-path/head-on remedial treatments** (20 sites, NPW of $5.84 million and BCR of 7.46), with **roadwork treatments** proving the most successful (12 sites, NPW of $5.69 million and a BCR of 7.82).

The treatment of mid-block 'Black spots' having varying, or **all types of crashes** (26 sites) produced a NPW of $7.26 million and a BCR of 7.39. Where a **combination of treatments** (10 sites) were implemented to address more **than one type of casualty crash** the NPW value was $5.72 million with a BCR of 8.4, while **delineation only treatments** (10 sites) achieved a NPW of $0.95 million with a BCR of 8.17.

1.0 INTRODUCTION

1.1 Background

Victoria's Accident Black Spot (ABS) Program was commenced in 1979 following the successful implementation of similar programs in Europe, England and the USA. The objectives of the program are to reduce the incidence and severity of crashes at locations that experience high numbers of casualty crashes by implementing targeted, cost effective remedial treatments.

The treatment of ABS sites has progressively increased from 4 during 1979/80 to a peak in the order of 300 during the late 1980's. The measures implemented during the program's inception were considered as either intersection or mid-block treatments, with the nature of the works then categorised as a subset of these broad classifications of ABS's.

In order to determine the effectiveness of the ABS Program, Monash University Accident Research Centre (MUARC) during 1989, undertook for VIC ROADS the detailed evaluation of the program since it had commenced. The report by Corben & Foong (1989) determined that at intersection 'Black Spots' there was a 33.4% reduction in casualty crashes following treatment, while for mid-block 'Black Spots' there was insufficient data available to enable the effectiveness of this component of the program to be determined.

The report by Corben & Foong recommended that a detailed evaluation of the effectiveness of mid-block 'Black Spot' treatments be undertaken when additional information enabling more sites to be examined became available.

With the availability of additional data and as a consequence of this recommendation, VIC ROADS engaged MUARC to undertake this study.

1.2 Objectives of the Study

The objectives of this study are to:

* determine the effectiveness mid-block ABS treatments overall

* determine the effectiveness of targeted mid-block ABS treatments

* assess the economic effectiveness of the mid-block ABS treatments.

1.3 Scope of the Study

The study investigated only those sites within the ABS program that were selected for treatment on the basis of their experienced accident history, and those sites which were included in the ABS program on the basis of a perceived safety problem, or were within a mass action program have been excluded from the analysis.

1.4 Selection and Treatment of Mid-Block 'Black Spots'

Mid-block locations considered as legitimate 'Black Spots' were those lengths of road which had been placed on VIC ROADS' ABS Program on the basis of their demonstrated accident history, as defined by the minimum accident frequency criteria stipulated at that time by VIC ROADS for the identification of 'Black Spots'.

When sites were initially selected as 'Black Spots' in Victoria they were chosen from a listing of mid-block locations ranked according to a 5-year casualty accident frequency. Sites were selected for treatment by progressively working down this list. A similar listing was also produced on the basis of pedestrian casualty crashes. This provided a listing of mid-block 'Black Spot' pedestrian locations which were considered for treatment. The minimum crash frequencies of 'Black Spot' sites varied each year as the investigation and treatment of sites was dependant on the availability of resources or funds.

During the mid-1980's the treatment of a number of the selected mid-block 'Black Spots' was deferred as they were located along tram routes. At that time Victoria was implementing its tram priority 'Fairway' program, and it was envisaged that the 'Fairway' works would either ameliorate the accident problem or incorporate into their design accident remedial treatments.

In March 1988 guidelines were produced which stipulated the accident frequencies that were required before sites could be considered for treatment because they were 'Black Spots'. The minimum casualty accident numbers for the previous 3-year period for mid-block locations were:

* For all accident types	5 / Km
* Pedestrians	4 / Km
* Fixed roadside objects	4 / Km
* Cyclist	4 / Km
* Skidding	4 / Km

The accident frequencies that qualified sites for treatment as 'Black Spots' were reviewed in 1990. The minimum number of all casualty crashes was retained at 5/Km, however the period in which they occurred was increased to 5 years. The treatment of high accident mid-block 'pedestrian' and 'roadside hazard' sites were considered as part of Mass Action projects.

2.0 STUDY METHOD

2.1 Introduction

The study method used was based on the comparison of the number casualty crashes occurring during a specified 'before' treatment period and an 'after' treatment period of similar duration.

The examination of 'before' and 'after' data was undertaken for:

* all of the mid-block 'Black Spot' sites treated, and for each year the treatments were implemented

* targeted treatments for both predominant and total casualty crashes occurring along mid-block locations following the implementation of the remedial works (ie., for:
  - pedestrian,
  - roadside hazards, includes poles,
  - off path / head on,
  - all types which may include some of the above).

The study also assessed the economic worth of the mid-blocks 'Black Spots' in terms both Benefit-Cost-Ratio (BCR) and Net Present Worth (NPW).

2.2 Data Collection

2.2.1 Site Data

Sites selected for inclusion in the analysis were chosen from a consolidated listing of sites on previous VIC ROADS mid-block ABS Programs. The primary source of this information was VIC ROADS' Program Management System PMS, a computer based data system which contains information on various traffic management programs for which VIC ROADS is responsible.

From the consolidated listing of ABS sites ineligible sites were deleted on the basis that:

* they were not legitimate 'Black Spots' (ie., sites included within the ABS Program for reasons other that their accident history, eg., treatment of sites that had the potential for crashes or were perceived to be unsafe locations).

* the sites were left untreated. Although selected as legitimate 'Black Spot' sites, the treatments were not implemented. A number of these sites were located on tram routes which were at the time undergoing the implementation of the 'Fairway' (1984/5) program.

* the conditions at the 'Black Spot' site had changed substantially since treatment was implemented (ie., the duplication of the carriageway, the establishment of a major shopping/office complex, etc.,).

The information to enable the above criteria to be applied was obtained from the examination of VIC ROADS documentation and where necessary with discussion with the project officers responsible for the original selection of sites.

Using the above criteria 69 mid-block 'Black Spot' sites (listed in appendix A), were identified for the evaluation of their remedial treatments.

Preliminary investigation of the sites also required the determination of the timing and nature of the works implemented. In some cases incomplete or unavailable documentation that failed to provide this information required that the site be investigated through the local government area, and where necessary the site was visited to confirm whether various works were actually carried out.

2.2.2 Crash Data

Crash data was collected for each of the selected sites from Victoria's State Traffic Accident Record (STAR).

Account was also taken of the revised accident severity coding of casualty crashes introduced in 1989. Crash information on the accident data base prior to 1989 was converted by VIC ROADS to the revised severities. Crashes before 1983 had to be investigated in greater detail to enable them to be converted (ie., crashes previously coded as property damage [PD] accidents now became either other injury [OI] or non-injury (NI) accidents.

2.3 Statistical Analysis

2.3.1 Introduction

The method of statistical analysis used was similar to that previously used by Corben & Foong in their report, 'Evaluation of Accident Black Spot Treatments, December 1989'. The method as outlined by Tanner (1958) was used to estimate the effects of treatments in terms of crash frequencies 'before' and 'after' implementation. This method used control ratios (discussed in the following section) to account for changes in environmental and traffic volume conditions. The Regression to the Mean Effect has also been considered and is discussed in section 2.3.3 of this report.

A Chi-square test as outlined in Tanner (1958) was used to assess the changes of the accident frequencies. Three levels of significance were used in the analysis, 1% (highly significant), 5% (significant) and 10% (mildly significant).

The calendar year in which a site was treated was considered as the 'treatment year', with the total year viewed as the implementation/settling-in period. This 'treatment year' was excluded from the analysis in order to minimise the bias effects on safety resulting from the construction/implementation of treatments. Where completion dates were unavailable and it was confirmed that remedial works had been undertaken, the second calendar year referenced (from the ABS Program in which it was identified) was used as the 'treatment year'. As highlighted by Corben & Foong 1989, most treatments treated in a financial year tended to be implemented in the latter part of their financial year (ie., February to June), or during the first part of the following financial year (ie., July to September).

Where sites were treated over a number of years or intermittently over more than one ABS Program, the 'before' period used was the period prior to the year of commencement of any works and the 'after' period beginning on the year following the completion year of the final works. Consequently, the economic benefit or cost of these mid-block 'Black Spot' treatments have been spread equally over the years following the year of the completed works.

2.3.2 Control Groups and Control Ratios

The control groups used included all of the reported casualty crashes that occurred in the local government area in which the 'Black Spot' mid-block was located.

Control ratios for each site were subsequently determined by dividing the total reported casualty accidents for the prescribed 'after' period years by the total casualty reported crashes occurring during the prescribed 'before' years period.

Appendix A details for each of the mid-block 'Black Spot' sites their respective control ratio (C-Ratio).

2.3.3 Regression-to-the-Mean (RTM) Effects

In order to eliminate the RTM effects, 'before' accident data that may have overlapped with crash data which was used to select the site for treatment was screened from analysis. Nguyen (1986) investigated the effects of RTM and reported that ignoring the RTM effect will systematically lead to an over-estimation of the effectiveness of the treatment for sites based on their recent crash frequencies.

Corben & Foong (1989) determined that there was a minimum lag of 24 months from the time a location was selected to be treated as a 'Black Spot' on the basis of its crash record and the year of treatment. While this reporting was applicable to both intersection and mid-block 'Black Spots', the nature of the treatments implemented along mid-block locations required a longer lag period (ie., roadworks, utility pole replacement/relocation and delineation treatments).

The 'before' and 'after' periods investigated were each of 3-year duration for all sites where it could be established that the 3-year 'before' period did not overlap the crash data period used to select the site for treatment (39 sites). In cases where VIC ROADS records failed to indicate when the mid-block 'Black Spot' was identified for investigation and treatment, the 'before' and 'after' periods were each of 2 year duration to ensure no overlap could occur (24 sites). For the 6 sites treated during 1989 a 2 year 'before' and 'after' period was also used.

2.4 Economic Analysis

In order to determine the economic worth of the mid-block 'Black Spot' program and the targeted treatments implemented, both Benefit-Cost Ratios (BCR) and Net Present Worth (NPW) have been calculated for each of the treated sites (Appendix A). These measures of economic worth have been calculated using the following relationships:

* BCR = Net Present Benefit (NPB)/Net Present Cost (NPC), and

* NPW = NPB - NPC,

Assumptions :

(i) Monetary values are expressed in present $ (1992).

(ii) The estimated cost of a casualty crash in an,
* Urban area - $ 60,000
* Rural area - $ 94,000
These values are based on the cost of casualty crashes derived by VIC ROADS (previously RTA) in 1988, and updated using Melbourne's Overall Consumer Price Index (Australian Bureau of Statistics).

It is also recognised that the cost of different types of crashes have been recently evaluated (Andreassen, 1992). However in order to retain consistency with previous 'Black Spot' investigations and to accord with current VIC ROADS casualty costings practices, the more general values of the cost of casualty crashes are used in this report.

(iii) Maintenance costs are estimated at 10 % of the capital cost of the treatments.

(iv) The environmental and travel costs of treatments are not considered to be significant and have therefore not been included in the analysis.

(v) The future year's benefits and costs have been discounted at the rate of 4% per annum to express the project cost in present day values. This rate is the value currently recommended by the Victorian Department of Management and Budget.

(vi) Project life used for, delineation -3 years,
other treatments -10 years.

3.0 RESULTS OF ANALYSIS

3.1 Casualty Crashes (Appendix B1 & B2)

The analysis of the crash data has revealed that for:

all mid-block treatments

(i) there was a 30.5% reduction (highly significant, $p < 0.01$) in casualty crashes resulting from the implementation of treatments at mid-block 'Black Spots'.

(ii) when considering the effectiveness of the treatment of mid-block 'Black Spots' chronologically, the following **reductions in casualty crashes** were achieved:

1980	Limited observations (ie., one location observed only).
1981	No observations.
1982	17.8% (not significant, $p>0.1$).
1983	10.3% (not significant, $p>0.1$).
1984	11.5% (not significant, $p>0.1$).
1985	13.2% (not significant, $p>0.1$).
1986	40.2% (highly significant, $p<0.01$).
1987	39% (highly significant, $p<0.01$).
1988	38.1% (not significant, $p>0.1$)
1989	41.7% (significant, $p<0.05$).

(iii) there was a reduction of 25.2% (highly significant, $p<0.01$) in casualty crashes where treatments were implemented to address a **variety of casualty crash types** (ie., no predominating crash types). Delineation works reduced all casualty crashes by 19.8% (mildly significant $p<0.1$), roadworks by 21.2% (not significant, $p>0.1$), and the implementation of other treatments or a combination of treatments, by 29.1% (highly significant, $p<0.01$).

pedestrian treatments

(iv) targeted **pedestrian treatments** achieved 52% (highly significant, $p<0.01$) reductions in pedestrian casualty accidents. The **overall impact of mid-block pedestrian treatments** also achieved a reduction in the total number of casualty crashes of 37.4% (highly significant, $p<0.01$) along the sections treated.

(v) while **new pedestrian operated traffic signals** reduced pedestrian casualty crashes by 49.5%, and all mid-block casualty crashes by 41.5% (both significant, $p<0.05$), **remodelled pedestrian signals** reduced pedestrian casualty crashes by 38.7% (not significant, $p>0.1$) and all casualty mid-block crashes by 43.8% (mildly significant, $p<0.1$).

(vi) **non-signal pedestrian treatments** (ie., pedestrian refuges, kerb extensions, etc.) reduced pedestrian casualty crashes by 68.6% (significant, $p<0.05$), and all casualty crashes by 27.8% (not significant, $p>0.1$).

roadside hazard treatments

(vii) **all roadside hazard treatments** reduced pole and fixed roadside object casualty crashes by 68.4% (significant, $p<0.05$), and all mid-block casualty crashes by 15.1% (not significant, $p>0.1$)

(viii) **pole removal/replacement** reduced fixed roadside object casualty crashes by 71.2% (mildly significant, $p<0.1$), while all mid-block casualty crashes reduced by 4% (not significant, $p>0.1$).

(ix) **guard fencing** reduced roadside hazard casualty crashes by 78.7% (not significant, $p>0.1$), and had no impact on other types of mid-block casualty crashes.

off-path/head-on treatments

(x) **all off-path/head-on treatments** used reduced these types of casualty crashes by 52.1% (highly significant, $p<0.01$), and all crashes by 41.8% (highly significant, $p<0.01$).

(xi) **delineation treatments** reduced off-path/head-on casualty crashes by 40.7% (mildly significant, $p<0.1$), and all casualty crashes by 10.3% (not significant, $p>0.1$).

(xii) **roadworks** (ie., pavement/curve reconstruction, road widening, channelisation) reduced off-path / head-on casualty crashes by 57.4%, and all casualty crashes by 55.8% (both highly significant, $p<0.01$).

3.2 Economic Evaluation (Appendix C)

The treatment of 'Black Spot' mid-block locations produced high economic returns. For **55 of the 69 mid-block 'Black Spot'** sites investigated for which cost or estimated cost of works data was available, the **NPW** of benefits that had accrued till the end of 1992 was approximately **$19.8 million**, with a **BCR of 7.59**.

Other major economic findings were that for:

*** pedestrian treatments**

NPW = $ 5.89 million ($368,000 per tmt) BCR = 7.46

*** new pedestrian operated signals**

NPW = $ 2.81 million ($401,000 per tmt) BCR = 6.31

*** remodelled or relocated pedestrian signals**

NPW = $ 2.14 million ($428,000 per tmt) BCR = 7.61

*** roadwork treatments for off-path/head-on types of crashes**

NPW = $ 5.69 million ($517,000 per tmt) BCR = 7.82

*** combination of works for the treatment of all types of crashes**

NPW = $ 5.72 million ($1.14 million per tmt) BCR = 8.4

*** delineation works for the treatment of all types of crashes**

NPW = $ 0.95 million ($106,000 per tmt) BCR = 8.17

* the **year** of implementation,

	NPW		**BCR**
1985	$ 1.34 million	($149,000 per tmt)	4.04
1986	$ 9.30 "	($715,000 " ")	9.03
1987	$ 3.69 "	($205,000 " ")	7.11
1988	$ 1.29 "	($323,000 " ")	20.94
1989	$ 2.97 "	($583,000 " ")	8.87

4.0 SUMMARY

4.1 Casualty Crash Reductions

The evaluation of the treatment of mid-block 'Black Spots' revealed that the effectiveness of the remedial works implemented was statistically highly significant in reducing casualty crashes. **Overall** there was a **30.5% reduction in casualty crashes** at the treated sites, this value compares favourably with reductions achieved at intersection 'Black Spots' of 33.4% (Corben & Foong 1989).

Treatments targeting **pedestrian casualty crashes** reduced these types of crashes by 52% and overall by 37.4% (both highly significant). New **pedestrian signals** offered significant reductions both in pedestrian casualty crashes of 49.5% and overall by 41.5%. **Remodelled or relocated pedestrian signals** however did not achieve a statistically significant reductions in pedestrian casualty crashes. Their impact on all types of casualty crashes though produced a mildly significant reduction of 43.8% along the mid-block in which they occurred.

Targeted **off-path/head-on treatments** reduced those types of casualty crashes by 52.1% and overall by 41.8% (both highly significant). **Roadworks** proved the most effective treatment within this category with a 51% reduction in these types of crashes, and overall 41.8% (both highly significant).

The treatment of mid-block 'Black Spot' sites experiencing **differing types of crashes** using a **combination of treatments** reduced casualty crashes by a highly significant 29.1%, while the **treatment of roadside hazards** reduced casualty crashes involving utility poles by a significant 68.4%. **Pole removal/replacement** reduced roadside hazard casualty crashes by 71% (mildly significant), roadside hazard treatments generally did not have a significant effect on other types of mid-block casualty crashes.

4.2 Economic Worth

When considering the economic worth of treating mid-block 'Black Spots', high economic returns were achieved. For **55 of the 69 mid-block 'Black Spot' sites** investigated (1980-1989) the NPW of the treatments with known cost or estimated cost data was approximately $19.8 million (1992), with a BCR of 7.59 (compared to a BCR of 7.13 for 'Black Spot' intersections, Corben & Foong 1989) .

Pedestrian treatments produced a NPW value of $ 5.89 million (BCR of 7.46), highlighted with the **installation of new pedestrian signals** (NPW of $2.81 million and BCR of 6.31), and **remodelled or relocated pedestrian signals** (NPW of $2.14 million and BCR of 7.61) as the major types of pedestrian crash reduction treatments.

Off-path/head-on remedial treatments also provided high economic returns, with NPW value of $5.84 million and BCR of 7.46. **Roadwork treatments** within this category had a NPW of $5.69 million and a BCR of 7.82.

Where a **combination of treatments** were implemented to treat more **than one type of casualty crash** the NPW value was $5.72 million with a BCR of 8.4, while delineation only treaments achieved a NPW of $0.95 million and a BCR of 8.17. The implementation of a combination of works also provided a NPW value of $1.14 million per treatment which was substantially greater that the NPW of single countermeasures.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The major conclusions from this study were that the treatment of mid-block 'Black Spots' provide high returns in terms of casualty crash reductions and economic worth (Section 3.0). The results of the study also reveal that the overall casualty crash reduction for mid-blocks following treatment is similar to that evaluated for intersection 'Black Spots'.

The study has identified a number of areas or issues that may provide the basis for further action that will improve the implementation and performance of remedial treatments. On this basis it is recommended that:

(i) where the treatment of high accident or 'Black Spot' sites is deferred pending the implementation of other works (ie., roadworks to improve traffic flow), follow-up will be required to ensure that the safety treatments or accident countermeasures are carried out. Should the period of deferment be of substantial duration it may be appropriate to implement remedial treatments on a temporary basis.

(ii) because of the high safety and economic returns offered by targeted remedial treatments, greater investigation should be undertaken at a planning stage of road based programs to determine the opportunity of building into the final design measures specifically targeting prevailing crashes.

(iii) those mid-block 'Black Spots' that failed to respond to remedial measures be investigated, and where appropriate and with the availability of funds implement a more relevant treatment/s.

(iv) an accurate schedule of the implementation of road safety treatments be maintained. This will enable a more ready and accurate evaluation of future road safety or 'Black Spot' programs to be undertaken. The basic information required includes:

* the crash frequency and the types of crashes on which the site was selected for treated under a road safety or 'Black Spot' program

* the accurate description of the location to be treated

* the type of remedial treatment selected and its cost

* commencement and completion dates of remedial works.

(v) as more high accident or 'Black Spot' sites are treated, the effectiveness of the works implemented should be monitored. This will enable a more accurate evaluation of treatments to be developed.

(vi) undertake detailed investigation of the multiple effect that may be derived with the implementation of more than one accident countermeasurse.

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APPENDIX A: SUMMARY OF MID-BLOCK `BLACK SPOTS'

NO.	LGA	MIDBLOCK LOCATION	YEAR	ACC	TMT	COST	NPC	NPB	NPW	BCR	C-RATIO	BEFORE	EXP-AFT	AFTER
						$	$	$	$					
1	SKI	Brighton Rd b/n Chapel St & Brunnings St	86	A	1	45,000	110,256	444,320	334,064	4.03	1.245	3	3.74	1
2	SKI	Fitzroy St b/n Beaconsfield Pde & Grey St	82	A	1	42,800	140,850	737,290	596,440	5.23	1.002	13	13.03	10
3	SKI	Grey St b/n Canterbury Rd & Barkly St	87	A	1	27,000	61,772	783,523	721,751	12.68	1.074	3	3.22	0
4	PRE	High St b/n David St-Bruce St & Preston St	87	A	1	22,000	50,330	530,460	480,130	10.54	1.089	2	2.18	0
5	DAN	Lonsdale St (PHE) b/n Cleeland St & Walker St	86	A	1	39,000	100,554	851,655	751,101	8.47	1.518	14	21.25	16
6	ELT	Main Rd b/n Prior St & Auther St	87	A	4	6,000	13,727	-17,033	-30,760	-1.24	1.149	2	2.3	3
7	KEI	Main Road West b/n Amy St & Esplanade West	87	A	1	22,000	50,330	-11,355	-61,685	-0.23	1.233	4	4.93	5
8	LIL	Main St b/n William St & Hutchinson St	86	A	1	40,680	98,003	639,958	541,955	6.53	1.317	2	2.63	0
9	ESS	Mt Alexander Rd b/n Grice St & Thorn St	87	A	1	29,300	67,029	180,064	113,035	2.69	1.054	2	2.11	1
10	FRA	Nepean Hwy b/n Beach St & Wells St	87&8	A	1	25,000	53,605	778,656	725,051	14.53	1.28	10	12.8	8
11	FRA	Nepean Hwy b/n Wells St & Davey St	88	A	1	4,600	9,866	514,237	504,371	52.12	1.141	5	5.71	2
12	CHE	Nepean Hwy b/n Swansea Rd & The Strand	87	A	1	29,000	66,342	106,903	40,561	16.11	1.324	8	10.59	4
13	MRL	Princes Hwy b/n Church St & Hoyle St	86	A	1	NA	NA	NA	NA	NA	1.275	2	2.55	2
14	FIT	Queens Pde b/n Hoddle St & Rushall Cres	85	A	4	10,000	27,002	406,361	379,359	15.05	1.222	3	3.67	2
15	CHE	Station St b/n Lincoln St & Lawrence St	87	A	1	6,500	14,869	158,165	143,296	10.64	1.323	2	2.65	2
16	CWL	Toorak Rd b/n Melton Av & Warrigal Rd	86	A	1	3,200	7,841	92,465	84,624	11.79	1.314	5	6.57	6
17	MLV	Warrigal Rd b/n Batesford Rd & The Blvd	86&7	A	1	16,860	38,573	601,836	563,263	15.6	1.141	5	5.71	2
18	PRA	Alexander Av b/n Chapel St & River St	86	B	2	NA	NA	NA	NA	NA	1.145	4	4.58	2
19	MLV	Carrol St b/n Tooronga Rd & Weir St	87	B	2	10,000	22,875	-71,377	-94,252	-3.12	1.282	2	2.56	3
20	OAK	Dandenong Rd b/n Drummond St & Atkinson St	84,7&8	B	5	NA	NA	NA	NA	NA	1.2	6	7.2	7
21	ELT	Heidelberg-Kinglake Rd b/n Church Rd & Red Shirt Gully	87	B	2	3,950	9,036	301,692	292,656	33.39	1.235	1	1.24	0
22	NOR	St Georges Rd b/n Miller St & Keon St	87	B	2	8,000	18,305	598,592	580,287	32.7	1.152	3	3.46	1
23	BRN	Th Esplanade b/n Weir St & Park Av	85	B	2	NA	NA	NA	NA	NA	1.289	9	11.6	13
24	PRA	Alexander Av b/n Williams Rd & River St	86	C	4	21,500	52,681	814,344	761,663	15.46	1.145	7	8.02	3
25	HBG	Beverley Rd b/n Burgundy Rd & Fay St	89	C	4	42,800	84,577	379,595	295,018	4.49	0.712	5	3.56	2
26	RIC	Church St b/n Brougham St & Gipps St	84&5	C	4	20,000	54,003	1,155,006	1,101,003	21.39	1.445	7	10.12	3
27	SUN	Churchill Av b/n Vine St & Hargreaves St	85	C	4	72,900	196,831	90,843	-105,988	0.46	1.28	2	2.56	2
28	DIA	Diamond Creek Rd b/n Aquaduct Rd & Larch Cres	87	C	4	18,000	41,181	1,287,216	1,246,035	31.26	1.257	5	6.29	1
29	MBN	Dynon St b/n Radcliffe St & Dryburgh St	84	C	3	1,800	3,709	160,395	156,686	43.24	0.971	5	4.89	2
30	SUN	Gordan St - Van Ness St b/n Macedon St & Hillside St	85	C	3	14,000	26,662	12,765	-13,897	0.48	1.409	3	4.23	4
31	NUN	Hawthorn Rd b/n Mahoneys Rd & Springvale Rd	85	C	3	3,800	7,238	137,085	129,847	18.94	1.237	2	2.47	0
32	NOR	Heidelberg Rd b/n The Esplanade & Westfield St	84	C	3	2,000	4,122	185,648	181,526	45.01	1.076	3	3.23	1

APPENDIX A: SUMMARY OF MID-BLOCK `BLACK SPOTS'

NO.	LGA	MIDBLOCK LOCATION	YEAR	ACC	TMT	COST	NPC	NPB	NPW	BCR	C-RATIO	BEFORE	EXP-AFT	AFTER
						$	$	$	$					
33	DIA	Henry St b/n Nell St & Charles St	87	C	4	15,000	34,317	124,098	89,781	3.62	1.257	2	2.51	2
34	SHB	Monbulk Rd b/n Glenharrow H'ts Rd & Kallista-Emerald Rd	82	C	4	6,000	19,743	111,932	92,189	5.67	0.866	4	3.46	3
35	LIL	Mt D'nong-Tourist Rd b/n Browns Rd & Inverness Rd	85	C	4	30,800	83,163	1,103,096	1,019,933	13.26	1.2	9	10.8	4
36	CHE	Nepean Hwy b/n BeachSt-Main St & Parana St	86&8	C	3	8,600	13,006	-152,070	-165,076	-11.69	1.261	1	1.26	4
37	WHI	Plenty Rd b/n Childs Rd & Allan Av	87	C	3	4,500	7,260	-144,855	-152,115	-19.95	1.158	8	9.26	11
38	DIA	Plenty Rd b/n Taunton Dr & Betula Av	83	C	3	800	1,689	258,630	256,941	153.13	1.11	6	6.66	2
39	BUL	Riddell Rd B/n Spavin Dve & Phillip Dve	89	C	4	39,550	78,152	450,161	372,009	5.76	0.925	2	1.85	0
40	SUN	St Albans Rd b/n Gilmour Rd & Ballarat Rd (Western Hwy)	86	C	4	65,500	160,482	752,701	592,219	4.69	1.515	9	13.64	9
41	BUL	Sunbury Rd b/n Bulla-Diggers Rd & Quartz Rd	83&4	C	3	2,000	5,846	-243,645	-249,491	-41.68	1.61	1	1.61	6
42	SPR	Wells Rd b/n Bowan Rd & Edithvale Rd	83	C	4	9,900	29,647	259,552	229,905	8.75	1.15	4	4.6	3
43	OAK	Westall Rd b/n Rosebank St & Rayhur St	85	C	4	NA	NA	NA	NA	NA	1.442	5	7.21	1
44	MRC	Balcombe Rd b/n Como Pde West & Davies St	87	D	5	21,300	48,732	170,331	121,599	3.5	1.348	2	2.7	0
45	MOO	Bluff Rd b/n Highett Rd & Linacre Rd	85	D	4	3,500	9,452	377,162	367,710	39.9	1.273	2	2.55	1
46	MBN	Brunton Av b/n Punt Rd & Jollimont St	83	D	3	25,000	52,804	-74,925	-127,729	-1.42	1.05	13	13.65	15
47	KNO	Burwood Hwy b/n Acacia Rd & Willow Rd	87	D	3	NA	NA	NA	NA	NA	1.457	4	5.83	3
48	KNO	Burwood Hwy b/n Acacia Rd, Forest Rd & Glenfern Rd	84&6	D	3	6,000	10,370	38,850	28,480	3.75	1.606	16	25.7	25
49	HAW	Burwood Hwy b/n Barton St & Yarra St	89	D	4	55,100	108,882	1,021,986	913,104	9.39	0.743	7	5.2	1
50	RIN	Canterbury Rd b/n Campbell St & Bedford Rd	89	D	3	350	488	14,153	13,665	29	0.695	6	4.17	4
51	RIN	Canterbury Rd b/n Heatherdale Rd & Belgrave Rd	89	D	3	275	383	231,435	231,052	604.27	0.695	4	2.78	0
52	SMB	Clarendon St b/n Dorcas St & Coventry St	86	D	4	NA	NA	NA	NA	NA	1.299	3	3.9	3
53	SMB	Clarendon St b/n Normanby Rd & Whiteman St	80	D	4	15,000	60,763	-236,030	-296,793	-3.88	1.016	2	2.03	3
54	PRA	Dandenong Rd b/n Hornby St & Orrong Rd	89	D	5	53,360	105,442	1,253,150	1,147,708	11.88	0.775	26	20.15	15
55	KNO	Dorset Rd b/n Boronia Rd & Burwood Hwy	85	D	3	4,300	8,190	-174,825	-183,015	-21.35	1.347	17	22.9	25
56	MBN	Flemington Rd b/n Dryburgh St & Melrose St	86	D	3	1,000	1,728	317,460	315,732	183.72	1.246	7	8.72	3
57	BRS	Hume Hwy b/n Box Forest Rd & Boundary Rd	86	D	5	50,000	122,505	2,394,367	2,271,862	19.55	1.235	33	40.76	26
58	SMB	Lakeside Dve b/n Albert Rd & Queens Rd	86&7	D	3	27,000	43,568	942,390	898,822	21.63	1.299	20	25.98	9
59	KNO	Lewis Rd b/d Burwood Hwy & Boronia Rd	86	D	5	180,500	442,249	3,426,086	2,983,837	7.75	1.606	20	32.12	9
60	OAK	McNaughton Rd b/n Centre Rd & Dandenong Rd	84	D	3	5,000	10,304	-181,485	-191,789	-17.61	1.409	2	2.82	5
61	PRE	Murray Rd b/n Spring St & High St	87	D	4	13,300	30,426	-858,955	-889,381	-28.23	1.158	3	3.47	7
62	FRA	Nepean Hwy b/n Eelrace Rd & Seaford Rd	85	D	5	20,000	54,003	-754,323	-808,326	-13.97	1.525	14	21.35	26
63	FRA	Nepean Hwy b/n Seaford Rd & Overton Rd	85	D	5	NA	NA	NA	NA	NA	1.525	11	16.78	17
64	MBN	Punt Rd b/n Blanche St & Route St	84	D	3	2,000	4,122	-34,410	-38,532	-8.35	1.126	3	3.38	4

APPENDIX A: SUMMARY OF MID-BLOCK `BLACK SPOTS'

NO.	LGA	MIDBLOCK LOCATION	YEAR	ACC	TMT	COST	NPC	NPB	NPW	BCR	C-RATIO	BEFORE	EXP-AFT	AFTER
						$	$	$	$					
65	RIC	South Eastern Fwy b/n Yarra Blvd & Toorak Rd	86	D	5	NA	NA	NA	NA	NA	1.188	6	7.13	2
66	MBN	St Kilda Rd b/n Arthur St & Toorak Rd	83	D	5	NA	NA	NA	NA	NA	1.05	6	6.3	3
67	MBN	St Kilda Rd b/n Dorcas St & Park St	82	D	5	NA	NA	NA	NA	NA	0.945	7	6.62	6
68	BRK	Tullamarine Fwy b/n Moreland Rd & Brunswick Rd	86	D	5	NA	NA	NA	NA	NA	0.961	32	30.75	27
69	FOO	Whitehall Rd b/n Francis St & Sommerville Rd	88	D	4	10,000	21,441	525,593	504,152	24.51	1.053	3	3.16	1

ABBREVIATIONS

LGA - LOCAL GOVERNMNET AREA

YEAR - Year tretment was implemeted

ACC - Accident type treated

- A Pedestian
- B Roadside hazard
- C Off-Path / Head-On
- D All Type

TMT - Type of Treatment Implemented

- 1 Pedestrian treatment
- 2 Roadside safety treatment
- 3 Delineation
- 4 Roadworks
- 5 Other treatment or a combination of the above

COST - Cost or estimeted cost in treatment year dollars

NPC - Net Present Cost in 1992 dollars

NPB - Net Present Benefit in 1992 dollars

NPW - Net Present Worth

BCR - Benefit Cost Ratio

C - Ratio - Ratio of before to after casualty crashes in the control area (ie. LGA in which the site is treated)

BEFORE - The number of casualty crashes in 3 years (2 years if treated in 1989 and for some other sites) prior to treatment

EXP-AFT - The expected number of casualty crashes in 3 years (2 years if site is treated in 1989 and for some other sites) if the site was untreated

AFTER - The number of casualty crashes in 3 years (2 years if the site was treated in 1989 and for some other sites) following the implementation of remedial works

APPENDIX B (1 & 2)

LEVELS OF STATISTICAL SIGNIFICANCE

***	Highly Significant	(P < 0.01)
**	Significant	(P < 0.05)
*	Mildly Significant	(P < 0.1)
N.S.	Not Significant	(P > 0.1)

APPENDIX B1: EFFECTIVENESS OF MID-BLOCK `BLACK SPOT' TREATMENTS

		A.PREDOMINATING MID-BLOCK CASUALTY CRASHES						B.ALLCASUALTY CRASHES					
	No. Sites	Before	Exp-Aft	After	A % Change	Prob	Sig Level	Before	Exp-Aft	After	B % Change	Prob	Sig Level
1. Pedestrian Treatments													
1.1 New Ped Operated Signals	7	21	27.7	14	-49.5	0.045	**	43	58.1	34	-41.5	0.0278	**
1.2 Remod / Reloc Ped Signals	5	14	14.7	9	-38.7	0.1589	N.S.	25	26.7	15	-43.8	0.0774	*
1.3 Non-Signal Improvements (eg. ped. refuges)	5	13	15.9	5	-68.6	0.0451	**	17	20.7	15	-27.8	0.2012	N.S.
SUB - TOTAL	17	48	58.3	28	-52	0.0034	***	85	105.6	64	-37.4	0.0038	***
2. Roadside Hazard Treatments													
2.1 Replace / Remove Pole	3	11	13.9	4	-71.2	0.0844	*	15	18.7	18	-4	0.4508	N.S.
2.2 Guard Fencing	2	4	4.7	1	-78.7	0.1997	N.S.	4	4.7	1	-78.7	0.1997	N.S.
2.3 Delineation & Rep/Rem Pole	1	3	3.6	2	-44.4	0.5135	N.S.	6	7.2	7	-2.8	0.9563	N.S.
SUB - TOTAL	6	18	22.2	7	-68.4	0.025	**	25	30.6	26	-15.1	0.2826	N.S.
3. Off-Path / Head-On Treatments													
3.1 Delineation	8	20	23.6	14	-40.7	0.0793	*	29	33.6	30	-10.3	0.2882	N.S.
3.2 Roadworks (eg pavement/curve recon.,channelisation)	12	43	51.6	22	-57.4	0.004	***	61	74.6	33	-55.8	0.0016	***
SUB - TOTAL	20	63	75.2	36	-52.1	0.0011	***	90	108.2	63	-41.8	0.0018	***
4. All Crash Type Treatments													
4.1 Delineation	10							92	115.9	93	-19.8	0.0794	*
4.2 Roadworks	6							20	20.3	16	-21.2	0.2281	N.S.
4.3 Other tmts. or comb. of tmts.	10							157	184.6	131	-29.1	0.01	***
SUB - TOTAL	26							269	320.9	240	-25.2	0.0016	***
TOTAL	**69**							**469**	**565.3**	**393**	**-30.5**	**0.0001**	***

APPENDIX B2: EFFECTIVENESS OF MID-BLOCK `BLACK SPOT' TREATMENTS BY YEAR COMPLETED

YEAR OF TREATMENT	NO. OF SITES	BEFORE	EXP-AFT	AFTER	% CHANGE	PROB	SIG LEVEL
1980	1	2	2	3	47.6	0.668	N.S.
1981	0	0	0	0	0	0	N.S.
1982	3	24	23.1	19	-17.8	0.2962	N.S.
1983	5	30.5	32.3	29	-10.3	0.3356	N.S.
1984	8	27	35.4	31.3	-11.5	0.2969	N.S.
1985	12	80.5	111.2	96.5	-13.2	0.1709	N.S.
1986	18	168	215.7	129	-40.2	0.0002	***
1987	20	72.5	89.9	54.8	-39	0.0066	***
1988	5	15.5	18.3	11.3	-38.1	0.1396	N.S.
1989	6	50	37.7	22	-41.7	0.0449	**
TOTAL	78	469	565.3	393	-30.5	0.0001	***

NOTE: Nine (9) sites were treated during more than one year.

APPENDIX C: ECONOMIC ANALYSIS OF MID-BLOCK `BLACK SPOT' TREATMENTS

ECONOMIC ANALYSIS OF MID-BLOCK TMTS	NO. OF SITES	COST ($)	BENEFIT ($)	BCR	NPW ($)	LEVEL OF SIG
TOTAL TREATMENTS	69	3,001,326	22,766,919	7.59	19,765,593	***
TARGET TREATMENT						
1. Pedestrian Tmts						
1.1 New Ped Op Signals	7	529,420	3,340,597	6.31	2,811,177	**
1.2 Rem/Reloc Ped Sigs	5	323,093	2,460,878	7.61	2,137,785	*
1.3 Non-Sig Imrovements	5	58,436	996,030	17.04	937,594	N.S.
(eg. ped refuges)						
SUB-TOTAL	17	910,949	6,797,505	7.46	5,886,556	***
2. Roadside Safety Tmts						
2.1 Replace/Remove Pole	3	22,875	-71,377	-3.12	-94,252	N.S.
2.2 Guard Fencing	2	27,341	900,284	32.93	872,943	N.S.
2.3 Delin/Rep or Rem Pole	1	NA	NA	NA	NA	N.S.
SUB-TOTAL	6	50,216	828,907	16.51	778,691	N.S.
3. Off-Path / Head-On						
3.1 Delineation Works	8	69,532	213,953	3.08	144,421	N.S.
3.2 Roadworks	12	834,777	6,528,544	7.82	5,693,767	***
SUB-TOTAL	20	904,309	6,742,497	7.46	5,838,188	***
4. All Types of Crashes						
4.1 Delineation	10	131,957	1,078,643	8.17	946,686	*
4.2 Roadworks	6	230,964	829,756	3.59	598,792	N.S.
4.3 Combination of Tmts	10	772,931	6,489,611	8.4	5,716,680	***
SUB-TOTAL	26	1,135,852	8,398,010	7.39	7,262,158	***
YEAR OF TREATMENT						
1980	1	60,763	-236,030	-3.88	-296,793	N.S.
1981	0	0	0	0	0	N.S.
1982	3 (1)	160,593	849,222	5.29	688,629	N.S.
1983	5 (1)	87,063	321,435	3.69	234,372	N.S.
1984	8 (1)	57,366	605,253	10.55	547,887	N.S.
1985	12 (3)	439,543	1,775,667	4.04	1,336,124	N.S.
1986	18 (5)	1,149,058	10,448,859	9.03	9,299,801	***
1987	20 (2)	604,404	4,298,910	7.11	3,694,506	***
1988	5 (1)	64,612	1,353,123	20.94	1,288,511	N.S.
1989	6	377,924	3,350,480	8.87	2,972,556	**

NOTE: 1. Nine (9) sites were treated during more than one year.
2. ( ) Denotes the number of sites with no available cost or cost estimate data.