Evaluation of the Black Spot Program

Report

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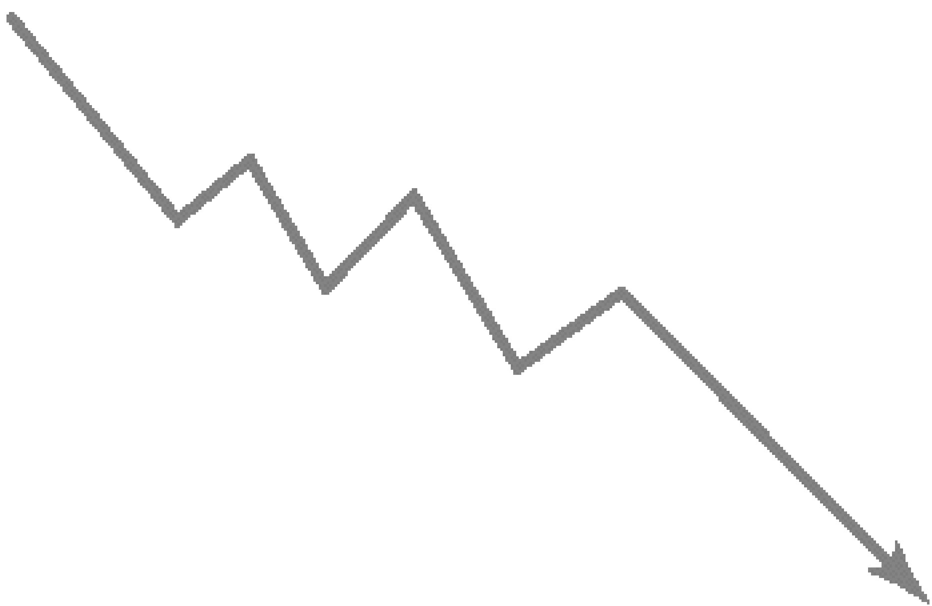
Report 90

EVALUATION OF THE BLACK SPOT PROGRAM



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FOREWORD

The objective of the Federal Government's Black Spot Program was to reduce the number and severity of crashes at black spot locations in conjunction with the introduction of a ten-point package of legislated road safety measures.

The evaluation of the Black Spot Program was part of the Portfolio Evaluation Plan of the (former) Department of Transport and Communications for 1992 to 1994. The Bureau of Transport and Communications Economics (BTCE) was nominated to conduct the evaluation. The Program was administered by the Federal Office of Road Safety (FORS).

A pilot study conducted by the BTCE, which involved an analysis of 51 black spot sites, was published as Working Paper 9: *Cost-effectiveness of 'Black Spot' Treatments—a Pilot Study*. The present larger scale study involves a cost–benefit analysis of treatments implemented at a sample of 254 black spot sites around Australia.

Road and traffic authorities in the states and territories provided data for the study, both direct to the BTCE and through FORS; the staff of the Road User Branch of FORS, particularly Kevin Rheese, provided data and assistance throughout the study; and Paul Blair of the Land Transport Policy Division, Department of Transport, provided assistance and support in setting up and maintaining several complex databases used in the study. The assistance of these organisations and individuals is greatly appreciated.

Because of the complexities inherent in the evaluation methodology used, this study required more than the usual checking and cross checking of data consistency and calculations accuracy. Consequently, not all of the limitations may have been adequately dealt with.

The study team comprised Joe Motha (Project Leader), Bogey Musidlak, Catharina Williams and Seu Cheng.

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May 1995

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ABSTRACT

This study evaluates the economic benefits of the Federal Government's Black Spot Program. The study assesses the crash reduction benefits of a variety of road engineering treatments based on a sample of 254 projects drawn from all states and territories.

Results are presented using both the crash-type and crash-severity methods of costing road crashes. Crash reduction factors which provide an estimate of the potential of various treatments to reduce crashes of specific types have also been estimated.

Overall, the decrease in injury crashes at the sample sites was over two-and-a-half times what could have been expected on the basis of general comparable crash trends in various jurisdictions over the relevant period. Fatalities fell by one-third, people hospitalised by two-thirds, and the number in need of medical treatment by one-half.

It was estimated using the crash-type method of costing crashes that the Black Spot Program projects from the Schedule of Acceptable Treatments (costing $244.7 million) had an overall net present value (in 1992 dollars) of $791.8 million and a benefit–cost ratio of 3.9. Benefit–cost ratios calculated using the same crash costing method ranged from 2.6 to 13.4 for various treatments.

The results of the evaluation strongly suggest that the Program has achieved its aim of improving safety at locations with a history of crashes involving death or serious injury.

SUMMARY

BACKGROUND

The Federal Government's Black Spot Program operated during the period 1990–91 to 1992–93. The 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 Black Spot Program was introduced in tandem with a package of intended state and territory legislative changes.

Funds allocated to the Program over the three-year period amounted to $270 million. A total of 3 176 black spot projects with a mean cost of $85 000 were approved under the Program. The Program was administered by the Federal Office of Road Safety (FORS). FORS commissioned the Australian Road Research Board (ARRB) to produce a 'Schedule of Acceptable Treatments' to be used by the states and territories in preparing their applications for projects to be funded under the Program. Provided there was a history of injury crashes at the site, a project involving any of the 30 treatments in the Schedule was considered as having a potential benefit–cost ratio of at least 2 and did not require any additional justification.

The Black Spot Program was selected for inclusion in the Portfolio Evaluation Plan of the (then) Department of Transport and Communications for the period 1992–94. A pilot study was published by the BTCE in October 1993 to provide an early estimate of the economic results of the Program and to develop a methodological framework for the present full-scale study. The pilot study was restricted to a sample of 26 projects in Victoria and 25 in NSW. These projects were completed during the first year of the Program.

The pilot study found that serious injury crashes at the treated sites in the sample fell by 50 per cent in Victoria and by 64 per cent in NSW, while other types of crashes also declined substantially. It was found that the treatments had a relatively greater impact on the incidence of right-angle and right-turn crashes which are generally associated with more serious injury. Benefit–cost ratios were estimated for the sample projects using the crash-severity and crash-type methods. The three most common treatments in the sample were new traffic signals, modified traffic signals and roundabouts. For the combined sample of NSW and Victorian projects, benefit–cost ratios using the crash-type method were 1.5 for new traffic signals, 6.8 for modified traffic signals and 4.1 for roundabouts. The corresponding benefit–cost ratios using the crash-severity method were 3.8, 3.0 and 2.1.

APPROACHES TO REDUCING CRASHES

Road crashes are multi-causal events involving the interaction of the road environment, vehicles and road users, and therefore multi-factor solutions are likely to be most effective in crash mitigation. Opinions in the literature on road safety are divided on whether attempts to change drivers' attitudes or other methods such as more enforcement or engineering programs have relatively greater potential for achieving a reduction in crashes.

Several crash causation models, which explain crashes as the consequence of driver behaviour that is not matched to either the road environment or to vehicle characteristics, or to both, have been proposed. Most of these models have recourse to some kind of compensatory or adaptive driver behaviour that may tend to offset to some extent the benefits of road improvements. This is one explanation that has been offered for the phenomenon of 'accident migration', where crashes are believed to migrate in the spatial sense from black spots that have been treated to surrounding areas. Although some studies have found evidence of crash migration, there is still some uncertainty about whether it is genuine or a mere statistical artefact. Nevertheless, behaviour feedback effects experienced by motorists would generally complicate the task of estimating the expected benefits of safety measures.

Some theories of crash causation suggest that the challenge of road engineering is to attempt to balance two opposing needs: to create a road environment requiring easy driving tasks while ensuring that drivers do not underestimate task difficulty and thereby lower their driving performance. This calls for creativity and innovation in implementing road safety measures.

PROGRAM EXPENDITURE

Total approved expenditure on the Black Spot Program amounted to $270 million. However, at the time that the analysis for this report was carried out, project details were available only for expenditure totalling slightly less than this amount.

Urban projects involving treatments in the 'Schedule of Acceptable Treatments' had a mean approved expenditure of $79 000 and accounted for 65 per cent ($171.8 million) of total Program expenditure. Four urban treatments—new traffic signals, modified traffic signals, roundabouts and channelisation—together accounted for almost half (48 per cent) of total Program expenditure.

Rural treatments from the Schedule had a mean approved expenditure of $84 000 and constituted less than one-quarter of total Program expenditure ($64.5 million). Three rural treatments—shoulder sealing, selective roadside hazard modification and overtaking lanes—accounted for $44.2 million or 68 per cent of total expenditure on rural projects.

Expenditure of $15.9 million was approved for road safety enhancement projects such as electronic speed cameras and breathalyser units, and $14.2 million for other unscheduled treatments at individual sites, representing 6 per cent and 5 per cent respectively of total expenditure.

Projects in the first half of the Program tended to be smaller in scale than those in the second half. During the first half of the program, mean expenditure on urban treatments from the Schedule was $68 000 and that for rural treatments was $33 000.

IDENTIFICATION OF BLACK SPOTS

The proper identification of black spots is important in terms of efficient resource allocation. If the most hazardous sites are identified and treated first, it becomes increasingly difficult to identify sites whose treatment will result in substantial social benefits.

The three broad approaches to identifying black spots are based on crash numbers, crash rates related to exposure to risk, and qualitative methods. The use of crash numbers is by far the most common method used worldwide. Several statistical techniques are available to identify black spots.

The confidence interval technique is a basic approach which involves comparing the crash rate at a site with the mean crash rate of similar sites to which is added a multiple of the standard deviation. The statistical quality control technique is a commonly used technique which involves calculating an upper control limit for crashes by using the normal approximation to the Poisson distribution. The technique of potential crash reduction employs regression analysis to estimate the expected number of crashes at particular categories of sites, and this is then compared with the observed number.

Crash-severity indices can be constructed using numbers of crashes corresponding to different levels of severity. These are combined into a composite index for a particular area and then compared with the indices for specific sites. Bayesian methods may also be used in identifying black spots. The Bayesian approach combines sample information with other available relevant information about sites.

Jurisdictions generally used computer databases of crash statistics and various statistical and economic approaches to identify and rank black spots. However, these approaches were invariably supplemented by the local knowledge of road safety personnel.

DATA AND SAMPLING ISSUES

Differences in the methods used in the jurisdictions to record crashes, as well as changes in such methods and crash reporting requirements over time, considerably complicated the process of data analysis. Various adjustments therefore had to be made to the data to ensure consistency and comparability. The BTCE considers that a greater degree of standardisation of reporting requirements and classification of crashes among jurisdictions would facilitate national road safety studies and enable more meaningful comparisons of results to be made between jurisdictions. Greater standardisation would also assist jurisdictions to share and exchange data more easily in their search for best practice in road safety.

The BTCE recommends that in future programs of this nature, initial program requirements should recognise the likelihood of different approaches to data processing and accounting by jurisdictions and provide guidelines for greater standardisation of procedures. For example, clear guidelines about what categories of expenditure should be included in project costs would be desirable.

A detailed procedure was adopted to select the sample of projects to be evaluated. Due to the need for at least one year of post-treatment data, only projects that were completed by about the end of 1991 could be considered for inclusion in the sample. The fact that the projects completed early in the Program were generally of a smaller scale than those completed later had an inevitable effect on the composition of the sample. However, the sampling process endeavoured to ensure that as far as possible the final sample reflected a representative spread of projects in terms of treatments, expenditure and geographical location. In addition, sample sites were spread around metropolitan areas in such a manner that these areas could be used as controls. The final sample consisted of 254 projects out of a total of 3 176.

The numbers of crashes associated with some treatments in the sample sites were relatively small. As there is relatively greater statistical instability associated with small crash numbers, the results of statistical tests applied to them can have high degrees of uncertainty. The effects of some treatments could therefore not be reliably determined because of the small crash numbers involved.

In the future, collaborative arrangements between the states and territories could provide a cost-efficient means of evaluating the effectiveness of black spot treatments. Using an agreed evaluation methodology and protocols for the exchange of information, each jurisdiction could conduct a small number of in-depth studies. Over a period of time, sound estimates of the benefits of a range of treatments could be obtained, and elements of best practice disseminated around the nation.

EVALUATION METHODOLOGY

The methodological approach to the study was mainly dictated by externally imposed constraints such as the time frame within which the study had to be conducted and the nature of the data that were available. A 'before and after' approach was adopted which involved comparing the observed number of crashes after treatment with the expected number had there been no treatment. Because the 'expected' number cannot be known, it was estimated using the number of crashes before treatment and other appropriate data.

Besides the effects of the treatment itself, a range of extraneous factors can contribute to an observed decline in crashes at a site after treatment. These factors include site-specific factors (events such as improvements in weather conditions at the site after treatment); maturation (the process by which crash data change over time, especially the generally declining trend in crashes per unit of exposure over time); regression-to-mean (the tendency of a variable such as the number of crashes which has an extreme value during a particular time period to 'regress' or move closer to its mean value in a subsequent period); under-reporting of crashes; effects of publicity about dangerous sites on drivers; statistical instability of crash data; and the possibility of 'migration' of crashes to sites in the vicinity of treated sites.

It was not possible to control for all extraneous effects in this study. Appropriate control areas in each jurisdiction were used to calculate the 'expected' crash numbers. These control areas accounted for general community crash trends and would therefore in the process have made allowance for any changes in the weather. Having assessed available data, most other effects were considered relatively insignificant.

The benefits of black spot treatments were estimated in terms of crash costs avoided. Two methods of calculating crash costs were used: crash type (where crashes are costed on the basis of the type of vehicle movements just before impact) and crash severity (where crashes are costed on the basis of the highest level of injury occurring in the crash). The basis of both methods was the human capital approach.

The cost–benefit analysis of projects was carried out at a discount rate of 8 per cent and alternative rates of 6 and 10 per cent. Project lifetimes (the periods during which crash reduction benefits were assumed to continue) were based on data provided by the states and territories. The results of the evaluation are reported in terms of the net present value (NPV) and benefit–cost ratio (BCR).

CRASH AND INJURY EXPERIENCE AT SAMPLE SITES

In the period after treatment (1992) there were substantial reductions in crashes at the 254 sample sites studied, relative to the period before treatment (1988–1990). Fatalities fell by one-third, hospitalisation injuries by two-thirds and injuries requiring medical treatment by almost one-half. In each year between 1988 and 1990 there were on average 25 people killed, 291 hospitalised and 881 requiring medical treatment at the 254 sample sites around the nation. Mean injuries per site per year were respectively 0.1 people killed, 1.1 hospitalised and 3.5 needing medical treatment. In 1992, at these same sites, there were 17 people killed, 105 hospitalised and 447 requiring medical treatment.

The numbers of seriously injured persons (killed and hospitalised) for many of the treatments analysed in the sample fell markedly. For example, for the four most common treatments implemented during the Program the reductions were: traffic signal modification 71 per cent; roundabouts 100 per cent; intersection channelisation 57 per cent; and new traffic signals 66 per cent.

Overall, the decrease in injury crashes at the sample sites was over 2.5 times what could have been expected on the basis of general comparable crash trends in various jurisdictions over the relevant period. Recorded property damage only (PDO) crashes dropped by 30 per cent, an improvement more than triple that indicated by control areas. The fact that treatments led to more pronounced declines in injury crashes and particular types of injury than in recorded PDO crashes suggests that Black Spot Program funding produced major effects not only on the frequency of collisions but also on the manner in which such impacts occurred.

EFFECTS OF SPECIFIC TREATMENTS

New traffic signals installed at 50 sites in the sample had a mean of 2.4 injury crashes per site per year between 1988 and 1990, and those in jurisdictions other than Victoria (which discontinued recording PDO crashes after December 1990) recorded a mean of 5.6 PDO crashes per year in this period. During 1992, injury crashes fell by just over 40 per cent, a reduction about 2.5 times that expected from the various local community crash trends. Recorded PDO crashes fell by a little over one-third, about 3.5 times what might be explained by applying control ratios in individual jurisdictions.

For the 59 sites in the sample at which traffic signals were modified, between 1988 and 1990, the annual mean number of injury crashes per site was 5.4 and the mean number of recorded PDO crashes (with the exception of Victoria) was 16.6. As capital costs were often modest, there was potential for rather high BCRs. Injury crashes fell from these levels by around one-half in 1992, a reduction about 2.5 times what might have been expected on the basis of control ratios. PDO crashes dropped by about 30 per cent, nearly three times what the various individual community crash trends might have predicted.

There were 31 sites in the sample at which roundabouts were constructed, with a mean of 2.5 injury crashes and 4.0 PDO crashes per site per year. Combined with the extensive capital outlays required for some projects, the rather low pre-treatment crash experience meant that very high crash reduction factors would be necessary for good BCRs to be achieved. The reduction in injury crashes at sample sites in 1992 was nearly 90 per cent, over 5.5 times as much as community trends in the various jurisdictions would have suggested. There were no persons killed or hospitalised in 1992, compared with a national mean of 32 such serious injuries in each year prior to treatment. PDO crashes declined by just over one-half, a fall of over six times what might have been expected purely on the basis of general crash trends in the individual jurisdictions.

Several more years of post-treatment data would be needed to establish whether these outstanding effects truly reflected the impact of treatment. Bearing in mind the heavy capital cost of several of these projects, BCRs for roundabouts with modest construction costs may be very high.

At the 32 sites in the sample where channelisation was undertaken at an intersection, prior to treatment the mean number of injury crashes per site per year was 4.3 and the mean number of annual recorded PDO crashes was 13.9. Comparatively high crash numbers at South Australian sites strongly influenced these means. Injury crashes at these sites dropped by just over 40 per cent in 1992, more than double what might have been expected on the basis of falls occurring in control areas in each jurisdiction. PDO crashes fell by one-third, about four times what could have been expected from community crash trends.

At the 15 sites in the sample where shoulder sealing was carried out, there was an annual mean of 3.3 injury crashes per site over 1988–90, and 4.6 recorded PDO crashes per site in three jurisdictions. Injury crashes fell by about 20 per cent overall, on a par with what general crash reductions would explain. PDO crashes increased by nearly 10 per cent. These comparatively mediocre results may have been due to difficulties in selecting suitable sites for treatment.

Crash reduction factors representing the crash reduction potential of various treatments in mitigating particular types of crashes were estimated. For example, the estimated crash reduction factors for right-angle crashes at new traffic signals and for right-turn and right-angle crashes at roundabouts were 74, 88 and 72 per cent respectively.

Where reductions in crashes were statistically significant, estimates of NPVs and BCRs were obtained for treatments using both the crash-type and crash-severity methods. For the crash-type method, BCRs were: traffic signal modification 6.8, roundabouts 5.6, channelisation 4.9, new traffic signals 2.6 and provision of medians 13.4. For the crash-severity method, BCRs were: provision of medians 5.0; roundabouts 9.2; traffic signal modification 7.7; channelisation 6.5; and new traffic signals 0.1.

PROGRAM ASSESSMENT AND METHODOLOGICAL IMPLICATIONS

Based on the crash-type method, the estimated NPV (in 1992 dollars) for the $244.7 million spent on treatments in the Schedule of Acceptable Treatments was $791.8 million and the BCR was 3.9. Corresponding estimates using the crash-severity method were $1 338.7 million and 5.9 respectively. Further benefits would have been obtained from non-Schedule treatments and road safety enhancement measures funded under the Program.

These results indicate that the entire Black Spot Program has delivered net benefits to the Australian community of at least $800 million, generating returns of around $4 for each dollar of expenditure. The results of the evaluation strongly suggest that the Program has achieved its aim of improving locations with a history of crashes involving death or serious injury.

An analysis of projects by magnitude of expenditure indicated that relatively low cost projects (under $100 000) produced the highest returns per 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.

The crash-severity BCRs were found, in most cases, to be greater than the corresponding crash-type BCRs. This finding was contrary to the findings of some previous research. The main reason for the atypical result is the sharp drop in high cost serious injury crashes and associated serious injuries at sample sites after treatment. 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.

Crash-type BCRs obtained in this study would be expected to display greater stability and consistency than crash-severity BCRs when evaluations of the effectiveness of black spot treatments are carried out in the future. The results obtained in this study in regard to the relative magnitudes of crash-type and crash-severity BCRs should therefore not be construed as detracting from the advantage of the better precision of the crash-type method in studies involving the analysis of crashes.

CHAPTER 1 INTRODUCTION

PURPOSE AND ADMINISTRATION OF THE BLACK SPOT PROGRAM

In December 1989 the Federal Government announced a two-pronged initiative aimed at reducing the national incidence and severity of road crashes. The initiative comprised a conditional allocation of $110 million for a fixed three-year term from 1 July 1990 to 30 June 1993 to eliminate a range of black spots, and a requirement that states and territories adopt a 10-point package of road safety measures. These measures included a 0.05 per cent blood alcohol concentration limit; nationally uniform speed limits; uniform points demerit scheme; zero blood alcohol limit for truck drivers and young drivers; graduated licensing for young drivers; compulsory bicycle helmet wearing; and daylight running lights for motorcycles. An additional $10 million was made available for research and public education.

The Black Spot Program was developed primarily to help accelerate the eradication of state and territory black spots (excluding those on national highways) and operated in accordance with provisions of the *Australian Land Transport Development (ALTD) Act 1988*. The initial allocation of $110 million was supplemented by $160 million consequent to Prime Minister Keating's 'One Nation' statement on 26 February 1992 (Keating 1992), and from resources from the subsequent Budget, raising the total expenditure over the life of the Program to $270 million. The funds made available under the Program also acted as a stimulus in generating local employment opportunities.

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 such locations. The Program helped to reduce or clear a backlog in state and territory black spot programs. A proportion of funds was also allocated to other tangible and visible road safety enhancement measures such as speed and alcohol limit control equipment, and bicycle and pedestrian safety initiatives (these were referred to as ‘Schedule 1A treatments’ and are listed in appendix II). Funding was also available for innovative treatments proposed by the jurisdictions (these were referred to as Schedule 1B treatments). Unlike some road funding programs which focus on the management of traffic and the efficiency of getting from one place to another, a key objective of the Black Spot Program was to effectively prioritise funds to areas of greatest road safety need and highest economic return.

Prior to the implementation of the Program, the Federal Office of Road Safety (FORS) retained the Australian Road Research Board (ARRB) to identify and categorise typical traffic engineering treatments with relatively high potential benefits. A ‘Schedule of Acceptable Treatments’ (table 1.1) was drawn up to provide a simplified basis on which the states and territories could submit applications for funding. A project involving any treatment in the Schedule was considered to have a potential benefit–cost ratio (BCR) of at least 2. As the Program sought to spread benefits widely across the community, preference was initially given to projects whose estimated cost was under $200 000.

Applications for funding black spot remedial projects were considered in the first instance by FORS. Authority to approve projects was vested with the Federal Minister responsible for Transport. The overall administration of the Program was carried out by FORS. The Notes on Administration of the Program are at appendix I. The application form for the jurisdictions to obtain funding under the Program is at appendix III and the financial statement required to be submitted by the jurisdictions at the end of each financial year is at appendix IV. Two alternative road signs that the jurisdictions were required to display at black spot sites being treated under the Program are at appendix V.

A total of 3 176 black spot projects with a mean cost of $85 000 were approved under the Program.

REASONS FOR EVALUATION

The Black Spot Program was selected for inclusion in the Portfolio Evaluation Plan (PEP) of the (then) Department of Transport and Communications for the period 1992 to 1994. The Program was considered to have a number of attributes which warranted its inclusion in the PEP. These included: a significant level of resource allocation;

TABLE 1.1 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.

high political and public interest; substantial policy significance; and lack of a pre-existing evaluation framework.

The Bureau of Transport and Communications Economics (BTCE) was nominated to conduct the study. The output of the study was to be a report to the Planning Evaluation and Audit Committee (PEAC) of the Department of Transport and Communications.

THE PILOT STUDY

A one-day workshop was jointly organised by FORS and the BTCE in Canberra on 22 October 1992. The workshop was attended by state and territory road and traffic authority representatives who were coordinating the Black Spot Program in their jurisdictions. The representatives offered their support for the evaluation of the Program, especially in regard to providing data. It was agreed at the workshop that the BTCE would conduct a pilot study using a total of about 50 projects divided approximately equally between New South Wales (NSW) and Victoria. The projects for evaluation were those where treatment was completed before the end of the first year of the Program. The aims of the pilot study were to provide an early estimate of the economic results of the Program and to establish a basic framework for more detailed development of an evaluation methodology for subsequent full-scale evaluation.

Scope and general approach of the pilot study

Due to data limitations and other constraints, the pilot study did not attempt to resolve various methodological issues. The results were meant to be approximate and caution was urged in generalising, particularly because of the small number of projects that were evaluated and the small number of crashes associated with those projects.

The pilot study analysed a total of 51 projects: 26 in Victoria (both urban and rural) and 25 in NSW (all urban). The sample projects were chosen from 137 eligible projects completed before the end of June 1991 by reference to the following predetermined selection principles:

- sample to reflect levels of overall expenditure on different treatments during the first year of the Program;
- sample to achieve a reasonable geographical balance among eligible projects;
- selection to be more likely as project expenditure increased, with only a few very low cost projects to be evaluated.

The mean cost of the treatments at the 51 sample sites was $122 000 compared with the mean for the entire Program which turned out to be $85 000. The analysis was undertaken within a cost–benefit framework. Despite the fairly narrow limits of the study, some

BOX 1.1 WHAT IS A 'BLACK SPOT'?

There is no universally accepted definition of a 'black spot'. To be classified as black spots, sites are generally assessed in terms of their degree of hazard or probability of being associated with a crash. The risk of a crash is not uniform throughout the road network. At certain locations the level of risk will be higher than the general level of risk in surrounding areas. Crashes will tend to be concentrated at these relatively high-risk locations. Locations which have an abnormally high number of crashes are described by terms such as 'high hazard', 'hazardous' or 'black spot' sites.

Although the term 'black spot' suggests a precise location, the term is also often used to refer to sections of road. Black spots are usually linked to particular characteristics of the road environment such as busy intersections and sharp bends.

Black spots are difficult to define precisely because there are many factors associated with them. These factors include degree and type of risk, road characteristics, traffic exposure, and crash severity. Sites with potentially hazardous features are sometimes described as 'grey spots'.

One approach to black spot analysis draws on medical concepts. This approach involves identifying the symptom (crashes at a site) and the dysfunctions at the site and prescribing remedial measures.

Medical experience indicates that a symptom is not always associated with the apparent area of origin of the problem. The medical approach requires an overall examination of the patient to facilitate diagnosis. By analogy, a black spot should be regarded as a manifestation of a dysfunction at a particular location on a road, considered not in isolation, but as part of a traffic network. Prescribed treatment may therefore involve the site in question, other sites, or even wider areas.

Traffic authorities sometimes set 'reaction levels' which are the number of crashes at which the authority initiates detailed investigation and remedial action. These reaction levels should be set with reference to the number and type of crashes (such as right-angle or right-turn crashes or crashes involving serious injury); type of road (such as a length of road section, defined limits of an intersection); and period of time (such as multiples of 12-month periods).

The Federal Black Spot Program adopted generic criteria for a black spot as a site, road length or area with a history of casualty crashes. This definition of a black spot facilitated participation by all states and territories as well as local government, and accommodated diverse administrative practices. Separate provision also existed for the approval of funding for road safety enhancement measures based on non-site-specific criteria.

alternative methodological approaches were considered and critical parameters were varied to test the sensitivity of the results.

The benefits of crash reduction were estimated in terms of the costs of crashes avoided. Two different methods were used to estimate crash costs: the crash-severity method (where costs are calculated on the basis of the most severe degree of injury sustained in the crash) and the crash-type method (where costs are calculated on the basis of different crash types classified by vehicle movements just before impact).

Alternative project lifetimes of 10 and 20 years were used. Four different measures were used to estimate project performance: net present value (NPV); benefit–cost ratio (BCR); internal rate of return (IRR); and payback period (undiscounted). A discount rate of 7 per cent was used and the results tested for sensitivity to discount rates of 5 per cent and 10 per cent.

Crash rates for the sample projects in NSW and Victoria were adjusted for overall crash reduction trends in each state using crash data for the metropolitan areas of the states. These areas were used as control groups.

Key results of the pilot study

In the Victorian sample of projects, serious injury crashes dropped by 50 per cent and other injury crashes by 58 per cent, compared with urban crash reductions of 27 per cent and 29 per cent respectively. In the NSW sample of projects, serious injury crashes fell by 64 per cent, other injury crashes by 38 per cent, and PDO crashes by 40 per cent, compared with aggregate urban area (combined Sydney, Newcastle and Wollongong statistical regions) crash reductions of 19, 22 and 10 per cent respectively.

When crashes for the Victorian projects were examined from the perspective of vehicle movements just before impact, it was found that right-angle injury crashes fell by 69 per cent, right-turn by 89 per cent, rear-end by 26 per cent, and other injury crashes by 33 per cent. Comparable reductions for all urban areas in Victoria (used as a control group) were respectively 32, 36, 27 and 26 per cent.

In the case of the NSW sample of projects, right-angle crashes decreased by 63 per cent and right-turn crashes by 53 per cent, rear-end crashes increased by 48 per cent and other crashes fell by 46 per cent. The

BOX 1.2 'ACCIDENTS' OR 'CRASHES'?

The term 'accident' has had a long history of usage to describe motor vehicle conflicts which result in injury to persons and/or damage to property, including the vehicles themselves. However, whether the term is appropriate is questionable.

In common parlance, the term 'accident' evokes notions of an 'unforseen contingency', 'an event without an apparent cause', an 'unexpected event', an 'unintentional act', 'chance or random occurrence' and the like. These notions essentially run counter to the rationale of road safety programs, including the Black Spot Program, which suggest that many accidents are avoidable and that the road toll can be reduced.

Accidents are often not purely random events. Some individuals and groups have above average accident involvement. For example, males aged between 17 and 20 years are over-represented in crash statistics, and certain personal characteristics of individual drivers can increase their likelihood of involvement in crashes. Some studies on personality characteristics of drivers have suggested that people 'drive as they live', implying that the driving behaviour of careful, considerate and tolerant people would reflect those qualities, resulting in their having relatively lower crash rates.

The use of the term 'accident' may also be objectionable to some people because it has connotations of a lack of accountability or liability and may imply that the person who caused the 'accident' should be excused or absolved of responsibility. A key issue in regarding an event as an 'accident' is whether it was unintentional. However, intent is usually difficult to establish. The major causal element in most crashes are human factors, which include errors of judgment on the part of road users. However, there are obvious difficulties in describing a person's death caused by drunkenness, excessive speed or other forms of irresponsible driving as an 'accident'. Doege (1978) puts it succinctly: 'an injury is no accident'.

Because of the controversy associated with the use of the term 'accident', the terms 'collision' and 'crash' are preferred, and the latter has been extensively used in this report. It must be noted that there is a very small proportion of traffic situations which may involve injury or vehicle damage where the term 'crash' is not appropriate (for example a fire in a motor vehicle caused by a malfunction in electrical systems). The term 'accident' has occasionally been used in this study, but only when it is associated with certain strongly established terminology.

reductions in the control area over the same period were respectively 17, 15, 11 and 17 per cent.

These comparisons suggest that in the first year after their implementation, the black spot treatments had a relatively greater impact on the incidence of right-angle and right-turn crashes, which are generally associated with more serious injury.

A detailed cost–benefit analysis was carried out for the three main treatments in the sample of projects: new traffic lights, modified traffic lights and roundabouts. The comparison between NSW and Victoria was complicated by the fact that NSW crash statistics included towaway PDO crashes whereas the Victorian data excluded PDO crashes (because Victoria discontinued recording PDO crashes for statistical purposes after December 1990). No attempt was made in the pilot study to adjust the Victorian crash data upwards to reflect PDO crashes.

Table 1.2 sets out comparative BCRs for the sample projects using the crash-type and crash-severity approaches to crash costing (see chapter 4). It is clear from table 1.2 that, with the exception of new traffic signals for Victoria (and consequently also for new traffic signals in NSW and Victoria combined), the crash-type BCRs were substantially higher than the crash-severity BCRs. The crash-severity approach is particularly sensitive to changes in fatalities which have a high social cost. The sample of sites in Victoria at which new traffic signals had been installed had two fatalities in 1989–90 (the 'before' year) and no fatalities in 1991–92 (the 'after' year). The change in the number of fatalities caused the crash-severity BCR to increase substantially relative to the crash-type BCR.

The combined net benefits to society from the 34 traffic signal and roundabout projects, which cost $4.4 million in 1990–91, were estimated, using the crash-type methodology, at about $19 million.

RATIONALE FOR BLACK SPOT TREATMENT

Road crashes are multi-causal events. Crashes occur due to the interaction of three factors: the road environment, vehicles and road users. In-depth studies of road crashes show that human factors, by themselves or in combination with other factors, account for about 95 per cent of crashes. For example, a study by Sabey and Staughton (1975) of about 2 000 road crashes in the United Kingdom found that the percentages of crashes attributable to the road user, the road

TABLE 1.2 BENEFIT–COST RATIOS BASED ON CRASH-SEVERITY AND CRASH-TYPE METHODS: PILOT STUDY[a]

Treatments	*Crash-type BCR*	*Crash-severity BCR*
NSW[b]		
New traffic signals (UH1)	1.1	0
New traffic signals (UH2)	7.5	2.1
Roundabouts (UH7)	7.2	2.9
Victoria[c]		
New traffic signals (UH1)	1.9	9.2
Modified traffic signals (UH2)	6.1	3.9
Roundabouts (UH7)	2.8	1.8
Combined NSW[b]/Victoria[c]		
New traffic signals (UH1)	1.5	3.8
Modified traffic signals	6.8	3.0
Roundabouts (UH7)	4.1	2.1

a. Crash data for the sample projects have been adjusted for general crash reduction trends using appropriate control area data.

b. NSW data include towaway PDO crashes.

c. Victorian data do not include any PDO crashes.

Source BTCE estimates based on data provided by the Roads and Traffic Authority (NSW) and VIC ROADS.

environment and the vehicle were respectively 95, 28 and 8.5. A similar study by Treat (1980) in Indiana, United States, found that the percentages were 94, 34 and 12. These percentages add up to more than 100 per cent because many crashes were attributed to multiple causes.

The Organisation for Economic Cooperation and Development (OECD 1976) estimates that adverse road design plays a contributory role in the occurrence of up to one-quarter of all road crashes, and that in a further substantial proportion of crashes human behaviour could be influenced by road engineering means. OECD conservatively estimates that up to one-fifth of crashes could be saved by safety improvements to the existing road network.

Murray and Carter (1980), drawing on results of the crash causation studies of Sabey and Staughton (1975), Treat (1980) and studies on causation of crashes in Tasmania and metropolitan Adelaide, estimate conservatively that there could be potential to attack the cause of about 15 per cent of road crashes through road and traffic improvements.

Given that the overwhelming majority of crashes are caused by human factors, there is considerable controversy over which measures would be most cost-effective in reducing crashes. Crash reduction measures broadly involve education, enforcement and engineering, and this broad approach to improving road safety has been embodied in the National Road Safety Strategy. In April 1992, Federal, State and Territory Transport Ministers agreed to endorse the National Road Safety Strategy as a coordinated approach to reduce road trauma into the next century. One of the objectives of the strategy is ‘safer vehicles, safer roads and safer road users’.

In regard to safer roads, the strategy aims to ‘seek coordinated use of best available practices in road safety; introduce corporate safety auditing principles into all road design, construction and maintenance; and use traffic management programs to address existing problems such as road hazards and to avoid new ones’. Among the expected outcomes of the strategy are ‘elimination of road hazards and the creation of more “forgiving” roadsides’. All states and territories have their own road crash reduction strategic plans which are consistent in purpose and spirit with the National Road Safety Strategy.

There are four basic approaches to reducing crashes by implementing treatments or countermeasures:

- single sites (black spots)—treatment of specific sites or short sections of road;

- mass action—application of a known remedy to locations with common crash problems or causal factors;

- route action—application of known remedies on a route with an abnormally high crash rate; and

- area-wide action—application of several treatments over a wide area.

There are some who believe (for example Hulscher 1984; Wilde 1982) that changing drivers’ attitudes and motivations offers the best scope for crash reduction. OECD (1994) observes that there are others who believe that attempts to improve safety by attitudinal change are unlikely to succeed in the long term and that other techniques such as more enforcement or engineering programs provide the best opportunities for crash reduction. Those espousing this approach argue that enforced behavioural changes induced by engineering measures involving the vehicle or road, including the treatment of black spots, will be more effective than subtle attempts to influence driver behaviour. In fact, it is likely that the popularity of engineering measures is due to relatively more being known about improving road conditions and vehicle characteristics, than about influencing human behaviour. However, as crashes result from a multiplicity of causes, multi-factor solutions are likely to be most effective in the longer term (OECD 1994).

CAUSES OF ROAD CRASHES

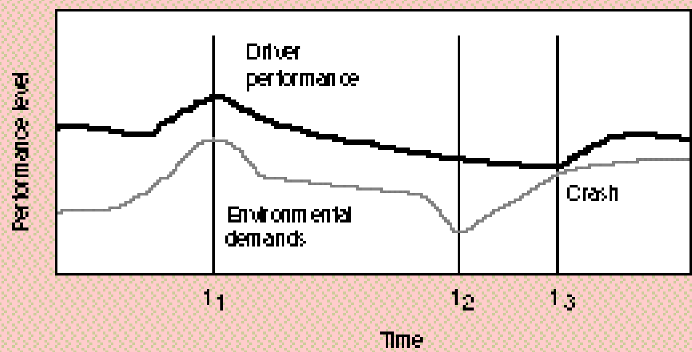
Several models of crash causation have been proposed in the road safety literature. These models generally explain crashes as being a consequence of driver behaviour that is not correctly matched with the demands of the road environment or to vehicle characteristics, or to both. The following discussion of these models is intended to shed some light on the issue of how optimum road safety benefits might be achieved.

Models of crash causation

Mahalel and Szternfeld (1986) cite the work of Blumenthal (1968) in explaining road crashes. Blumenthal perceives a crash as a problem of faulty coordination between the level of performance of the driver and the performance demands of the road environment. Figure 1.1 is a hypothetical representation of the performance level of the driver and the performance demands of the road network as a function of time. The performance level of the driver varies with time because of factors such as lack of concentration, fatigue, drowsiness and illness. The demands of the road environment vary due to factors such as rates of traffic flow, geometric features of the road, and type of road. It is assumed that there is usually an adaptation of driver performance to the demands of the road system, and therefore the driver's performance level increases with increasing road demands (time t_1 in figure 1.1) and decreases with decreasing demands (time t_2). A crash occurs when the level of performance of the driver does not match the performance demands of the road environment (time t_3).

According to this model of crash causation, engineering improvements in the road network lower the environmental demands. Consequently, the gap between the performance level of the driver and the performance demands of the road environment increases, reducing the probability of a crash.

FIGURE 1.1 INTERACTION BETWEEN ENVIRONMENTAL DEMANDS AND DRIVER PERFORMANCE



Source: Adapted from Mahalel and Szternfeld (1986).

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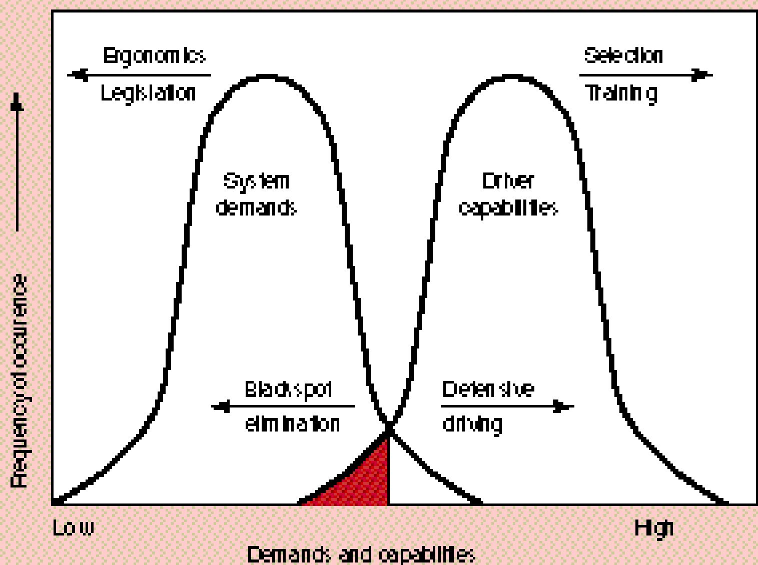
A similar model (Brown 1972, 1982) is shown in figure 1.2. The precise nature of the two distributions in the figure is not known, but the statistically low probability of individual crashes suggests that most of the time the system demands and driver capabilities are separated by a safety margin. Both distributions will have high and low tails to describe changes in demands and skills over time and in different parts of the road network. A crash occurs when a driver is temporarily unable to meet a peak system demand.

The model depicted in figure 1.2 suggests that crash prevention involves preventing overlap between the tails of the two distributions. One way of achieving this is by shifting the curves away from each other. Examples of this strategy are ergonomic redesign of the whole traffic system, extensive legislative constraints on road user behaviour, and good driver selection and training. Alternatively, the two distributions can be prevented from overlapping by reducing their spread. Examples of this strategy include black spot remedial treatment, which would reduce peak system demands, and teaching drivers defensive driving skills, which would reduce periods of low driver capability. The arrows in figure 1.2 indicate the effects of the remedial measures on system demands, drivers’ capabilities, black spots and lapses in skill.

One of the key shortcomings of such simple models is that they assume that the two distributions vary independently, whereas in reality, traffic demands and driver capabilities involve interactive effects. There is a

FIGURE 1.2 A MODEL OF ROAD CRASH CAUSATION AND PREVENTION



Brown (1972, 1982).

substantial body of theory which suggests that engineering improvements to the road system by themselves are inadequate to ensure the expected decreases in crashes. An engineering improvement in the road system will have the expected degree of effectiveness only if driver behaviour remains unchanged. The theory attributes the lack of the expected degree of effectiveness of safety measures to the fact that driving is a self-paced task. This means that it is the driver who largely determines the degree of difficulty of the task and the level of performance. There are several models and theoretical constructs which have been proposed to explain human behavioural change and its relationship to road crashes. A brief overview of some of these models and their implications for improving road safety is presented below.

Impact of human behavioural change on road crashes

The idea that an adaptive mechanism operates to reduce the effectiveness of safety measures has a long history in road safety, going back at least to a paper by Gibson and Crooks (1938) which deals with the issue of drivers’ adaptation to better brakes. They consider that better brakes in a vehicle will not by itself make driving the vehicle safer. Instead, they argue that better brakes reduce the minimum stopping distance. The driver soon becomes accustomed to this, and then allows the same relative stopping margin as before.

Cownie and Calderwood (1966) discuss the concept of compensatory behaviour by drivers in response to a safety measure. They postulate that crashes are the product of a closed loop process involving feedback from the consequences of drivers' decisions (including crashes and traffic conflicts) to subsequent decisions in similar traffic situations. Cownie and Calderwood recognise the need for this feedback process to be taken into account in implementing safety measures. They consider that the introduction of a measure intended to enhance safety could have the unintended effect of reducing safety because of the elimination from the system of a 'warning' received by drivers.

Naatanen and Summala (1974) similarly stress that in considering safety measures, their effects on the actual behaviour of the driver should be estimated. They point out that certain countermeasures such as broadening and straightening roads have been found to be ineffective in reducing crashes. They attribute this to a decrease in subjective risk experienced by the driver, as for example by changes in the traffic environment which appear to make driving safer. Under these conditions a driver can drive faster and overtake other vehicles more frequently before an increase in subjective risk is experienced, thereby decreasing safety. The model of motivational factors in driver decision making proposed by Naatanen and Summala suggests that the best effect could be obtained from countermeasures which make the traffic system objectively safer, whilst simultaneously increasing the subjective risk.

O'Neill (1977) presents a decision theory model of danger compensation involving utility maximisation by the driver. The model assumes that drivers are 'rational' in that they have stable goals and make decisions to maximise the expected value of these goals. Some of these goals can be achieved more effectively by unsafe behaviour. One such goal may be the time spent at destination, and this may be increased by driving at a higher speed, or generating smaller gaps between vehicles when overtaking or merging. The driver's motivation to achieve these goals is counteracted by the desire to avoid a crash. The driver's choice of behaviour reflects a balance of these two forces. The driver chooses a behaviour that maximises the goals of driving minus the expected loss due to a crash. An environmental safety improvement shifts this balance, and possibly the crash rate, one way or another.

O'Neill's model analyses the degree and direction of this shift. He shows mathematically that, under certain conditions, rational drivers may react in such a manner that a safety innovation makes matters worse. O'Neill stresses the need to take danger compensation into account before a safety change is introduced. In practical terms, O'Neill's approach emphasises driver judgment and motivation for specific behaviour, rather than the engineering of roads and vehicles.

Wilde (1982, 1986) proposes the controversial theory of risk homeostasis which holds that the number of crashes in a country depends only on drivers' 'risk tolerance' or the crash rate they are prepared to tolerate. Safety improvements are considered to be only temporary, with crashes returning to an equilibrium level over time. According to this theory, long-term safety improvements require approaches involving motivational safety measures that increase drivers' desire to be safe. Risk homeostasis is discussed in more detail in appendix VII.

A motivational approach to understanding and modifying driver behaviour is also proposed by Mahalel and Szternfeld (1986). Their approach has recourse to the Yerkes–Dodson law cited by Kahneman (1973) which relates performance to arousal: the quality of performance is an inverted U-shaped function of arousal (figure 1.3). The law states that for a given task there is a certain level of arousal at which performance reaches an optimum. Figure 1.3 also shows that the relationship between level of arousal and level of performance is also a function of the complexity of the task. This means that if a task is simplified, but at the same time its perceived level of difficulty is decreased, a decline in performance might result because of a decrease in the level of arousal.

The simplification of the driving task could cause the driver to underestimate the difficulty of the task and therefore result in a decrease in the driver's level of arousal. The resulting decrease in performance could cause a crash. The situation is illustrated in figure 1.3. Assume that in order to reach an optimum performance level (level A) a complex task requires an arousal level a. After an engineering improvement is implemented, assume that the task is simplified so that a higher level of performance (B) can be reached. It would appear that the expected increase in the level of performance would reduce the probability of a crash. However, if after the engineering improvement the arousal level drops to c, there is an underestimation of the difficulty of the task and the new performance level C will be lower than the original performance level A which was optimal for the complex task.

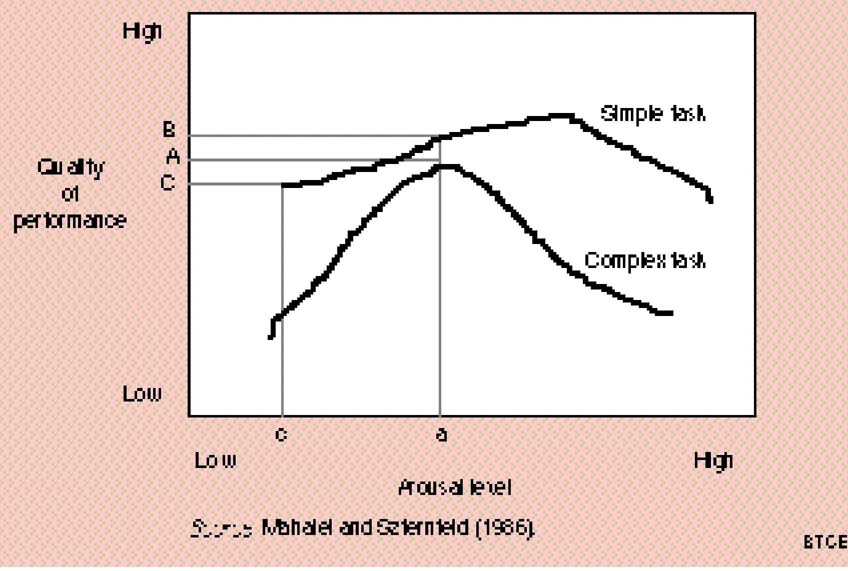


FIGURE 1.3 THE RELATIONSHIP BETWEEN AROUSAL AND PERFORMANCE (YERKES-DODSON LAW)

Source: Mahalel and Szternfeld (1986).

Mahalel and Szternfeld (1986) use the terms ‘detection’ and ‘criterion’ derived from signal detection theory to explain the possible responses of drivers to engineering improvements. Both detection and criterion stem from a perception by the driver that a situation is not complex or dangerous, and this leads to overconfidence in the road system. The detection problem relates to a decrease in a driver’s stress when experiencing engineering improvements and more comfortable driving conditions. Under these conditions, the driver’s level of arousal is lowered and attention is spread over non-relevant cues. The result is poor detection of problems and a low level of performance.

The problem of criterion relates to increased reliance on the road system and other drivers. The resulting change in behaviour results in low performance. The combined outcome of biased criterion and poor detection is a lowering of the driver’s performance and an increased probability of crashes.

Mahalel and Szternfeld concede that engineering improvements do lead to decreases in the number of road crashes. However, they contend that when there is an objective simplification of the driving task that causes an underestimation of driving difficulty the problem of biased criteria and deficient detection may emerge with a consequent increase in crash probability. The practical implications of this theory are not that improvements should not be made, but that the improvements should not cause a drop in the level of arousal below a critical level, thereby decreasing the gap between environmental demands and performance level. The theory suggests that the challenge of road engineering is to attempt to strike an optimal balance between opposing needs: to create a road environment requiring easy tasks on the one hand, while on the other, to ensure that underestimation of task difficulty resulting in lower performance does not occur.

The literature provides some examples of how this difficult balance might be achieved and points to the need for creativity and innovation in achieving it. Denton (1973) demonstrated the crash-reducing potential of painting a geometric pattern of bars with decreasing spacing on a motorway in the United Kingdom. The pattern provides the illusion that drivers are travelling faster than their actual speeds and therefore causes them to reduce speed. This measure raises the subjective risk while the objective risk remains unchanged. In similar vein, Shinar, Rockwell and Malecki (1975) painted stripes on a curve to provide the illusion of a narrower road. In terms of the Mahalel and Szternfeld model, this change causes a higher estimation of difficulty, encourages more severe criteria, and increases arousal. Shinar et al. found that the average speed and the proportion of speeding both decreased after the stripes were introduced.

Naatanen and Summala (1974) suggest that crash barriers be constructed along the middle line of wide two-lane roads. Such barriers reduce the more serious head-on crashes but may increase the number of minor crashes. The barriers would increase the subjective risk and be a source of negative feedback in the traffic system. Another example from the same researchers is the case of the lateral edge of the road surface with a dangerous drop of several centimetres to the road shoulder, which may be obscured by tall grass. An obvious treatment would be to raise the surface of the road shoulder to eliminate the drop and reduce run-off-road crashes. Another approach, involving the raising of subjective risk levels, is to cut the grass so that drivers can perceive the dangerous edge.

Evans (1985,1991) suggests a formalism to classify observed effects of safety measures into an organised framework. The approach involves the following expression

$$\Delta S_{Act} = (1 + f)\Delta S_{Eng} \qquad (1)$$

where ΔS_{Eng} is the reduction in some harm measure (such as crashes or fatalities) expected from an engineering measure, ΔS_{Act} is the actual realised change in safety (the two quantities may differ because road users may alter their behaviour), and f is a feedback parameter which characterises the degree to which road users respond to the safety change. If road users do not change their behaviour in response to the safety change, then f=0 and the engineering expectations are completely fulfilled. If the safety change is in the expected direction but of lesser magnitude than expected, then $-1<f<0$ and the safety change is less than the expected amount. If the safety change has no effect, then $f=-1$.

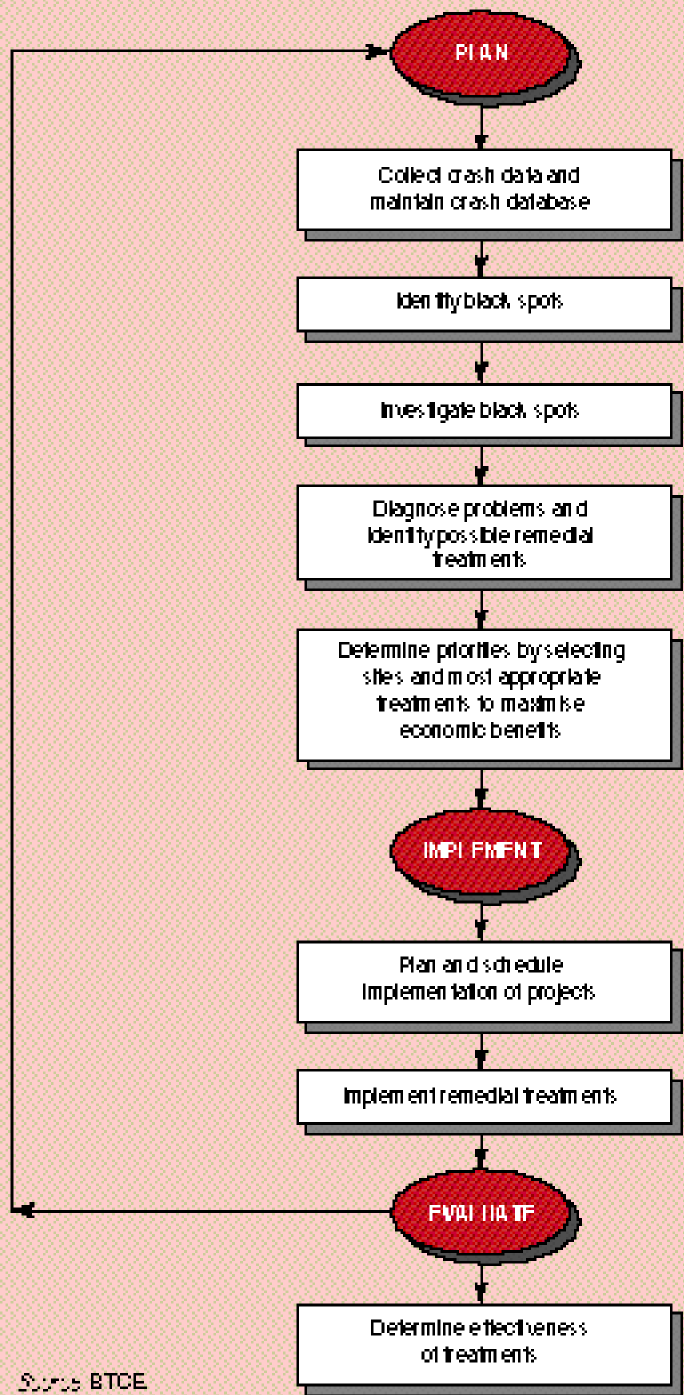
Evans surveyed the road safety literature and found responses (that is, values of f) in ranges beyond those illustrated above. Because of this wide range of values, Evans prefers the term ‘human behaviour feedback’ to terms such as ‘risk compensation’ and ‘danger compensation’ to describe road user responses in the range $-1<f<0$. He argues that risk is not necessarily the dominant, and certainly not the sole, determinant of driver behaviour and that all that is observed is a road user response. To label it ‘risk compensation’ is to unjustifiably assume an understanding of the cause of the response. Evans concludes that behaviour feedback effects are widespread in traffic safety systems and that road users respond in some degree to just about everything of which they are aware. Changes made to increase safety have in some cases actually reduced safety, while other changes expected to reduce safety, but made for other reasons, have actually increased safety. In sum, behaviour feedback effects complicate the task of estimating the expected benefits of proposed safety measures.

MANAGEMENT PROCESS IN BLACK SPOT TREATMENT

The primary function of road safety management is to reduce the frequency and severity of crashes. A coordinated management system involving an integrated sequence of processes can effectively identify problems in the road system and improve the quality of decision making in identifying and implementing safety measures. The processes involved in black spot treatment are set out in figure 1.4.

There are three main tasks involved: planning, implementing and evaluating. Good planning requires maintaining a comprehensive crash database which is used to identify and rank black spot sites. The results of evaluation feed back to the planning process to improve the quality of future decisions. Regrettably, evaluation is often an afterthought and is not developed until the implementation is in progress. It is vital that

FIGURE 1.4 SCHEMATIC REPRESENTATION OF PROCESSES INVOLVED IN BLACK SPOT TREATMENT



Source: BTCE

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a sound evaluation design be incorporated in the planning process. The evaluation design dictates the nature of the data required for the evaluation. The evaluation should ideally provide an indication of how effective a particular strategy or safety measure has been in reducing the frequency and severity of crashes as well as information about how its effectiveness could be increased.

In the case of the Black Spot Program, the decision to evaluate the overall Program was not incorporated in the planning process. As a result, various methodological constraints were imposed on the study. Foremost among them was the use of a basic before and after design with some refinements. Given that there are several factors other than a particular safety measure that can contribute to observed outcomes, stronger experimental designs would produce more reliable estimates of the actual effects of a safety measure. The stronger designs require planning in order that the required data, especially data for suitable control sites, may be obtained. However, the use of stronger designs is often precluded by the need for policy makers to obtain relatively quick results using short periods of data collection. This necessitates the caveat that the results of short-term studies normally involve a relatively greater degree of imprecision in the estimates of benefits.

A collaborative arrangement between the states and territories could provide an effective means of evaluating black spot treatments in the future. A basic requirement would be an agreed evaluation framework. Each state and territory could conduct a small number of in-depth studies. The standardisation of crash recording and reporting and the use of consistent definitions and procedures would facilitate this process. By this means, over a period of time, sound estimates of benefits of various treatments may be obtained in a cost-efficient manner and information about progress towards best practice widely disseminated.

CHAPTER 2 EXPENDITURE ON THE BLACK SPOT PROGRAM

OVERALL NATIONAL EXPENDITURE

Federal expenditure on approved black spot projects between 1990–91 and 1992–93 amounted to $270 million. Over three thousand (3 176) projects were completed during the three years of the Program at a mean cost of $85 000 per project.[1] Funds under the Program were available for:

- works on public roads, regardless of ownership or control; and
- capital expenditure on equipment having road safety improvement potential.[2]

Prior to the commencement of the Program, FORS had retained ARRB to identify and categorise a range of treatments with high potential benefits. The treatments were classified by FORS into four categories: high potential urban (UH); high potential rural (RH); medium potential urban (UM); and medium potential rural (RM). These treatments are listed in the Schedule of Acceptable Treatments in table 1.1. The

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1. The mean cost is for all projects (scheduled treatments, safety enhancements and other innovative treatments) undertaken under the Black Spot Program. The analysis of expenditure set out in this chapter is based on the data that were available at the time the analysis was carried out. Total approved expenditure at the time was $267.2 million, which included $0.7 million for projects that were subsequently approved. Therefore, the analysis does not include some disbursements and variations in expenditure that occurred towards the end of the Black Spot Program. Each jurisdiction was required to submit a financial statement to the Federal Minister responsible for Transport shortly after 30 June of each year of the Program. The data used in this analysis were derived from these statements of expenditure provided by each jurisdiction.
2. Funding under the Black Spot Program was not provided for projects on declared national highways, for purchase of road building plant or equipment, or for the operation or maintenance of any road safety enhancement equipment that was purchased or installed under the Program.

Schedule consists of a total of 30 treatments, with UH and RH comprising nine treatments each, and UM and RM, six treatments each. The analysis in this chapter has been carried out in accordance with this classification of treatments.

To be eligible for funding, projects were required to have a BCR of at least 2, and a recorded history of fatalities or serious injuries. A project involving any treatment listed in the Schedule was regarded as having a benefit–cost ratio greater than 2 and was accepted by FORS without the jurisdictions being required to provide further justification. This arrangement formed the basis on which applications for funding projects were submitted by the jurisdictions to FORS for Ministerial approval.

Funds were also made available under the Program (up to 10 per cent) for other tangible and visible road safety enhancement projects (appendix II) such as random breath testing equipment, electronic speed cameras and radar equipment (referred to as Schedule 1A treatments). Additionally, there was provision for funding innovative treatments (requiring more detailed supporting argument) proposed by the jurisdictions (referred to as Schedule 1B treatments).

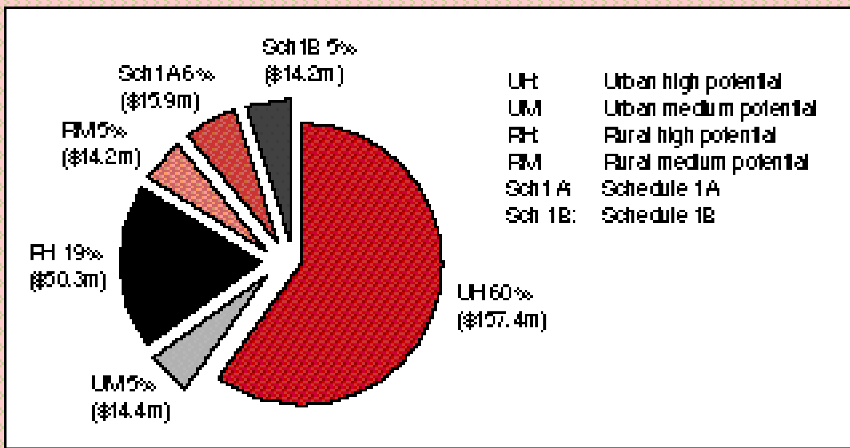
Most approved projects involved a single treatment. In cases where more than one treatment was involved, the project was classified for purposes of statistical analysis under what was considered the primary or most important treatment. The analysis in this chapter is based on approved expenditure which may differ slightly from actual expenditure.

Figure 2.1 shows the composition of total national approved expenditure on black spot projects by treatment category. Urban treatments accounted for $171.8 million or 65 per cent of total expenditure. Expenditure on rural treatments amounted to $64.5 million or 24 per cent of total expenditure. Expenditure of $15.9 million was approved for road safety enhancement projects (Schedule 1A) and $14.2 million on other innovative treatments (Schedule 1B), representing 6 per cent and 5 per cent respectively of total expenditure.

EXPENDITURE ON URBAN PROJECTS

As previously noted, urban projects made up 65 per cent ($171.8 million) of total Program expenditure. The major proportion of Program funds

FIGURE 2.1 COMPOSITION OF TOTAL EXPENDITURE BY TREATMENT CATEGORY



Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

(60 per cent or $157.4 million) was expended on UH treatments while the UM category accounted for 5 per cent ($14.4 million).

Projects involving three urban treatments—new traffic signals (UH1), modification of existing traffic signals (UH2) and roundabouts (UH7)—in aggregate involved expenditure of $102.9 million, accounting for 38 per cent of total Program expenditure and 60 per cent of total urban expenditure. These three treatments, together with intersection channelisation (UH3), which ranked fourth in terms of expenditure,

TABLE 2.1 EXPENDITURE ON SELECTED URBAN TREATMENTS

Treatment type		*Total expenditure ($million)*	*Percentage of total expenditure (per cent)*	*Percentage of urban expenditure (per cent)*
UH7	Roundabouts	40.0	15.0	23.3
UH1	New traffic signals	34.8	13.0	20.2
UH2	Modified traffic signals	28.1	10.5	16.3
UH3	Channelisation	25.7	9.6	14.9

Source BTCE estimates based on data provided to FORS by states and territories.

represented almost half (48 per cent) of total Program expenditure and 75 per cent of total urban expenditure (table 2.1).

Total and mean expenditure for all urban treatments, and the number of projects involving these treatments, are set out in table 2.2. There were 2 187 urban projects approved with mean expenditure per project of approximately $79 000.

Expenditure characteristics of various urban treatments

Of the fifteen urban treatments the top three in terms of mean expenditure were new traffic signals, UH1 ($119 000), selective roadside hazard modification, UH8 ($115 000), and roundabouts, UH7 ($99 000).

Of all Schedule treatments, roundabouts (UH7) involved the highest total expenditure ($40 million) and the second largest number of projects (405). Expenditure on roundabouts constituted 23 per cent of total urban expenditure. Expenditure on individual projects ranged from $5 000 to $760 000 due to the variation in the size of roundabouts and associated road work. Table 2.3 shows the distribution of expenditure on roundabouts with the total expenditure on roundabouts disaggregated into six expenditure ranges. There were 278 projects involving roundabouts which cost less than $100 000 each, comprising 69 per cent of the total number of projects involving roundabouts.

New traffic signals ranked second in terms of total expenditure ($34.8 million), followed by modified traffic signals ($28.1 million), which involved the largest number of urban projects (501). New and modified traffic signals together accounted for $62.9 million or 36 per cent of total urban expenditure. New traffic signals (UH1) involved mean expenditure of $119 000 per project—the highest of all urban treatments (table 2.2). Individual project expenditure on new traffic signals (UH1) ranged from $5 000 (minor work such as provision of an audible signal for pedestrians) to $602 500 (major installation of new traffic signals and associated road work).

Table 2.4 sets out the distribution of expenditure on new traffic signals classified into five expenditure ranges. The medium expenditure range ($50 000 to $150 000) comprised 218 projects or 75 per cent of all projects involving new traffic signals.

Expenditure on traffic signal modification (UH2) ranged from $500 to $1 million with a mean of $56 000 (table 2.5). This type of treatment

TABLE 2.2 NUMBER OF PROJECTS AND TOTAL AND MEAN EXPENDITURE: URBAN TREATMENTS

Treatment type		*Number of projects*	*Total expenditure ($ million)*	*Mean expenditure[a] ($)*
UH1	New traffic signals	291	34.8	119 000
UH2	Traffic signal modification	501	28.1	56 000
UH3	Intersection channelisation	379	25.7	68 000
UH4	Provision of medians	110	8.5	77 000
UH5	Median closures	35	2.6	73 000
UH6	Pedestrian refuges	88	2.0	23 000
UH7	Roundabouts	405	40.0	99 000
UH8	Selective roadside hazard modification	125	14.4	115 000
UH9	Improved lighting at pedestrian facilities	37	1.5	40 000
UM1	Improved skid resistance	32	2.1	65 000
UM2	Protected turning bays	86	6.6	77 000
UM3	Local area traffic management	61	3.1	51 000
UM4	Clearway provisions	5	0.3	52 000
UM5	Median barriers	15	1.4	96 000
UM6	Red light cameras	17	0.9	55 000
All urban		2 187	171.8	79 000

a. Mean expenditure is total approved expenditure for all projects of a particular type divided by the total number of such projects. Mean expenditure has been rounded to the nearest thousand dollars. Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.3 DISTRIBUTION OF EXPENDITURE ON ROUNDABOUTS (UH7)

Expenditure range ($'000)	*Total expenditure ($)*	*Number of projects*	*Mean expenditure[a] ($)*
≤50	5 061 755	170	30 000
50–100	8 046 202	108	75 000
100–150	6 153 280	48	128 000
150–200	5 397 250	30	180 000
200–300	8 015 789	32	250 000
>300	7 361 700	17	433 000
All UH7	40 035 976	405	99 000

a. Mean expenditure has been rounded to the nearest thousand dollars. Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.4 DISTRIBUTION OF EXPENDITURE ON NEW TRAFFIC SIGNALS (UH1)

Expenditure range ($'000)	*Total expenditure ($)*	*Number of projects*	*Mean expenditure[a] ($)*
≤50	697 425	20	35 000
50–100	10 860 455	132	82 000
100–150	11 094 405	86	129 000
150–200	5 425 225	31	175 000
>200	6 677 500	22	304 000
All UH1	34 755 010	291	119 000

a. Mean expenditure has been rounded to the nearest thousand dollars.
Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.5 DISTRIBUTION OF EXPENDITURE ON TRAFFIC SIGNAL MODIFICATION (UH2)

Expenditure range ($'000)	*Total expenditure ($)*	*Number of projects*	*Mean expenditure[a] ($)*
≤50	7 727 984	343	23 000
50–100	6 323 725	87	73 000
100–150	4 037 095	33	122 000
150–200	2 862 980	16	179 000
>200	7 109 000	22	323 000
All UH2	28 060 784	501	56 000

a. Mean expenditure has been rounded to the nearest thousand dollars.
Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

involved projects such as right-turn lane marking, right-turn slot/parking lanes, red arrow hold, and phase alteration. The majority of these projects (86 per cent) involved expenditure of less than $100 000. However, there were a few high cost projects approved which may have involved a combination of two or more treatments (for example, a project in Darwin, Northern Territory, cost $1 million and another in Frankston, Victoria, cost $0.6 million).

Although selective roadside hazard modification (UH8) ranked second in terms of mean expenditure ($115 000 per project), there were only

125 projects of this type carried out. Some of these projects involved very high costs. For example, in Footscray, Victoria (bridge widening) and in Parramatta, NSW (provision of extra merging lane) each project cost $1.5 million. Two projects in Victoria, one in Melbourne (road under bridge to re-route heavy vehicles) and one in Sunshine (widening existing carriageway) each cost $0.8 million. Other treatments of this type included installation of overhead and warning signs and utility pole relocations.

Expenditure on intersection channelisation (UH3) amounted to $25.7 million, making up 15 per cent of total urban expenditure. There were 379 projects involving this treatment (projects included provision of give way signs and construction of seagull islands) with a relatively low mean cost of $68 000 per project. Pedestrian refuges (UH6) had the lowest mean cost per project ($23 000) of all urban treatments. The largest contributors to total expenditure in the UM category were projects involving protected turning bays (UM2) and local area traffic management (UM3) with shares of $6.6 million and $3.1 million respectively.

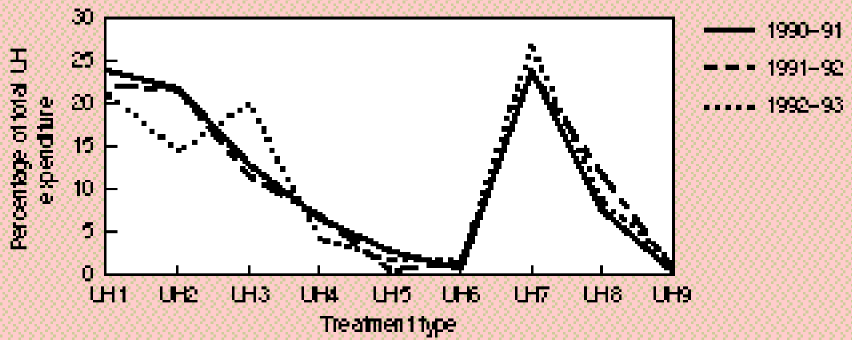
Distribution of urban expenditure over Program life

Over the three years of the Black Spot Program, the distribution of expenditure on urban treatments showed, with a few exceptions, a fairly stable annual pattern. Figure 2.2 shows that over the three years, there was a declining trend in the proportion of funds spent on new traffic signals (UH1) and a marked drop in the proportion of funds spent on the modification of traffic signals (UH2). Many traffic signal modifications were implemented at sites with a high risk of right-turn crashes which are generally associated with serious injury. Such sites were likely to have been treated early in the Program.

Over the duration of the Program there was a marked increase in the proportion of funds spent on intersection channelisation (UH3). The longer lead times for these projects may have been mainly due to the need for planning in order to effect changes in environmental conditions such as the relocation of utilities. In some cases, intersection channelisation may have been carried out at sites where other types of treatment, such as traffic signals, had been implemented earlier in the Program.

It is evident from figures 2.2 and 2.3 that for virtually all urban treatment types, the largest proportion of expenditure was undertaken in 1992–93,

FIGURE 2.2 DISTRIBUTION OF EXPENDITURE ON URBAN TREATMENTS, 1990–91 TO 1992–93



Source BTCE estimates based on data provided to FORS by states and territories.

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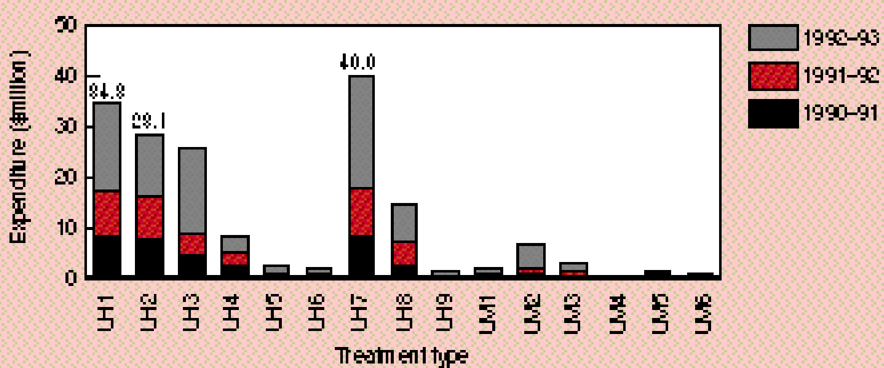
FIGURE 2.3 EXPENDITURE ON URBAN TREATMENTS, 1990–91 TO 1992–93



Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

which was the final year of the Program. This was mainly because of the increase in funding that occurred in early 1992 consequent to the 'One Nation' statement (Keating 1992). Also, the first two years of the Program would have provided the jurisdictions with both time and additional experience, thus enabling them to more thoroughly study and identify their black spot sites, to produce economic assessments, and to prepare applications for funding.

EXPENDITURE ON RURAL PROJECTS

Rural treatments constituted less than a quarter ($64.5 million) of total Program expenditure. Rural high potential (RH) treatments accounted for 19 per cent ($50.3 million) of total expenditure and rural medium potential (RM) treatments made up 5 per cent ($14.2 million) of the total (figure 2.1).

Table 2.6 shows the number of projects for each rural treatment and the distribution of total and mean expenditure. The number of rural projects (764) was about one-third the number of urban projects (2 187). Shoulder sealing (RH1) was the primary rural treatment implemented in terms of

TABLE 2.6 NUMBER OF PROJECTS AND TOTAL AND MEAN EXPENDITURE: RURAL TREATMENTS

Treatment type		*Number of projects*	*Total expenditure ($ million)*	*Mean expenditure[a] ($)*
RH1	Shoulder sealing	174	22.5	129 000
RH2	Lighting at isolated intersections	30	1.9	62 000
RH3	Site specific edgelining	36	1.5	42 000
RH4	Selective roadside hazard modification	187	14.2	76 000
RH5	Curve delineation	45	1.2	27 000
RH6	Provision of pavement markers, guide posts, corner cube reflectors	104	2.2	21 000
RH7	Staggering of cross intersections	14	2.0	142 000
RH8	Warning and direction signs	39	1.3	34 000
RH9	Protected right turns	35	3.5	100 000
RM1	Superelevation on isolated curves	13	1.6	124 000
RM2	Median barriers	14	1.7	125 000
RM3	Improved sight distance	24	2.2	91 000
RM4	Overtaking lanes	32	7.5	235 000
RM5	Improvements to divided highways	0	0	0
RM6	Acceleration and deceleration lanes	17	1.2	70 000
All rural		764	64.5	84 000

a. Mean expenditure is total approved expenditure for all projects of a particular type divided by the total number of such projects. Mean expenditure has been rounded to the nearest thousand dollars. Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

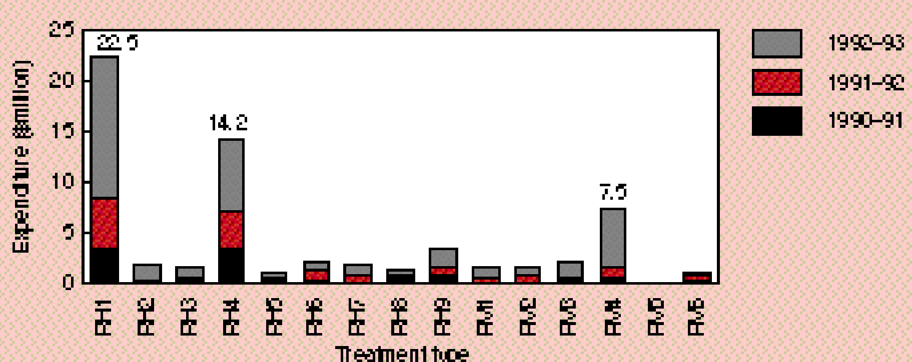
expenditure, representing $22.5 million or 35 per cent of total rural expenditure. In second and third place were selective roadside hazard modification (RH4), and overtaking lanes (RM4), which accounted for $14.2 million and $7.5 million respectively.

The most common treatments applied in rural areas were selective roadside hazard modification, RH4 (187 projects), shoulder sealing, RH1 (174 projects), and provision of pavement markers, guide posts and corner cube reflectors, RH6 (104 projects). There was no expenditure on improvements to divided highways (RM5) during the Program.

The mean approved expenditure for a rural treatment was $84 000—slightly higher than the mean of $79 000 for an urban treatment. Six types of rural treatments had mean expenditure of $100 000 or more compared with only two types of urban treatments. This difference reflects the relatively greater area of road surface treated and greater labour inputs in many rural projects. Overtaking lanes (RM4) had the highest mean expenditure ($235 000) followed by staggering of cross intersections, RH7 ($142 000).

Expenditure on rural treatments had a wider spread of mean values than was the case for urban treatments, ranging from $21 000 for the provision of pavement markers, guide posts and corner cube reflectors (RH6) to $235 000 for overtaking lanes (RM4).

FIGURE 2.4 EXPENDITURE ON RURAL TREATMENTS, 1990–91 to 1992–93



Source: BTCE estimates based on data provided to FORS by states and territories.

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Distribution of rural expenditure over Program life

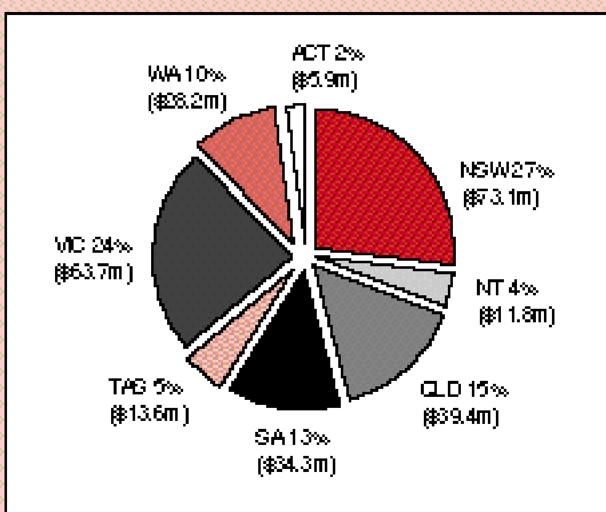
Figure 2.4 shows the distribution of expenditure on rural treatments over the life of the Program. As was the case with urban treatments, it is evident that for most rural treatments, the largest proportion of total expenditure was incurred in the final year of the Program.

EXPENDITURE BY JURISDICTION

Figure 2.5 shows the distribution of expenditure by jurisdiction. Initially, an allocation of $110 million in federal funding was made available to the jurisdictions over the three-year life of the Black Spot Program. The annual allocation of funds to each jurisdiction was predetermined by the Federal Government. Total funds available were subsequently increased by $160 million, primarily as a result of Prime Minister Keating's 'One Nation' economic statement of February 1992 (Keating 1992).

The largest expenditure on black spot treatments was incurred by NSW ($73.1 million or 27 per cent), followed by Victoria (63.7 million or 24 per cent). The lowest expenditure on black spot treatments was in the ACT ($5.9 million or 2 per cent).

FIGURE 2.5 COMPOSITION OF TOTAL EXPENDITURE BY JURISDICTION



Source: BTCE estimates based on data provided to FORS by states and territories.

BTCE

Several factors determine the number and type of projects carried out in each jurisdiction. Among these factors are the number of hazardous sites, funding constraints, type and severity of crashes that have occurred, site geometry, and expected effectiveness of different treatment options. Variations in the number, type and mean cost of treatments between jurisdictions would therefore be expected.

Tables 2.7 and 2.8 set out the distribution of urban expenditure and rural expenditure respectively, by magnitude and jurisdiction. All jurisdictions spent a significant proportion of their total expenditure on relatively low cost treatments (under $100 000). There were approximately 1 700 urban and 575 rural projects with expenditure of under $100 000 each undertaken during the Program.

Figure 2.6 shows total expenditure (excluding Schedule 1A and 1B treatments) by jurisdiction and treatment categories. Differences in the composition of the four treatment categories in each jurisdiction are evident from the figure.

The pie charts comprising figure 2.7 show the distribution of expenditure on urban and rural treatments (excluding Schedule 1A and 1B treatments) for each jurisdiction. All jurisdictions except the Northern Territory spent more than half their black spot funds on urban treatments. The Northern Territory spent slightly less than half their funds (47 per cent) on urban treatments. Western Australia, NSW and Victoria spent 94, 92 and 76 per cent respectively of their total funds on urban treatments.

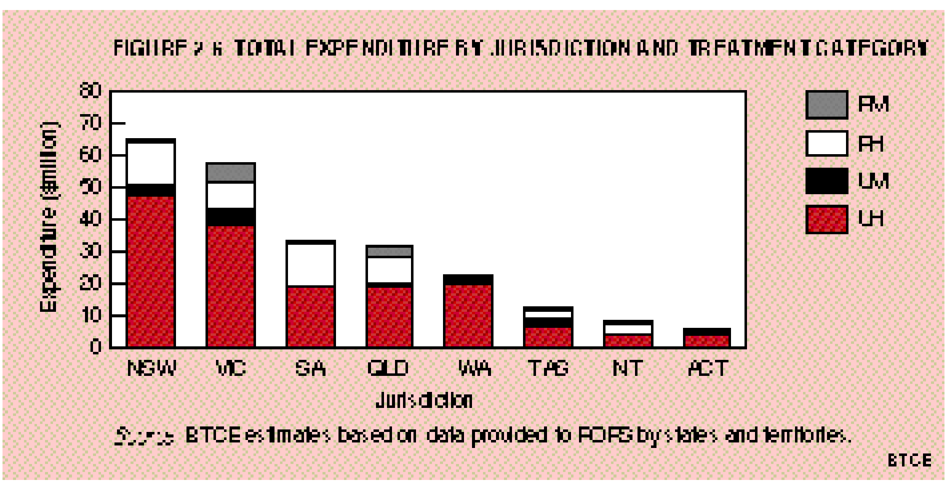
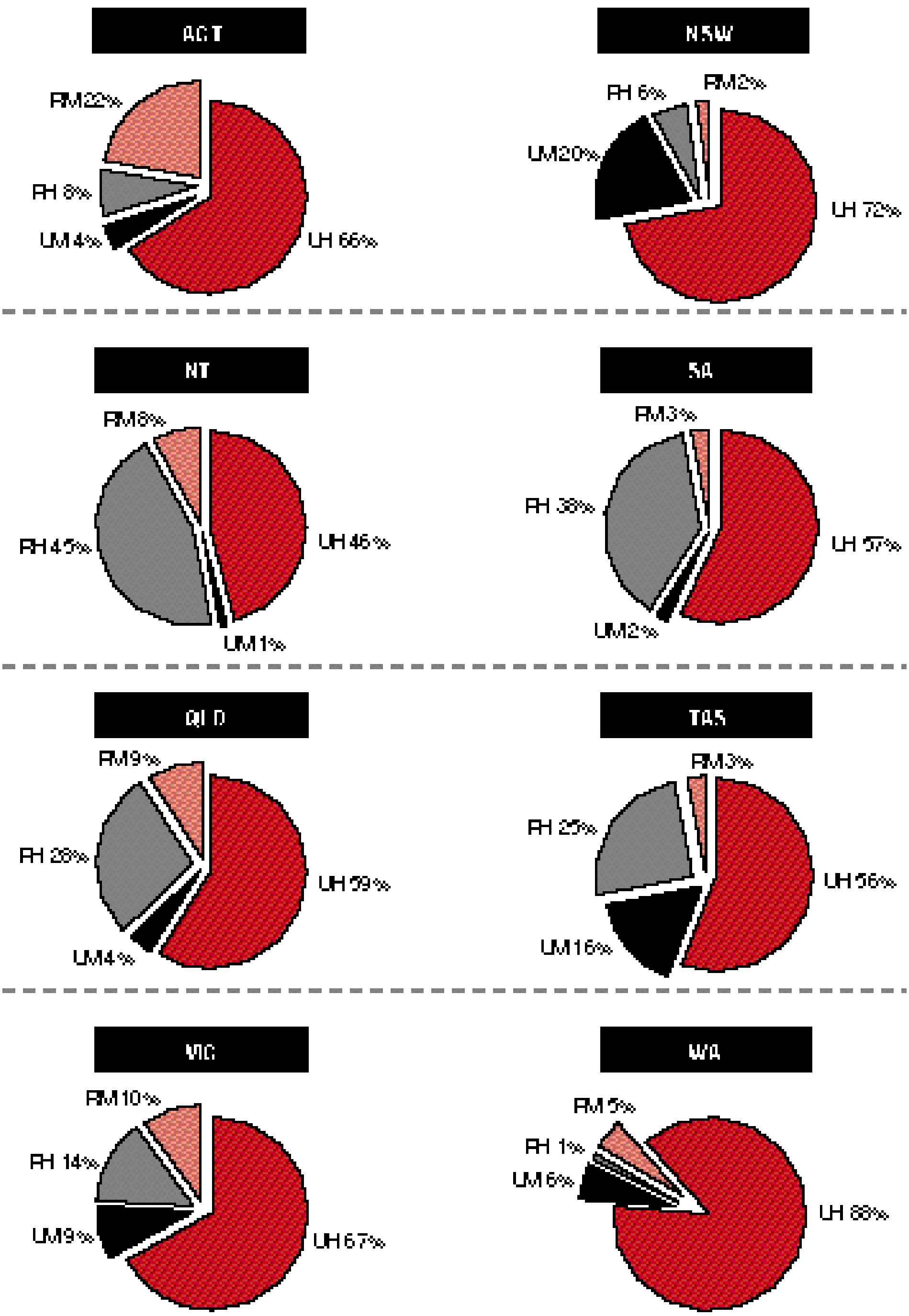


FIGURE 2.6 TOTAL EXPENDITURE BY JURISDICTION AND TREATMENT CATEGORY

Source: BTCE estimates based on data provided to FORS by states and territories.

FIGURE 2.4 COMPOSITION OF EXPENDITURE BY TREATMENT CATEGORY FOR EACH JURISDICTION



Source: BTCE estimates based on data provided to FDRS by states and territories.

TABLE 2.7 DISTRIBUTION OF URBAN EXPENDITURE BY MAGNITUDE AND JURISDICTION

($)

Jurisdiction		*Magnitude of project* ≤50 000	*50 000–100 000*	*100 000–150 000*	*150 000–200 000*	*>200 000*	*All projects*
ACT	Total cost	510 000	165 000	360 000	720 000	2 125 000	3 880 000
	No. of projects	21	2	3	4	7	37
	Mean cost[a]	24 000	82 000	120 000	180 000	304 000	105 000
NSW	Total cost	7 246 000	9 310 000	6 179 000	6 852 000	21 399 000	50 986 000
	No. of projects	286	123	47	37	53	546
	Mean cost[a]	25 000	76 000	131 000	185 000	404 000	93 000
NT	Total cost	196 500	333 500	150 000	195 500	3 060 129	3 935 629
	No. of projects	10	4	1	1	9	25
	Mean cost[a]	12 000	83 000	150 000	195 000	340 000	157 000
QLD	Total cost	3 158 767	7 486 633	4 295 300	3 453 000	1 525 000	19 918 700
	No. of projects	110	91	33	18	4	256
	Mean cost[a]	29 000	82 000	130 000	192 000	381 000	78 000
SA	Total cost	4 350 200	4 428 000	4 965 000	1 951 000	3 630 000	19 324 200
	No. of projects	207	60	39	11	12	329
	Mean cost[a]	21 000	74 000	127 000	177 000	302 000	59 000
TAS	Total cost	2 521 740	1 570 210	473 200	1 642 700	2 419 080	8 626 930
	No. of projects	148	23	4	10	9	194
	Mean cost[a]	17 000	68 000	118 000	164 000	269 000	44 000
VIC	Total cost	5 810 320	6 174 615	8 426 490	4 285 500	19 069 105	43 766 030
	No. of projects	271	79	67	25	48	490
	Mean cost[a]	21 000	78 000	126 000	171 000	397 000	89 000
WA	Total cost	3 519 778	7 018 346	4 462 680	2 561 030	3 859 400	22 421 234
	No. of projects	145	98	37	15	15	310
	Mean cost[a]	24 000	72 000	121 000	171 000	257 000	69 000
All	Total cost	27 313 305	36 486 304	29 311 670	21 660 730	57 086 714	171 858 723
	No. of projects	1198	480	231	121	157	2187
	Mean cost[a]	23 000	76 000	127 000	179 000	364 000	79 000

a. Mean cost has been rounded to the nearest thousand dollars. Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.8 DISTRIBUTION OF RURAL EXPENDITURE BY MAGNITUDE AND JURISDICTION

($)

		Magnitude of project					
Jurisdiction		*≤50 000*	*50 000–100 000*	*100 000–150 000*	*150 000–200 000*	*>200 000*	*All projects*
ACT	Total cost	0	295 000	0	0	1 365 000	1 660 000
	No. of projects	0	4	0	0	3	7
	Mean cost[a]	0	74 000	0	0	455 000	237 000
NSW	Total cost	1 116 000	3 496 000	2 217 000	2 230 000	5 333 000	14 392 000
	No. of projects	33	41	17	12	18	121
	Mean cost[a]	34 000	85 000	130 000	186 000	296 000	119 000
NT	Total cost	191 000	955 000	965 000	550 000	1 700 000	4 361 000
	No. of projects	6	10	7	3	5	31
	Mean cost[a]	32 000	95 000	138 000	183 000	340 000	141 000
QLD	Total cost	2 642 100	2 473 400	1 991 000	2 084 000	2 404 000	11 594 500
	No. of projects	161	33	14	11	8	227
	Mean cost[a]	16 000	75 000	142 000	189 000	300 000	51 000
SA	Total cost	2 163 000	2 908 000	1 846 000	1 800 000	5 259 000	13976 000
	No. of projects	78	37	14	10	16	155
	Mean cost[a]	28 000	79 000	132 000	180 000	329 000	90 000
TAS	Total cost	748 811	480 888	908 432	0	1 126 400	3 264 531
	No. of projects	58	7	7	0	3	75
	Mean cost[a]	13 000	69 000	130 000	0	375 000	44 000
VIC	Total cost	1 722 381	1 287 892	1 290 555	542250	9 101 550	13 944 628
	No. of projects	84	19	10	3	23	139
	Mean cost[a]	21 000	68 000	129 000	181 000	396 000	100 000
WA	Total cost	62 900	66 000	226 200	0	957 600	1 312 500
	No. of projects	3	1	2	0	3	9
	Mean cost[a]	21 000	66 000	113 000	0	319 000	146 000
All	Total cost	8 646 192	11 962 180	9 444 187	7 206 250	27 246 550	64 505 359
	No. of projects	423	152	71	39	79	764
	Mean cost[a]	20 000	79 000	133 000	185 000	345 000	84 000

a. Mean cost has been rounded to the nearest thousand dollars. Figures may not add to the total due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

Jurisdictions with substantial proportions of total expenditure on rural treatments were Northern Territory (53 per cent), South Australia (41 per cent) and Queensland (37 per cent). The observed difference in the proportion of expenditure allocated to urban and rural treatments by the jurisdictions reflects differences in the geographical spread of their major road networks and the nature of their crash experience.

As previously noted, most jurisdictions spent the major proportion of their funds on urban treatments. Table 2.9 shows the distribution of expenditure on major urban treatments in all jurisdictions.

In terms of the proportion of total urban expenditure approved, the roundabout (UH7) was the major treatment adopted (except in the case of Queensland, South Australia and Western Australia), followed by treatments involving traffic signals (UH1 and UH2) and channelisation (UH3). In Queensland and South Australia, new traffic signals accounted for the largest share of urban expenditure.

Table 2.10 shows the expenditure on selected rural treatments by jurisdiction. No clear pattern of rural expenditure among jurisdictions is evident from the table. Most jurisdictions, except the ACT, implemented shoulder sealing (RH1) and selective roadside hazard modification (RH4). These two rural treatments together constituted 57 per cent of total rural expenditure.

Approved expenditure on road safety enhancements and innovative treatments (Schedule 1A and 1B) amounted to $30.1 million or 11 per cent of total Program expenditure. Table 2.11 shows the distribution of the expenditure on Schedule 1A and 1B treatments.

The pattern of the distribution of expenditure on various treatments by jurisdictions would be expected to reflect, to some extent, the relative effectiveness of these treatments based on past experience. The cost–benefit analysis of the effectiveness of the treatments will shed some light on whether the expenditure patterns for various treatments generally reflect their relative degrees of effectiveness.

TABLE 2.9 DISTRIBUTION OF URBAN EXPENDITURE ON SELECTED TREATMENTS BY JURISDICTION

(per cent of urban expenditure)

Jurisdiction	*UH1* *New traffic signals*	*UH2* *Mod. traffic signals*	*UH3* *Channel-isation*	*UH7* *Roundabouts*	*UH* *Other*	*UM*	*Total urban expenditure ($'000)*
ACT	13	25	22	28	6	6	3 880
NSW	15	9	15	21	18	22	50 986
NT	6	25	27	38	2	2	3 936
QLD	40	5	14	28	7	6	19 919
SA	25	24	17	6	25	3	19 324
TAS	15	5	12	37	8	22	8 627
VIC	19	17	6	24	22	12	43 766
WA	12	35	23	18	5	7	21 421
All jurisdictions	19	15	14	22	16	13	171 859

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.10 DISTRIBUTION OF RURAL EXPENDITURE ON SELECTED TREATMENTS BY JURISDICTION

(per cent of rural expenditure)

Jurisdiction	*RH1 Shoulder sealing*	*RH4 Roadside hazard mod.*	*RH Other*	*RM*	*Total rural expenditure ($'000)*
ACT	0	0	26	74	1 660
NSW	21	38	33	8	14 392
NT	56	24	5	15	4 361
QLD	39	23	14	25	11 595
SA	52	20	20	8	13 976
TAS	37	2	52	9	3 265
VIC	28	15	15	42	13 945
WA	9	1	6	85	1 313
All jurisdictions	35	22	21	22	64 505

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE 2.11 DISTRIBUTION OF EXPENDITURE ON SAFETY ENHANCEMENTS (SCHEDULE 1A) AND INNOVATIVE TREATMENTS (SCHEDULE 1B), BY JURISDICTION

	Schedule 1A ($'000)	*Schedule 1B ($'000)*
ACT	350	0
NSW	4 153	1 800
NT	1 092	2 640
QLD	5 249	2 455
SA	1 203	245
TAS	1 590	307
WA	2 186	1 918
VIC	30	4 840
Total	15 853	14 204

Source BTCE estimates based on data provided to FORS by states and territories.

CHAPTER 3 IDENTIFICATION OF BLACK SPOTS

In general, black spots may be described as deviant or aberrant sites because of their higher level of hazard relative to sites which are otherwise similar and at which crashes can be reduced by engineering improvements. Therefore, in identifying hazardous locations, it is implicitly assumed that the hazard mainly derives from the physical features of the road network. There is mounting evidence, both in Australia and overseas, that relatively low cost treatments are highly cost-efficient in reducing crashes at black spots.

Strictly, the term 'black spots' should be used to refer to intersections or precise locations in the road network which are particularly hazardous. Mid-block black spots are hazardous sections of road. The term 'black areas' is sometimes used to describe areas within which clusters of crashes occur. For convenience, the term 'black spot' is used in this study in a general context to refer to specific sites as well as to mid-block sections.

The distinction between intersections and sections of road between intersections (links) is important in the context of black spot identification. Crash causal factors at intersections and links are generally different, and consequently different types of treatments are appropriate in each case. The precise location of a crash is usually, but not always, clear. There may be some crashes close to intersections which may be classified either as intersection or non-intersection crashes. If the location is imprecise, it is important to investigate the factors that contributed to the crash to determine if the geometry of the intersection was a major causal factor. If this is found to be the case, the crash would warrant classification as an intersection crash. Road traffic authorities generally classify as intersection crashes those crashes that occur within a specified distance (commonly 10 metres) from an intersection.

The proper identification of black spots for the purpose of treatment is of considerable importance in the context of the efficient and effective use of limited road safety resources. If the most hazardous sites are identified and treated first, it becomes increasingly difficult to identify sites whose treatment will result in substantial social benefits.

There are three basic indicators which reflect the degree of hazardousness of a road location: the absolute number of crashes (in total or disaggregated by severity or type); the crash rate relative to an exposure measure such as traffic volume; and the degree of severity of crashes.

ISSUES IN BLACK SPOT IDENTIFICATION

Observed and expected crashes

The number of crashes or crash rate at a particular location is a random variable whose realised value in a particular case cannot be predicted with absolute accuracy. This makes the process of identifying truly hazardous locations subject to considerable uncertainty.

The benefits of black spot treatment could be overstated unless allowance is made for random fluctuations in crash numbers. Due to the regression-to-mean effect (appendix VI) an abnormally high number of crashes in one period is likely to be followed by a lower number closer to the mean number of crashes in the subsequent period, even without any treatment being applied. It is therefore important that the black spot identification process takes account of the underlying real or systemic crash incidence as well as random fluctuations.

Elvik (1988a) argues that the theory of black spot identification rests on the assumption that it is possible, by means of statistical techniques, to identify and assess the separate contributions of three sources of variation in crash numbers: general risk factors, local risk factors and random variation. The underlying concept is that general risk factors explain variation in the normal expected number of crashes within a population of sites, whereas local risk factors explain why a specific site has had a worse safety record than would be explained by the combined contributions of general risk factors and random variation. This means that a true black spot is a site where the expected number of crashes is sufficiently high that it cannot be ascribed merely to the combined effect of general risk factors and random variation.

To determine whether a site is a black spot from a statistical perspective it is necessary to compare the expected number of crashes at the site with the expected number of crashes at similar sites. The expected number of crashes is the true long-term crash rate (per unit time such as a year) when general risk factors and exposure remain constant. Merely comparing the observed number of crashes at similar sites would not take account of the regression-to-mean effect. In order to locate true black spots it is necessary to identify deviant or aberrant variation in the expected number of crashes rather than normal variation.

However, the expected number of crashes for a particular site is generally not known. Available information about a site includes the recorded number of crashes and factors that affect the expected number of crashes such as traffic volume and site characteristics. The expected number of crashes therefore needs to be estimated using available information.

Risk and exposure

The number of crashes at a site is a function of risk factors and exposure factors. Exposure is the number of opportunities that are available for crashes to occur. Exposure is usually measured in terms of units of traffic volume such as vehicle throughput or vehicle-kilometres travelled per unit period of time.

If risk remains constant at a site and exposure increases, the number of crashes is likely to increase. It follows that some sites can have a larger number of crashes purely because they have more traffic than otherwise similar sites. For this reason, in the process of identifying black spot sites it is important that the sites being investigated be grouped and compared with sites with similar traffic volumes, in addition to being comparable in other respects.

If the identification of black spots is based solely on total crash numbers, sites with high traffic flows are more likely to be chosen. But sites with high annual average crash totals are not necessarily those with the best scope for crash reduction. This is because there is a distinction between locations at which the high values of average annual crash totals have been generated by low risk / high exposure conditions and those by high risk / low exposure conditions (McGuigan 1982). McGuigan argues that there is greater potential for crash reduction at sites with high risk / low exposure conditions. This is because most remedial treatments do not change existing traffic volumes. Rather, crash reductions are generally achieved by improving site conditions. High risk sites are generally those with poor site conditions and such sites offer more scope for crash reduction than sites with low risk (those where site conditions range from average to good).

Time interval

The time interval used in the process of black spot identification should preferably be a multiple of a year. The use of multiples of a year will prevent possible distortions of crash trends by seasonal factors. A short time interval, such as one year, will enable early action to be taken at sites at which sudden increases in crash numbers or crash severity have occurred. However, due to random fluctuations in crash data, the reliability of the data increases with a longer time interval. A longer time interval allows the smoothing of random fluctuations, revealing the underlying trend. However, the use of a relatively long time interval may distort the analysis, because changes in underlying road and traffic conditions could cause changes in the pattern of crashes.

May (1964) used crash data collected over a 13-year period at 433 intersections to study the effect of time interval on the reliability with which black spots can be identified. He concludes that the optimal time interval should be three years and that there is no significant gain in reliability beyond a three-year period. Nicholson (1987) suggests that a period of five years be used for optimum statistical reliability.

The foregoing considerations suggest a dual approach to the identification of black spots with respect to time interval. The use of a relatively short period such as a year would help in identifying sudden changes in crashes, and a longer period of between three and five years would increase reliability.

Implications of errors in the identification process

The initial black spot identification process usually involves two stages. In the first stage, the crash history of all sites is reviewed to prepare a 'short list' of hazardous locations for further examination. The second stage involves a more detailed examination, usually with site inspection, to prescribe cost-efficient treatment. Hauer and Persaud (1984) liken the first stage of the process to a sieve which should catch the hazardous sites, while allowing the non-hazardous sites to pass through. Various 'sieves' or identification techniques are described below.

Hauer and Persaud propose that the quality of the sieve or 'sieve efficiency' should be measured by the number of sites selected for closer examination; the number of truly deviant sites among those selected for closer examination ('correct positives'); the number of sites that are not deviant but have been captured by the sieve and selected for closer inspection ('false positives'); and the number of truly deviant sites that are not identified as requiring attention ('false negatives').

Higle and Hecht (1989) discuss the implications of false positives and false negatives.[1] If the number of false negatives is low, it is an indication that the set of sites selected for closer examination contains most of the sites that are actually hazardous. If the number of false positives is high, the selected set of sites is likely to contain many sites that are not actually hazardous. The relative severity of these two types of errors must be considered in an evaluation of the effectiveness of identification techniques. A false negative error could result in a hazardous location not being identified and treated, with possibly serious consequences. False positive errors on the other hand, may or may not result in the needless treatment of locations that are not truly hazardous, depending on available resources and the judgment of road safety authorities. Therefore, false negatives have considerably more serious implications than false positives.

GENERAL METHODS FOR IDENTIFYING BLACK SPOTS

There are three broad categories of methods for identifying black spots: crash numbers; crash rates based on exposure; and qualitative methods.

Crash numbers

The use of crash numbers is the simplest and by far the most commonly adopted primary method of identifying black spots. Silcock and Smyth (1984) carried out a survey of highway authorities in the United Kingdom to determine the methods used to identify black spots. They found that 74 per cent of respondents used annual crash totals alone, without reference to any measure of exposure such as traffic flow. This is to be expected, given that crash totals for sites are usually readily available.

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1. The concepts of 'false negatives' and 'false positives' are akin to type I and type II errors respectively, in the testing of statistical hypotheses.

The use of a crash pin map is a basic method of identifying black spots and has been one of the earliest methods used in many countries. Each crash is represented by a pin on the map. The type of crash may be represented by the colour of the pin used (for example a red pin for a head-on crash, a green pin for a right-turn crash). The severity of crash consequences may be represented by the size of the pin head used. The use of two pin maps—one showing crashes in the current year and the other the crashes during the preceding year—are useful for comparison purposes. Photographing the maps before the pins are removed at the end of each year would provide a record of the patterns of clusters where crashes were concentrated.

The basic pin map procedure can be automated by computer using geographical information system (GIS) software. Specialist microcomputer packages have also been developed which can be used to analyse crash data and identify black spots. For example, the Transport Research Laboratory (TRL) in the United Kingdom has developed a Microcomputer Accident Analysis Package (MAAP) which is used in many countries.

In using crash numbers to identify black spots, several factors need to be considered. McGuigan (1982) points out that the concept of crash numbers is meaningless unless it is related to some independent variable, which is usually time. A crash number, therefore, is a disguised form of crash rate, with crash number as the dependent variable and time as the independent variable.

Given the random nature of crash occurrence, crash numbers observed over relatively short periods of time can be subject to substantial random variation. Ideally, an average annual crash number over a period of a few years should be used to assess the degree of hazardousness of a site.

A disadvantage of using crash numbers is that they do not take account of traffic exposure and the severity of crashes. However, totals based on numbers of crashes by degree of severity may be used. Fatal crashes are the most costly and attract a high degree of public attention. Nil injury or PDO crashes are the least costly and are subject to considerable under-reporting. Fatal crashes are relatively rare events and fatal crash statistics are therefore subject to a relatively high degree of instability.

One option for capturing the effects of crash outcomes is to combine the number and severity of crashes into a composite index. A composite index could incorporate the relative costs of different types of crashes but would not take account of exposure. A composite index would incorporate the relative costs of different types of crashes (by level of severity or movements prior to impact) and provide an estimate of the crash reduction benefits that would accrue from treatment.

There are advantages in using several indicators to identify black spots. The use of total crash numbers helps to limit the number of potentially hazardous sites for further investigation. The use of the total number of serious injury crashes would ensure that these costly crashes are investigated early, and the use of a composite index would provide an indication of the sites where treatment is likely to provide the best economic returns.

Crash rates based on exposure

Approaches to black spot identification based on crash totals or crash costs do not take account of exposure to the opportunities for crashes. Exposure can be taken into account by adjusting crash rates on the basis of some measure of traffic flow. Traffic flow measures that can be used are crashes per million vehicle-kilometres for a section of road or crashes per unit of vehicle throughput for an intersection (such as crashes per 100 000 vehicles per annum). The comparison of crash rates on sections of road and at intersections is therefore not straightforward.

An advantage in using crash rates standardised by traffic flow is that it allows comparisons to be made between sites with similar characteristics but with different degrees of exposure. However, in identifying black spots, the use of crash rates based on traffic flow may tend to favour the selection of sites with low traffic flows. This is because in calculating the crash rate, the traffic flow measure is in the denominator: a small number of crashes together with a very low traffic flow will result in a relatively high crash rate. A certain number of crashes will always occur, and remedial measures to reduce such crashes will have little or no effect.

The sole use of traffic flow based crash rates to identify black spots can therefore be misleading. Use of flow based crash rates to identify black spots can be made more reliable by using information on crash numbers in conjunction with crash rates. To be classified as black spots, sites with high crash rates could also be required to satisfy a criterion based on a certain minimum number of crashes. But the setting of a threshold number of crashes can be quite difficult and involves some subjectivity. If the threshold level is set too low, locations with limited crash reduction possibilities may be included, whereas if it is set too high, sites with considerable scope for reduction may be excluded.

A major constraint in using crash rates relative to traffic flow is the generally scant amount of data available on traffic flow. Gathering such data over the entire traffic network would be a very costly exercise. In the survey of highway authorities by Silcock and Smyth (1984) mentioned earlier, none of the 4 per cent of respondents who identified black spots on the basis of crash rates with respect to traffic flow used this method as the sole criterion for determining which sites should be investigated further.

Qualitative methods

On-site investigation of crashes immediately after their occurrence is a useful method for determining causation. If the main causes can be identified, remedial action usually becomes apparent. However, crashes are normally the result of a complex interaction of a number of causal factors, and the identification of subtle but important factors is not always straightforward. Also, remedial action once identified is not necessarily cost-efficient.

Hazardous sites may be identified in the process of road use during which an assessment is made of the likely causes of hazardous situations encountered by road users. The anticipation and avoidance of hazardous situations while driving may suggest means of averting them. This is a subjective or judgmental approach based on feelings, hunches, expectations and other personal factors. Reports by motorists, concerned citizens, lawyers and politicians as well as assessments by motoring organisations, the police, and other personnel who attend the scene of crashes, can be useful in identifying and investigating sites considered hazardous. Litigation trends and insurance company reports can also provide indicators of the hazardousness of sites.

Although such subjective means of hazardous site identification have some value, especially if early investigation of sites helps in forestalling the occurrence of crashes, they have their limitations. Because subjective identification involves human perception, it is possible that more glaring or obvious causal factors such as excessive speed are given a higher priority, while less visible but possibly more important factors such as the condition of the road surface, are not detected.

Some attempts have been made to identify black spots by using professional judges (safety experts). Taylor and Thompson (1976) describe a procedure used to derive a Hazardousness Index (HI). They define a HI as:

HI = Accident factors + Objective non-accident factors + Subjective non-accident factors

$$HI = Ax_1 + Bx_2 + \ldots\ldots + Fx_6 + Gx_7 + \ldots\ldots + Ix_9 + Jx_{10} \quad (1)$$

where A, B, etc. are weighting coefficients and x_1, x_2 etc. are scaled factor values.

Non-accident factors were derived from available literature and contacts with safety personnel. Objective non-accident factors are those that are quantifiable, while subjective non-accident factors require some sort of expert judgment. The purpose of the formula is to establish the relative hazardousness of black spots and thereby to provide a first step in determining treatment priorities.

With the assistance of safety personnel, the large number of accident and non-accident factors was reduced. Table 3.1 contains the final list of factors included in the Hazardousness Index formula.

A scale was then developed to convert raw data for each factor into a hazardousness index component. The establishment of a weight or coefficient for each factor was accomplished through workshop sessions, which involved the use of personal judgment, and visits to field sites with safety personnel. Accident factors were assigned a combined weight of 51.3 while objective and subjective non-accident factors were assigned weights of 25.3 and 23.4 respectively.

Thompson (1980) notes that the two subjective factors used (driver expectancy and adequacy of information system) may provide a relatively large contribution to the identification of crash potential. Differentiating between these two factors was difficult for safety experts during site visits. Safety experts assumed that drivers expect to see a certain type of information at all sites. As a result, the safety experts experienced a certain amount of difficulty in ascertaining whether or not the safety deficiency was a driver expectancy problem or an information system deficiency problem. Thompson observes that the results of the study on developing a hazardousness index seem to support the premise that a single subjective factor could be developed which incorporates both driver expectancy and information system deficiencies.

TABLE 3.1 FACTORS INCLUDED IN HAZARDOUSNESS INDEX

Factor	*Percentage weight*
Accident rate	14.5
Number of accidents	19.9
Accident severity	16.9
Accident factors	**51.3**
Traffic conflicts	7.3
Erratic manoeuvres	6.6
Sight distance	5.3
Volume/capacity ratio[a]	6.1
Objective non-accident factors	**25.3**
Driver expectancy[b]	13.2
Adequacy of information system[c]	10.2
Subjective non-accident factors	**23.4**

a. The volume/capacity ratio was selected over average daily traffic (ADT) because it incorporates the basic traffic volume data and normalises this data to take account of the number of lanes, traffic mix, traffic control devices, etc.

b. Driver expectancy relates to the driver's readiness to respond to situations, or the presentation of information, and depends mainly on the driver's experience.

c. Drivers obtain information from the roadway, roadway environment, other traffic, and system control devices. The total information system must help the driver to identify and avoid a hazard.

Source Taylor and Thompson (1976).

Although the concept of combining various quantitative and subjective factors into a composite index has some appeal and merit, it is data intensive and costly in terms of time and effort required.

STATISTICAL TECHNIQUES FOR IDENTIFYING BLACK SPOTS

Three broad categories of approaches to identifying black spots have been described in the previous section. Some specific techniques of black spot identification, and their strengths and weaknesses, are discussed below.

Confidence interval technique

A fairly fundamental technique of identifying black spots is based on the assumption that the observed crash numbers or rates are normally distributed. The method involves calculating the mean crash number or rate for all sites of a particular type in a defined region over a given period of time. A critical or threshold value is calculated by adding to the mean crash number or rate a multiple of the standard deviation of the crash numbers or rates for all similar sites in the region during the same period. The multiple of the standard deviation adopted depends on the desired level of statistical confidence.

A site in the region is deemed hazardous if the number of crashes or crash rate associated with it during the same period of time is greater than the critical value. Symbolically, a location *i* is considered hazardous if:

$$C_i > \mu + k\sigma \qquad (2)$$

where C_i is the crash number or rate at the location, μ is the mean crash number or rate of the population of similar locations, σ is the standard deviation of the population and *k* corresponds to the critical values of conventional statistical hypothesis testing. The value of *k* is obtained from the normal distribution function. The value of *k* for the 95 per cent confidence level is 1.645.

Higle and Hecht (1989) conducted a simulation study to evaluate four techniques of black spot identification. These were the confidence interval technique, statistical quality control technique, and two closely related Bayesian techniques. Higle and Hecht found that the confidence interval technique identified a smaller number of sites and consequently yielded a greater number of false negative identifications and larger magnitudes of false negative error than the other techniques. They also found that many of the false negative identifications associated with the confidence interval technique resulted from its apparent sensitivity to the sample mean and standard deviation of the observed crash rates. This sensitivity, which was not observed with the other techniques, led Higle and Hecht to cast doubt on the reliability of the confidence interval technique for identifying hazardous locations.

Statistical quality control technique

A statistical quality control technique, similar to that used in industry, is fairly simple and effective in identifying black spots. The technique, sometimes referred to as the 'rate-quality' technique, is discussed by Norden et al. (1956), Morin (1967), and Iskandar and Dunne (1992). The method is recommended in NAASRA (1988). The approach involves assuming that the number or rate of crashes at a site or per unit length of road follows a Poisson distribution. An upper control limit (UCL) is fixed at a desired level of statistical significance. Sites whose crash numbers or rates fall outside the upper control limit are regarded as black spots.

BOX 3.1 THE POISSON PROCESS AND DISTRIBUTION

A Poisson process is a mathematical model of a random series of events in space or time, and has the following properties:

- the number of events occurring in a particular time interval or specified region is independent of the number that occurs in another time interval or region (the process has no memory);
- the probability that a single event will occur during a very short time interval or very small region is proportional to the length of the time interval or size of the region; and
- the probability that more than one event will occur during a very short time interval or small region is negligible.

The probability distribution of the number of events occurring during a Poisson process is called the Poisson distribution and is given by:

$$p(x) = \frac{e^{-\lambda}\lambda^{x}}{x!} \quad x = 0,1,2....$$

where *p(x)* is the probability of an event occurring *x* times, λ is the mean of the distribution and *e* is the base of natural logarithms.

The Poisson distribution gives the probability of an event occurring randomly 0,1, 2.... times when the probability of occurrence, *p*, is small, but the number n, of occasions when it can occur, is large. The Poisson model is therefore also commonly known as the 'model of rare events'. Because it is often used to describe failures or errors, it is also known as the 'model of catastrophic events'. The Poisson distribution has the interesting property that its mean and variance both equal λ ($\lambda = np$). When *n* is large and *p* is small, the Poisson distribution approximates the binomial distribution.

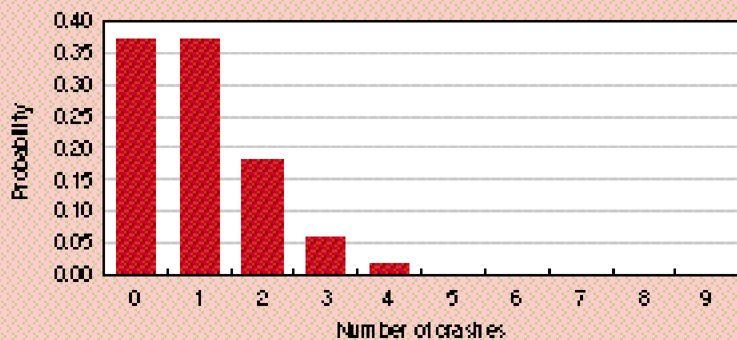
Several statistical models have been suggested in the literature to describe 'accidental' events including road crashes. However, road crashes have been most commonly modelled by the Poisson distribution, and it has been applied in various ways in the statistical analysis of crashes.

For example, given a mean crash rate per year for a group of similar drivers, the Poisson model can be used to calculate the proportion of drivers in the group who will have a certain number of crashes per year. Similarly, in the case of a site which has a certain mean number of crashes per year, the Poisson model can be used to generate the probability that the site will have a particular number (0, 1, 2 etc.) of crashes per year.

The shape of the Poisson distribution varies with the value of the mean λ, as illustrated in figures 3.1, 3.2 and 3.3. The three figures show Poisson distributions which describe the probability of crashes at sites with mean numbers of crashes of 1, 2 and 4 per year respectively. As figure 3.1 shows, when λ is 1 or less, the probability distribution is skewed to the right. However, as λ increases, the distribution becomes more bell-shaped as shown in figures 3.2 and 3.3.

The Poisson process is a mathematical concept and cannot therefore be expected to describe real events exactly. Whether particular events are in reasonable agreement with a Poisson distribution has to be empirically determined. Some researchers have questioned the assumed general validity of the Poisson distribution to describe crashes, as some locations have been found to have either significantly greater or lesser variance in their crash frequencies than would accord with the Poisson distribution.

FIGURE 3.1 POISSON DISTRIBUTION WITH MEAN EQUAL TO 1



Source: BTCE

BTCE

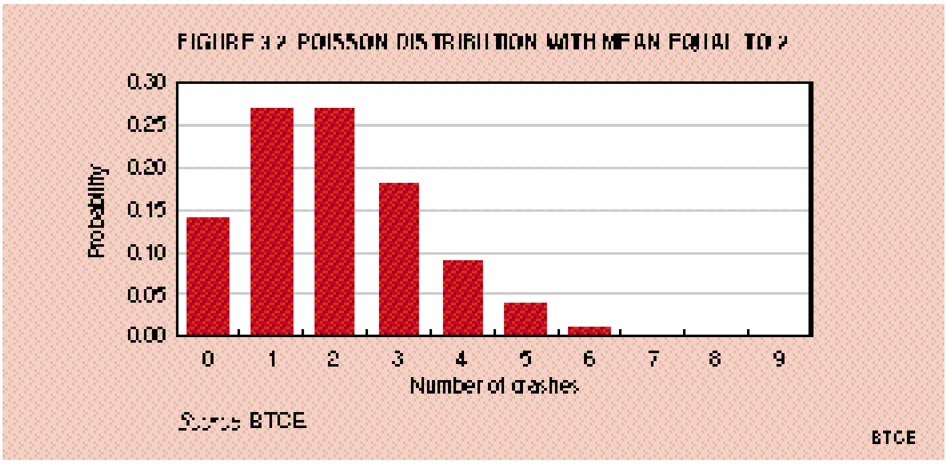


FIGURE 3.2 POISSON DISTRIBUTION WITH MEAN EQUAL TO 2

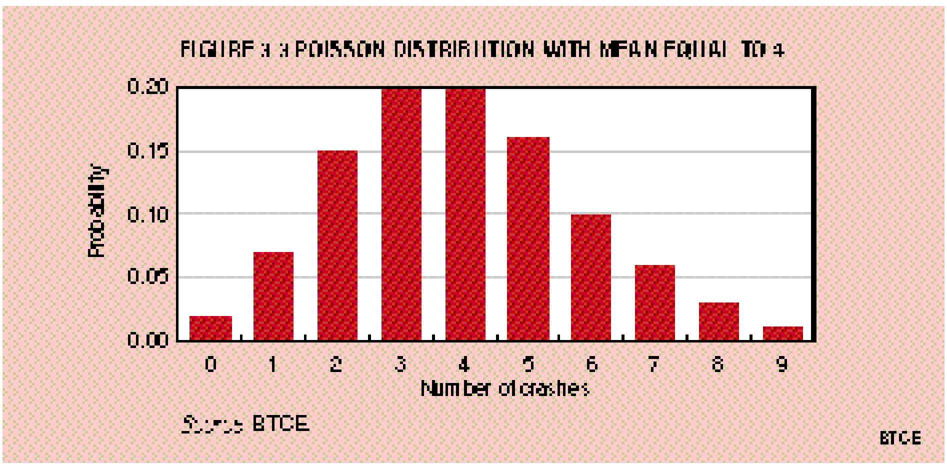


FIGURE 3.3 POISSON DISTRIBUTION WITH MEAN EQUAL TO 4

The derivation of control limits involves approximating the Poisson distribution by the normal distribution. An outline of the main steps in the derivation of the UCL is set out below (see Norden et al. 1956; Morin 1967).

The number of crashes occurring at a site during a given period of time is assumed to follow a Poisson distribution:

$$p(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}, \quad x = 0,1,2 \qquad (3)$$

where

$p(x)$ is the probability that x crashes will occur at the site during the given time period,

e is the base of natural logarithms, and

λ is the expected number of crashes at the site during the given time period.

In the case of a mid-block section, if a measure of exposure is introduced, the equation may be written as:

$$p(x) = \frac{e^{-rm}(rm)^x}{x!} \qquad (4)$$

where r is the expected crash rate in crashes per million vehicle-kilometres and

m is the number of vehicles in millions.

The expected number of crashes λ, or crash rate r, at a site or road section is never known and an estimate has to be used. The estimate could be the crash number or rate for the system of sites being studied, or in the case of a mid-block section, the crash rate for the entire road. Having estimated λ or r, an UCL is calculated. The UCL for the observed crash number (or rate) x, at the 0.05 level of significance is defined by:

Probability ($x \geq UCL$) = 0.05

Approximate estimates of the UCL are given by the equations:

$$UCL = \lambda + a\sqrt{\lambda} + \frac{1}{2} \text{ for crash numbers} \qquad (5a)$$

$$UCL = r + a\sqrt{\frac{r}{m}} + \frac{1}{2m} \text{ for crash rates} \qquad (5a)$$

where a is a constant.

Values of a corresponding to given values of the level of significance can be obtained from tables of the Poisson distribution. For example, at the 0.05 level of significance (95 per cent confidence interval), a=1.645. This means that there is a 5 per cent chance that the site may be identified as having a significantly high crash rate when the site is not actually hazardous.

In applying the Poisson method to mid-block sections, although a single value of r is computed for the entire road, specific sections of the road will have varying traffic volumes, resulting in different values of the UCL. A control chart can be constructed as a graph with the number of crashes on the vertical axis and road sections on the horizontal axis, and with the UCL plotted on the graph.

Iskandar and Dunne (1992) proposed a non-distributional model to determine the UCL for crash numbers in respect of mid-block sections. This technique is not as data intensive as the Poisson technique because it requires only the total number of crashes and the length of the road section. The method involves the selection of a decision criterion for the identification of a mid-block section, such as a certain number of crashes over a given distance in a given number of years. If a total of c crashes over a given period of time is recorded over a specified length of road divided into k equal sub-sections, the technique uses the theory of combinatorics to derive the following expression for $\pi_{c,k}$, the probability of at least one black sub-section, given c crashes over k sub-sections:

$$\pi_{c,k} = 1 - \frac{P_k(c, C_t)}{P_k(c)} \qquad (6)$$

where

C_t is the threshold number of crashes based on a predetermined decision rule,

$P_k(c, C_t)$ is number of partitions of the integer c into at most k parts in which no part is greater than C_t–1 and

$P_k(c)$ is the number of partitions of the integer c into at most k parts without restriction.

The $\pi_{c,k}$ can be calculated recursively using a computer program. Iskandar and Dunne (1992) applied both the Poisson model and non-distributional model to crash data on a section of the Hume Highway. They found that the Poisson model generally produced more sensitive control limits than the non-distributional model and suggest that this advantage of the Poisson model must be weighed against the greater simplicity of the non-distributional model.

Higle and Hecht (1989) found that the standard statistical quality control technique performed in a similar fashion to two Bayesian techniques.[2] They found that the statistical quality control technique yielded results that were virtually indistinguishable from those of the Bayesian techniques with the advantage that it was, unlike the Bayesian techniques, computationally straightforward. Higle and Hecht also found that the statistical quality control technique produced low numbers of false negative identifications and correspondingly low false negative errors. However, this came at the expense of an increase in the number of false positive identifications which may have been due to sensitivity to the volume of traffic at the sites. Higle and Hecht consider that the relatively large number of false positive errors produced by this method is disconcerting but may not be serious given that it is the false negative identifications that are serious and to be avoided.

A study by RACV Consulting Services (1985) reviewed procedures for identifying hazardous locations. The statistical quality control procedure based on the Poisson distribution was the main technique used in the study. The study adopted a retrospective procedure (which tested the performance of identification methods against actual economic results) for urban intersections, given that appropriate data were available in South Australia. The sample consisted of treated and untreated intersections in Adelaide during the period 1972 to 1979. A prospective procedure (which tested the performance of identification methods against expected economic results) was chosen to study urban road sections and rural locations because data for these locations in all Australian states and territories were less detailed, and countermeasure implementation less common, than for urban intersections.

The RACV study found that the best identification procedure for intersections is based on the measure ‘casualty accident rate significantly greater than the system average’ and for road sections on ‘casualty accident number related to distance significantly greater than the system average’. The statistical confidence band above the system average is determined by standard critical values based on the Poisson distribution.

2. The two Bayesian techniques were very similar.

Potential crash reduction

McGuigan (1981, 1982) examined crash data for junctions and road links in the Lothian region in the United Kingdom. He found that for certain types of junctions and road links statistically significant correlation existed between the number of crashes and an index related to traffic flow such as traffic throughput (the sum of entering traffic flows) or root product flow (square root of the cross flow product). The stratification of locations on an urban or rural basis, and by type of junction, provided better estimates of the number of crashes at these locations.

In such cases, as crashes increase with increasing traffic flow, the crash rate can be used to predict the total number of crashes. The method involves the use of regression equations to provide expected annual average crash totals. The difference between the observed (O) and expected (E) annual average crash total can be calculated. McGuigan called the difference (O-E) Potential Annual Accident Reduction (PAAR) (also more generally referred to as Potential Accident Reduction [PAR]) which could be used as a black spot ranking criterion in preference to crash rate and annual average crash total. A mathematical exposition of the concept is given below.

The expected number of crashes $\hat{Y}_i$ for location i is given by

$$\hat{Y}_i = X_i . R_{cat} \qquad (7)$$

where X_i is the selected traffic flow index and R_{cat} is the average crash rate for the appropriate location category and traffic flow index.

The actual number of crashes Y_i can be expressed as

$$Y_i = X_i . R_i + e_i \qquad (8)$$

where

R_i is the true crash rate at location i, and

e_i is the random error (natural variability in crashes).

The difference d_i, between actual and expected numbers of crashes is:

$$d_i = (Y_i - \hat{Y}_i) = X_i (R_i - R_{cat}) + e_i \qquad (9)$$

When d_i is large and positive it suggests that for the given volume of traffic, crashes at location *i* occur more frequently than at other locations of similar type. By definition, location *i* can be described as a black spot.

Consider the assumptions that the effect of the random error is small and that by undertaking appropriate remedial work it is possible to reduce the value of R_i to that of R_{cat}. Under these assumptions, d_i is a measure of the potential crash reduction and a list of black spots could be ranked in descending order of d_i.

The use of crash numbers and crash rates cannot be used to rank locations of different types because crash numbers and crash rates vary according to the type of location. It would therefore be misleading to rank black spots using crash totals or crash rates which are not categorised by location type. However, potential crash reduction values take account of locational characteristics and can be used to rank a range of location types.

The following are procedural steps to produce a ranked black spot listing (McGuigan 1981).

- Categorise locations according to a predetermined set of location types.
- Using appropriate traffic indices, determine expected crash totals for each location.
- Calculate the value of d_i for each location.
- From each category select those locations whose values of d_i exceed some preselected threshold value such as the upper 95 per cent confidence limit (in order to select those locations at which the high crash totals are unlikely to be due to chance).
- Rank the selected locations in descending order of d_i. The ranking does not necessarily imply that it is also a ranking on the basis of required remedial action because the costs of remedial measures are not taken into account.

To use the PAR method it is necessary to estimate expected crash frequencies for each site. These can be estimated using established regression relationships for particular types of sites if adequate data on traffic flow is available. Examples of such derived relationships are found in Hakkert and Mahalel (1973), United Kingdom, Department of Transport (1981) and Brude and Larsson (1987).

Maher and Mountain (1988) examined the issue of whether the extra data and effort required to calculate PAR values, compared with annual accident total (AAT), is justified in terms of the additional crash reduction benefits to be gained. Using a statistical model based on the gamma[3] and Poisson distributions, and artificially generated data sets, Maher and Mountain showed that although there are circumstances in which PAR can outperform AAT by as much as 50 per cent, the use of more typical values of parameters in the estimation of PAR seem to indicate that the advantage of using it may be very much less.

Maher and Mountain (1988) also found that the advantage of using PAR is heavily dependent on good estimation of the expected number of crashes ($\hat{Y}_i$) and that if the regression relationships which produce the $\hat{Y}_i$ are inaccurate, any advantages may disappear altogether. These findings suggest that the arguments in favour of using PAR in preference to crash totals to identify black spots are not compelling.

RACV Consulting Services (1985) found that, in terms of the actual economic return of the projects, the PAR method displayed relatively poor performance in identifying and ranking sites when it was tested against other methods on a sample of treated sites in Adelaide.

Crash index methods

All road crashes are not equal in terms of their human injury consequences. One important basis for differentiating among crashes is the degree of severity of injuries sustained. Black spots can be identified not merely on the basis of absolute numbers of crashes or crash rates, but also on the basis of the economic costs of the crashes to

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3. A gamma distribution with probability density function *f(x)* is given by:

$$f(x) = \frac{x^{\alpha-1}e^{-\lambda x}}{\lambda^{-\alpha}\Gamma(\alpha)}$$

where α and λ are parameters of the distribution, and Γ(α) is the gamma function given by:

$$\Gamma(\alpha) = \int_0^\infty x^{\alpha-1}e^{-x}dx$$ for real and positive values of α.

society. Crash severity indices can be used for this purpose. For example, the following severity index may be constructed:

$$SI = S_1 N_1 + S_2 N_2 + S_3 N_3 + \ldots\ldots S_n N_n \qquad (10)$$

where S_1, $S_2 \ldots S_n$ are severity factors based on the relative severity or costs of crashes of particular severity and N_1, $N_2, \ldots N_n$ are the numbers of crashes associated with each level of injury severity. A similar approach can be used for crash types. A set of severity factors can be constructed using the costs of fatal, hospital, medical and nil injury crashes. For example, using crash costs for 1993 (BTCE 1994), the following set of severity factors may be used: fatal crash, 150; hospital injury crash, 23; medical injury crash, 2.4; nil injury crash, 1.

Using this method, the average index for the entire road network can be compared with the index for a particular spot or section. Hazardous sites will have indices higher than the average index for the network.

In some countries equivalent accident numbers (EAN) values are used to subjectively weight crashes. For example, in South Korea, the EAN numbers used for initial ranking purposes are 12 for a fatal crash, 3 for an injury crash and 1 for a PDO crash (Ross Silcock Partnership 1991). Canada uses equivalent material damage (EMD) values which take account of the frequency and severity of crashes at a site (PIARC 1994). The EMD is defined as:

$$\text{EMD} = 9.5(\text{F+SI}) + 3.5(\text{MI}) + 1(\text{MDO}) \qquad (11)$$

where

F = fatal crash

SI = crash with serious injury

MI = crash with minor injury

MDO = crash with material damage only

The EMD for a particular site can be compared with the average value for similar sites. The EMD is identical to the equivalent property damage only (EPDO) index that has been used by several highway authorities in the United States (Deacon 1975).

The use of such weighting methods could assign to fatal crashes a much greater weight than hospital injury crashes. In such circumstances the weighting system would tend to disproportionately focus on sites with fatal crashes which are subject to a relatively high degree of instability. The greater influence of fatal crashes could be moderated by reducing the severity factor for fatal crashes or by combining fatal crashes with serious injury crashes. However, there is no clear cut means of determining an optimal set of weights and the process must rely on judgment.

Bayesian methods

Bayesian analysis has been proposed as a means of identifying black spots. In the Bayesian approach, the actual crash rate at a location is treated as a random variable and a combination of the regional crash patterns and crash history of the location is used to determine the probability that the location is hazardous. An advantage claimed for the approach is that it permits the pooling of data from similar sites to improve the estimation process.

Higle and Witkowski (1988) used a two-step Bayesian procedure to identify black spots. The first step involved a gross estimation of the probability distribution of the crash rates across the region. This regional distribution and the crash history at a particular site were used to obtain a refined estimate of the probability distribution associated with the crash rate at that particular site. The estimation procedure relies on the assumptions that the number of crashes at a location follows a Poisson distribution and that the probability distribution of the regional crash rate is a gamma distribution. Under these assumptions, the observed number of crashes will collectively follow a negative binomial distribution.[4] A major part of the estimation procedure involves determining the values of the parameters of the gamma distribution. Various methods are available for estimating the values of these parameters. The most commonly used are the method of moments and the method of maximum likelihood (see appendix VI).

4. The negative binomial distribution is also known as Pascal’s distribution. It is the probability distribution for the number of Bernoulli trials, x, needed to achieve n successes with each trial having probability p of success and q of failure. A Bernoulli trial is one of a sequence of independent events with fixed probability p of success and ($1-p$) of failure. The collective outcome of a sequence of Bernoulli trials is described by a binomial distribution. The negative binomial distribution is given by:

$$p(x) = \binom{x-1}{x-n} p^n q^{x-n}$$

for $x>n$ where $0<p<1$ and $q=1-p$.

In the second step of the analysis, the observed crash rate at each site is used in combination with the estimate of the regional probability distribution to obtain the site-specific probability density functions using Bayes Theorem. Under the assumptions of the analysis, the resulting probability distribution is a gamma distribution. The parameters associated with this distribution are obtained using the original gamma parameters and the observed crash data. With this information, and predetermined threshold levels, hazardous locations can be identified. The method is computationally intensive and requires the use of computer programs. Further development of the application of Bayesian techniques to black spot identification is required before practical use of the techniques is possible.

In the study referred to earlier by Higle and Hecht (1989), the performance of Bayesian techniques was found to be very similar to that of the statistical quality control technique. A major disadvantage of the Bayesian techniques is their computational complexity.

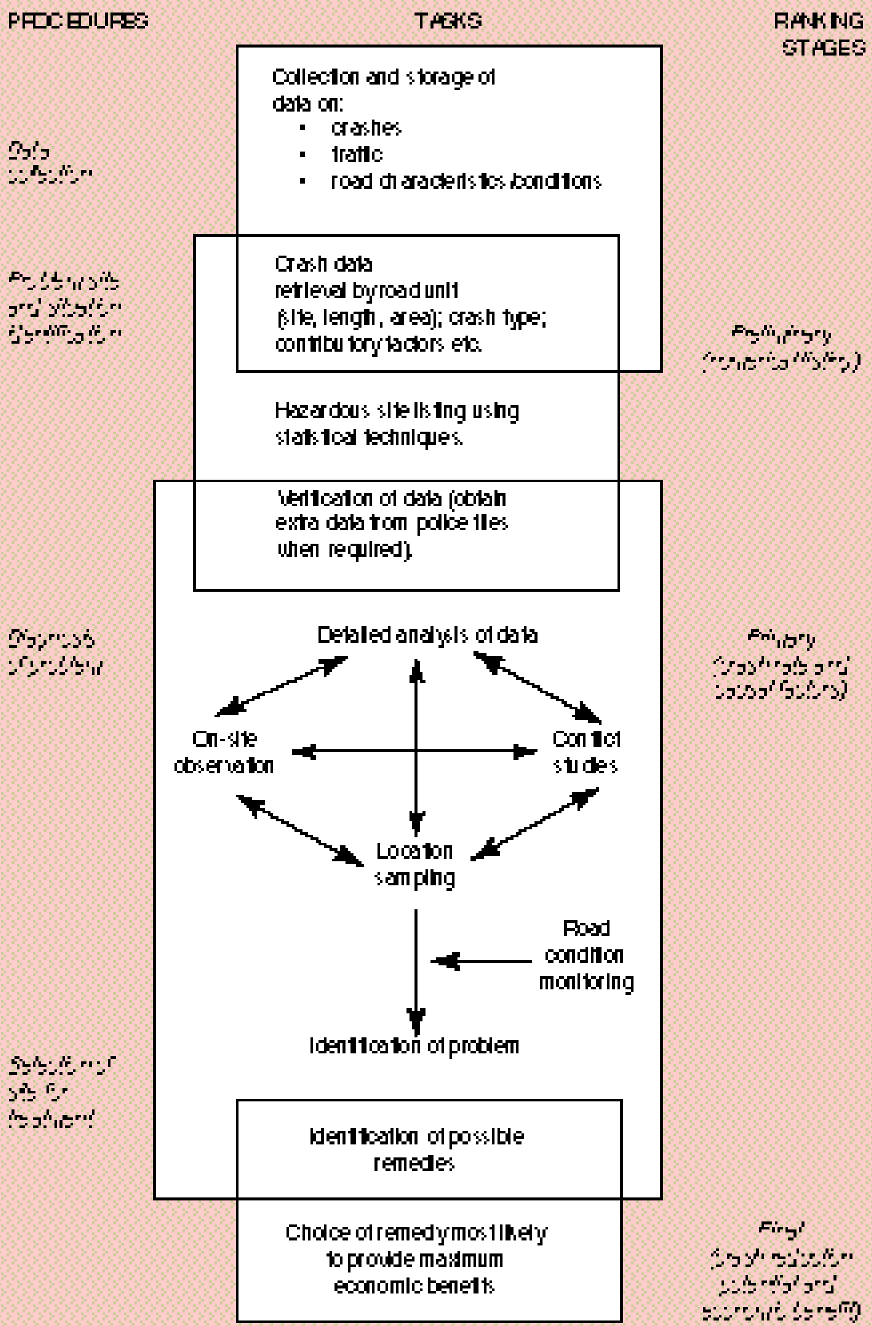
PROCEDURES FOR IDENTIFYING AND TREATING BLACK SPOTS

A comprehensive black spot program includes identifying hazardous locations, diagnosing the problems at these locations, identifying possible remedies and selecting and implementing the remedies most likely to provide maximum economic benefits. Figure 3.4 shows schematically the three key stages of identification, diagnosis and selection, together with the various techniques associated with each of these stages.

In the preliminary stage, the entire crash database is monitored to identify hazardous sites. Identified sites at which crash occurrence is higher than average, and which have a discernible pattern of crashes, are further investigated in the diagnostic stage. Several techniques can be used in the diagnostic stage, including on-site observations, location sampling, conflict studies, and road condition monitoring.

On-site observations include retrospective studies of road and traffic factors at sites where crashes have occurred, and 'on-the-spot' studies which examine details of the road, environment and vehicles, and characteristics of road users.

FIGURE 3.4 OVERVIEW OF PROCEDURES FOR IDENTIFICATION AND TREATMENT OF BLACK SPOTS



Source Adapted from The Institution of Highways and Transportation (1990).

BTCE

Location sampling involves the grouping of crash data for sites with similar characteristics to obtain sufficient data for meaningful assessments to be made of crash causal and contributory factors.

Conflict studies involve observations of vehicle movements at locations on the road network to assess the type and frequency of traffic conflicts or ‘near crashes’.

Road condition monitoring involves continual checking of the physical characteristics of the road network.

The final selection of sites for treatment takes account of the results of the preliminary and primary ranking stages. The final ranking process must take account of measures of exposure, specific site features which may have an undue influence, the severity of crashes, and the crash-reducing potential of appropriate remedial measures.

PROCEDURES ADOPTED BY THE JURISDICTIONS TO IDENTIFY BLACK SPOTS

In September 1992 the BTCE sent a questionnaire to all states and territories, in part requesting basic information on the procedures used in identifying black spots. Special reference was made to the identification of sites for treatment under the Black Spot Program. Requests for updated information were made in November 1994. The responses received are summarised below.

Australian Capital Territory

The procedures for identifying black spots are detailed in the document *ACT Road Safety Improvement Guidelines* published by the Traffic and Roads Section of the ACT Department of Urban Services (the latest edition was published in January 1995). The method of identifying sites for improvement is based on an analysis of the frequency of crashes of specific types.

In assessing the need for improvements, a ranking system is used which weights the severity of different types of crashes. Ratios of non-casualty to casualty crashes by crash type have been calculated.

The top 500 intersections and 200 mid-block locations identified on the basis of the ranking system are continually monitored over both seven-year and two-year periods to ensure that trends over time are identified.

Intersections and mid-block locations ranked in this way form the basis for projects which are considered for improvement. A review of the traffic conditions at the higher ranking locations is undertaken by the Traffic and Roads Section or on their behalf by a consultant. The review establishes existing traffic conditions, identifies deficiencies, and considers factors which may change the current traffic conditions in the future. Options to rectify deficiencies are identified and indicative costs estimated.

A technical and economic evaluation of the various options identified is then undertaken and compared with the base 'do nothing' case. The technical assessment considers how a particular option may improve traffic conditions in the short term and also in the medium term, taking into account any factors which may influence traffic growth.

The economic assessment of the option considers the 'whole of life' costs and benefits discounted to present values and compared with the base case 'do nothing' option. Economic outputs such as net present value, net present benefit and net present cost are used to assess the relative advantages of particular options. The costs include capital costs, recurrent costs, maintenance costs, and costs of crashes and delays. Benefits include reductions in crashes, delays, and vehicle operating and maintenance costs.

The crash costs used in the economic analysis have been derived from ACT data on crash types. The ratio of net present value to capital cost is calculated for each option and is used in determining ranking of projects. Discount periods of 5 to 25 years are adopted depending on the scale of the project. A period of 10 years is normally used for an intersection improvement project. A discount rate of 7 per cent is used, and sensitivity testing is carried out at 4 per cent and 10 per cent.

Based on the individual projects that have been identified and assessed, a rolling program is developed. Projects within the program are ranked in terms of the ratio of net present value to capital cost, net present value, and ratio of net present benefit to net present cost.

The number of projects included in the implementation program depends on the level of available funding. Projects require a minimum BCR of 2 to be included in the one-year program, although a project with a lower BCR can be included in the forward program which is reassessed on an annual basis.

New South Wales

Sydney region

Listings of intersection black spots are generated from computerised databases. In the case of specific mid-block crash types such as run-off-road, head-on, pedestrian etc., listings of black spots are manually generated. However, automated mid-block black spot site identification is to be introduced shortly using a GIS. Submissions from councils are also considered in identifying black spot sites.

The criteria for identifying and treating intersection black spots are three or more crashes a year and a BCR of 2. In the case of mid-blocks, the criteria are three or more crashes over a 100-metre road length during a five-year period and a BCR of 2.

During the course of the Black Spot Program a change was made in the approach to identifying black spots: the classification of crashes by type using road user movement (RUM) codes was adopted. Consequently, BCRs were also calculated using crash costs by type of crash classified by RUM codes, rather than average crash costs based on injury severity.

Northern region

Black spots were identified primarily on the basis of the frequency of crashes involving serious injury. Information sources used to identify black spots were black spot lists from the NSW Road Safety Bureau, advice from councils, and local knowledge.

There were no fixed critical parameters that a site had to satisfy to warrant investigation. The potential for an adequate BCR was generally used as the criterion. Access has recently been obtained to a GIS for northern region crash data. Northern region intends to develop procedures for the analysis of road network performance using both crash frequencies and critical crash rates for intersections and road sections.

Western region

A location must have on average a minimum of one crash per year to warrant further investigation. A quarterly report is down loaded from the crash database, extracting locations that have more than five crashes during the past five-and-a-quarter years. The cost to the community of each of these locations is then calculated by analysing the casualty statistics and applying economic crash cost estimates.

BCRs for potential treatments are then calculated. If two locations have the same BCR, the risk of future crashes is estimated using the Road Safety Audit process and the experience of local road safety officers.

Geocoding of crashes in the western region commenced in March 1995. This will result in crash location data becoming progressively more reliable over several years. A database is being developed to enable monitoring of performance of special projects. Information on locations treated with black spot funding will be recorded in this database. Documentation on the procedures for identifying, prioritising and monitoring black spots will be prepared in 1995.

Southern region

The published list of intersection black spots prepared annually by the NSW Road Safety Bureau ranks intersections by severity across the State, by region and by other categories. This list was used to identify black spots within the region and to compare intersections between zones, regions and across the State.

Analysis of road sections was carried out using the Roads and Traffic Authority's (RTA) PC CRASH computer program which interrogates a database of crashes over the past five years. The database is updated quarterly and provides a means of calculating crash rates and other crash statistics over road lengths.

The most recent method of black spot identification involves the preparation of crash maps using the RTA's GIS and the geocoded locations of crashes. The system allows crashes to be mapped and clusters of crashes at road locations to be identified. Crashes can be filtered before mapping so that, for example, all urban crashes involving pedestrians, crashes involving bicycles, and all fatal crashes can be mapped.

Some statistical techniques have been used in the past in an attempt to identify and separate seasonal variations in crash data, but these techniques are no longer used. Simple ranking and comparison with expected or average crash histories is the most common technique currently used. Decisions to treat black spot sites are based on rankings of sites and local knowledge.

Northern Territory

Black spots were identified using several procedural steps.

- The Northern Territory Police crash records were used to obtain a list of road locations where crashes had occurred.
- The data were assessed manually to establish those locations with a history of repeated crashes of particular types.
- Information relating to site location and geometry and traffic statistics, including vehicle types and traffic volume, were collected for each of the identified potential black spots.
- Data were collected for all recorded crashes including minor and property damage crashes along the identified sections of the road or at the identified sites.
- Road safety problems for each identified high risk site (potential black spot) were diagnosed from all available information in police crash records. In particular, data associated with each crash such as type of crash, time, vehicle type, injured persons' details, drivers' blood alcohol readings, light and weather conditions, contributing circumstances, and road user movement, were individually assessed and summarised.
- Local knowledge was sought from the relevant regional office.
- The most appropriate countermeasures applicable to specific recurrent road crash types were selected. This was usually done by recourse to the 'Schedule of Acceptable Treatments' in the Black Spot Program Notes on Administration (appendix I).
- The project cost of the selected treatment and the value of the expected safety improvement of the project were established.
- The projects were ranked using the above information.

Projects with the highest BCRs were given priority. The other identified projects were assessed on the basis of the BCR together with estimated expenditure, the recorded crash history, and effectiveness of selected treatment type. Crash reduction factors used were based on National Association of Australian State Road Authorities (NAASRA) documentation and additional local knowledge.

Queensland

The Notes on Administration of the Black Spot Program required that eligible projects should have a BCR of at least 2 and a recorded history of fatalities or serious injuries. Advice from FORS indicated that at least one injury crash per year for three years would be required for a project to be eligible for funding.

The initial selection of sites for the Black Spot Program was carried out at a local level (district, region or local government) using the above criteria. The selected projects were submitted to the (former) Road Safety Division within Queensland Transport for consideration. BCRs were re-calculated for all submitted projects on a consistent basis, and the projects were ranked on the basis of the BCRs. The highest ranked projects were generally selected for inclusion in the Program, although this approach was modified, if necessary, to ensure an equitable distribution of projects throughout the State.

Initially, crash costs were based on crash-severity. This was changed in the latter stages of the Program to costs based on crash-type. In calculating estimated benefits, crash reduction factors used were based on a number of studies, both interstate and overseas, including information contained in RACV Consulting Services (1985).

For state-controlled roads, the methods for the selection of projects changed during the term of the Program. Initially, district staff simply interrogated their crash databases (Phylak) to identify sites with eligible crash histories. Since 1992, when the Traffic Accident Remedial Program (TARP) underwent a major review, a more refined process has been adopted. A rate quality control method which uses critical crash rates was applied. The TARP process is similar to that outlined in RACV Consulting Services (1985), except that crash costs are used in place of the number of crashes (or any other equivalent).

For local government-controlled roads, most local governments did not have a crash database system on which to base project selection. Local knowledge was generally used for initial selection of sites. Where possible, manual searching of crash report forms (through Queensland Transport or Queensland Police sources) was carried out to confirm crash numbers and types at the selected locations. All local governments have since been provided with access to crash databases for the roads under their control.

South Australia

Intersection black spots were identified from three years of crash data published quarterly by the (then) Department of Road Transport. Additional information on hazardous sites was obtained in investigating complaints from external sources.

In the case of road lengths, crash statistics for three years were generally examined (up to six years in some cases). Input from regional staff was usually confined to the practicality of projects before final selection. Local government projects were identified using the method in RACV Consulting Services (1985). Crash reduction factors for various treatments were also derived from this publication. The councils provided all required information on project types and costs.

Selection of projects to be treated was based on crash experience and BCRs. Account was taken of the ability to undertake and complete the treatment work, which had a bearing on the mix of projects. It was also considered desirable to have a variety of treatments in the program.

A standard schedule of estimated savings for certain types of injury based on NAASRA documentation was used in the cost–benefit analysis (CBA).

Tasmania

The process of black spot identification was developed by a black spot coordinating committee which comprised representatives of the Department of Road Transport and representatives from the southern, north-west and northern councils.

Identification of black spots was generally carried out in accordance with the recommendations of RACV Consulting Services (1985). Black spots were ranked using BCRs. A standard schedule of casualty costs was used in the CBA ranging from $650 000 for a fatal injury to $9 000 for a property damage crash.

Victoria

Black spot sites were identified for investigation from mass crash data on the basis of crash numbers. Published guidelines were used to aid in this process (VIC ROADS 1992). The guidelines provide information and procedures for project ranking, evaluation of mass action projects, and calculation of net present worth of projects.

Investigation involved development of potential treatments and economic analysis of expected returns to crash reduction. All work was done by regional or local government personnel with submissions being centrally checked for consistency and randomly audited. Projects were nominated for funding on the basis of BCR rankings. The grid recording system used was based on Melways Street Directory grid system.

More recently, a facility has been developed to extract data from the crash database and represent it in the form of a map. This facility enables sites, road lengths and areas which have experienced crashes to be more easily identified. Using this method, crashes can be displayed by attributes such as crash type.

Western Australia

Intersection black spots were identified from the database of the Department of Main Roads, which produced a listing of the intersections in Western Australia with two or more casualty crashes during the most recent three calendar years. All intersections in the list were deemed to be black spots. The black spots were ranked in order of indicative crash costs. Supplementary information to assist in the process of identification was solicited from local authorities and the public.

In the case of road sections, letters were sent to all local government authorities in Western Australia and to all managers of regional offices of the Department of Main Roads, seeking their advice on road sections which had two or more casualty crashes in the most recent three calendar years. The road sections thus identified were then checked against the database of the Department of Main Roads and those confirmed to have met this criterion were deemed to be black spots.

Problematic crash types and vehicle movements were identified by officers of the Department of Main Roads from each site’s three-calendar-year crash history. Treatment was determined by recourse to a standard list of treatments used by the Department, and in conjunction with professional judgment of Departmental personnel and local government agreement. A notional minimum limit for a project was set at $5 000.

CHAPTER 4 EVALUATION METHODOLOGY AND ISSUES

Several different experimental designs are available to evaluate the effect of an intervention such as an engineering treatment implemented at a black spot site. These designs range from simple 'before and after' comparisons to more sophisticated techniques using time series, matched comparison groups, and random assignment of sites to treatment and comparison groups. The approach adopted in this study was largely influenced by the availability of appropriate data, and the time frame in which the study was required to be carried out. The constraints imposed on the selection of an evaluation design by the circumstances of the study and data availability are discussed further in chapter 5.

The methodology adopted in this study for the evaluation of the effectiveness of black spot treatments incorporates a 'before and after' approach within the general framework of cost–benefit analysis (CBA). The 'before and after' approach involves using data on crashes that occurred before and after a particular treatment to estimate the effect of the treatment. The two time periods are commonly referred to as the 'before' and 'after' periods. The rationale of the before and after study is explained in detail in appendix VI.

In its most basic form, a before and after approach applied in the evaluation of black spot treatments involves a straightforward comparison of the crash experience at sites before and after treatment. But this is a naive approach, because it does not take account of several extraneous factors that can mask the true effect of a treatment. Stronger experimental designs with various degrees of sophistication can provide more control over the influence of these extraneous or confounding factors and may be used if the study is appropriately planned and if required data can be obtained. In this study, a before and after approach using relatively short time series crash data was adopted. Although the range of factors that can affect the evaluation has been identified and described, available data did not permit quantitative estimates to be made of the effects of all these factors.

FACTORS AFFECTING THE EVALUATION

A before and after study seeks to determine the true effect of a particular intervention or treatment. In the case of a treated black spot site, the expected effect is a reduction in the number and/or severity of crashes at the site. However, the observed reduction may be due to the treatment alone, it may be due to any of a number of other factors unrelated to the treatment acting individually or in combination, or it may be due to any one or a combination of these other factors acting together with the treatment. This means that if the treatment has any effect at all, the effect may be masked by other factors. A key issue, therefore, is to be able to disaggregate the effects of the various confounding factors and to uncover the true effect of the treatment.

Factors besides the treatment that can affect the number and type of crashes at a treated black spot site are described below.

Site-specific factors

Specific events other than the treatment itself could account for at least a part of an observed change in the number and/or severity of crashes at a site: improvements in weather conditions; a decrease in the number of vehicles using the particular site caused by changes in traffic flow patterns; local media publicity promoting safety; and increased traffic law enforcement at or near the site by the police.

Due to the lack of site-specific before and after data on these various possible events, it was not possible to assess their effects. However, given the relatively short periods before and after treatment, and annual crash data used, it is likely that site-specific factors had negligible net effects. There were few indications of major changes in traffic flows, and the control area procedure (described later) used for estimating what would have happened in the absence of treatment would have accounted for most variations in the weather.

Maturation (trends over time)

The term 'maturation' originated from studies in the behavioural sciences involving individuals who changed over time for reasons such as ageing, fatigue and sophistication. In regard to crash studies, maturation refers to the process by which the crash data mature or change over time, as distinct from site-specific factors, which refer to particular events in time. The key maturation effect in regard to the evaluation of black spot treatments in Australia, and several other countries, is the general long-term downward trend in road crash fatalities and serious injuries, especially in terms of risk exposure such as distance travelled (crashes per 100 000 vehicle-kilometres).

Haight (1994) attributes the constantly falling fatality rate per vehicle-kilometre of travel in most countries to the gradual maturation of road transport as a system, and the correspondingly maturing behaviour of road users, particularly drivers. The general decline in crash rates may be attributed to a range of factors acting together, encompassing education and publicity campaigns, improvements in vehicle technology and safety features, increased seat belt wearing rates, deterrents such as fines and penalties, safety programs aimed at influencing road user behaviour, improved medical facilities, and improvements in the road network, including treatment work carried out at hazardous sites.

In the present study, an adjustment was made for the extent to which reductions in crashes could be attributed to these general community trends. The adjustment was carried out using urban and rural areas within each jurisdiction as control groups, and involved estimating the difference between the expected number of crashes at each site had there been no treatment (that is, based just on general community trends) and the observed number of crashes after the treatment. Further details of the procedure are provided in the section on 'Controlling confounding effects' in this chapter.

Regression-to-mean effect

If black spot sites are chosen for treatment solely on the basis of their high recent crash record, the chosen sites may have a high true mean crash rate together with some upward element of chance effects or random fluctuation. Such sites are likely to have fewer crashes in a subsequent period even if no treatment is carried out because the number of crashes will tend to gravitate towards the long-term mean value. Under these conditions the effect of the treatment is likely to be over-estimated. This is the regression-to-mean (RTM) effect for which an adjustment should ideally be made in order to determine the real or true effect of the treatment.

Statistical methods to adjust for regression-to-mean bias are generally very data intensive, and the adjustments are also subject to varying degrees of bias depending on the quality of the data available. For some sites the bias may be positive (under-estimation of the treatment effect) while for other sites it may be negative (over-estimation of the treatment effect). When a sample of projects is evaluated, as in the present study, it is possible that biases of opposing sign offset each other or produce only a small net overall effect. Statistical methods for correcting RTM bias generally require data for sites similar to those being evaluated. It was not possible, in the circumstances and time frame of this study, to obtain the required data. Adjustments for possible RTM bias at individual sites were therefore not made.

The methods used by the jurisdictions to identify their black spots and select sites for treatment (as described in chapter 3) indicate that sites were not chosen solely on the basis of crash history. Statistical information was generally tempered by local knowledge and judgment. In fact, in major metropolitan centres the ‘top’ black spots were often central business district (CBD) intersections which had a large number of crashes, most of which involved very low degrees of injury or only vehicle damage. However, these sites had low crash rates because of their high traffic volumes. Many of these sites were not selected for treatment under the Black Spot Program. Similarly, a number of sites with substantial crash histories were not selected for treatment because rectification was too costly. Also, in some cases the lead times for relocation of utilities and other planning matters meant that the projects could not be completed within the time frames required by the Program. If, as it appears, most sites were chosen for treatment on the basis of their high underlying level of risk, the effects of RTM bias are likely to be low.

Because of the limited time frame of the Black Spot Program, states and territories were sometimes subjected to time pressures in identifying black spots and in making submissions for funding. Given these pressures, it is possible that some treated sites were identified mainly on the basis of their high recent crash experience. This may suggest that, in the case of these sites, it was more likely that crashes would have declined, rather than increased, in the subsequent period (due to the RTM effect), and therefore that these sites may be associated with an over-estimation of the treatment effect. However, in the context of the CBA that was carried out on the treated sites, the crash costs used, being based on the human capital approach, were lower bound estimates and the benefits of crash reduction are therefore conservative. Any effects due to RTM bias are expected to be substantially overshadowed by the benefits of crash reduction that were actually due to the treatments.

A more detailed exposition of regression-to-mean, including its implications and the methods available to deal with it, is in appendix VI.

Under-reporting of crashes

Inferences about road safety should properly be drawn on the basis of the number of crashes that actually occur. In practice, inferences are drawn on the basis of an analysis of crashes that are reported. Difficulty in discerning actual changes in safety over time occurs when such changes are intertwined with changes in the propensity to report crashes.

A change in the manner in which crashes are recorded in a jurisdiction could cause an apparent change in the number and / or severity levels of crashes. Such a change in the recorded statistics could also occur if there was a change in the inclination of road users to report crashes, if the jurisdiction decided to change the manner in which crashes were classified for statistical purposes, or if there was a change in crash reporting requirements (such as the thresholds for property damage that usually apply to PDO crashes).

Incomplete crash reporting is a universal problem. Hauer and Hakkert (1988) reviewed 18 studies on crash reporting in several countries (not including Australia). The study revealed considerable variability in the degree of non-reporting. Their rough estimates are that fatalities may be known with an accuracy of about 5 per cent, whereas some 20 per cent of injuries requiring hospitalisation and about 50 per cent of all injuries are not found in official statistics. They estimate that reporting of PDO crashes is likely to be even lower than 50 per cent. In general, the less severe the injury classification of the crash, the less reliable is the number of reported crashes.

There is also evidence that the propensity to report crashes varies between urban and rural areas. For example, Roosmark and Fraki (1969) found, in a study of the extent of under-reporting of road crashes in Sweden, that there was a statistically significant difference between the estimated and official numbers of personal injury crashes in rural areas but not in urban areas.

BOX 4.1 ILLUSORY SAFETY BENEFITS: THE REGRESSION-TO-MEAN EFFECT

One of the most difficult issues in road safety evaluation studies is how to assess the real benefit of a safety intervention.

Among several rival explanations for an observed reduction in crashes at a treated site is what is known as the ‘regression-to-mean’ effect. This effect was first identified by Sir Francis Galton over a hundred years ago but has only comparatively recently gained currency in road safety. Galton noticed that, on average, tall parents had shorter children and that short parents had taller children. The children’s heights tended to ‘regress’ or revert toward the mean level of the population.

‘Regression-to-mean’ (also sometimes called the ‘regression effect’ or ‘bias-by-selection’) refers to the simple notion that when some condition is extreme or abnormal, it is likely to be less extreme (or closer to normal) in a subsequent period. For example, a scorching summer day is more likely to be followed by a cooler day than an even warmer day.

Regression may be a plausible explanation for at least a part of the results of an intervention in any extreme situation. Black spots are usually selected for treatment because they have experienced a large number of crashes in a recent period. Due to statistical randomness associated with the occurrence of crashes, a site with a high number of crashes in a given period is likely to have a lower number in the subsequent period, even without any treatment. Some part of the observed ‘benefits’ of a treatment could therefore be illusory.

Hauer (1980b) illustrates the regression-to-mean effect as follows:

> ...consider a group of 100 persons each throwing a fair die once. Select from the group those who have thrown a six. There might be some 16 such persons. (This is roughly analogous to the arranging of all road sections in the order of increasing number of accidents and selecting the top 16 per cent.) In an effort to cure the ‘proneness to throw sixes’, each of the selected persons is administered a glass of water and asked to throw the die again. One can expect that all but two or three persons have been cured. This ‘success’ of the water cure is attributable entirely to the process of selection for treatment.

How can the regression-to-mean effect be eliminated? An effective method is to randomly assign similar candidate sites to a treatment group and to a control group. Because of the random assignment, it is likely that any regression effect present would affect both groups to a similar degree. But for practical and ethical reasons, such controlled experiments are seldom possible.

Several statistical methods for adjusting for the regression-to-mean effect have been proposed in the literature. Most of these methods depend on various assumptions about crash data which may not be justifiable. For a detailed description of these methods and the issues involved see appendix VI.

Although a crash may actually be reported to the police, due to property damage limits below which reporting is not mandatory in individual jurisdictions, the crash may not appear in official statistical records which are the source of most crash data. If these damage limits are not revised in line with inflation, the increasing cost of vehicle repairs will mean that the number of reported crashes will increase, even if there is no overall increase in the number of crashes over time. Such a situation will distort crash statistics and provide misleading information for analysts and policy makers.

Crashes involving minor or nil injury are clearly not well represented in official statistics (box 4.2). If, following a treatment, serious injury crashes decline but PDO crashes increase, the under-reporting of PDO crashes would mean that the effectiveness of the treatment would be overstated. In crash studies, a common approach is to assume a certain ratio of PDO crashes to injury crashes. For example, in costing road crashes that occurred in 1988, BTCE (1992) assumed a ratio of 6.8 nil injury crashes to each reported casualty crash—a ratio estimated by Atkins (1981). The use of such ratios may be justified for estimating total crashes but, as Andreassen (1990) points out, general average ratios between reported and unreported crashes have no known validity at specific sites.

For purposes of black spot evaluation, if the probability of a crash being reported at a particular site remains constant over the period of the evaluation, the reliability of the analysis will not be significantly affected (Hauer and Hakkert 1988). The effect of incomplete reporting in these circumstances is merely to prolong the time required to collect a fixed amount of crash data. However, this assumption may be simplistic. Hauer and Hakkert argue that many of the factors that affect the probability of a reportable crash being reported change with time and location.[1] Certain treatments are likely to change the mix of the number and type (and therefore the severity) of crashes, thereby affecting the probability of crashes being reported.

Hauer and Hakkert found that the variance of the estimate of the safety effect of a treatment is inversely proportional to the square of the average proportion of crashes reported. This means that the accuracy of statements about the safety effect of a treatment would deteriorate rapidly as the proportion of crashes reported falls, and as the uncertainty

1. These factors include crash severity, structure of insurance premiums, age and sobriety of driver, age of victims, inclination to seek compensation, number of vehicles involved, proximity to police station, and workload of the police force.

BOX 4.2 UNDER-REPORTING OF CRASHES: AUSTRALIAN EVIDENCE

Available Australian evidence suggests considerable under-reporting of crashes. Searles (1977, 1980) examined a sample of insurance claims where at least one of the parties was insured by the National Roads and Motorists' Association (NRMA) in Sydney. Searles found that some 75 per cent of the crashes in the sample did not appear in the official statistics. Of the crashes that did appear in the official statistics, 94 per cent were recorded as nil injury crashes.

A study of under-reporting of crashes in South Australia (White 1991) found that 85.6 per cent of those who were involved in a reportable road crash actually reported it to the police. The percentage of reported crashes was slightly higher for the Adelaide Statistical Division (ASD) (86.6 per cent) than for the rest of the State (81.1 per cent). This difference was presumed to reflect an under-reporting of single vehicle crashes, which are more common in rural areas. In rural areas, the lower propensity to report crashes was ascribed mainly to the extra inconvenience involved in travelling to a police station. Crashes in which someone sustained injuries requiring medical treatment were slightly more likely to be reported (88.5 per cent) than minor crashes (84.3 per cent).

Giles (1990), analysed Western Australian road crash data for 1988 and reported that only 64 per cent of hospitalised crash victims had been included in police records. Rosman and Knuiman (1994), in their linkage study of hospital and police records in Western Australia, used data for the period October 1987 to December 1988 and also found that only 64 per cent of hospital in-patient casualties from 'reportable traffic accidents' had matching police entries, suggesting that the maximum level of under-reporting was 36 per cent. Although the overall linkage rate was 64 per cent, it varied from 29 per cent for motorcyclists in single vehicle crashes to 79 per cent for motor vehicle drivers.

Steadman and Bryan (1988) compared the number of persons injured in road crashes in Victoria in 1985, as reported by the Victorian ABS Office (based on police records), with the number of persons claiming health care costs from the Motor Accidents Board (MAB) of Victoria (which at that time handled all claims for health-related road crash costs involving Victorian registered vehicles). They found that about 42 per cent of injured persons had not reported their crashes to the police.

The Roy Morgan Research Centre (1994) carried out a survey of households in Victoria to estimate the extent of under-reporting of road crashes. They used a Computer Assisted Telephone Interview (CATI) survey which produced details from 16 843 people. The study found that the number of people recorded on the police crash database was only 78 per cent of the total number of such crash involvements estimated by the survey. Thus the police reporting rate for all injury crash involvements in Victoria was estimated to be 78 per cent of the true level. The reporting rate was found to be lowest for young people (under 18 years, reporting rate 58 per cent), females (reporting rate 62 per cent) and less severe crashes (reporting rate 73.4 per cent). Within the types of road users involved, under-reporting was greatest for cyclists in Melbourne (reporting rate 35.5 per cent) and drivers in the rest of Victoria (reporting rate 65 per cent).

In regard to PDO crashes, the Roy Morgan study estimated that the number of these crash involvements per year per 1000 residents was 59. People living in Melbourne reported 9.7 times the number of PDO road crash involvements as injury crash involvements (compared with 6.8 times as many for people living in the rest of Victoria and 8.8 times as many for all Victorians). Almost one-third of the PDO crashes resulted in damage estimated at less than $500. However, this proportion was higher for bicycle damage where 46.5 per cent of bicycles required less than $500 of repair work.

FORS (1993) compared police and hospital data for persons hospitalised as a result of road crashes in 1990. They found that the Australia-wide total of road crash admissions based on hospital admission records was about 60 per cent higher than total police records of persons hospitalised. A proportion of the difference was attributed to instances of multiple admission of an individual from a given crash and some imprecision in hospital data. Nevertheless, FORS concluded that the number of people seriously injured in road crashes Australia-wide in 1990 was likely to have been 25 to 50 per cent higher than suggested by police records. The lower numbers in police data appeared to result primarily from under-reporting of crashes. FORS found some indication that those least likely to appear in police data suffered relatively low severity injuries.

A study by KPMG Peat Marwick (1993) using hospital and police data for 1990–91, found that minor injuries were under-reported in police statistics in Australia to the extent of at least 50 per cent or more.

about the prevailing level of crash reporting increases. Hauer and Hakkert conclude that credible statements about road safety can only be made if the proportion of crashes reported to the police is high, stable over time and location, and accurately known.

Problems encountered with changes in crash reporting over time in some jurisdictions are described in chapter 5. The general approach adopted in the present study was to use all available reported crash data in the analysis. No adjustments were made for unreported crashes at sample sites as these would have been arbitrary. In the absence of site-specific information, it is thus possible that projects which showed, on the basis of reported crash data, positive net benefits of a certain magnitude, could have shown greater or lesser benefits if complete crash data had been available.

Publicity effects

A decline in crashes following treatment at a site could be related to several types of publicity effects. These include the high level of community publicity associated with the number of fatal or serious injury crashes at the site, the signs displayed at the site indicating that it is being treated under the Federal Government's Black Spot Program (appendix V), general publicity associated with the Black Spot Program, or a combination of these. These publicity effects could lead to a (perhaps temporary) increase in driver caution and a consequent reduction in crashes that has little to do with the effectiveness of the treatment itself. The cognitive nature of this factor makes it very difficult to identify or measure.

Instability

Crash data are susceptible to chance or random fluctuations when recorded over a period of time. In general, the smaller the sample size, the greater this statistical instability. A major part of the instability in crash data may be due to numerous site-specific events which individually cause small amounts of variation and which collectively represent the crash history of the site.

After all confounding effects are removed from the data, appropriate statistical tests can be used to determine with a specified level of confidence whether the observed change in crashes following the treatment can be attributed to the treatment or is due to chance.

In this study the methodology proposed by Tanner (1958) has been used to test whether changes in crashes after treatment were statistically significant (appendix VIII).

Accident migration

The term 'accident migration' when used in the road safety literature generally refers to migration of crashes in a spatial context: crashes at a black spot site decline after it has been treated, but there is subsequently an apparent increase in crashes in the vicinity of the site. The issue of accident migration is controversial and unsettled.

If accident migration actually occurs, one of the possible reasons to explain it involves the concept of risk compensation. Risk compensation involves adaptive behavioural responses to increased safety of vehicles and the road environment, resulting in drivers taking greater risks. For example, the safety benefits that are available to drivers on account of road improvements may instead be appropriated by them as performance benefits such as greater speed. If this effect is conclusively identified, it would suggest that there is an externality imposed on other road users which should be taken into account in the CBA of the road improvement. However, estimating the magnitude of this effect will depend on the ability to measure behavioural responses and their effects. The concepts of accident migration, risk compensation, and related issues are amplified in appendix VII.

A proper assessment of accident migration would have required sites in the neighbourhood of each treated black spot to be included in the area to be studied and would therefore have required extensive amounts of data. Such an analysis was beyond the scope of the present study.

CONTROLLING CONFOUNDING EFFECTS

A key issue in before and after studies involving black spot sites is estimating how many crashes would have occurred at the sites had they been left untreated. Several approaches could be adopted in this estimation process. A simple method is to assume that the number of crashes would have remained the same. Another approach is to use a time series to extrapolate the trend in crashes at the site. A common approach, however, is to use a control (or comparison) group of similar sites.

BOX 4.3 DO ROAD CRASHES 'MIGRATE'?

The term 'accident migration' which occurs in the road safety literature refers to the increase in crashes in the vicinity of a black spot site after it has been treated.

Crashes appear to 'migrate' from the treated site to nearby, untreated sites. The possible existence of crash migration has serious implications for road safety because the benefits of crash reductions at treated sites may be wholly or partially negated by increases in crashes elsewhere in the road network.

Crash migration has been subject to some empirical investigation. The results of most of these investigations indicate that there is some evidence of a migratory effect. However, there is uncertainty about whether the effect is genuine or whether it is merely a statistical artefact. Because of various methodological difficulties, the existence of crash migration has not yet been conclusively demonstrated and explained.

Even if it were established conclusively that crash migration does occur, a major difficulty would be to identify likely causes. Several alternative explanations have been offered, including the controversial theory of risk homeostasis which defies empirical validation.

For a detailed account of crash migration see appendix VII.

Control sites

In using control sites, it is assumed that factors other than the treatment will affect both the treated and control sites in a similar manner. The use of control sites therefore involves the implicit assumption that, other things being equal, the control sites will indicate what would have happened at the treated site had the treatment not been implemented.

The expected number of crashes at a site during the after period is equal to the number of crashes at the site in the before period multiplied by the control ratio. The control ratio is the ratio of the number of crashes at the control site or area in the after period to the number in the before period. The reduction in crashes is the expected number of crashes in the period after treatment minus the number actually observed.

In the circumstances of the present study, it would have been extremely difficult to identify suitable control sites corresponding to each sample site to be evaluated, and to obtain before and after crash data for these control sites. A practical alternative was to use the urban or rural areas in each jurisdiction as controls, depending on whether urban or rural sites were being analysed. It was assumed that the use of these relatively large areas as controls would take account of the effects of major changes in the road system, such as general crash reduction trends over time, discussed earlier. This approach was possible because of the availability of crash data for these areas. An advantage of the approach was that because the control areas were very much larger than the individual sites being studied, random variability in crash data for the control areas relative to individual sites was expected to be negligible.

As the control areas used were the urban and rural areas in each state and territory, many of the treated sites themselves formed part of the control areas. Because of this inclusion, the number of crashes in the after period in the relevant control areas was likely to be smaller than they otherwise would have been. This means that the control ratios (the ratio of crashes in the after period to those in the before period) would be reduced slightly. Consequently, the expected number of crashes in the after period would be correspondingly diminished, as would the estimated reduction in crashes after treatment. However, because of the small number of treated sites relative to the number of sites in the control group, the effect is minuscule.

An obvious difficulty with using large control groups is that they may not be very similar, in terms of various traffic and environmental characteristics, to the sites being studied. For this reason, they may not be sufficiently sensitive to changes specific to the sites being studied. On the other hand, small control groups may be subject to considerable random variation in crashes. Moreover, what constitutes ‘similarity’ is not always clear cut.

Hauer et al. (1991) used 26 yearly counts of reported injury crashes in the Canadian provinces to examine which of several simple methods of predicting the expected number of crashes performed best. Hauer et al. found that ‘similarity’ (in terms of geographical, demographical, and other characteristics) between the treated site and control sites is only one consideration. The size of the group of control sites, as measured by the number of crashes, was also found to be important. Similarity became relevant only when several hundred crashes occurred in the control group. Hauer et al. also found that the use of more data and more sophisticated methods did not always improve prediction.

For example, they found that the count of fatal crashes in the control group had to be about 1 000 in order for the control group to be a better predictor than the simple method of using the past year's crash count for prediction.

To estimate the expected number of crashes in the after period had there been no treatment, the appropriate control ratio was applied to the number of crashes in the before period. The control ratios were calculated for both the crash-severity and crash-type methods and separate calculations were carried out for each method (see below). Crash data for the treated sites were adjusted for the unequal before and after periods by averaging.

The observed crash numbers in the after period were then subtracted from the calculated 'expected' numbers to obtain the estimated change due to the treatment. The difference between the observed and expected crash numbers was multiplied by the relevant crash costs (by both severity and type) to obtain the crash cost savings attributable to the treatments.

ESTIMATING CRASH REDUCTION BENEFITS

Road trauma is a major public health issue, exacting a heavy toll in terms of human life, pain and suffering, and the resources of society. The BTCE (1994) estimated that the social cost of road crashes in 1993 was at least $6.1 billion. A study by FORS (1991) found that although road crashes were responsible for just over 2 per cent of total deaths each year, they accounted for almost 7 per cent of years of statistical life lost through all causes of death—more than years lost through cerebrovascular disease or lung cancer. The study also found that when only years of life lost before the age of 65 or during the working age span were considered, road crashes accounted for more years lost than years lost through all forms of heart disease, and about three-quarters of years lost through all types of cancer.

The primary aim of black spot treatment work is to reduce the number and severity of crashes, thereby releasing resources for alternative community use, such as raising national productivity, and reducing pressure on medical and health services.

Approaches to estimating human costs of crashes

In evaluating the effectiveness of black spot treatments, crash reduction benefits are generally estimated in terms of crash costs avoided. There are two methods currently in use in Australia to assess road crash costs: crash-severity and crash-type. The conceptual basis for estimating human costs in both methods is the human capital approach (also known as the accounting or ex-post approach). The human capital approach measures the lost output or productivity of individual crash victims due to premature death or disability. This is generally done by discounting to a present value the crash victim's potential future output as measured by the anticipated stream of earnings. Other costs are added to the estimates of lost productivity to obtain estimates of the overall social cost of crashes. The other costs include monetary estimates of pain, grief and suffering, the value of non-market output such as the services of those involved in household and community duties, and resource costs such as vehicle damage, insurance administration and medical, hospital, police and ambulance costs.

The human capital approach produces lower bound estimates of the overall cost of road crashes because it is difficult to capture within the human capital framework the full range of costs that society incurs on account of crashes. It is especially difficult to assign monetary values to intangibles such as grief, pain, suffering and stress. Within the human capital framework, if these are valued at all, it has to be done on a somewhat arbitrary basis.

The other approach of significance in estimating road crash costs is based on society's willingness to pay for reductions in risk to life and limb. The willingness to pay approach is widely regarded as having greater theoretical validity than the human capital approach in economic appraisals involving human life. However, willingness to pay is not as straightforward to apply as the human capital approach and involves more complicated methodological issues. Essentially, the approach seeks to measure individual incremental rates of substitution of wealth for changes in risk of death or injury. The approach is better suited to valuing intangible effects of crashes because individuals are expected to take account of the full range of effects of crashes on their welfare in determining what they are willing to pay to reduce the risks involved.

The willingness to pay approach (particularly studies using contingent valuation methods) generally produces estimates of the human costs of crashes which are considerably higher than those calculated using the human capital approach. For example, New Zealand adopted a

BOX 4.4 IS IT 'BETTER TO BE DEAD THAN STUCK IN TRAFFIC'?

Efficiency in resource allocation requires that scarce resources be channelled to projects that yield the greatest benefits. The benefits of road improvements are generally of three main types: vehicle operating cost savings, travel time savings and reductions in crash costs.

Improvements in road capacity reduce congestion resulting in better fuel utilisation and greater travel time savings. Reduced pavement roughness results in lower vehicle maintenance costs. Road improvements can reduce both the frequency and severity of crashes, thereby reducing the overall cost of crashes to society. In addition to the three main types of benefits, road improvements can also stimulate productivity improvements and in certain circumstances provide environmental benefits as well.

However, road improvements sometimes involve a trade-off between safety and mobility. Measures which improve mobility by saving travel time can reduce safety and vice versa. For example, an expansion of road capacity to reduce congestion can inadvertently increase the number of fatalities by increasing the speed of travel. It is therefore important that both safety and mobility effects be explicitly evaluated if resources are to be efficiently and equitably allocated in transport investment.

In evaluating benefits of road improvements, CBA is generally used. The 'value of life' and the value of time are expressed in money to enable them to be conveniently analysed within the framework of CBA. The values of statistical life and time used in cost–benefit studies involving road improvements are key determinants of the results of such studies. The results are generally used to guide public policy on road infrastructure priorities. However, the most economically efficient outcome suggested by the results of a CBA, using particular valuations or assumptions, may not necessarily be a safer outcome.

The valuation of both time and life involves difficult theoretical and empirical issues. In Australia, life has been traditionally valued in terms of the human capital or output approach which actually measures the value of livelihood. One of the major components of crash costs in this approach is the discounted present value of an individual's future earnings lost due to injury or premature death.

Another conceptually different approach to valuing life maintains that individuals value life because of a desire to avoid death and injury rather than just to maintain future earnings. According to this approach, the value of life should be measured in terms of individual preferences for reductions in physical risk aggregated over society. A commonly adopted method of determining the strength of these preferences involves measuring what individuals are prepared to pay for reductions in the risk of death or injury. The approach is therefore generally known as 'willingness to pay'. Empirically determined values of life based on willingness to pay are typically several multiples of values based on the human capital approach.

Empirical approaches to valuing time are of two main types: stated preference studies which use interview or questionnaire methods; and revealed preference studies which evaluate choices people make involving trade-offs in travel time. The value of travel time can vary in different circumstances such as when travelling for the purpose of work or leisure and also depends on factors such as a person's income.

If the value of life and the value of time used in CBA are not in the proper relationship with each other, curious inconsistencies can result, as the following example (adapted from T. Miller, pers. comm.) illustrates. On average, a person who dies in a road crash loses 41.8 years of life (FORS 1991). Suppose that an equivalent period is spent waiting in traffic and assume that this time is valued at the average wage rate of $15.24 per hour (derived from ABS 1993). On this basis, the value of the expected lifetime lost amounts to $5.6 million. If future years of life are discounted at a rate of 8 per cent, the value per life lost reduces to $1.7 million. The value of life adopted should be higher than this threshold, as the value of a lifetime lost would be expected to be greater than the value of equivalent time lost in traffic. If this is not the case, it would imply that the situation is such that, as Hauer (1994) muses, 'it is better to be dead than stuck in traffic.'

Changes in the values of either statistical life or travel time can affect the rankings of potential projects assessed using CBA. The use of values of life based on the human capital approach in CBA can result in safety being accorded a lower priority relative to travel time savings and vehicle operating costs. On the other hand, the use of higher values of life based on willingness to pay could shift resources from certain road improvements which would mainly facilitate mobility to those that would primarily improve safety. Such a change would be expected to have relatively greater implications for urban and rural roads than for major highways for which mobility benefits tend to predominate. Several studies, including the present one, have shown that many urban black spot treatments have high BCRs, and such treatments will become increasingly attractive when crash cost savings are more highly valued.

value per life saved of $2 million in 1991 based on a willingness to pay study, whereas the previous value based on human capital was $235 000 (Miller and Guria 1991). For a more detailed assessment of the two approaches, see BTCE (1992) and Motha (1990). Because both the crash-severity and crash-type costs used in this study are based on the human capital approach, the benefits of crash reduction should be regarded as lower bound values and would have been substantially larger if willingness to pay values had been used.

It is expected that the variability in crash cost estimates (which are used to value the benefits of crash reduction consequent to treatment) is far greater than most other sources of uncertainty in the evaluation of the effectiveness of treatments.

Crash-severity method of costing crashes

The crash cost estimates based on the crash-severity method used in this study are those provided in BTCE (1992). The crash-severity method adopts the crash, classified by the highest degree of severity of the victims involved, as the costing unit. In the BTCE study, four categories of crashes, based on the degree of injury severity sustained by those involved, were adopted: fatal injury, hospitalisation, medical treatment and nil injury. For example, a fatal crash is one in which at least one person involved in the crash dies. Other persons involved in the crash may or may not be injured, and those that are injured may sustain serious injuries requiring hospitalisation, or minor injuries requiring medical treatment or first aid.

The injury severity classification therefore does not provide any information about the distribution of injuries of persons involved in a crash other than the person sustaining the highest degree of injury. The estimated crash costs using the severity method are mean costs for each of the four severity classes. Unlike the case of the crash-type cost estimates (see below), costs based on crash-severity incorporate estimates for unreported PDO crashes.

The costs in 1992 dollars of four classes of crashes based on degree of severity, derived by adjusting 1988 costs in BTCE (1992), are as follows.

Fatal injury crash	$780 416
Hospital treatment crash	$111 419
Medical treatment crash	$11 707
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 costs of crashes involving fatalities or hospitalisation. Crashes in general are random, infrequent events and fatal crashes are even less common. In an analysis of a black spot treatment, the occurrence of just a single fatal crash either just before or after the implementation of the treatment can radically skew the results of the analysis. This possibility increases the instability of estimates derived using costs based on crash-severity. In the present study, the effect of fatal crashes has been moderated by using a weighted combination of fatal and hospitalisation crash costs.

Crash-type method of costing crashes

In this context ‘type’ refers to vehicle movements just before impact and is generally based on the recording of crashes in collision diagrams and subsequent coding. The general approach to costing by crash-type adopted in this study is based on the work of the Australian Road Research Board (ARRB).[2]

Different types of crashes have characteristic outcomes in terms of the number and injury severity of the casualties involved as well as the number of vehicles involved and the extent of damage to them. Some crash types such as head-on crashes would be expected to produce more severe injuries and vehicle damage than others such as rear-end crashes. Andreassen (1986) noted that the number and severity of casualties associated with particular crash types was fairly consistent over the period of time he examined. On the basis of historical data, it was therefore possible to predict the ‘expected’ casualty outcomes of a crash of a particular type. This enabled ‘standardised’ injury profiles and costs to be calculated for each crash type. In the crash-type method, standardised costs per person and per incident are aggregated to produce a standardised cost for each type of crash.

Black spot treatments can affect the overall distribution of crashes in terms of both incidence and severity. For example, following the installation of right-turn phases at an intersection, right-turn crashes may decline but side-swipe and rear-end crashes may increase. In such cases it is necessary to determine the net change in crash costs.

2. Detailed exposition of the crash-type methodology and estimation of crash costs is found in the following Australian Road Research Board publications authored by D. Andreassen: ARRB (1991); ARRB (1992a,b,c and d).

Compared with costs based on crash severity, costs specific to each crash type would be expected to provide relatively more precise estimates of the net change in crash costs following the implementation of a black spot treatment.

Further, the method also provides estimates of the average number of people with different levels of injury from 'fatal' through to 'not injured'. These estimates are useful in assessing the impacts of certain safety measures such as seat belts which are expected to change the distribution of casualty outcomes of crashes without necessarily changing the overall number of crashes.

A costing method based on crash types is therefore useful in understanding both the incidence and severity effects of various treatments and enables the costs of the crash types affected by the treatment to be used in the CBA. Because it is based on more disaggregated data and incorporates information about all similar crashes occurring in the community, the crash-type method is less vulnerable to the effects of random changes in fatalities and serious injuries at a site than the crash-severity method.

Andreassen (1992) obtained very much greater NPVs and BCRs for black spot treatments with the use of crash-type costs than with crash-severity costs. With some exceptions, this experience was corroborated in the BTCE's pilot study of the Black Spot Program (BTCE 1993). The present study has generated results which are somewhat different (chapter 8).

Calculation of crash-type costs

Andreassen (1986) examined several years' aggregate crash data from the mid-1980s and found that the injury profiles for different types of crashes in a particular jurisdiction tended to remain fairly stable. In these circumstances, the strong law of large numbers[3] and the central

3. This law states that if a sequence of independent random variables has variance σ_n such that

$$\sum_n \frac{\sigma_n{}^2}{n^2}$$

is finite, then the sequence of averages of the given sequence converges almost everywhere.

limit theorem[4] suggest that as the number of crashes of a particular type increases, average injury profiles would converge to actual population values.

Despite the earlier general stability of injury profiles in crash types over time, the declines in injury rates were not the same across all levels of injury severity during the period examined in the present study, and consequently injury profiles of crashes changed markedly over a few years. The fact that such changes occurred does not necessarily undermine the usefulness of the crash-type methodology in assessing road safety issues (as annual costs still closely reflect recent crash experience) but highlights possible pitfalls in simply projecting costs into the future on the assumption that they remain constant.

Standardised crash-type costs estimated by ARRB (1992d) are made up of weighted sums of standardised 'per person' casualty costs for different casualty classes (the weights being the values in the injury profiles), and 'per crash'[5] costs for vehicle damage repairs and other incident-related costs for each crash type. The casualty outcomes and costs for the different crash types were based on crashes reported to the police in 1987 and 1988.

The per person costs were based on five casualty classes generally used in crash reporting. These are: killed within 30 days of the crash; admitted to hospital; injured requiring medical treatment; injured, not requiring medical treatment; and not injured. The calculation of crash costs by type involved the summation of costs per injured person and incident costs (including vehicle repair costs).

Costs per person comprised lost productivity, medical costs, hospital costs, ambulance costs, funeral costs, rehabilitation and pain and suffering. Standardised costs per person were derived for each of the five casualty classes using age and gender distributions of persons involved in crashes and mean community income by age and gender.

4. This theorem says that if each term in a sequence of sums of independent identically distributed random variables has finite variance, as the number of random variables increases, their standardised mean approaches the unit normally distributed random variable. This means that if a sufficiently large number of samples are successively drawn from a population, the mean of the sample values can be considered as approximating an outcome from a normally distributed random variable.

5. ARRB uses the term 'per accident'.

Casualty outcomes were determined for each crash type in urban and rural areas using Victorian and NSW data for 1987 and 1988.[6] The standardised costs per person for each casualty class were applied to the distribution of casualty outcomes (that is, the number of persons per crash) for each crash type, to obtain the person costs per crash for each crash type. These person costs were calculated separately for urban and rural crashes.

Incident costs are costs associated with the crash and include costs of vehicle repair, insurance administration, crash investigation and reporting by police, legal work, delays to other traffic, attendance by emergency services, operation of the compensation scheme, and alternative transport while vehicles are repaired. Vehicle repair costs were estimated using data provided by two major insurance companies in Victoria. Vehicle costs were estimated only for crashes involving one or two vehicles. [7]

ARRB added the incident costs to the person costs to generate the standardised cost per crash for 19 common crash types for both urban and rural environments. The costs (in 1991 dollars) ranged from $16 900 for a rural 'hit animal' crash to $154 000 for a rural 'head-on' crash. The infrequent rural 'hit railway train' crash extended the cost range to $240 200.

Standardised casualty class costs per person in 1991 dollars (ARRB 1992d) were:

Death	$625 065
Hospital admission	$107 267
Medical treatment	$7 003
Not requiring medical treatment	$817
Not injured	$306

6. ARRB noted that the cost estimates for Victoria were close to those for Australia as a whole.
7. The standardised costs estimated by ARRB have been based only on crashes involving cars, that is, in single vehicle crashes the vehicle was a car, and in two vehicle crashes at least one of the vehicles was a car. Data on crashes in NSW indicate that cars are involved in over 90 per cent of crashes reported to the police. The use of the estimates for all types of crashes (including those where other types of vehicles are involved) is likely to result in little loss of accuracy. The estimates exclude the costs of unreported crashes.

The procedure adopted in the present study generally follows the approach of ARRB (1992d) to calculate standardised costs for each crash type, and is described below.

Complete data relating to 1992 for 15 different groups of crash types and an 'other' category were obtained from all jurisdictions. From these data, the injury profile for an average crash of each type was obtained by dividing the total numbers of casualties (killed, hospitalised etc.) by the number of associated crashes. These injury profiles for each crash type were multiplied by ARRB's standardised costs of casualties (fatality, hospitalisation etc.) set out above (adjusted to 1992 dollars) to obtain the total personal injury cost for each crash type.

Incident costs, including property damage, were also derived from ARRB (1992d). The calculations in that report were based on one-vehicle and two-vehicle crashes. However, aggregate data obtained for the present study indicated that for some crash types (for example rear-end crashes) the mean number of vehicles per crash was greater than two.

The approach 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 estimates to take account of the differences in the mean number of vehicles involved in some crash types. Only the vehicle repair cost and insurance administration component of ARRB's incident costs were increased in proportion to the mean number of vehicles actually involved. The other components were treated as invariant irrespective of the number of vehicles per crash.

The rationale for this adjustment is that even though any events subsequent to the initial impact are random and unpredictable before a particular crash, the community must bear the cost of losses for all those involved, and not just for the occupants involved in the initial impact.

In the calculation of injury profiles, two-vehicle and multiple-vehicle crashes of the same type were examined separately to check whether there were differences in underlying injury patterns. Where there were several hundred multiple-vehicle crashes, the injury profile was noticeably worse than for the two-vehicle crashes. The adjustments for vehicle repairs and insurance administration involved relatively small amounts and hence final estimates would not change much if future research indicated more appropriate ways of making such adjustments.

The estimated standardised costs for each crash type are set out in appendix IX.

Differences between the methods of costing crashes

A methodology based on crash types is useful in understanding both the crash incidence and severity effects of various treatments and enables the cost of the crash types significantly affected by the treatment to be used in the CBA. Because the crash-type method involves a greater degree of disaggregation, provided there are sufficient crashes being studied, it has a much better chance of distinguishing between systematic and random changes in crash severity after site treatment.

Applying the crash-type method to the evaluation of site treatments involves identifying in advance the different types of crashes whose frequency of occurrence is likely to be affected by a particular treatment, and then testing whether the changes actually observed after the treatment are statistically significant.

As part of the analysis in this study, the method of combining different crash frequencies devised by Tanner (1958) was applied to determine the statistical significance of changes in crash numbers before and after treatment (appendix VIII). Tanner's elegant methodology avoids making any assumptions about the distribution of crashes at individual sites (or in individual jurisdictions), and is to that extent non-parametric. However, by postulating that the numbers of crashes observed in the before and after periods are actual realisations of a Bernoulli trial[8] with probabilities involving control ratios, Tanner establishes a limiting distribution for the logarithm of individual crash-reduction effects, and therefore enables confidence bands for those effects to be established.

While statements about overall changes in the number of fatalities and injuries are of great interest to the media and lay observer, the underlying phenomenon is that of the change in the distribution of crash types. In statistical terms, crashes are rare, random events and therefore the casualty outcome of any particular crash cannot be accurately predicted. At a specific location, it is possible that after treatment the overall number of crashes falls markedly but that a fatality occurs, perhaps in unusual circumstances.

8. One of a sequence of independent events with fixed probability p of success and (1–p) of failure. The collective outcome of a sequence of Bernoulli trials is described by a binomial distribution.

If such a chance fatality occurred in the period immediately before a treatment but not immediately after, any 'treatment' (including a 'do nothing' situation) would demonstrate a beneficial effect. If a fatality occurred after a treatment, unless the number of non-fatal crashes fell dramatically and compensated for the fatal crash at the site, the treatment may be branded a failure. The effects of applying average crash costs based on crash severity was illustrated in BTCE (1993). In the present study, in order to avoid the problems associated with chance fatal injuries, fatalities and hospitalisations were combined to form a 'serious injury' category for which a weighted standardised cost was developed.

While it was beyond the scope of this study to inquire into the quality of the crash-type codings provided by the jurisdictions, it was evident that some of the changes over time in the aggregate data probably reflected procedural changes adopted in the jurisdictions as much as actual changes in crash patterns. This was particularly so in regard to the extent to which 'first aid' injuries and head-on, U-turn and run-off-road crashes were reported. As the numbers of crashes of these types were relatively low at sample sites, such uncertainties were not expected to have a significant effect on the estimates derived in this study.

As noted earlier, if very large numbers of crashes are observed, the law of large numbers and central limit theorem suggest that both the crash-severity and crash-type approaches would provide satisfactory means of estimating any crash reduction benefits that accrue from treatments. Provided the crash cost estimates used are reasonably consistent, overall estimates of benefits obtained by the use of the two methods should not vary widely. However, when the numbers of crashes involved are small, large differences in estimates obtained using the two methods may be obtained. Andreassen (1992) has emphasised that results of cost–benefit calculations based on the crash-severity approach are far more susceptible to the influence of chance fluctuations in serious injury crashes, notably fatal and hospitalisation crashes, than if the crash type approach is used.

Fatal and hospitalisation crashes have rather low probabilities of occurrence, but as they have relatively high costs, even small changes in the number of such crashes will produce large variations in dollar values when projected into the future as a constant stream. The pilot study of the Black Spot Program (BTCE 1993) presented some examples of major differences that arose depending on the year in which small numbers of fatalities or hospitalisations occurred. The pilot study's

BCRs generated by the crash-type method were generally larger than those generated by the crash-severity method.

The standardised cost estimates derived using the crash-type method incorporate substantial crash experience over a period of time and therefore these costs are likely to be relatively more stable over time than estimates obtained using the crash-severity method. Further, as the crash-type methodology involves the classification of vehicle movements prior to collision, it provides a framework for identifying possible causes of crashes. This information may be of value during physical inspections of sites to determine if aspects of site layout or engineering could be altered to reduce crash risk or whether improved signage might be of assistance.

In sum, it is mainly in the ability to differentiate between chance and systemic components of observed changes that the crash-type methodology has theoretical and practical advantages.

COST–BENEFIT FRAMEWORK AND ISSUES

Cost–benefit analysis (CBA) is a technique for identifying and evaluating the total social costs and social benefits of a project. The technique can be used when many of the costs and benefits can be expressed in monetary terms. Projects are deemed worthwhile if the present value of benefits exceeds the present value of costs.

A cost–benefit approach was adopted in the economic evaluation of the Black Spot Program. This has been done by estimating costs of the projects selected for evaluation in terms of the value of resources used, and comparing these costs with the value of benefits of the projects. Both costs and benefits were compared in present value terms. The main expected benefits of treatments at black spot sites were reductions in crashes that would otherwise have occurred.

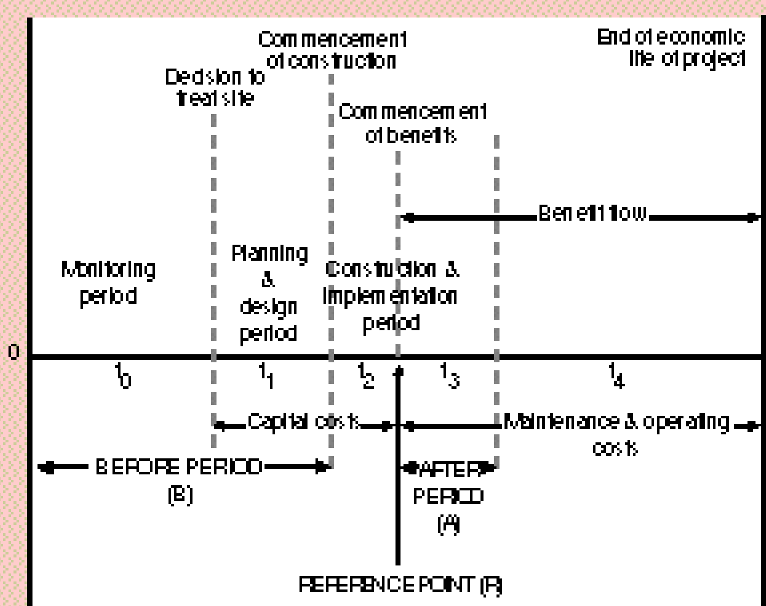
Several measures are available for assessing the economic benefits of projects. These include the first year rate of return (FYRR), net present value (NPV), benefit–cost ratio (BCR), internal rate of return (IRR) and payback period. These measures are described in appendix X. In this study, results have been reported in terms of the NPV and BCR.

A framework for analysis

Figure 4.1 is a schematic representation of the time frame and flows of benefits and costs in black spot remedial projects. All costs and benefits are discounted to the reference point R. The ‘before’ period consists of the period t_1 during which preparations are made to treat the site including planning and design work, plus a prior period t_0 for which crash data were available and were used by the jurisdictions in identifying the site as a black spot.

During period t_2, construction or installation of the safety measure or treatment occurs, probably accompanied by some disruption to traffic flow. The BTCE initially considered a methodology by which the effects of treatments during 1991 (during which most of the treatments in the sample were completed) could be estimated and valued. The process would have involved a fairly intricate assessment and weighting of crashes occurring at individual sites in quarterly periods after treatment.

FIGURE 4.1 SCHEMATIC REPRESENTATION OF TIME FRAME, BENEFIT FLOW AND COSTS OF BLACK SPOT REMEDIAL PROJECTS



Source BTCE

BTCE

However, this process would have required a much higher level of computational effort than that required to establish the crash changes during 1992, which were then assumed to continue for the lifetime of the treatment. Furthermore, it is unlikely that the crash reduction benefits that accrued during part of 1991 (the actual period depending on when each treatment was completed) would have in aggregate constituted more than 5–10 per cent of overall Program benefits. The flow of benefits, measured in terms of crash reduction, was therefore regarded as commencing in 1992.

Consequently, any treatment benefits that might have accrued in 1991 were not taken into account, and therefore estimates of BCRs may tend to be lower than they would otherwise have been. Some ‘settling down’ effects could have occurred in 1991, especially if novel or unusual treatments had been implemented and this might have justified disregarding some benefits (or disbenefits) that accrued in 1991. However, advice from Black Spot Program coordinators in the jurisdictions was that the road network is virtually saturated with traffic control devices in metropolitan areas so that any ‘settling-down’ effects would have been very transient.

The stochastic or random nature of crashes requires relatively large amounts of data to be collected over long periods for meaningful analysis. Nicholson (1987) has suggested that five years is the optimum time period for crash data analysis from the viewpoint of statistical reliability, assuming annual crash counts are used (which avoids seasonal variations) and that the crashes are governed by a constant or stationary Poisson process (see box 3.1).[9] Given the short after period (1992) that had to be used in the present study, in order to improve statistical reliability, projects which were judged to be similar in regard to certain key characteristics such as treatment type and cost were aggregated for purposes of analysis.

The estimated crash reduction benefits in period t_3 (figure 4.1) were assumed to continue unchanged in period t_4, that is, throughout the economic life of the project. The longer the project lifetime used in the analysis, the less plausible is the assumption that the observed crash reduction benefits in period t_3 would continue undiminished. It is likely that, over time, the effectiveness of the treatment would be eroded by

9. The process is stationary in time because it does not depend on initial conditions. A stationary process has the property that the joint distribution of X(t), X(t+a) (where X is a random variable) is a function of time only through the time interval a from t to t+a, and does not depend on t.

a range of factors. These include compensatory behaviour by road users who may grow accustomed to the changed traffic conditions and lower their risk perceptions, physical degradation of the treatment through use and weathering, and changes in the volume and composition of traffic flows over time. There is also the possibility that additional engineering work may be done at the site or in its vicinity in the course of time, thus bringing about further changes in the pattern of crashes at the site.

Gregory and Jarrett (1994) examined the long-term effects of crash remedial schemes for a set of 105 high-risk sites in Essex, United Kingdom, which were treated during the period 1978 to 1985. For most of these sites, 11 years' data were available (1979–1989) and for some as much as 16 years' data were available (1974–1989). Various statistical methods were used to determine whether crash remedial treatments degraded over time. Account was taken of systematic differences between sites, time trends, variations between different districts and the regression-to-mean effect. The study found no firm evidence that crash remedial treatment had degraded over time. However, the authors note that more definite evidence of degradation may be obtained if even longer periods of time are analysed.

In the present study, estimates of the lifetimes of different treatments (that is, the period during which the stream of crash reduction benefits is assumed to last) have been based on data provided by the jurisdictions. The general approach was to use modal values of project lifetimes in the range of values provided by the jurisdictions, supplemented by judgment and information in the road engineering literature. Information on project lifetimes is set out in appendix XI.

Capital costs are incurred in periods t_1 and t_2. For most projects, the actual timing of the flow of capital costs was not known. It was therefore assumed that all capital costs were incurred at one point in time (point R in figure 4.1). Maintenance and operating costs are incurred during t_3 and t_4.

In order to obtain an estimate of the overall effectiveness or net benefits of the Black Spot Program, the results obtained for the sample of projects were expanded to the whole population of treated sites on the basis of capital expenditure categories. The expansion process yielded an estimate of the net benefits of the Black Spot Program in terms of present value. The expansion process assumes that the characteristics of projects sampled for evaluation are representative of projects carried out during the entire Program. However, this assumption has to be tempered by the fact that the projects selected for evaluation were those completed during the early part of the Program and also did not include all treatments undertaken during the Program.

Costs and benefits of treatments to road users

Direct costs and benefits to road users resulting from black spot remedial treatments are of three main types: changes in crash costs (an overall reduction would be expected); changes in vehicle operating costs; and changes in travel time.

Net changes in crash costs

Crashes at treated black spot sites would be expected to decrease after treatment. However, it is possible that certain types of crashes decrease while other types increase. Changes in the pattern of injury severity in crashes may also occur after treatment. Benefits of black spot treatments were assessed in terms of crash costs avoided. Therefore, a measure of the benefit (or disbenefit) of treatment would be the net change in crash costs.

As explained earlier, two different sets of crash costs have been used in this study based on the crash-severity and crash-type methods.

Vehicle operating costs

Remedial treatment at a black spot may change vehicle operating costs by affecting the quantity of fuel consumed. Fuel costs can be influenced by speed changes and idling due to queuing delay, changes in road geometry, and installation of traffic control devices. For example, changes in the rate of fuel use occur during the sequence of deceleration, stopping and acceleration due to an intersection. Fuel costs can also be affected by changes in the quality of the road surface such as degree of roughness.

Changes in fuel consumption costs, if estimated, should be calculated net of tax because taxes on fuel are transfer payments. Available data did not allow an assessment to be made of changes in fuel consumption rates for individual sites.

Travel time

Black spot treatments usually cause changes in the level of mobility, and therefore affect travel time. Some measures which improve safety also facilitate mobility (for example improvements in vehicle technology). However, certain measures which improve safety can impede mobility. Such measures are usually associated with speed, such as speed limits, but also include road engineering treatments such as traffic signals and speed humps. When estimating changes in travel time due to treatments, it is necessary to take into account all occupants of vehicles.

The valuation of travel time involves complex philosophical and theoretical issues. The value of travel time can be measured using empirical approaches such as revealed preference methods. However, a relatively common approach to valuing changes in travel time for work-related travel is to use the hourly wage rate of vehicle occupants. But the use of the wage rate has been criticised on the grounds that the marginal value of time may not be the same for two individuals even if their wage rates are equal, and that the marginal value of time may vary for the same individual depending on the activities for which the time is used.

Changes in the value of travel time for leisure trips pose even more difficult valuation problems. In fact, for some individuals the marginal value of leisure time may be zero, because the individual may not be willing to pay anything for a saving in time. In practice, various arbitrary values have been used for valuing leisure time. Another approach has been to use 'equity' time values which assign the same value of time to all individuals regardless of the purpose for which the time is used.

Apart from the absolute amount of change in travel time, the proportional change is also relevant. For example, a delay of 10 seconds in a half hour journey is likely to be less significant to a commuter than a delay of 5 minutes. Whether the value of a unit of time should be the same irrespective of its absolute or proportional size is therefore also a controversial issue. Consequently, the issue arises of whether small changes in travel time should be valued at the same rate as larger changes, or whether a lower rate should be applied to small changes. Most black spot treatments are likely to cause small changes in travel time of a minute or less for individual road users. One view is that such small time savings are too small to be used for other activities and indeed may not even be perceived or felt by travellers.

In the case of certain projects, such as those involving intersections, small savings in time by some road users may be accompanied by small delays to others, resulting in negligible net change from an overall social cost–benefit perspective. However, during the construction period, disruption to traffic can result in substantial delays both in the vicinity of the site as well as elsewhere in the road network. Costs and benefits during the construction period have not been taken into account in this study as detailed information was available for only a very few sites.

In the pilot study of the Black Spot Program (BTCE 1993) indicative vehicle delay cost data published by VIC ROADS (1992) were used. However, in the present study it was not possible to obtain reliable data relating to time savings or delays experienced by vehicle occupants consequent to black spot treatments at specific sites. In view of the theoretical complications described above, no attempt was made to address travel time aspects of treatments, and the benefits of treatments were assessed solely on safety considerations.

Capital and recurrent costs

In addition to the costs and benefits that accrue to road users described above, black spot remedial projects entail capital and recurrent costs. The costs that should be used in the analysis are economic or resource costs and should therefore exclude transfer payments such as taxes and subsidies. The tax components of construction and maintenance costs of projects were considered small in comparison with the overall costs, and therefore adjustments for tax were not made.

Capital costs

Capital costs include the cost of property required for the project, design and management fees, and construction costs. If projects involve the use of land, the economic cost of the land should be included. A reasonable estimate of this cost would be market value. In the case of most treatments the cost of land was not relevant, as treatments were applied to existing roads and the cost of land was a sunk cost.

The capital costs of projects used in the analysis were provided by the jurisdictions.

Recurrent costs

Recurrent costs comprise maintenance costs and operating costs. Maintenance costs include routine ongoing maintenance costs and special costs arising from damage or breakdowns. Operating costs include costs of power for projects such as traffic signals and improved lighting at pedestrian facilities and isolated intersections.

For the purpose of CBA, it is necessary to determine the net annual difference between the maintenance and operating costs after and before treatment and not just the costs after treatment. For example, the recurrent cost of adding a separate right-turn phase to a set of existing traffic signals would be the incremental maintenance and operating cost, not the maintenance and operating cost for the whole set of signals.

Maintenance and operating costs used in the study were provided by the jurisdictions and are summarised in appendix XI.

Residual or salvage value

Residual or salvage value is the monetary value of the elements of a project at the end of its economic life. Residual value should be added to the benefit stream or subtracted from the cost stream.

Many black spot treatments were likely to have residual values close to zero. In some cases the residual values may have been negative because of the need for substantial expenditure to remove what is left of a treatment, as for example the removal of a roundabout. Even if a treatment were to have a positive residual value, it is likely to be negligible in present value terms.

The residual values of some projects, such as those involving the installation of traffic signals, could be expected to bear some proportional relationship to the capital cost. Therefore, in the absence of precise data on residual values, one approach would have been to assume that they are a certain proportion (say 5 per cent) of the capital cost. However, in the case of many engineering treatments, once the treatment is implemented, the original capital expenditure becomes a sunk cost. Changes in technology or road engineering techniques can make a treatment obsolete over time. The residual value of the treatment would then be its scrap value which would bear no relationship to its historical cost.

In view of the foregoing factors, and given the small contribution residual value is likely to contribute to overall project benefits, all treatments were regarded as having zero residual value.

Externalities

Externalities exist when individuals or firms have to bear costs for which they are not compensated, or obtain benefits for which they do not pay.

Apart from motorists, there are other categories of road users and non-road users who bear costs and obtain benefits as a consequence of black spot remedial work. Examples are inconvenience and delays caused to pedestrians, noise and inconvenience caused to residents in the area when construction work is carried out, delays to users of other modes of transport such as trams, and changes in property values and retail business turnover caused by changes in traffic flow patterns. A travel time benefit of reduced crashes at treated black spots is the time saved by motorists as a result of vehicles not being compelled to slow down, stop or re-route after a crash.

Another type of external effect has to do with possible compensatory or adaptive behaviour by road users in response to a safety measure. For example, if drivers appropriate safety benefits in the form of performance benefits such as increased speed which results in an increase in the number of crashes, they impose a negative externality on other road users. To the extent that this occurs, it should be reflected in the overall analysis of costs and benefits. However, the issue of compensatory behaviour is not well understood and defies measurement (see chapter 1 and appendix VII).

A social CBA should take account of external effects, but most of these effects are very difficult to identify precisely and to value. From an overall social perspective, it is possible that some of the benefits and costs would offset each other, producing no net change. It is also expected that any net effects would be small in comparison with the uncertainties in the estimation of crash costs. Taking account of external effects was beyond the scope of this study.

Macroeconomic effects

The Black Spot Program was implemented during a period of recession when high levels of unemployment prevailed. Individual black spot projects would therefore have been expected to generate substantial employment benefits.

In addition to its direct effects on employment, construction expenditure also affects total demand in the economy through multiplier effects. The impact on output, employment and demand occurs directly due to the construction expenditure as well as indirectly through the effect on supply industries and induced increases in consumer spending. Estimating the macroeconomic effects of the Black Spot Program was beyond the scope of this study.

Discount rate

A discount rate is used to convert a stream of future benefits and costs to present values. Discounting is necessary because money has a time value. For example, if $100 invested now yields $108 in one year, $108 earned one year in the future has a present value of $100 at a discount rate of 8 per cent. Some issues that arise in the selection of a discount rate are discussed in box 4.5.

Three discount rates have been used in this study. As recommended by the Department of Finance (1991), a benchmark discount rate of 8 per cent has been used in the CBA. To test the sensitivity of the results to changes in the discount rate, alternative discount rates of 6 per cent and 10 per cent were also used.

The higher the discount rate, the lower the net present value. The discount rate of 10 per cent is closer to rates of return obtained in the private sector, while the 6 per cent rate is more in the nature of a social rate of time preference. In the case of black spot projects, the low social time preference rate would be of lesser relevance because the lifetimes of projects are relatively short.

Sensitivity analysis

The evaluation of projects using CBA involves estimating benefits and costs which are subject to uncertainty. Sensitivity analysis involves assigning alternative values for critical but uncertain variables, and determining the effect of varying these values on project performance, as measured by indicators such as the NPV and BCR.

Variables used for sensitivity testing were the discount rate (6, 8 and 10 per cent) and crash reduction benefits based on the crash-severity and crash-type approaches.

Estimates of project benefits

Estimates of the benefits of the sample of projects, based on the analytical framework described above, are presented in chapter 8. The estimates in chapter 8 are presented in terms of NPVs and BCRs. All results in chapter 8 are based on statistically significant changes in crash numbers consequent to treatment, and only statistically significant results have been reported. Estimates of overall Black Spot Program benefits, based on an extrapolation of the sample estimates to the entire population of black spot projects, are also presented in chapter 8.

A corresponding set of estimates, which have not been subject to the process of testing for statistical significance, are presented in appendix XIII.

BOX 4.5 IS THERE A 'RIGHT' DISCOUNT RATE FOR THE BLACK SPOT PROGRAM?

Project benefits and costs that occur in the future can be made comparable with those that occur in the present by the use of a discount rate. The process of discounting is necessary because a certain amount of dollars today is worth more than the same amount of dollars at some future time (the dollars invested today would yield a larger number of dollars in the future). Discount rates are used to convert future costs and benefits into present values and can therefore be regarded as an exchange rate that reflects the trade-off between the present and future value of money.

Although the concept of discounting is straightforward, there is no consensus about what the appropriate social discount rate should be in any given situation. Approaches to selecting discount rates are controversial and sometimes contradictory. Different approaches to selecting discount rates stem from the variety of rates of return in different sectors of the economy, reflecting differences in the productivity of capital as well as risk levels for specific activities. Discount rates therefore also serve to allocate capital funds among competing uses.

A concept associated with discount rates is 'time preference'. Individuals have a limited lifetime and are not likely to look very far ahead for returns on investments. Society, on the other hand has permanency as it is constantly replenished by individuals being born, and will therefore look further into the future for returns on investments. The consequence of the difference between private and social time preference is that society would discount the future less heavily than individuals and opt for a lower discount rate.

Another concept—'opportunity cost'—dictates that it is difficult for society to apply a lower discount rate to public sector projects relative to private sector projects, because capital which could be more profitably used in the private sector would then be attracted to the public sector.

The foregoing considerations generate different approaches to the selection of discount rates. Consequently, there is no 'right' discount rate for the evaluation of the Black Spot Project, or for that matter, for other purposes. The choice of an appropriate discount rate involves value judgments.

One approach to selecting the discount rate to use in a public sector project evaluation, such as that of the Black Spot Program, is that the rate should be indicative of the opportunity cost of public capital in other uses, including private sector investment possibilities. This approach suggests a fairly high discount rate, close to the rates of return in the private sector.

Another approach is to use a lower rate reflecting a social rate of time preference. This approach gives more weight to future costs and benefits and therefore places more emphasis on the welfare of future generations.

On the other hand, when there are urgent public needs, such as a rising road toll, the use of a high discount rate would appear to be appropriate because it will favour projects whose net benefits occur early. This would be consistent with an individual time preference approach. Individual road users could argue that if road improvements are funded substantially from taxes and fuel excises paid by them, the appropriate discount rate to use would be that which represents the trade-off between present and future benefits preferred by them. The treatment of black spots typically involves low cost projects whose benefits are expected immediately after implementation. The discount rate favoured by road users would therefore be expected to be relatively high.

A third approach is to relate the discount rate to the cost of capital. In the case of government, this would generally involve the cost of borrowing as reflected in the long-term bond rate.

A fourth approach, recommended by the Department of Finance (1991) is to use a project-specific discount rate which takes account of the market risks involved in the investment. In the absence of a project-specific discount rate, the Department of Finance recommends a benchmark discount rate of 8 per cent in real terms. This rate is broadly consistent with estimates by the Department of Finance of real, before-tax rates of return in the Australian corporate sector.

CHAPTER 5 DATA AVAILABILITY AND RELATED ISSUES

EVALUATION DESIGN CONSTRAINTS

The degree of precision in estimates of the effects of road safety treatments depends considerably on the level of planning undertaken in the overall design of the evaluation, the selection of projects for evaluation, and the quantity and quality of the data available.

As discussed earlier, strong evaluation designs involve matching treatment sites with comparison or control sites. The strongest evaluation designs involve a random assignment procedure where sites are assigned to treatment groups and control groups on a random basis, and the number of crashes are recorded before and after treatment. The purpose of randomisation is to make the control group and the treatment group as similar as possible in all respects, except for the treatment. However, such a design requires careful planning before treatments are implemented. In using it, the expected number of crashes in the after period for the treatment group is calculated with reference to the number of crashes observed in the control group.

As the exact nature of the evaluation had not been decided when the Program was initiated, very strong experimental designs involving matching and randomisation were not possible. Weaker designs involving similar comparison sites therefore had to be considered. However, it is usually extremely difficult to identify untreated sites with characteristics similar to treated sites. Sites with bad crash histories are generally treated as a matter of priority, which means that ‘similar’ untreated sites that can be used for comparison do not usually exist. To have attempted to collect data on similar untreated sites, given the large number of projects involved in the Black Spot Program, would have placed a considerable burden of site identification and data extraction on the jurisdictions.

The best that could be done in the circumstances was, as is described in chapter 6, to spread the sample of the sites to be evaluated around metropolitan and rural areas in each jurisdiction in such a manner that crash trends (percentage changes from year to year before and after treatment) were likely to mirror the changes in an appropriate wider urban or rural area for which crash statistics were readily available. Using this approach, the most recent crash experience in that wider area could be used, with the application of appropriate control ratios, to estimate what would have happened at the treated sites in the absence of treatment.

At the commencement of this study, information was requested from the states and territories about their crash databases and other relevant data that were available. Their responses, and subsequent detailed discussions with various officers in a number of jurisdictions, determined what was considered feasible during the course of the study and forms the basis for much of this chapter.

COLLECTION OF ROAD CRASH DATA

All states and territories maintain crash databases based on information in police crash reports. These reports are compiled either after police attendance at the crash site or as a result of someone involved in a crash making a report at a police station. Although there have generally been a number of changes in the nature of the information collected and stored in relation to crashes over time, it is usually possible to obtain the crash history of a site for a period of 20 years in most jurisdictions.

Current databases may have records going back as far as 1968, as in the case of South Australia. In several jurisdictions there are significant discontinuities in the data series because of the addition or alteration of data fields and modification of reporting or recording criteria. For instance, in NSW the legal obligation to report all crashes ceased in 1988, and instead, only crashes where total property damage exceeded $500 were required to be reported. The decrease in the number of crashes reported during the year after the change was far in excess of what would have been predicted from previous reporting trends. In Western Australia the property damage threshold for reporting crashes increased from $100 to $300 in 1980, and further increased to $1 000 in 1988.

The storage format for crash records varies across jurisdictions. In some jurisdictions single records are created for each crash, with injury particulars listed for a given maximum number of those involved, together with vehicle information, vehicle movements prior to the crash, and other details. In other jurisdictions the primary record is for the vehicles involved, and any information about the crashes themselves needs to be extracted through vehicle data.

However, a more common format for data storage is a three-tier system dealing separately with crash details, vehicle details and casualty details through a linked crash number and, where appropriate, one or more linked vehicle numbers. This relational database approach enables all crash particulars to be stored in a manner requiring the least amount of memory capacity. Some programming is usually needed to extract more detailed information pertaining to different aspects of crashes.

The data storage arrangement currently used in each jurisdiction has been influenced by the manner in which the transition was made from paper records to an electronic database, as well as by detailed planning for subsequent major equipment upgrades.

The data coding process

Specialised coders, who may be employees in state and territory road and traffic authorities, or contractors, enhance the entries made by police in the crash reporting form by inferring other particulars from these entries and any sketch or verbal description of the crash that may be available. The coders also resolve any inconsistencies that may be present in the raw crash data as best they can.

It appears that in several jurisdictions there is very little contact between road and traffic authorities and the police. When contact is made, it is usually to clarify the exact location of the crash. An exception is Queensland, which has the most detailed crash reporting form and the shortest period of coding experience (the ABS undertook data entry before March 1991). Authorities in Queensland indicated that over half the crash reports required direct clarification from the police.

In Victoria, VIC ROADS staff use the collision diagram and description of the crash and various numerical codes to pinpoint metropolitan crashes on the Melways grid. A similar process is used to record rural crashes on detailed maps. VIC ROADS staff also make the appropriate definitions for classifying accidents (DCA) entry for each crash type. Under this system of classification, basic crash types are further disaggregated in terms of the manoeuvres or movements those involved in a crash were making or attempting to make before the impact.

In all jurisdictions the correct identification and entry of site particulars presents a number of difficulties, especially in rural areas. In rural areas stated distances may be very approximate and particular landmark references obscure, or even misleading, to those unfamiliar with the area. In provincial cities there may be several different road names along a single stretch of road. Consequently, when a crash does not occur at an intersection, pinpointing the location with reasonable precision may be difficult, particularly when there is a hazardous section along a length of road, rather than some obvious spots whose physical characteristics would be expected to be hazardous.

In some jurisdictions an arrangement is in place to number roads, and to measure distances from their origins, in order to minimise the possibility of ambiguity. In other jurisdictions approximate distances from the nearest prominent landmark are recorded.

Intersections in metropolitan areas may be given grid reference coordinates or be numbered in some systematic fashion. Sometimes an intersection attains a permanent presence in a database when a certain number of crashes have been recorded there over a period of time. Most of the sites treated during the early part of the Black Spot Program were intersections, so there can be a fairly high degree of certainty about their identification and the presentation of their crash data.

Mistakes in spelling the names of roads may lead to a failure to extract from a database all crash particulars relevant to a site in question unless all the possibilities for errors in entry have been explored. This has been one area in which the skill of coders has resulted in a more reliable database being available for analysis.

With developments in GISs and the assignment of grid references to sites, confusion resulting from the use of local names and changes in street names or misspellings can generally be avoided. Such electronic mapping techniques also enable wider areas to be quickly scanned for possible crash patterns that can be addressed with a comprehensive set of measures. Black Spot Program funding was provided for a number of projects of this type, in accordance with provisions allowing financial support for measures with the potential to enhance safety (Schedule 1A treatments).

Just as there are marked differences among jurisdictions between what is reported or recorded, arrangements vary for general access to the database or to specific crash particulars. In many jurisdictions information about fatal crashes can be obtained the day after the crash, if needed. Generally a week or more will elapse between the receipt of forms or data records from police sources and the completion of enhancement work on the data by coding personnel. For instance, updating of the database occurs weekly in Western Australia where most records are available from the police within three weeks.

The most populous jurisdictions indicated that some 90 per cent or more of casualty records are coded within three months of the crashes involved. Nevertheless, in NSW, as police records may still be dribbling in a year or two after the relevant crashes occurred, quarterly reporting is done on the basis of reports received from the police, rather than on the basis of crashes which occurred in that period. The quarterly reports are released some five or six months after the particular quarter has ended, but NSW Road Safety Bureau staff and other authorised personnel can obtain earlier access to incomplete data.

EVOLVING CRASH DATABASES

The databases of the jurisdictions continue to undergo major reassessment and change for a number of reasons. For instance, towards the latter part of this study it appeared that South Australia, Tasmania, and the ACT, which maintain unique crash classification and coding systems that have developed historically, would adopt some form of the road user movement (RUM) system in the future.

This study examined the crash records between 1988 and 1990 at selected treated sites and compared them with the records in 1992, with appropriate adjustments for general community trends in crashes. Over these years there were some major changes relating to the reporting and recording of crashes in a number of jurisdictions and this raised problems of consistency in the data series.

Some major changes since 1988

In Victoria, from May 1988, Transport Accident Commission (TAC) compensation to crash victims could be paid only if the crash had been reported to the police. This had an immediate impact on the reporting profiles of crashes, with a major downward shift in the reported severity of crashes and more minor crashes being quite noticeable.

Victoria also moved from a four-tier classification of personal injuries (killed, hospitalised, treated, first aid) to a three-tier one in which the two least serious injury categories were combined. The effects of this change were noticed when the 1992 aggregate crash data supplied showed different patterns from the 1988–91 data used for the pilot study (BTCE 1993).

After consultation with Victorian authorities it was decided to update the earlier data to be consistent with the most recent data. One consequence of this was the need to revise upwards by around 10–20 per cent earlier estimates (BTCE 1993) of the costs of particular types of crashes, such as right-angle, right-turn, and rear-end.

While actual legal reporting obligations in Victoria did not change over the period from 1988 to 1992, the entry of PDO crash particulars into the VIC ROADS crash database was discontinued after December 1990. Subsequent shifts in the severity patterns of crashes mean that previous ratios of injury crashes to PDO crashes are no longer likely to be accurate.

In Queensland, the mandatory reporting threshold for PDO crashes was raised from $1 000 to $2 500 in December 1991. Early in 1989, responsibility for maintaining the official State crash database was transferred from the ABS to the Statistics Unit of the Queensland Department of Transport. When records from 1990 and earlier had to be examined to establish road movements prior to crashes, records had to be obtained from paper files held at a number of different locations. A separate declared roads database with enhanced site and crash information has been maintained by the Road Transport and Safety Division and its predecessors, to assist in the planning of road works where the Queensland State Government has responsibility. The classification of crashes in that database uses different coding from that of the State database and injury particulars are available for at most four people involved in any crash.

In Western Australia, as already mentioned, the reporting limit for PDO crashes rose in 1980 and 1988, with immediate impacts on the level of crashes entered in the database. At the beginning of 1989, RUM coding was introduced, based on the practice in NSW. In the following year, a slightly different coding arrangement began to apply so appropriate adjustments had to be made in the course of this study as well as inferences about 1988 data based on the contents of other available fields.

New police reporting procedures were introduced in South Australia in 1992, and the use of collision diagrams on report forms was discontinued, making it much harder to deal with inconsistencies in the new data. A substantial backlog of unrecorded 1992 crashes built up, as the Office of Road Safety had to record these crashes using a limited range of police crash descriptions, without location and other information that was previously available. South Australian data was a major concern throughout the study, particularly when it was necessary to maintain continuity with data series that existed for years before 1992.

In circumstances of continual change such as those outlined above, it is necessary to identify and deal with incompatibilities that may be present in the data that are available. Sometimes it is possible to make estimates of data that are no longer available by applying certain ratios of crashes or injuries on the assumption that such ratios have remained stable over the period in question. However, such procedures become fraught with uncertainty when the mix and severity of crashes is changing, as was the case over the study period.

As indicated by the changes in individual jurisdictions mentioned above, the general trend has been to include gradually fewer crashes in databases, either by adjusting the level at which reporting obligations apply, or by making changes to the reported crashes that are included in a database. Pressure on available resources may exacerbate this trend unless additional funding sources, such as insurance companies, are persuaded of the benefits to them of improved road crash statistics as a fundamental input to the formulation of road safety strategy.

THE RANGE OF INJURIES IN CRASHES

The traditional approach to classifying crashes has been based on the highest level of injury sustained by anyone involved.

Fatalities

Fatalities are the most accurately reported of all casualties due to road crashes. For statistical purposes, all Australian jurisdictions attribute the cause of death to road crashes when death occurs up to 30 days after the crash.

Since 1991, FORS has had responsibility for maintaining and enhancing fatal crash data and presenting the data in a monthly publication titled *Road Crash Statistics*. FORS also commissions studies to examine various trends in fatal and hospitalisation crash statistics and to make comparisons of crash involvement among different types of road users.

Some jurisdictions release periodic updates of information about fatal crashes, partly to maintain public awareness through the media attention that is generated. For example, each month the Office of Road Safety in South Australia releases a four-page bulletin with information on crash involvement and statistics for the current and previous year.

Hospitalisation injuries

After fatal injury, the next most serious injury category is hospital admission or treatment. There is no uniform approach among the jurisdictions for police recording and checking of hospital admission information. In Victoria for instance, the coding is described as ‘sent to hospital’ and simply refers to people despatched to hospital in an ambulance from the scene of the crash.

It has long been recognised that not all people who enter hospital as a result of road trauma appear on police reports or database records. As well, not all those who are despatched to hospital in ambulances are actually admitted to hospital, many being treated as casualties and discharged. A number of studies have been undertaken on the relationship between reported crash statistics and hospital admission records (box 4.2).

Recording procedures in hospitals around Australia are such that linked identifiers for individuals injured in a particular crash are not available, and hence matching of appropriate records to obtain information on multiple admissions of the same individual, and average hospital stays and costs, is difficult.

During the course of this study, the data obtained in relation to hospitalisation were taken at face value, and cost estimates based on ARRB (1992d) were applied. Because Victorian cost estimates (BTCE 1993) had to be revised, and because Victorian experience was quite different from other jurisdictions in terms of hospitalisations resulting from road crashes (FORS 1993), Victorian data were subjected to detailed scrutiny.

Information was provided by VIC ROADS on the results of matching several years of hospital admission and road crash records. The material supplied showed that the low representation of some road user categories such as cyclists and motorcyclists was offset by over-representation of other categories. The aggregate numbers of hospital admissions appeared to reasonably match the aggregate ‘sent to hospital' numbers on police report forms. As there was no means of investigating whether this result held uniformly across all types of vehicle crashes, adjustments to the hospitalisation data were not made in the case of Victoria.

Other injuries

Injuries less severe than hospitalisation are sometimes reported as a single category (as in the ACT and Victoria), or as either of two generic possibilities: 'medical treatment' (whether at a hospital with discharge immediately thereafter or through a medical practitioner elsewhere) and 'first aid' or 'injured but did not require medical treatment', where the assistance provided by ambulance officers and others in attendance is adequate and the injured person does not require further medical attention.

The distinction between these two less serious injury categories does not appear to be made uniformly in all parts of the same jurisdiction at all times. The nature of the fluctuations in aggregate statistics from year to year suggests that some recorded changes may be due as much to changes in recording policy as to any actual events associated with crashes. However, as unit costs attributed to first aid crashes as well as their number at the sites evaluated were rather low, these uncertainties will have a negligible effect on BCRs.

In this study, only the 'medical treatment' category has been used for those jurisdictions where a distinction is made between the two least severe injury categories (that is, the 'first aid' category has been disregarded other than in the calculation of injury profiles). Where no such distinction between injury categories is made, the numbers in the 'other injury' classification have been used in any analysis of injuries requiring medical treatment.

Uninjured persons

Details of those involved in a crash are also recorded differently in different jurisdictions. In some jurisdictions, this information appears in the crash file, or can be extracted from the casualty file together with all the individual injury particulars. However, in NSW, the total number involved in a crash is entered in the 'traffic unit' file, and can therefore be extracted only through programming which scans entries in both that file and the casualty file. Especially when there has been no police attendance, the number involved in the crash may not be known, or may not have been reported by the informant.

Injury particulars or non-injury status for those involved in crashes are recorded in Victoria, South Australia and Tasmania, and for drivers and casualties in the Northern Territory. Elsewhere, details of those involved but not injured are not necessarily available, and estimates of average vehicle occupancy in metropolitan or rural areas are also not readily available.

As the unit costs are only several hundred dollars for those not injured, any reasonable approach taken to estimate the total costs of nil injuries is not likely to have a significant effect on BCRs. Figures for uninjured persons in each crash were available for Western Australia, Tasmania and the Northern Territory, while estimates for NSW crash types in 1987 and 1988, and average figures for Victorian casualty crashes in the same period, were obtained from ARRB (1992d).

The NSW figures were applied uniformly for each year, and were extended to Queensland as there were some similarities in casualty patterns and reporting thresholds between the two states. Victorian estimates of uninjured persons in crashes involving pedestrians were taken from ARRB (1992d) while estimates for other crash types were made by subtracting the other injury components of the profile from the metropolitan and rural mean values given in that report. The same numbers and procedures were used to obtain estimates of the uninjured for South Australia and the ACT.

CLASSIFICATION OF CRASHES

The narrowest injury severity classifications (involving three categories) occur in South Australia and the ACT (fatal, injured, PDO), and in Victoria (fatal, sent to hospital, other injury). As these three jurisdictions made available the contents of a number of fields in their databases, in the cases of South Australia and the ACT it was possible to develop separate classifications for hospitalisation and other injury crashes.

The most extensive classification of crashes (involving six categories) occurs in Western Australia. There are four separate injury crash categories, according to the degree of injury sustained, as well as two PDO categories (major and minor) depending on whether any vehicles are towed away or not.

The other four jurisdictions have five categories of crash severity: one for each injury level (fatal, hospital, medical, first aid) and one for property damage. Despite this apparent uniformity, there are differences among the four jurisdictions in reporting thresholds which apply to PDO crashes. Consequently, there is a great diversity in the proportion of PDO crashes in total recorded crashes, ranging from zero in Victoria since 1991 to an estimated 95 per cent in the ACT. Other jurisdictions have reported PDO crashes comprisingp between 70 and 90 per cent of all reported crashes.

Reporting and recording thresholds

Next to Victoria, NSW and the Northern Territory have the most stringent conditions for recording crashes. In NSW the requirement to report all crashes was discontinued in 1988 and replaced with a $500 property damage threshold. Only those PDO crashes where at least one vehicle is towed away are recorded, the rest remain on microfilm.

In the Northern Territory it is obligatory to report all crashes, but PDO crashes where no vehicle has been towed away have been classed as 'incidents' and not officially recorded. Information on non-towaway PDO crashes will probably be included in the database in the near future.

It is also obligatory for all crashes to be reported in Tasmania and the ACT, and all the information reported is recorded electronically. In the case of the ACT, while the number of injury crashes is very low, the total number of recorded crashes is larger than for some of the more populous jurisdictions.

In South Australia, Queensland and Western Australia reporting thresholds have changed from time to time. In South Australia the level of property damage at which there is an obligation to report is $600. Western Australia changed from a threshold of $600 to $1 000 in November 1988, while Queensland increased its threshold from $1 000 to $2 500 in November 1991.

Table 5.1 summarises the injury and other particulars each jurisdiction records about individuals. It also includes a summary of the extent to which information about PDO crashes is recorded.

TABLE 5.1 INJURY AND OTHER PARTICULARS RECORDED ABOUT INDIVIDUALS IN CRASHES, AND PDO INFORMATION, BY JURISDICTION

Crash records	*NSW*	*VIC*	*QLD*	*WA*	*SA*	*TAS*	*ACT*	*NT*
INJURY	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal
SEVERITY	Hospital admission	Serious injury (loaded into ambulances)	Hospital admission	Hospital treatment	Hospital admission	Hospital admission	Hospital admission	Hospital admission
	Medical treatment	Other injury	Medical treatment, not admitted	Medical attention	Hospital treatment	Injury, not detained in hospital	Injury, not detained in hospital	Hospital treatment
	Injury, no treatment	No injury	First aid or no treatment	No medical attention	Private doctor	First aid		Injured, no treatment
					No treatment	No injury		No injury
Data collected for:	All casualties: number not injured can often also be inferred	All occupants	Casualties	Casualties	All occupants	All occupants	Casualties	Drivers and casualties
SEAT BELTS (Worn, not worn, not fitted)	Drivers and those injured	Drivers and occupants	Casualties	Since Jan. 1989, casualties	From 1992	All occupants	Casualties	Drivers and casualties
BLOOD ALCOHOL (drivers)	Breath test	Whether blood or breath test applied	Recorded for fatalities and injuries	Since Jan. 1989 blood and alcohol tests	Alcotest or breath analysis by police	Sobriety assessment	Sobriety and alcohol percentage	Sobriety, breath analysis, blood test and other drug results

TABLE 5.1 INJURY AND OTHER PARTICULARS RECORDED ABOUT INDIVIDUALS IN CRASHES, AND PDO INFORMATION, BY JURISDICTION (continued)

Crash records	*NSW*	*VIC*	*QLD*	*WA*	*SA*	*TAS*	*ACT*	*NT*
	Blood sample	Hospitals give police blood samples			Forensic science supply blood test results monthly	Blood alcohol content test		
PDO CRASHES Reporting obligations and recording criteria	Reporting where total damage ≥$500; recorded where at least one vehicle towed away; unrecorded information on microfilm	Reporting where at least one injury or vehicle owner not present; PDO crashes not recorded since Jan 1991	Reporting where total damage ≥$2 500	Reporting where total damage ≥$1 000	Reporting where total damage ≥$600	All crashes to be reported	All crashes to be reported	All crashes to be reported; if no injury or towage, treated as 'incident' to date
Towing for vehicles (same as for injury crashes)	Towing recorded and vehicle type	Towing recorded, plus extent of damage (five categories) and catching fire	Towing recorded General extent of damage entered	Towing recorded	Towing recorded Estimates for repair costs	Towing recorded	Towing recorded Extent of damage (five categories)	Towing and catching on fire recorded Extent of damage (four categories)

Source Data provided by states and territories.

Implications for a national study

The differences in crash recording described above have implications for an overall national analysis. When, as occurred during the period of this study, there are differential impacts on the various levels of severity of crashes recorded in the different jurisdictions, simply measuring changes in aggregate numbers of recorded crashes is not a sound basis for comparison between jurisdictions.

In this study, over half the recorded crashes at sites in the evaluation sample occurred in South Australia, the preponderance of these being PDO crashes. Next most prominent in both aggregate and average terms was Western Australia, while the ACT also had a high mean number of crashes per site per year during the period before treatment.

Victoria had the largest number of injury crashes, followed closely by South Australia, Western Australia and NSW. Had national average crash costs been calculated on the basis of overall national crash experience, the results would not have reflected crash experience in individual jurisdictions as closely as costs calculated separately for each jurisdiction and subsequently combined. The latter approach was therefore taken in this study. As already noted, crash patterns differed across the jurisdictions and it is only for the more severe injury crashes that meaningful comparisons can be made, and even in this case, as explained above, some of the definitions used are not uniform.

All jurisdictions record whether any vehicles are towed away from a crash site. Victoria and the territories include in the police report form a number of classifications relating to the extent of vehicle damage, while South Australia and Queensland also request police estimates of repair costs.

Other particulars relating to a reported crash, such as whether a vehicle caught fire or was towing another object, are captured in the databases of some jurisdictions. Also, in some jurisdictions a separate data field dealing with the types of vehicles involved in crashes is available and this permits the study of crashes involving selected classes of road users, such as truck drivers, motorcyclists or pedestrians.

ARRB’s estimates of vehicle repair and insurance administration costs, and other incident costs, were used in generating estimates for this study. However, for some crash types, the average number of vehicles involved was consistently greater than two. In such cases, the vehicle repair and insurance administration costs were increased in proportion to the number of vehicles, as additional costs would be expected from further impacts. In the absence of research findings on how these costs increase, a simple linear approach was adopted in scaling up the costs.

CRASH TYPES AND THEIR CLASSIFICATION

It is known that certain site treatments can increase one or more types of crash at particular sites, while either the overall number of crashes or their severity (or both), decline. For instance, if new traffic signals are installed without a protected right-turn phase at a previously unprotected intersection, both the number of rear-end and right-turn-against crashes can rise (Andreassen 1970). Nevertheless, in this case the avoidance of right-angle crashes of high severity is likely to confer a greater social benefit than the additional costs due to the new types of crashes.

In these circumstances, the use of aggregate standardised ‘fatal’ or ‘injury’ crash costs to estimate the benefits from crashes avoided will often not accurately measure benefits accruing to society as a result of changes in different crash types. When there are several types of crashes each of different mean cost and varying patterns of crash reduction, only a disaggregated approach involving separate costings for changes in the incidence of each crash type will provide a proper comparison between the periods before and after treatment. When a measure is likely to affect both the number and severity of crashes, and is targeted at particular crash types, aggregated analysis of crashes is conceptually unsound.

Road user movements (RUMs)

While jurisdictions have historically used a crash-severity approach (based on average costs of crashes involving different levels of injury) there has been a growing move towards a RUM system for coding crashes and estimating costs. Under this classification, basic crash types (pedestrian or right-angle, for instance) form the columns of a grid describing the nature of the movements those involved were making just before the collision. Within each of these columns, there are further row distinctions relating to the finer detail of those movements, such as in which quadrant of an intersection a right-angle crash occurred.

Figure 5.1 illustrates the classification by crash type using the RUM coding grid in longest use, that of NSW. Annual reports issued by the (former) Road Safety Bureau of NSW have indicated that most crashes are concentrated in the pedestrian, right-angle, right-turn, rear-end, side-swipe, head-on and various run-off-road categories.

Similar classifications have been adopted in Queensland (for the roads over which the State Government has responsibility), Western Australia and the Northern Territory, while the closely-related DCA has been used in Victoria for many years, and has been adopted for the state database in Queensland. The main differences between the two methods of classification, apart from the actual numbering used, lie in whether movements off a curve to the left or right are coded separately, and the manner in which U-turn crashes are classified. Further, some jurisdictions assign the number at the top of a column as the one which identifies all crashes not elsewhere described in that column, while others use the number at the bottom of the column for that purpose.

Without a proper collision diagram and description of the crash, it is often very difficult to assign a coding confidently. On the basis of the analysis of batches of NSW and Victorian crash data, ARRB (1992d) has drawn particular attention to coding mismatches for the categories involving vehicles running off a straight road or a curve, and either hitting or not hitting objects. It appears that there are variations of approach in deciding how to describe events subsequent to a car running off the road. In South Australia, collision diagrams on the police report form were discontinued in April 1992.

In the course of the present study, for the five-year period 1988–1992, a total of 14 separate data collections in eight jurisdictions were examined. South Australia developed a number of algorithms to convert its system of 13 separate crash codings and 17 vehicle movement prior to crash codings, into the groupings of RUM codes needed for the analysis. Tasmania examined its original paper records of ‘angle’ crashes at sample sites in order to classify them as right-angle and right-turn crashes. Queensland provided access to collision diagrams to establish crash type details which were not entered in its database before 1990.

Where there have been differences in approach, as in the two separate Queensland data collections, or differences over time as in Western Australia, considerable care was devoted to converting codings to a uniform, comparable basis before the data were used in the evaluation of treated sites.

Officials from Tasmania, South Australia and the ACT, the three jurisdictions which currently retain their own historical method of classifying crashes, have indicated that varying levels of investigatory or implementation planning work has been undertaken with a view to adopting some type of RUM classification in the near future. These moves could become a catalyst for discussions among the jurisdictions to standardise the codings used, so that data and published results on the effectiveness of treatments could be more readily interchanged. Early agreement on some degree of standardisation among the jurisdictions would be highly desirable. Even if all jurisdictions were to change to RUM systems, minor differences in such systems could impede the sharing of information and results.

Table 5.2 summarises the manner in which the various jurisdictions record crash types and severities.

SUPPLEMENTARY CRASH INFORMATION

A number of factors other than chance variations and site features can affect the extent of injuries in a given crash or series of crashes. For instance, if seat belts are not worn, the risk of serious injury to occupants increases when there is a high-speed impact.

In wet weather, the number of crashes, particularly rear-end ones, tends to increase but the associated injury severity may diminish because the speeds prior to impact are usually fairly low. Independent of other factors, official reports by road safety authorities indicate that a large proportion of those seriously injured in crashes have high blood alcohol concentrations. For instance, in 1993, 32 per cent of all drivers and motorcyclists killed in road crashes were found to have had a blood alcohol concentration in excess of 0.05 per cent (FORS, pers. comm.).

When ‘before and after’ comparisons are made, and overall crash numbers are rather low, some assessment of the impact of such factors would be desirable to ensure that apparent changes were not largely due to these factors rather than to motorists’ responses to the features of sample sites.

Some of these matters were taken account of by the use of wide geographical areas as controls. For instance, there is incorporated in the individual control ratios for general crash reductions an implicit function of the weather and any systematic changes in the propensity to use seat belts or other relevant driver or passenger behaviour across the community. Changes beyond these community trends may justifiably be attributed to the effects of treatments at individual sites.

TABLE 5.2 CLASSIFICATION OF CRASHES BY JURISDICTION

Crash records	*NSW*	*VIC*	*QLD*	*WA*	*SA*	*TAS*	*ACT*	*NT*
CRASH-SEVERITY CODING	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal	Fatal
	Hospitalisation	Serious injury	Hospitalisation	Hospitalisation		Hospitalisation		Hospitalisation
	Medical treatment	Other injury	Medical treatment	Medical treatment	Injury	Medical treatment	Injury	Medical treatment
	First aid		First aid	First aid		First aid		First aid
	Towaway PDO		PDO	Major and minor PDO, according to whether any vehicle towed away	PDO	Towaway and other PDO	PDO	Towaway PDO; other PDOs treated as 'incidents'
CRASH-TYPE CODING	Road user movements (RUM); 'other' categories numbered x9	Definition for coding accidents (DCAs); 'other' categories numbered 1x9	RUM codes on declared roads ('other' categories numbered x9) and DCAs on official State database ('other' categories numbered 1x9)	RUM codes adopted Jan. 1989; 'other' categories originally numbered x9 then x0 from 1990	Extensive vehicle action codes from which RUM can often be inferred	7 multiple-vehicle ('angle' crashes most common) and 10 single-vehicle collision codes; expect switch to modified RUM	9 multiple-vehicle and 13 single-vehicle collision codes; expect switch to RUM	RUM codes adopted in 1990; 'other' categories numbered x9

TABLE 5.2 CLASSIFICATION OF CRASHES BY JURISDICTION (continued)

Crash records	*NSW*	*VIC*	*QLD*	*WA*	*SA*	*TAS*	*ACT*	*NT*
CRASH-TYPE CODING	Sketch and summary on police form	Sketch and description for fatality or injury collision	Sketch and summary	Sketch and summary	Sketch and description discontinued by police April 1992, replaced with standardised descriptions only	Sketch and description	Sketch and description	Sketch and description

Note 1. x represents a constant for numbers between 0 and 9 inclusive.

Source Data provided by states and territories.

Recording of information

There is the question of whether (especially when crashes are classified by injury severity and when the number of observed crashes is fairly small) differences in the wearing rates for seat belts or any high blood alcohol levels detected may have had an appreciable influence on the consequences, and hence the classification, of those crashes. As Privacy Act considerations in several jurisdictions would have made it difficult to obtain blood alcohol concentration readings within the time frame of the study, these details were not sought from the jurisdictions. Codings for the wearing of seat belts were obtained, but time did not permit the detailed analysis necessary to detect whether this was a factor in any shifts in crash-severity patterns.

The jurisdictions deal with the issue of seat belt wearing or blood alcohol detection in a number of different ways. Actual seat belt codings used include ‘worn’, ‘not worn’, ‘not fitted’ and ‘failed’, and may be combined with information collected about the usage of helmets by bicyclists and motorcyclists.

Police report forms have sections for recording seat belt wearing details for all occupants in a crash in Tasmania, for drivers and casualties in NSW and the Northern Territory, for casualties in Queensland, Western Australia (since 1989), South Australia (since 1992) and the ACT, and for drivers and occupants of vehicles in Victoria.

Numerous variations also exist in the manner in which weather and road conditions at the time of a crash are coded. Some jurisdictions just concentrate on whether roads are wet or dry when the crash occurs, and perhaps whether they are sealed or not. Several jurisdictions include separate records for the presence of other potentially adverse atmospheric conditions such as smoke or high winds.

In South Australia, the road condition data field indicates only whether it was sealed or unsealed and wet or dry while the atmospheric field states whether it was raining or not at the time of the crash. Across jurisdictions it was consistently found that up to 10 per cent of crashes on wet roads occurred after it had stopped raining.

The improved processing capacity of available information systems, and the possibility of police or others entering crash particulars directly on site using a portable computer suggest that there are prospects for upgrading the accuracy and level of detail in crash statistics and accessing this information more quickly.

Standard forms should be designed to minimise confusion among users, and special safeguards should be incorporated to prevent the entry of contradictory or incorrect data. Adams (1988b) reports that in questioning police personnel in the United Kingdom about how, when reporting crashes, they distinguished between slight and serious shock, it transpired that a number thought this referred to electric shock. Unless those responsible for recording the raw data are properly trained, and understand the implications of inaccurate data, it may be difficult to locate missing particulars or to resolve inconsistencies at a later date.

It is useful to collect certain data locally for the purpose of analysis. However, at a time when operating hardware is changing, and crash coding systems are being revised in some jurisdictions, there are opportunities for seeking national agreement on minimum crash data sets to be collected in all jurisdictions. Information and evaluation results derived from a common data set could be shared among the jurisdictions and assist in pointing to better ways of targeting available road safety funds.

EXTENT OF CRASH REPORTING

As already mentioned, amendments to Victoria's Transport Act in 1988 made it necessary for people to report crashes to the police before any insurance or compensation payments could be claimed from the Transport Accident Commission. Together with other influences (such as apparent changes in the provision of ambulance services and the degree of verification by police that people recorded as being sent to hospital were actually admitted for treatment rather than discharged as day patients) this change had a significant effect on crash reporting. Much higher numbers of minor injury and PDO crashes were recorded in 1989, but the recorded numbers of the more serious crashes declined.

Table 5.3 illustrates the changes in recorded Victorian urban crashes between 1988 and 1990 (before the recording of PDO crashes was discontinued). In spite of a change in severity classifications in 1989, it was clear that a substantial shift down the scale of injury occurred.

When reporting requirements are linked with potential loss of rights to compensation for failure to report, a much higher rate of reporting occurs. Obviously, the larger the pool of crash data available to road safety practitioners, the better are the chances of quantifying particular effects arising from interventions or treatments and valuing their benefits to society.

TABLE 5.3 SEVERITY CLASSIFICATIONS FOR VICTORIAN URBAN CRASHES (MELBOURNE STATISTICAL DISTRICT), 1988–1990

Quarter	*Fatal*	*Personal injury*[a]	*Serious injury*	*Other injury*	*Property damage/ nil injury*	*Total*
1988	**364**	**14 264**			**23 999**	**38 627**
March	80	3 366			4 924	8 370
June	105	3 817			6 092	10 014
September	92	3 567			6 670	10 329
December	87	3 514			6 313	9 914
1989	**380**		**4 842**[b]	**12 475**[b]	**19 814**[b]	**37 511**
March	101		1 196	2 965	4 418	8 680
June	100		1 332	3 552	5 203	10 187
September	103		1 250	3 181	5 506	10 040
Dececember	76		1 064	2 777	4 687	8 604
1990	**254**		**3 816**	**10 286**	**17 262**	**31 618**
March	66		1 009	2 720	4 272	8 067
June	69		975	2 718	4 415	8 177
September	62		887	2 644	4 588	8 181
December	57		945	2 204	3 987	7 193

a. Injury crashes were separated into two categories, serious injury and other injury, in 1989.

b. There may be a discontinuity from previous reported injury crash trends due to the new TAC compensation eligibility requirements introduced in May 1988.

Source Data provided by VIC ROADS.

Conservative estimates of treatment effects can be obtained from a narrow database. However, additional information, particularly on PDO crashes, can be useful in providing a more complete and balanced estimate of the overall impact of treatments. In recent years, better vehicle safety features, road engineering treatments, and other factors have combined to produce marked reductions in injury severity in the types of crashes which are expected to produce the worst injury outcomes. This means that the profiles of injury in different crash types have changed. Therefore, the use of past ratios of injury to PDO crashes to make current or future estimates (where there are gaps in PDO data) can lead to inaccuracies.

The crash-type methodology, with average injury profiles obtained on the basis of all available crashes, can produce numerical estimates of the benefits or disbenefits of particular treatments. However, the greater the number of crashes recorded and used in the analysis, the greater is the level of confidence that can be placed in any assessment of trends.

The actual degree of reporting of crashes involving different levels of injury to occupants varies among jurisdictions. The degree of compliance with reporting requirements depends on various social, cultural and geographical factors and any potential financial consequences in relation to insurance or injury compensation claims.

Under-reporting of crashes is discussed in detail in chapter 4.

DATA ON BLACK SPOT PROJECTS

The records of projects undertaken during the Black Spot Program were stored on Superbase, a database management system with substantial flexibility for the addition and modification of field characteristics or individual data entries. The database contained about 3 200 project entries, each with up to 52 individual fields for project details. As quite complex cross-sectional reports could be generated quickly, this appears to have been an adequate mechanism for storing records.

Notes on Administration

The original Notes on Administration issued for the Program (appendix I) required financial statements to be submitted to the Minister responsible for Transport as soon as practicable after 30 June each year. A 10 per cent limit was set on carry over of approved funds from one year into a subsequent year, and written notification, including provision of final cost, was required within 90 days from the physical completion of projects.

Treatments selected from the Schedule of Acceptable Treatments (table 1.1) did not require further benefit–cost justification provided they were to be applied to sites which had a recorded history of fatalities or serious injuries. It was also made clear that projects estimated to cost less than $200 000 would be given favoured consideration relative to larger projects: the aim of the Program was to encourage low-cost, high-return projects.

A number of projects in 1991–92 were merely continuations of approved work not completed at the end of the previous financial year. Although some of these carried-over projects were for very small amounts of expenditure, several jurisdictions made fresh submissions in respect of them, thereby giving them the status of 'new' projects. It therefore appears that some jurisdictions were not at that stage aware of the 10 per cent carry-over limits.

Following concerns conveyed to FORS by several jurisdictions about the reporting burden, the process for making variations to approved amounts of funding was simplified in 1992, allowing the Minister to approve an entire schedule of variations to projects rather than having to approve each one individually. Further, instead of jurisdictions having to report individually on the completion of each project, quarterly reports on project status, completed projects, and final costs, were permitted.

Gaps in the data

During the course of this study, and the pilot study which preceded it, there were serious reservations about the quality of reporting in relation to project completion times, and delays in receiving final project cost details and other important particulars. For example, many traffic signal modifications (UH2) comprised or included the installation of separate right-turn phases, which generally result in reductions in potentially serious right-turn crashes. Despite several rounds of enquiries it was not possible to establish which projects completed before 1992 included a separate right-turn phase in the treatment.

If the usefulness of accurate work-in-progress data had been stressed at the outset, and efforts made to obtain such information routinely, evaluation of the Program's benefits could have been undertaken with greater confidence.

Several Black Spot coordinators indicated that even allowing for the different possible definitions of when project work was regarded as completed, they treated dates obtained from their regions as estimates usually correct to the month, but sometimes only to the quarter. This explanation was offered in response to queries as to why projects were recorded as concluding almost invariably at the beginning or end of months in some jurisdictions. It was necessary to delete six sample projects because their completion dates fell well into 1992, and not in 1991 as earlier advised by the relevant jurisdictions. About a dozen changes to the Schedule classification of the treatments were also notified by the jurisdictions after the sample was selected.

The jurisdictions also found project costs difficult to finalise quickly as little could be done about late bills coming in from contractors or suppliers. To avoid the unnecessary creation of additional data records, a number of jurisdictions gave project managers the right to report directly to the central financial ledger.

Attempts to establish what costs, if any, were associated with project planning and implementation by the jurisdictions proved unsuccessful. The Notes on Administration made it clear that recurrent costs should not be included, nor should the costs of purchase of road-building plant or equipment.

The experience of the Black Spot Program suggests that in programs of this nature, initial guidelines should recognise the likelihood of different approaches and methods of calculation among the jurisdictions, and more detailed information should be provided by the administering authority about what can be included as project costs. For instance, it is possible that certain corporate overheads were included as part of project costs, although the BTCE is aware that this did not happen in all jurisdictions.

Further, while the storage of entries of little value or which are blank for most observations cannot be warranted, useful information can be lost if particular fields are simply updated. For instance, opportunities for making comparisons between estimated start times, finish times or costs and final outcomes depend on the creation of separate fields for revised cost data and project completion times. It will be difficult to investigate changes which occurred in the second and third years of the Black Spot Program because comparative data involving dates were not captured automatically.

FORS, which administered the Black Spot Program, was of the view that the Program was results-oriented rather than process-oriented. The intention was to administer the Program to allow participation by all states and territories with minimal interference in jurisdictional administrative matters. Thus, there was explicit recognition of alternative approaches. FORS indicated that they were aware of, for example, the differing treatment of corporate overheads. However, their concern was not that approaches differed, but that practices did not extend beyond the boundaries of guidelines. FORS acknowledges that prior planning for comprehensive evaluation would have allowed the initial specification and subsequent collection of data in the required form. However, as it turned out, evaluation planning was carried out after Program commencement.

Exposure data

One of the key statistics required for Bayesian estimates of regression-to-mean and other phenomena related to road safety is some measure of exposure to the risk of crashes.

A knowledge of traffic volumes at individual sites before and after crashes would make it possible to investigate whether changes in crash experience were significantly influenced by changes in traffic flows.

Discussions with the jurisdictions indicated that they had insufficient resources to maintain comprehensive records of traffic volumes. Some jurisdictions had a systematic program for obtaining traffic counts on major roads over a cycle of several years, while others tended to concentrate most available resources on responding to field requests for data associated with specific planned work.

In the case of the sites chosen for evaluation, it was clear from the commencement of the evaluation that 'before' exposure data would not be available for most of the sites. Nevertheless, when requesting information from the jurisdictions about crash and project management data relating to individual sites, questions were included about the annual average daily traffic (AADT) flows at these sites both before and after the implementation of the relevant treatment work.

Exposure information was received for only 58 sites in both periods sought, three of these being for sites whose late completion of treatment work necessitated their deletion from the sample. The most common feature was a 'no change' description (for 33 sites). Where changes were indicated, they were most commonly less than 10 per cent, over a period of between one and two years. Only in a few instances was it clear that the actual measurements of traffic volume that were provided had been taken over comparable periods.

Levels of exposure prior to treatment were known for 30 sites, and levels of exposure following treatment were available for 27 sites. Consequently, exposure information was unavailable for just under 60 per cent of all sites in the sample.

Discussions with a number of officers responsible for traffic flow measurements in different jurisdictions indicated general changes in metropolitan traffic flows to have been of the order of only 2 to 5 per cent in most areas over the period considered in the study. Consequently, no systematic adjustments were attempted to take account of exposure changes after treatment. However, four sites were excluded from further consideration following receipt of information that traffic patterns had changed markedly as a result of further work being carried out there or at some nearby site.

Better ways of exchanging data

While the importance of keeping costs of administration to a minimum is recognised, there do appear to be ways of improving data collection without making a substantial impact on available resources.

Significant Program administration resources were spent transferring information from hard-copy returns provided by the jurisdictions to computer systems. During this study a mixture of electronic and paper records were used, and it was quite predictably found that the electronic records were far more convenient, as they could be manipulated into a number of formats.

It is therefore recommended that at the commencement of future programs of similar scope, priority be given to negotiating general formats for electronic reporting and information exchange protocols with the jurisdictions. If these procedures are implemented, data will be captured when they are most accessible, re-keying time and errors will be reduced, and available resources can be deployed on quality control and the timely provision of feedback on ambiguities and apparent problems in the data.

FORS has noted the significant advances in information technology that have occurred since the Black Spot Program was initiated, particularly in regard to the standardisation of data formats and greater compatibility between formats. FORS has indicated that the possibility of electronic data transfer at the commencement of the Program was examined and considered not feasible. Some exchange of electronic data occurred towards the end of the Program and FORS has acknowledged that any future program would benefit from electronic data transfer.

CHAPTER 6 SELECTION OF PROJECTS FOR EVALUATION

In evaluating road safety treatment effects in the presence of seasonal variations, a complete year's post-treatment crash data is the absolute minimum required for meaningful analysis.

Having three to five years' post-treatment crash data for comparison with pre-treatment data is desirable. It allows any instability in crash or injury numbers to be set in context, and thereby enables any causal component of changes in crash experience to be separated from underlying chance factors with greater confidence. As the earliest of the Black Spot Program projects were completed in late 1990, obtaining crash data for these ideal periods of time was not possible.

ESTABLISHING THE SITES ELIGIBLE FOR EVALUATION

The normal lead times for comprehensive crash data to become available in some jurisdictions were as much as six months. Without such records, estimates of the crashes that would have occurred at the sites selected for evaluation in the absence of treatment would have involved a higher degree of uncertainty.

When the process of requesting data from the jurisdictions began in October 1993, details of crashes which occurred after the middle of 1993 were therefore not expected to be uniformly available. Consequently, Black Spot Program projects which were completed during the 1992–93 financial year were ruled out for evaluation purposes at the outset.

During the pilot study of projects in Victoria and NSW, several substitutions for projects initially selected for evaluation had to be made (BTCE 1993) because project start and finish dates were several quarters outside the previously reported time frames. Project start and finish dates were taken as indicative only, most of them probably accurate to the month, but some perhaps only to the quarter, or worse.

To safeguard against the prospect of large numbers of project substitutions being required, the cut-off date for completion of projects was set as the end of 1991. States and territories were supplied with lists of projects with actual or anticipated completion times occuring before 15 February 1992. Projects which appeared capable of meeting this criterion or for which there was no specified start or finish date were included.

Where aspects of the dates provided were anomalous (for instance, if the time taken to complete the treatment work appeared excessive for the expenditure involved), each jurisdiction was asked to verify the dates and to notify the BTCE of any changes that were necessary. Details were also requested of any other projects brought forward and finished before the middle of February 1992.

As a result of this process, the number of projects eligible for evaluation was reduced from about 750 to 558. The short list of 558 projects represented around 20 per cent of all projects with treatments drawn from the Schedule prepared by FORS (table 1.1). While selection of the projects for evaluation was complicated by very late responses from two jurisdictions, a list of selected projects was forwarded to each jurisdiction just before Christmas 1993.

PROJECT CHARACTERISTICS DURING THE FIRST HALF OF THE PROGRAM

A simple stratification of the eligible projects by jurisdiction and level of expenditure would not have been satisfactory as a basis for estimating the costs and benefits of the entire Program. This is because the composition and characteristics of the projects in the first half of the Program were different in many respects from those in the second half. The projects completed early in the Program were generally of a smaller scale than the later ones—total Program funding unexpectedly more than doubled during the life of the Program and the later projects often involved relatively more planning and extensive coordination to relocate various utilities.

As indicated in chapter 2, mean approved expenditure over the entire Program was around $79 000 for urban treatments and about $84 000 for rural treatments. By comparison, projects in urban areas completed during the first half of the Program had a mean of $68 000 (median $40 000) while projects in rural areas had a mean of $33 000 (median

$9 000). Any representative sample of projects therefore needed to be weighted towards the upper end of expenditure among first-half projects.

Some types of treatment were seldom implemented during the first half of the Program, or subsequently became increasingly common. For instance, only 17 of a total of 158 projects in the categories RH3 (site-specific edgelining), RH8 (warning and direction signs), RM1 (superelevation on isolated curves), RM2 (median barriers), RM3 (improved sight distance) and RM4 (overtaking lanes) were completed during the first half of the Program. For all of these treatments, the number of projects undertaken during the first half of the Program did not amount to more than one-eighth of their total number during the entire Program.

In the case of the rural treatment responsible for the largest amount of expenditure, RH1 (shoulder sealing), only 23 of a total of 174 projects completed during the Program could be considered for evaluation. Mean expenditure on these 23 eligible projects was less than three-quarters of the overall Program mean for this type of treatment.

Among urban treatments, only 7 of a total of 91 projects in the categories UH9 (improved pedestrian lighting), UM1 (improved skid resistance), UM4 (clearway provisions) and UM6 (red light cameras) were eligible for consideration. Of 61 Local Area Traffic Management (LATM) schemes (UM3), only four were completed in the first half of the Program, none of them costing more than $50 000. Discussions with LATM designers suggested that at least 12 months were necessary for community consultation and decision making before one of these schemes could be successfully implemented.

Selective roadside hazard modification (UH8) involved expenditure of nearly $15 million overall, but only 9 of the 125 projects were completed before 1992, at a total cost of around $1 million. Even roundabouts, which accounted for the largest share of Black Spot Program funds with $40 million spread over 405 approved projects, conformed to this pattern: only 49 were completed during the first half of the Program.

The marked increase in projects undertaken during the second half of the Program meant that it was impossible to select sufficient projects involving some treatments implemented prior to 1992 to form part of a representative sample of projects undertaken during the entire Program.

On the other hand, well over half the RH5 (curve delineation) projects and nearly two-fifths of the RH6 (pavement markers, guide posts and corner cube reflectors) projects were completed in 1990 or 1991. In the Program’s first year, a very large number of low-cost signage proposals were approved in Queensland, making mean expenditures in these categories during the first half of the Program only half those for the overall Program. Only five of the 66 projects involved were selected for evaluation.

Another situation encountered was where virtually all the projects within a particular treatment category and range of expenditure were carried out in one jurisdiction. For instance, all the small roundabouts (costing less than $20 000) completed by the end of 1991 were constructed in Tasmania, whereas over the entire Program, one in three such roundabouts were sited elsewhere. About half the RH6 treatments were applied outside Queensland, but only two of them were completed by the end of 1991.

Given this set of imbalances, it was concluded that no straightforward sampling technique applied to the eligible projects could produce a grouping representative of the whole Program. Therefore, in order to help generate reliable estimates of Program benefits and costs, the initial focus had to be on overall Program expenditure and project numbers.

PROCEDURES FOR SELECTING THE SAMPLE TO BE EVALUATED

Related to the problem of quantifying crash reduction benefits was the challenge of estimating the crash reduction effects of some of the treatments most commonly applied. To attain this second objective, sufficient sites at which these treatments were applied needed to be selected to enable some firm conclusions to be drawn.

The pilot study experience of 5 to 10 crashes per site per year (BTCE 1993) indicated that 10 sites would often not be sufficient to make confident estimates about the impact of treatments on different types of crashes, especially in light of the limited post-treatment data that were available. In some circumstances even 20 projects involving a particular treatment might not be enough for this purpose.

Six urban treatments accounted for over 80 per cent of both the number of projects and approved funding. They were UH1 (new traffic signals), UH2 (modification of traffic signals), UH3 (intersection channelisation), UH4 (provision of medians), UH7 (installation of roundabouts) and UH8 (selective roadside hazard modification).The small number of available projects in the UH8 category has already been mentioned. There were only 29 median projects, over half of them costing less than $50 000 each, and 143 modifications of traffic lights of which more than two-thirds cost less than $50 000. The three remaining treatment categories had between 49 and 73 projects, with four-fifths of the new traffic lights and half the roundabouts costing more than $50 000.

Considering these relative magnitudes, if the effects of other urban treatments were also to be properly evaluated, it was necessary to choose at least 200 projects with UH and UM treatments for detailed study.

In the case of rural treatments, three treatments, RH1 (shoulder sealing), RH4 (selective roadside hazard modification) and RH6 (pavement markers, guide posts, and corner cube reflectors), accounted for 60 per cent of both the number of projects and available funds. The spread of project numbers and expenditure for other rural treatments was wider than for urban treatments.

The large number of low-cost RH6 projects and the late implementation of RH1 treatments have already been mentioned. To enable meaningful estimates of rural treatment effects to be made, it was necessary to select a minimum of 50 rural projects, which together with the 200 urban projects amounted to an overall minimum of 250 projects for the Black Spot Program evaluation.

Use of total Black Spot Program expenditure

The decision to select at least 250 projects for evaluation was the starting point in an intricate sampling process. In the first instance, known Black Spot Program expenditure (either approved, or as varied and subsequently recorded) was calculated for each treatment type, and a notional allocation made of one project to be evaluated for each million dollars of expenditure.

The 18 sites where the UH9, RH3, RH8, RM1 and RM2 treatments were applied involved such low expenditure that none of them could sensibly be chosen for evaluation. A total of $22 million had been spent on roadside hazard modification (UH8 and RH4). However, only nine UH8 treatments had been completed, five of them quite minor, and only four RH4 projects could be considered for selection.

It was noted earlier that projects involving roundabouts took some time to come on stream. Even though overall expenditure on roundabouts was respectively 15 to 40 per cent higher than that for new and modified traffic signal projects, the number of projects available for inclusion in the sample was relatively small. Unless a disproportionate number of minor projects involving roundabouts were to be included, 35 projects was about the maximum number that could be chosen for evaluation.

Similarly, for rural shoulder sealing, only by including all treated sites could the notional expenditure-related allocation be reached. One effect of such a decision would have been to make the sites chosen for evaluation depart sharply in mean expenditure from the overall pattern of the Program, giving rise to the possibility of misleading estimates of Program effectiveness. To ensure representativeness, the number of rural shoulder sealing projects to be included in the sample was restricted to 15.

The considerations discussed above, together with the impact of minor numbers of some treatments, led to the reassignment of over 40 sample projects. Consequently, 15 extra new traffic signal installations, 20 more modifications of traffic signals, and five additional intersection channelisation projects were included in the sample.

Where possible, the number of projects within a moderate or large grouping of projects was rounded up to the next highest multiple of five for the purpose of improving effectiveness estimates. The number of projects in some small treatment categories were adjusted downwards when it was not possible to include many projects costing at least $50 000.

This process produced the initial target of around 250 projects. The provisional selected sample included 50 UH1 projects (new traffic signals), 50 UH2 (modified traffic signals), 30 UH3 (intersection channelisation), 10 UH4 (medianisation), 35 UH7 (roundabouts) and 10 UM2 (protected turning bays) among the urban treatments. The main rural treatments which could be evaluated were shoulder sealing (RH1) and hazard modification (RH4) both with 15 projects.

Stratifying by level of expenditure and selection ratios

At this point in the selection process, the eligible population of projects was segmented into four streams: minor projects with expenditure less than $20 000 (228 projects); small projects each costing between $20 000 and $50 000 (123 projects); medium projects costing between $50 000 and $100 000 (104 projects) and major projects requiring an outlay of at least $100 000 each (103 projects). It was therefore necessary to reduce the number of smaller projects in the sample relative to the number of larger projects.

A reduction in the number of major projects in the selection process, even to the extent of about 20 per cent, would have had as a virtually inevitable consequence the inclusion of a disproportionate number of minor projects. This would have focused excessive evaluation effort on projects on which relatively small amounts had been spent, while producing less reliable estimates of the benefits gained from larger projects on which nearly 75 per cent of total funds were spent.

Consequently, all 103 projects with expenditure of at least $100 000 were included in the evaluation sample. As one of the projects consisted of a grouping of a number of Victorian projects, in its place two specific sites from that group were included in the sample.

The next step was to decide what proportions (‘selection ratios’) of the remaining three expenditure categories to adopt for the sample. As in the pilot study, in order to maximise the reliability of estimates, selection for inclusion in the sample was to be more likely as the level of expenditure on projects increased. It became clear that including slightly more than half the medium-sized projects was desirable and that perhaps a bit less than half the small ones should be targeted, with somewhere between one in six and one in ten for the minor ones.

However, at this point, the composition of the rural treatments in the first half of the Program had to be taken into account. Only 13 of the 159 eligible projects were in the major expenditure category, while 98 involved expenditure less than $20 000 and 29 were in the small expenditure category. Because of the large number of minor expenditure projects completed during the first half of the Program, median expenditure for all eligible projects was only $9 000 while their mean was just under $33 000.

To select a group of projects more representative of the rural part of the Program, it was necessary to include further medium and small projects at the expense of minor ones. The minor projects comprised only one-third of total Program projects, compared with nearly two-thirds of these projects completed during the first half of the Program.

The final selection ratios were around 0.6 for medium projects, 0.5 for small projects, 0.2 for minor urban projects and 0.1 for minor rural projects.

Table 6.1 sets out the composition and mean expenditure of eligible urban projects by jurisdiction. The number of projects chosen for evaluation from each jurisdiction and the mean expenditure for those projects are shown in brackets underneath the numbers of eligible projects and their mean expenditure. Total eligible projects are also shown for each jurisdiction.

TABLE 6.1 URBAN TREATMENTS, ELIGIBLE AND SAMPLE PROJECTS[a] BY PROJECT EXPENDITURE AND JURISDICTION

Urban	*Mean expenditure ($)*	*Minor*[b]	*Small*[c]	*Medium*[d]	*Major*[e]
ACT, 15	65 000	5	6	1	3
(7)	(116 000)	(0)	(3)	(1)	(3)
NSW, 62	65 000	17	17	16	12
(40)	(80 000)	(6)	(8)	(14)	(12)
NT, 2	220 000	0	0	0	2
(2)	(220 000)	(0)	(0)	(0)	(2)
QLD, 38	81 000	4	9	14	11
(26)	(97 000)	(0)	(7)	(8)	(11)
SA, 76	64 000	23	15	18	20
(39)	(100 000)	(4)	(6)	(9)	(20)
TAS, 30	21 000	21	6	2	1
(13)	(33 000)	(6)	(4)	(2)	(1)
VIC,105	81 000	44	20	16	25
(50)	(147 000)	(7)	(9)	(9)	(25)
WA, 71	66 000	16	21	18	16
(39)	(95 000)	(2)	(10)	(11)	(16)
AUSTRALIA	Selection ratio	25/130 = 0.19	47/94 = 0.5	54/85 = 0.64	90/90 = 1

a. Details of eligible projects are shown without brackets and details of sample projects are shown in brackets.
b. Less than $20 000.
c. $20 000 to less than $50 000.
d. $50 000 to less than $100 000.
e. $100 000 and over.

Source BTCE estimates based on data provided to FORS by the states and territories.

As can be seen from the table, about half of the eligible projects were generally chosen. In NSW and Queensland, the proportion was more like two-thirds, in the first instance because of a need to compensate in the national mix for the relatively small number of projects completed early in NSW, and in the case of Queensland because a host of low-cost rural treatments could not be considered for evaluation.

Table 6.2 provides the same information for rural treatments as table 6.1 does for urban treatments. The number of projects chosen for evaluation and their mean expenditure are shown in brackets.

Very low mean expenditures in Tasmania and Queensland meant that much lower proportions of their rural projects were selected than for NSW, South Australia and Victoria.

Geographical considerations

The selection of projects for evaluation was undertaken with three main objectives:

- to choose a group of projects through which reliable estimates of national costs and benefits for the entire Program could be made;
- to have adequate numbers of projects relating to particular types of treatments in order that estimates of their crash reduction effects could be made; and
- to obtain a geographical spread of project sites in order that appropriate urban or rural areas could be used as control groups (see chapter 4).

Because of the above considerations, the projects chosen for inclusion in the sample may not constitute an overall Program cross-section for a particular state or territory when either the urban / rural or project expenditure mix is considered. By themselves, the chosen projects may therefore not provide a reliable indication of the overall relationship between Program costs and benefits in each state or territory, although they can be combined reasonably well for estimation on a national basis.

For example, there was a relative scarcity of NSW projects in the eligible population, and although the few rural projects were of a fairly large scale, the urban projects were at the lower end of the expenditure range. In the selection process, NSW sites tended to be favoured to ensure that the composition of the sample did not reflect an excessive divergence from relative expenditure levels.

TABLE 6.2 RURAL TREATMENTS, ELIGIBLE AND SAMPLE PROJECTS[a] BY PROJECT EXPENDITURE AND JURISDICTION

Rural	*Mean expenditure ($)*	*Minor* [b]	*Small* [c]	*Medium*[d]	*Major* [e]
ACT, 1 (1)	122 000 (122 000)	0 (0)	0 (0)	0 (0)	1 (1)
NSW,12 (8)	104 000 (129 000)	1 (1)	3 (0)	4 (3)	4 (4)
QLD, 95 (19)	13 000 (42 000)	79 (7)	10 (7)	5 (4)	1 (1)
SA, 12 (7)	70 000 (126 000)	1 (1)	5 (1)	3 (2)	3 (3)
TAS, 10 (3)	24 000 (40 900)	6 (1)	2 (1)	2 (1)	0 (0)
VIC, 28 (15)	48 000 (65 000)	10 (3)	9 (6)	5 (2)	4 (4)[f]
WA, 1 (0)	8 000	1 (0)	0 (0)	0 (0)	0 (0)
AUSTRALIA	Selection ratio	13/98 = 0.13	15/29 = 0.52	12/19 = 0.63	13/13 = 1

a. Details of eligible projects are shown without brackets and details of sample projects are shown in brackets.
b. Less than $20 000
c. $20 000 to less than $50 000
d. $50 000 to less than $100 000
e. $100 000 and over
f. One large composite project was subsequently split into two of its much smaller component parts.

Source BTCE estimates based on data provided to FORS by the states and territories.

In the case of Tasmania, on the basis of the size of projects, a much lower proportion than in other jurisdictions would have been chosen. Hence to ensure that selection in Tasmania was more consistent with other jurisdictions, an additional three projects were chosen. This final adjustment in the selection process increased the sample of projects to 270.

Table 6.3 illustrates, for each jurisdiction, the relationship between both the numbers of eligible and chosen projects and their mean levels of expenditure, as well as indicating mean levels of expenditure per project for the entire Program.

TABLE 6.3 KEY PROJECT PARTICULARS BY JURISDICTION

Jurisdiction	*Eligible projects*	*Sample projects*	*Major projects*[a]	*Mean eligible expenditure ($)*	*Mean sample expenditure ($)*	*Mean Program expenditure*[b] *($)*
ACT	16	8	3	69 000	117 000	132 000
NSW	74	48	16	71 000	88 000	100 000
NT	2	2	2	220 000	220 000	149 000
QLD	133	45	12	32 000	73 000	66 000
SA	88	46	24	65 000	105 000	75 000
TAS	40	16	1	22 000	37 000	45 000
VIC	133	66	29[c]	75 000	127 000	95 000
WA	72	39	16	65 000	95 000	71 000
AUST	558	270	103	58 000	98 000	83 000

a. Major projects are those with expenditure of $100 000 or more.

b. As the Program means are based on actual, rather than approved, expenditure for completed projects, they differ from entries in tables 2.7 and 2.8.

c. One large composite project was subsequently split into two of its much smaller component parts.

Source BTCE estimates based on data provided to FORS by the states and territories.

Of the 103 major expenditure projects which were automatically included, 18 from NSW and Victoria were projects that were included in the pilot study (BTCE 1993). It was decided to include all projects that comprised the sample used in the pilot study and this meant that an additional 33 projects were added involving a number of different treatments (there was a total of 51 projects in the sample for the pilot study). The remaining 134 projects (to make up the sample of 270) were chosen treatment by treatment, with reference to the eligible projects in each expenditure category and the geographical spread of project locations already determined for each state and territory.

As the traffic signal projects were the greatest in number, their selection was held back until the very end of the exercise to retain maximum flexibility for meeting the geographical objective of spreading the projects across wider metropolitan or rural areas. Such wider areas could therefore be used as control areas to facilitate a better assessment of the likely crash experience at the chosen sites in the absence of treatment.

The rural projects were chosen first, bearing in mind the desirability of spreading them around each jurisdiction as well as incorporating the projects of as many of the states and territories into the sample as was possible. Projects for which expenditure had been less than $5 000 were generally avoided unless their number was so great that their absence would have meant that the sample did not reflect the whole range of expenditure.

In a few instances where a slightly higher proportion of small urban projects was selected relative to medium projects, it was because of the need to maintain a balance in terms of the geographical spread of projects.

Table 6.4 summarises the outcome of the selection process for each rural treatment by expenditure category, giving numbers of projects chosen in brackets. It also includes information about the relative numbers of eligible and selected projects.

Table 6.4 highlights how the project selection process pushed mean project expenditure levels much closer to those for the Program as a whole. At best, there were prospects of estimating crash-reduction effects for five different treatments (RH1, RH4, RH6, RH9 and RM6), but none of these treatments had sufficient projects to enable further assessment of whether the level of expenditure had a significant impact on crash reduction.

Table 6.5 shows the composition of eligible urban projects by level of expenditure, and indicates the choices which were made.

With the relatively larger number of urban projects selected for evaluation, it appeared possible to make comparisons of BCRs at different expenditure levels for some of the more commonly applied treatments. In that case, appropriately weighting the BCRs for each expenditure level would have provided a better estimate of overall Program effectiveness of a particular treatment than just making a single estimate based on all the relevant projects involved in that treatment.

After the selection process was completed, 16 projects had to be eliminated from the sample. This was because for some projects the completion dates were well into 1992, and for others because additional work at or near the site made comparisons unsound, or because it turned out that the level of Black Spot Program funding finally attributed to them was minor. Several jurisdictions subsequently provided information about improved classification of projects according to the

TABLE 6.4 RURAL PROJECTS[a], COMPOSITION OF SAMPLE BY TREATMENT AND EXPENDITURE

Treatment[b]	*Minor*[c]	*Small*[d]	*Medium*[e]	*Major*[f]	*Mean expenditure ($)*	*Median expenditure ($)*
RH1, 23 (15)	2 (0)	9 (5)	7 (5)	5 (5)	76 000 (92 000)	61 000 (72 000)
RH2, 11 (2)	5 (1)	6 (1)	0	0	20 000 (22 000)	25 000 (22 000)
RH3, 4 (0)	4 (0)	0	0	0	3 000	3 000
RH4, 24 (15)	8 (3)	8 (7)	6 (3)	2 (2)[g]	48 000 (49 000)	33 000 (37 000)
RH5, 31 (2)	30 (2)	1 (0)	0	0	5 000 (11 000)	4 000 (11 000)
RH6,40 (5)	38 (4)	2 (1)	0	0	5 000 (15 000)	2 000 (15 000)
RH8, 5 (0)	5 (0)	0	0	0	3 000	2 000
RH9, 6 (5)	1 (1)	2 (1)	1 (1)	2 (2)	115 000 (133 000)	51 000 (81 000)
RM1, 1 (0)	0	0	1 (0)	0	98 000	98 000
RM2, 1 (0)	1 (0)	0	0	0	5 000	5 000
RM3, 2 (0)	1 (0)	0	1 (1)	0	80 000 (80 000)	80 000 (80 000)
RM4, 4 (2)	1 (0)	0	1 (0)	2 (2)	80 000 (126 000)	76 000 (126 000)
RM6, 7 (6)	2 (2)	1 (0)	2 (2)	2 (2)	73 000 (78 000)	80 000 (80 000)

a. Details of eligible projects are shown without brackets and details of sample projects are shown in brackets.

b. Subsequent advice from various jurisdictions necessitated a reclassification of some treatments.

c. Less than $20 000.

d. $20 000 to less than $50 000.

e. $50 000 to less than $100 000.

f. $100 000 and over.

g. One large composite project was subsequently split into two of its much smaller component parts.

Source BTCE estimates based on data provided to FORS by the states and

TABLE 6.5 URBAN PROJECTS[a], COMPOSITION OF SAMPLE BY TREATMENT AND EXPENDITURE

Treatment [b]	*Minor* [c]	*Small* [d]	*Medium*[e]	*Major* [f]	*Mean expenditure ($)*	*Median expenditure ($)*
UH1, 68 (52)	1 (0)	10 (7)	27 (15)	30 (30)	104 000 (116 000)	91 000 (108 000)
UH2, 135 (60)	62 (11)	31 (14)	21 (14)	21 (21)	49 000 (85 000)	24 000 (59 000)
UH3, 57 (30)	22 (5)	15 (7)	9 (7)	11 (11)	58 000 (94 000)	25 000 (68 000)
UH4, 27 (12)	6 (1)	9 (4)	8 (3)	4 (4)	43 000 (89 000)	45 000 (73 000)
UH5, 10 (3)	5 (1)	1 (0)	2 (0)	2 (2)	44 000 (85 000)	20 000 (102 000)
UH6, 12 (2)	8 (1)	4 (1)	0	0	15 000 (21 000)	7 000 (21 000)
UH7, 48 (36)	10 (4)	12 (8)	13 (11)	13 (13)	108 000 (134 000)	56 000 (69 000)
UH8, 9 (5)	5 (1)	1 (1)	1 (1)	2 (2)	109 000 (189 000)	18 000 (90 000)
UH9, 3 (0)	2 (0)	1 (0)	0	0	22 000	18 000
UM1, 3 (2)	1 (0)	1 (1)	0	1 (1)	54 000 (80 000)	32 000 (80 000)
UM2, 19 (10)	7 (1)	5 (3)	4 (3)	3 (3)	56 000 (86 000)	46 000 (61 000)
UM3, 4 (1)	1 (0)	3 (1)	0	0	26 000 (48 000)	27 000 (48 000)
UM5, 3 (2)	0	1 (0)	0	2 (2)	120 000 (164 000)	109 000 (164 000)
UM6, 1 (1)	0	0	0	1 (1)	106 000 (106 000)	106 000 (106 000)

a. Details of eligible projects are shown without brackets and details of sample projects are shown in brackets.
b. Subsequent advice from various jurisdictions necessitated a reclassification of some treatments.
c. Less than $20 000.
d. $20 000 to less than $50 000.
e. $50 000 to less than $100 000.
f. $100 000 and over.

Source BTCE estimates based on data provided to FORS by the states and territories.

Schedule of treatments, or variations in actual expenditure, so there may be minor departures from the numbers provided in tables 6.4 and 6.5. Appendix XII provides some basic particulars relating to each project included in the evaluation sample and not subsequently dropped.

ESTIMATING PROGRAM BENEFITS FROM SAMPLE PROJECT BENEFITS

While there is no certainty that crash reduction effects during the first half of the Program are comparable with those for the second half, the detailed process of stratification by expenditure and geographical dispersion described above provides a means for estimating total crash reduction benefits for the Program.

The benefits resulting from the four separate expenditure categories can each be increased in proportion to the ratio the overall Program expenditure in that category bears to the expenditure for the corresponding projects selected for evaluation. The four separate estimates of Program benefits by each category of expenditure can then be aggregated to estimate total Program benefits.

TABLE 6.6 PROJECT DETAILS FOR THE SAMPLE AND PROGRAM BY EXPENDITURE LEVEL

Expenditure level [a]	*Projects*	*Number of projects*	*Total expenditure ($)*	*Mean expenditure ($)*
Major	Sample	95	18 381 956	193 500
	Program	802	170 762 239	212 900
Medium	Sample	62	4 471 612	72 100
	Program	622	43 281 868	69 600
Small	Sample	63	2 213 804	35 100
	Program	721	23 251 823	32 200
Minor	Sample	34	420 696	12 400
	Program	813	7 397 714	9 100
TOTAL[b]	Sample	254	25 488 068	100 300
	Program	2 958	244 653 644	82 700

a. Minor, less than $20 000; small $20 000 to less than $50 000; medium, $50 000 to less than $100 000; and major, $100 000 and over.

b. The total of 2 951 projects which can be obtained from tables 2.7 and 2.8 was based on available project details at the time of that analysis.

Source BTCE estimates based on data provided to FORS by the states and territories.

Table 6.6 compares mean expenditures for each expenditure category for the 254 projects finally included in the sample, with those for projects approved and completed for the entire Program. Although there were further variations subsequently advised to FORS by the jurisdictions in the expenditure reconciliation process, it is not expected that the overall proportions would have changed significantly.

CHAPTER 7 CRASH TRENDS BETWEEN 1988 AND 1992

THEORETICAL ASSUMPTIONS ABOUT CRASH DISTRIBUTIONS

Much of the literature dealing with crash reductions consequent to safety interventions assumes there is a constant underlying mean annual crash rate at individual sites. Such an assumption can only be made in circumstances where crash numbers fluctuate somewhat from year to year, but are not subject to marked upward or downward trends.

Various models have been suggested for the analysis of crash data, either at individual sites or collections of them. These include the use of the Poisson distribution, negative binomial distribution and various compound or generalised Poisson models (Kemp 1973), and the logarithmic series distribution (Andreassen and Hoque 1986). A Poisson distribution has usually been assumed for crashes at a particular intersection in the course of a year, on the theoretical basis that the number of crashes can be approximately modelled as a collection of rare events arising from a very small but constant probability of impact as two vehicles approach the intersection. It has been noted that in some cases the observed spread of crash numbers has been greater than or less than that expected for a Poisson distribution whose mean and variance are equal (Nicholson 1985).

As discussed in chapter 4 and appendix VI, a part of the apparent reductions in crash numbers following treatments has sometimes been ascribed to the regression-to-mean effect. In such studies, for the sake of mathematical convenience, it is usually further assumed that the mean crash rates at a group of sites similar to those where treatment work has been carried out come from a gamma distribution (appendix VI). In these circumstances, the observed numbers of crashes in the group of similar sites come from a negative binomial distribution. Apart from the tasks of verifying that the experience at individual sites is consistent with the Poisson distribution assumption and that site means follow a gamma distribution with particular parameters, there is also the question of identifying which sites should be included in the group that is defined to be similar to the treated sites.

During the early 1980s when aggregate crash numbers were reasonably steady or just increasing slowly, provided it was possible to identify sufficient sites with characteristics similar to those at the treated sites, the ‘constant underlying distribution’ assumption mentioned above may have been justifiable, or at least provided a starting point for plausible approximation. However, by the late 1980s, the combination of a number of factors led to overall crash numbers falling at a very rapid rate, making assumptions of constant underlying crash rates at individual sites rather difficult to sustain.

CHANGES IN CRASH TRENDS BETWEEN 1988 AND 1992

Several factors have contributed to the marked decline in crashes. These include campaigns for targeting particular problems, and enforcement of legislation aimed at producing a safer road environment. A statistical analysis by Pettitt et al. (1992) found that a decline in economic activity was associated with significant reductions in crash numbers in 1990 and 1991.

Table 7.1 shows how the numbers of crashes of different levels of severity varied in the period between 1988 and 1992 covered in this study. As noted in chapter 5, the different criteria which apply for reporting and recording crashes in the jurisdictions mean that these numbers represent varying cross-sections of all crashes which occurred.

The number of fatal crashes in Australia fell by just over 20 per cent over the period 1988 to 1990 and by just under one-third over the period 1988 to 1992. As can be inferred from the table, the number of fatal crashes in 1992 was over one-quarter less than the mean number during the years 1988 to 1990.

Hospitalisation crashes dropped by nearly 10 per cent between 1988 and 1990 and by just under one-quarter over the full five years, reflecting a pattern of improvement different from that for fatal crashes. After a slight increase in 1989, major decreases occurred over the next three years. The number of hospitalisation crashes in 1992 was one-fifth less than the mean number between 1988 and 1990.

TABLE 7.1 RECORDED CRASHES IN AUSTRALIA BY DEGREE OF INJURY SEVERITY, 1988–92

Crashes	*1988*	*1989*	*1990*	*1992*	*Comparison (per cent)*[a]
Fatal	2 572	2 406	2 051	1 738	74
Hospitalisation	22 034	22 186	20 016	17 041	80
Other injury	55 599	56 639	52 407	45 711	83
PDO[b]	119 375	121 403	116 465	106 474	89
Total crashes	199 580	202 634	190 939	170 964	86

a. The ratio of the number of crashes in 1992 to the mean of those in 1988,1989 and 1990, corresponding to the 'before' and 'after' periods used in this study.

b. As Victorian PDO data were not available after 1990, they have been excluded from earlier years to facilitate comparisons.

Source BTCE estimates based on data provided by states and territories.

Other injury crashes (estimated in the case of Victoria), where on-the-spot first-aid treatment or medical treatment elsewhere was required, decreased by 6 per cent up to 1990, and fell by nearly one-fifth over the period 1988–1992. Again, the pattern was of smaller improvements than for more serious injury crashes, and of moderate annual gains after an increase in 1989. The number of crashes experienced in 1992 was one-sixth less, on average, than that between 1988 and 1990.

Recorded PDO crashes fell by 2.5 per cent between 1988 and 1990 and declined by a further one-tenth up to 1992, again indicating steady improvement after an initial increase. Recorded non-injury crashes in 1992 declined by just over one-tenth from the mean number between 1988 and 1990.

Shifts of this magnitude, indicating marked drops in aggregate numbers of crashes, with the greatest impact on those crashes with the most severe injury consequences, are not consistent with an assumption of constant underlying crash rates at individual sites. Evidence of atypical behaviour at black spot sites compared with trends elsewhere would be needed to sustain such an assumption. In particular, in order to credibly assume that Poisson distributions with constant means at individual sites did apply, it would have to be shown that there was no declining trend during the pre-treatment period from 1988 to 1990.

It was found that the sites chosen for evaluation generally had even greater drops in crashes from year to year than those experienced in the wider community, making assumptions of constant underlying crash rates in either the period prior to treatment, or that following treatment, quite untenable. In these circumstances, any conclusions drawn from comparisons of means from two assumed different Poisson distributions would not have been soundly based. Further, the absence of more than one year's post-treatment crash data would have posed problems in regard to the reliability of any assessment of changes in crashes during the period after treatment.

Annual shifts in numbers of crashes also varied considerably between jurisdictions, although the general patterns were of reductions in numbers of crashes. These reductions usually became greater in percentage terms as the level of injury severity rose.

Fatal crash numbers rose initially in the Northern Territory, Victoria and Western Australia during 1989. By the end of 1992, however, fatal crashes had been reduced by one-third or more in the ACT, NSW and Victoria, by nearly one-third in South Australia, one-quarter in Queensland, about one-eighth in Tasmania and Western Australia, and one-tenth in the Northern Territory.

Hospitalisation crashes started to rise in both territories, Tasmania, Victoria and Western Australia. By the end of 1992, in Queensland they were marginally higher than they had been in 1988, while in Western Australia and the ACT they were marginally lower. On the other hand, South Australia and Victoria experienced reductions of around one-third over the period 1988 to 1992, Tasmania and NSW over one-quarter, and the Northern Territory around one-sixth.

Injury crashes not involving fatality or hospitalisation fell by one-third in Victoria but data about PDO crashes were not available for the entire period. The numbers of medical injury crashes went up noticeably in Queensland and the ACT over the five-year period. They fell by around one-third in NSW, around one-sixth in South Australia and the Northern Territory, one-seventh in Western Australia and one-fifteenth in Tasmania.

Between 1988 and 1992, PDO crashes rose in Queensland and South Australia, fell only marginally in Tasmania, decreased around 15 per cent in NSW and both territories, and dropped by nearly one-quarter in Western Australia. Some of the change in Western Australia was attributable to an increase, late in 1988, in the reporting threshold for damage incurred, from $300 to $600. However, there was also a steady downward progression in crashes after 1990, suggesting that a substantial portion of the overall change arose from actual improvements in road safety.

Table 7.2 provides a comparison of the three most severe injury categories (fatal, hospitalisation and medical treatment) between 1988 and 1992 for each state and territory. The least severe injury category, first aid crashes, has been excluded because not all jurisdictions record these crashes, and because some variations in recorded crashes from year to year appear to be more a result of changes in reporting or recording practice than actual crash experience.

In light of this complex set of crash patterns, there would have been obvious pitfalls in establishing changes in crash numbers for Australia and then applying uniform control ratios to estimate what would have happened at individual black spot sites in the absence of treatment. This is because the proportions of crashes in the different jurisdictions could be expected to vary widely from treatment to treatment as the composition of the sample of treated sites showed substantial fluctuations.

TABLE 7.2 COMPARISON OF INJURY CRASH NUMBERS BETWEEN 1988 AND 1992 IN JURISDICTIONS

Crash category	*Fatal*		*Hospitalisation*		*Medical treatment*	
	1988	*1992*	*1988*	*1992*	*1988*	*1992*
State/territory						
ACT[a]	31	20	162	155	294	395
NSW	912	576	6 869	5 097	18 283	12 384
NT	46	42	321	270	409	330
QLD	483	363	3 216	3 218	3 602	4 111
SA	206	142	1 934	1227	3 419	2 814
TAS	68	59	522	374	862	805
VIC	681[b]	365	7 270[b]	4 746	16 632[b]	11 176
WA	88	77	1 334	1 322	6 089	5 211

a. ACT data exclude off-road crashes.

b. Data are from 1989 and comprise the categories fatal, serious injury and other injury.

Source BTCE estimates based on data provided by states and territories.

A uniform weighting of general community trends in the different jurisdictions could not therefore be applied to help determine the effects of different treatments. No assessment of the effects of treatment could be satisfactorily undertaken without reference to the different local crash trends. As it turned out, the composition of crashes at sample sites in the period before treatment did change markedly from treatment to treatment, and therefore the application of localised control ratios was essential.

FUTURE CRASH TRENDS

Because the crash trends from 1988 to 1992 varied widely for different levels of injury severity, caution was also required in adapting estimates of costs provided in previously published research. Simply indexing such costs could not be justified without first verifying that more recent patterns of crashes remained close enough to previous patterns to warrant this.

Although the research team did not expect to be able to collect complete 1993 data for this study at the time the request for crash particulars for sample sites was made to jurisdictions, these data became available as part of late data returns from some jurisdictions. It was noticeable that crash numbers at sample sites rose from the levels experienced in 1992, just as did crashes throughout the entire community. The gap between observed changes in crashes at sample sites and those occurring in the wider community may still have remained the same. In that case, the projection forward of a constant stream of crash reduction benefits would be justified.

On the other hand, it is possible that the gap has become narrower or wider, and that this deviation will continue fairly systematically into the future. Under such circumstances, that phenomenon should be incorporated within the future stream of benefits, perhaps simply by incorporating a constant percentage widening or narrowing each year.

In the early 1990s a number of states and territories adopted crash reduction targets under their road safety strategies, in some cases aiming for substantial general decreases in the years ahead. For instance, the Roads and Traffic Authority of NSW set a target of a 25 per cent reduction in the level of serious casualties over the 1990s (RTA 1992).

Following a major road safety conference, ‘Safely on the Road to the Year 2000’, in Canberra in October 1993, work on a national action plan for road safety was expedited. In June 1994, state and territory transport ministers agreed to implement 11 short-term initiatives. Some of these initiatives involved publicity and enforcement activity, some dealt with drinking and driving, others with the most vulnerable road users, and several with road safety audits and national coordination of black spot eradication efforts. Potential road safety improvements flowing from such initiatives, and any tendency for the impact of treatment work at the sites to degrade over time, would tend to cause a reduction in the treatment effect over future years.

On the other hand, a resurgence in economic activity might add sufficiently to traffic volumes and distances travelled to balance or outweigh the impact of concerted crash reduction efforts. In that case, if the reductions in crash numbers at sample sites remained fairly constant, the effect of the relevant treatments would be greater with the passing of time.

As it is not certain whether the treatment effect at individual black spot sites will remain much the same as it was in 1992, or alter systematically in some way, no attempt was made to adjust the stream of crash reduction benefits upwards or downwards after 1992. Sensitivity testing might be carried out using constant annual adjustment factors of say 2, 5 and 10 per cent upwards and downwards to reflect a range of different possible changes in treatment effects in future years.

Despite the various uncertainties outlined above, the data relating to general community crash trends strongly suggest that even in the complete absence of treatment at the sample sites, falls in the numbers of crashes could have been expected immediately after the treatment period. If these trends had not been taken into account, the benefits attributable to the Black Spot Program would have been grossly overstated.

DETERMINING APPROPRIATE CONTROL SITES

As discussed in chapters 4 and 5, the most rigorous methodologies of a ‘before and after’ nature involve paired comparisons of very similar sites, of which one, chosen at random, is treated while the other is not. In these cases, the treatment effect can be estimated by examining the differences in crash numbers at both sites in the period after the work at the treated site has been completed. As sites were chosen for treatment before an evaluation methodology was established, this procedure could not be implemented.

A slightly less rigorous approach involves finding suitable comparison sites after the event, and estimating treatment effects by comparing the crash experience of the treated and untreated sites. Such an approach relies on the ability to identify untreated sites whose key characteristics are virtually the same as those of the treated sites. However, in the absence of systematic data on exposure and other factors related to the degree of risk at the sites, even this level of methodological rigour was not possible.

An attractive related possibility is to compare crashes at treated sites with crashes in their immediate vicinity in order to estimate what would have happened in the absence of treatment. While there is always a degree of subjectivity about defining the precise limits of such control areas, the immediate local government area would have been one possibility if relevant crash data had been readily available.

The research team explored the possibility of obtaining suitable localised control data with a number of jurisdictions, even though they recognised that such a procedure might be difficult to apply to an extensive national evaluation. Because of the manner in which crash locations are generally coded in databases (as described in chapter 5) the task of extracting summary records for an entire council area would have been a burdensome one in most jurisdictions. Though methodologically appealing, this particular course was not pursued further due to the practical difficulties involved. Instead, the process of site selection chosen (described in chapter 6) involved selecting those wider urban or rural areas, for which summary statistics were conveniently available, to serve as the control areas.

During the selection process, sites were deliberately spread around metropolitan areas in such a manner that it could be reasonably expected that general trends influencing crashes in the community would also apply to these sites as a group, or as sub-groups segmented by the particular treatment applied. In this case, estimating the treatment effect would be a matter of taking the difference between the crashes observed at the sites after treatment, and the expected crashes estimated by applying the community trends over the same period.

There may well have been better control groups for each metropolitan set of treated sites chosen for evaluation, but it is not clear how they could have been defined systematically for the national evaluation, or whether adequate data on these groups could have been conveniently extracted from the crash databases of each jurisdiction.

IMPLICATIONS OF CRASH COST ESTIMATES

As discussed in chapter 4, the two available methods of estimating the cost of road crashes are the crash-severity method and the crash-type method.

Crash-severity method

The crash-severity method is based on the highest level of injury severity sustained by those involved in a crash. This method has been adopted by the BTCE for the purpose of consistency in comparing costs of accidents in different transport modes (BTCE 1992).

In the pilot study of the Black Spot Program (BTCE 1993), it was noted that the occurrence of rare fatal crashes can have a major influence on the level of benefits attributed to a safety intervention. On the one hand, it is unrealistic to project small changes in fatal crashes uniformly over the lifetimes of the treatments because their occurrence involves substantial randomness, while on the other, it is also inappropriate to completely ignore such severe effects. The changes in the numbers of such crashes over limited periods are also often too small to determine whether they are of statistical significance.

Consequently, it was decided to pool the fatal and hospitalisation crash categories into a single category covering all serious injuries, and to use a weighted average by number of crashes to estimate the cost of these crashes. The estimate arising from this procedure, which assumes that there is a thin line between whether or not a fatality occurs, was $170 000 per crash in 1992.

As mentioned in chapter 5, a number of jurisdictions maintain a separate ‘first aid’ or ‘minor injury’ category, and some also classify their PDO crashes according to whether or not any vehicles are towed away. In the absence of research findings indicating the extent, if any, to which a vehicle being towed away increases repair costs, the same repair estimates were used for both PDO categories.

In the case of first aid crashes, an estimate was required for the cost of the personal injury component. It was necessary to take account of the mean number of persons who sustained injuries requiring first aid in these crashes. The approach taken was to use estimates of personal injury costs in ARRB (1992d) to interpolate between the PDO and medical treatment categories, resulting in an estimate of $6 000 for each first aid crash.

Uncertainties in the estimates of the cost of these least severe injury crashes will not have much impact on BCRs for treatments because typically over 80 per cent of benefits are derived from reductions in hospitalisation and fatal crashes. Total reductions in costs of medical injury and PDO crashes are also each of greater magnitude than reductions involving first aid crashes.

As hospital and health expenses associated with more serious crashes were originally estimated by BTCE (1992) on the basis of average stays in hospital rather than by dividing total hospitalisation costs by the number of people involved, the extensive decreases in serious injury crashes throughout the community in the period covered by the study would not of themselves have given rise to substantially higher unit costs. In this methodology, the major contributors to the costs of serious crashes are lost earnings and family and community losses. These are also unlikely to have been substantially altered by the decline in numbers of people seriously injured.

However, if the lost productivity calculations arising from human capital considerations were replaced by those based on the ‘willingness to pay’ criterion, estimates of unit costs for serious injury crashes would rise significantly and therefore lead to much higher BCRs for treatments.

Crash-type method

The crash-type method of costing crashes is based on the movements of vehicles or individuals just prior to the crash. It involves calculating mean personal injury costs for each type of crash, and adding this amount to vehicle repair costs and various other costs related to the crash.

Using data from the mid-1980s, ARRB (1992d) concluded that the average injury profiles for particular types of crashes remained fairly stable over time. In other words, the quantities obtained by dividing total injuries in each category by the total number of crashes of each type, did not change very much. As a result, cost estimates based on a particular year’s data could be indexed in a straightforward manner to provide estimates of costs in later years. However, for the reasons set out below, previously published estimates could not be indexed upwards for the period covered by this study.

As has been mentioned in chapter 5, with effect from January 1991 Victoria changed its crash recording policy to exclude PDO crashes from its database. While the aggregate number of injuries remained the same, they now needed to be divided by a much smaller number of crashes, causing significant increases in the estimates of costs for recorded crashes.

As noted earlier in this chapter, there were major differences in community trends relating to the various levels of injury experienced in crashes. Consequently, there was a possibility that some types of crashes were affected quite differently from others. While simple indexing might still have been appropriate for some crash types, in this overall climate of crash reductions increasing with the level of severity, it could not be expected to remain applicable across the board.

Injury profiles for the same crash type have varied quite markedly among the states and territories, in part because the population of crashes recorded on the database in each jurisdiction has not always been the same, but also because average vehicle occupancy and speed have varied.

ARRB's (1992d) estimates showed fewer occupants per vehicle in Melbourne than in Sydney, and indicated substantial differences in the costs attributed to different types of crashes. For instance, right-turn crashes in Melbourne were estimated to cost nearly twice as much as those in Sydney, and rear-end crashes over twice as much.

Further, reductions in particular levels of injury have been occurring at different rates from jurisdiction to jurisdiction, as outlined earlier in this chapter. In these circumstances it would be inappropriate for a single indexing factor to be used for the whole of Australia.

Similarly, attempting to establish national average costs to apply in an evaluation of this nature would be fraught with danger, as the proportions of crashes in particular jurisdictions varied greatly for different treatments. Because the weights applied to obtain national estimates could not be expected to be appropriate for a diverse range of composition of crashes by jurisdiction, it is unlikely that the application of such national estimates would lead to accurate estimates of Program benefits.

National averages were neither calculated nor used in this study. Instead, each jurisdiction was asked for either aggregate crash data including injury data or summary tables containing such information.

Injury profiles and estimates of personal injury costs were then calculated separately for each jurisdiction, as well as control ratios comparing what happened in metropolitan and rural areas before and after treatment work was carried out at the black spot sites.

An indication of the different injury patterns in recorded crashes around the nation can be gauged from the variability in person-costs in urban areas in 1992 for the three most common categories, those of right-angle, right-turn and rear-end crashes (table 7.3). It must be noted that these costs relate to all crashes entered on the various databases: as pointed out in chapter 5, they are based on entirely different proportions of all crashes occurring in the various jurisdictions.

One of the noticeable features in this period of sharp drops in numbers of crashes was a much greater volatility in estimated personal injury costs or crash costs for various types of crashes than appeared in the ARRB (1992d) study. For example, table 7.4 shows variations in the injury profile components and estimated personal injury costs for crashes involving pedestrians and rear-end crashes in the Sydney, Newcastle and Wollongong metropolitan areas over the period 1988 to 1992.

TABLE 7.3 PERSON-COSTS[a] FOR THE MOST COMMON TWO-VEHICLE[b] URBAN CRASHES IN AUSTRALIA, BY JURISDICTION[c] 1992

($)

Crash type (two-vehicle)	*ACT*	*NSW*	*NT*	*QLD*	*SA*	*TAS*	*VIC[d]*	*WA*
Right-angle	8 900	11 900	21 400	22 000	5 100	9 600	48 000	11 900
Right-turn	6 600	11 000	16 900	29 500	5 800	8 800	47 700	14 600
Rear-end	500	6 100	7 000	13 200	1 300	6 200	19 100	5 100

a. The calculation of standardised costs was based on the recorded crashes in each jurisdiction. Numbers have been rounded to nearest 100 dollars.
b. The incident costs incorporate an adjustment for greater mean vehicle numbers in crashes classified as involving two vehicles.
c. Caution must be exercised when comparing cost figures among jurisdictions because crash recording arrangements and coding systems vary among jurisdictions.
d. Victorian data does not include PDO crashes.

Source BTCE estimates based on data provided by states and territories.

Over this period, the number of crashes involving pedestrians fell by nearly 30 per cent and estimated personal injury costs fluctuated between a high of $64 741 in 1988 and a low of $55 481 in 1991. Recorded rear-end crashes (those involving injury or towage of at least one vehicle) declined by just over 20 per cent during this period and estimated personal injury costs showed even higher levels of fluctuation, ranging from $5 056 in 1991 to $6 665 in 1989.

Substantial fluctuations in annual experience for particular crash types also occurred in jurisdictions where the number of crashes did not fall steeply over the period covered in the study. For instance, in Tasmania, where all crashes are required to be reported and recorded, there were even greater variations among estimated personal injury costs in urban areas for crashes involving pedestrians and rear-end crashes, as illustrated in table 7.5.

Fluctuations of the kind illustrated in tables 7.4 and 7.5 do not of themselves undermine the validity or usefulness of the crash-type methodology for assessing the benefits from avoided crashes. They do, however, show that there is some uncertainty associated with the savings from an avoided crash in a particular future year. One means of handling this uncertainty systematically would be to develop scenarios based on possible low, medium and high values of crash cost savings in each year, rather than assuming the same unit savings carry forward into future years.

Tables 7.4 and 7.5 also show that the mean numbers of vehicles involved in a particular type of crash can often be substantially greater than two. This raised the question of whether any adjustment should be made to vehicle damage costs estimated by ARRB (1992d) on the basis of two-vehicle crashes.

In the absence of guidance from empirical studies, the approach adopted was to inflate estimates of vehicle damage and insurance administration costs in line with the mean number of vehicles involved in a particular type of crash. Any error arising from such a linear technique is likely to be rather small overall as the mean number of vehicles per crash is generally between 2.05 and 2.25, rising as high as 2.5 for rear-end crashes in some jurisdictions.

As Victoria, Tasmania and South Australia provided particulars of crashes electronically, it was possible to divide their data into those for two-vehicle crashes of particular types, and those for multiple-vehicle crashes where the initial impact was of a particular type. In each case,

TABLE 7.4 INJURY PROFILES FOR CRASHES INVOLVING PEDESTRIANS, AND REAR-END CRASHES, NSW METROPOLITAN[a] AREAS, 1988–92

		Persons				*Mean per crash*					
	Crashes	*Killed*	*Hospitalised*	*Medically treated*	*Receiving first aid*	*Vehicles*	*Persons killed*	*Persons hospitalised*	*Persons medically treated*	*Persons receiving first aid*	*Personal injury cost[b] ($)*
Pedestrian											
1988	3 370	148	1 035	2 101	282	1.01	0.044	0.307	0.623	0.084	65 400
1989	3 132	123	883	2 048	228	1.01	0.039	0.282	0.654	0.073	60 000
1990	3 196	136	933	1 862	418	1.01	0.042	0.292	0.583	0.131	62 700
1991	2 718	89	780	1 584	405	1.00	0.032	0.287	0.583	0.149	56 000
1992	2 403	78	802	1 400	240	1.00	0.032	0.334	0.583	0.100	60 800
Rear-end											
1988	9 615	14	289	2 821	315	2.44	0.001	0.030	0.293	0.033	6 300
1989	9 093	18	286	2 648	266	2.46	0.002	0.032	0.291	0.029	6 700
1990	8 917	10	250	2 301	414	2.46	0.001	0.028	0.258	0.046	5 600
1991	8 288	4	231	2 052	400	2.46	0.000	0.028	0.248	0.048	5 100
1992	7 579	7	255	1 953	371	2.48	0.001	0.034	0.258	0.049	6 000

a. Comprises the Sydney, Newcastle and Wollongong regions.

b. Expressed in 1992 dollars rounded to the nearest 100 dollars.

Source BTCE estimates based on data provided by Roads and Traffic Authority (NSW).

TABLE 7.5 INJURY PROFILES FOR CRASHES INVOLVING PEDESTRIANS, AND REAR-END CRASHES, TASMANIAN URBAN AREAS, 1988–92

		Persons				Mean per crash					
	Crashes	*Killed*	*Hospitalised*	*Medically treated*	*Receiving first aid*	*Vehicles*[a]	*Persons killed*	*Persons hospitalised*	*Persons medically treated*	*Persons receiving first aid*	*Personal injury cost*[b] *($)*
Pedestrian											
1988	203	12	66	99	26	2.09	0.059	0.325	0.488	0.128	76 400
1989	185	6	51	94	20	2.07	0.032	0.276	0.508	0.108	54 400
1990	200	8	62	91	29	2.08	0.040	0.310	0.455	0.145	62 600
1991	204	7	58	91	30	2.08	0.034	0.284	0.446	0.147	56 100
1992	194	3	55	100	15	2.05	0.015	0.284	0.515	0.077	44 500
Rear-end											
1988	569	0	17	80	30	2.24	0.000	0.030	0.141	0.053	5 200
1989	570	0	24	95	41	2.20	0.000	0.042	0.167	0.072	6 800
1990	599	1	15	99	54	2.22	0.002	0.025	0.165	0.090	5 900
1991	565	0	8	89	43	2.21	0.000	0.014	0.158	0.076	3 600
1992	601	0	23	99	28	2.19	0.000	0.038	0.165	0.047	6 200

a. In Tasmania the total number of pedestrians involved in crashes is included in the figure for vehicles (for example, in a crash involving one pedestrian and one motor car, the crash is coded as involving two vehicles).

b. Expressed in 1992 dollars rounded to the nearest 100 dollars.

Source BTCE estimates based on data provided by the Tasmanian Department of Transport and Works.

TABLE 7.6 DIFFERENCES IN INJURY CONSEQUENCES IN TWO-VEHICLE AND MULTIPLE-VEHICLE URBAN CRASHES, VICTORIA, 1988–92

			Persons			*Mean per crash*				
DCA[a] group	*Year*		*Killed*	*Sent to hospital*	*Injured*	*Vehicles*	*Persons killed*	*Persons sent to hospital*	*Persons injured*	*Personal injury cost[b] ($)*
110–119 Right angle										
Two vehicle										
	1988	3 767	56	1581	3 917	2.00	0.015	0.420	1.040	57 900
	1989	3 848	51	1435	4 475	2.00	0.013	0.373	1.163	52 200
	1990	3 043	42	942	3 632	2.00	0.014	0.310	1.194	45 800
	1991	2 384	30	830	2 781	2.00	0.013	0.348	1.167	49 100
	1992	2 317	34	750	2 610	2.00	0.015	0.324	1.126	47 700
Multi-vehicle										
	1988	325	3	189	395	3.16	0.009	0.582	1.215	72 400
	1989	351	8	153	525	3.17	0.023	0.436	1.496	66 000
	1990	252	2	120	331	3.15	0.008	0.476	1.313	60 500
	1991	194	6	94	269	3.22	0.031	0.485	1.387	76 100
	1992	208	4	69	289	3.25	0.019	0.332	1.389	52 200
130–132 rear-end										
Two vehicle										
	1988	3 218	14	531	3710	2.00	0.004	0.165	1.153	24 100
	1989	3 129	15	396	3764	2.00	0.005	0.127	1.203	20 300
	1990	2 635	11	289	3170	2.00	0.004	0.110	1.203	18 100
	1991	2 189	8	246	2549	2.00	0.004	0.112	1.164	18 000
	1992	2 221	5	226	2632	2.00	0.002	0.102	1.185	16 000

TABLE 7.6 DIFFERENCES IN INJURY CONSEQUENCES IN TWO-VEHICLE AND MULTIPLE-VEHICLE URBAN CRASHES, VICTORIA, 1988–92 (continued)

			Persons			*Mean per crash*				
DCA[a] *group*	*Year*		*Killed*	*Sent to hospital*	*Injured*	*Vehicles*	*Persons killed*	*Persons sent to hospital*	*Persons injured*	*Personal injury cost*[b] *($)*
Multi-vehicle										
	1988	1 154	4	292	1492	3.30	0.003	0.253	1.293	33 500
	1989	1 225	6	203	1715	3.31	0.005	0.166	1.400	25 200
	1990	963	4	141	1365	3.32	0.004	0.146	1.417	22 700
	1991	779	4	151	1017	3.31	0.005	0.194	1.306	28 100
	1992	874	6	148	1202	3.33	0.007	0.169	1.375	26 800

a. Definitions for classifying accidents.

b. Expressed in 1992 dollars rounded to the nearest 100 dollars.

Source BTCE estimates based on data provided by VIC ROADS.

the number of people in each category of injury was summed separately and divided by the relevant number of crashes. By updating ARRB's (1992d) standardised unit costs for each type of injury, it then became possible to derive estimates of personal injury costs for each of the crash types, according to whether the crashes were two-vehicle, multiple-vehicle or not further disaggregated. It was found that the multiple-vehicle crashes almost always had more severe injury consequences than the two-vehicle crashes. Table 7.6 illustrates these differences for right-angle and rear-end injury crashes in Victoria.

In these circumstances, the use of injury profiles from two-vehicle crashes only would result in sizeable underestimates of the personal injury costs arising from different types of crashes. Although a multiple-vehicle crash involves a further chance element beyond the initial impact, a full estimation of costs to the community of crashes should take account of the additional costs normally involved. Therefore, in this study, injury profiles have been derived for the complete available recorded numbers of crashes coded as being of a particular type.

CHAPTER 8 EVALUATION RESULTS

The Notes on Administration of the Black Spot Program state that the Program 'aims to improve the physical condition or management of locations noted for a high incidence of crashes involving death and serious injury... and to encourage implementation of safety-related road management techniques that have proven road safety value'. The results presented in this chapter will enable a judgment to be made on whether these aims have been achieved.

Only statistically significant results are presented in this chapter. A set of results which was not subject to statistical tests is presented in appendix XIII.

CRASH AND INJURY ANALYSIS FOR OVERALL SAMPLE

The following analysis compares the mean numbers of crashes at sample sites over the period 1988 to 1990 before treatment with those that occurred in 1992, after treatment. An overall analysis is provided, followed by separate analyses for the types of treatment implemented most often. The analysis of PDO crashes excludes data for Victoria, where recording of these crashes was discontinued with effect from January 1991.

Overview of crash experience

Table 8.1 provides details of crashes and injuries at sample sites before and after treatment. In the three-year period prior to the commencement of treatment work (1988–90), total annual injury crashes at the 254 sites selected for evaluation had a mean of 1 004. While the overall mean number of injury crashes per site per year was 4.0, the crash experience varied widely among jurisdictions, ranging from means of 1.2 in the ACT, 1.4 in Tasmania and 1.6 in Queensland, through to 2.7 in NSW, 4.3 in the Northern Territory, 4.5 in Western Australia, 4.8 in Victoria and 7.1 in South Australia.

At five sites, on average 25 or more people were killed, hospitalised or required medical treatment in each of the three years prior to treatment. The mean annual number of significant injuries lay between 10 and 25 at a further 21 sites. On the other hand, 10 sites had no recorded crashes for the entire period covered by the study. Eleven other sites did not have any people killed, hospitalised or requiring medical treatment between 1988 and 1990.

Prior to treatment, the greatest proportions of injury crashes at the sample sites were in South Australia (31 per cent), Victoria (29 per cent), Western Australia (18 per cent) and NSW (11 per cent). The greatest post-treatment proportions of injury crashes at these sites in 1992 were, in decreasing order, 41 per cent in South Australia, 23 per cent in Victoria, 15 per cent in Western Australia and 9 per cent in NSW, indicating the different rates at which changes in the number of crashes occurred in these jurisdictions.

In each year between 1988 and 1990 there were, on average at these 254 sites around the nation, 25 people killed, 291 hospitalised and 881 requiring medical treatment. Means per site per year were therefore

TABLE 8.1 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*[a]
Injury crashes	**1 004**	**543**	**46 (32)**
PDO crashes[b]	2 276	1 600	30
Persons seriously injured	**317**[c]	**122**	**61**
Killed	25	17	33
Hospitalised	291	105	64
Persons medically treated	881	447	49

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Excludes Victorian experience.

c. Persons killed and hospitalised do not add to persons seriously injured because of rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

respectively, 0.1 people killed, 1.1 hospitalised and 3.5 needing medical treatment. Differences between the jurisdictions became more pronounced as the severity of injury under consideration lessened. For instance, the mean number of people hospitalised per site per year between 1988 and 1990 ranged from 0.5 to 1.7, while the mean number of people requiring medical treatment varied between 1.0 and 5.4.

In 1992, at these same sites, there were 17 people killed, 105 hospitalised and 447 requiring medical treatment. Thus, in the period after treatment, fatalities fell by one-third, hospitalisations by two-thirds, and the number in need of medical treatment by almost one-half.

At treated sites, no fatalities were recorded during 1992 in either of the territories, Tasmania or Western Australia, nor did any of the 10 sites in the territories have a crash resulting in a hospitalisation injury. Among the states, the improvements in the numbers of serious injuries ranged from just under 50 per cent in South Australia and NSW through to 75 per cent in Victoria and 90 per cent in Tasmania.[1]

The reduction in the number of people requiring medical treatment was nearly one-half nationally, ranging from 15 per cent in Tasmania and just over 20 per cent in South Australia, to between 60 and 70 per cent in Western Australia and both the territories.[2] In NSW and Western Australia, this fall was slightly greater than that for more serious injuries. Elsewhere, the fall was less than for serious injuries, slightly so in Queensland, and by 20 or more percentage points in other jurisdictions.

The evidence from these sample sites therefore strongly suggests that the Black Spot Program achieved its aim of lowering the incidence of deaths and serious injuries at treated sites.

Injury crashes

Figure 8.1 shows the distribution of injury crashes before and after treatment, by jurisdiction. Figures 8.2 and 8.3 show the distributions of seriously injured and medically treated persons respectively before and after treatment, by jurisdiction.

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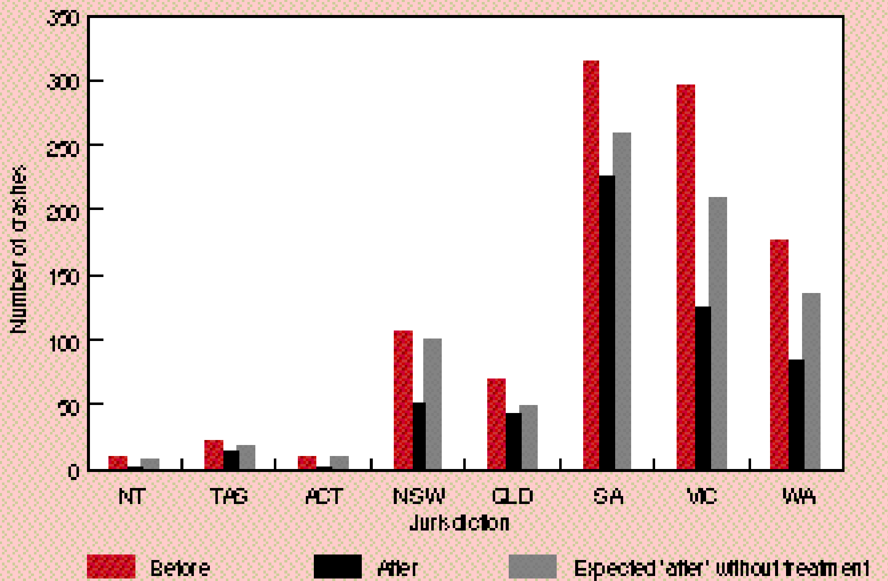
1. The number of people involved was very small in the case of Tasmania.
2. The numbers of people involved were very small in the case of the territories.

FIGURE H.1 DISTRIBUTION OF INJURY CRASHES BY JURISDICTION

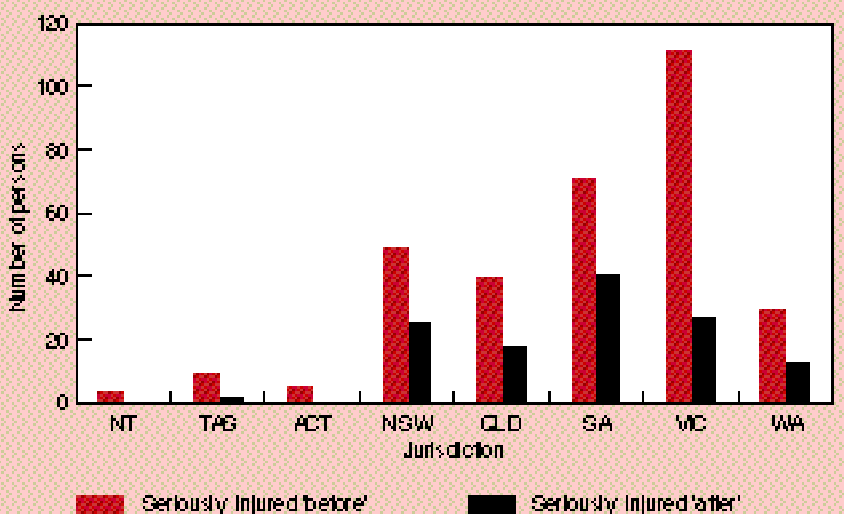


Note All jurisdictions: Before (1 004), After (543), Expected 'after' without treatment (786).

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE H.2 DISTRIBUTION OF SERIOUSLY INJURED PERSONS BY JURISDICTION

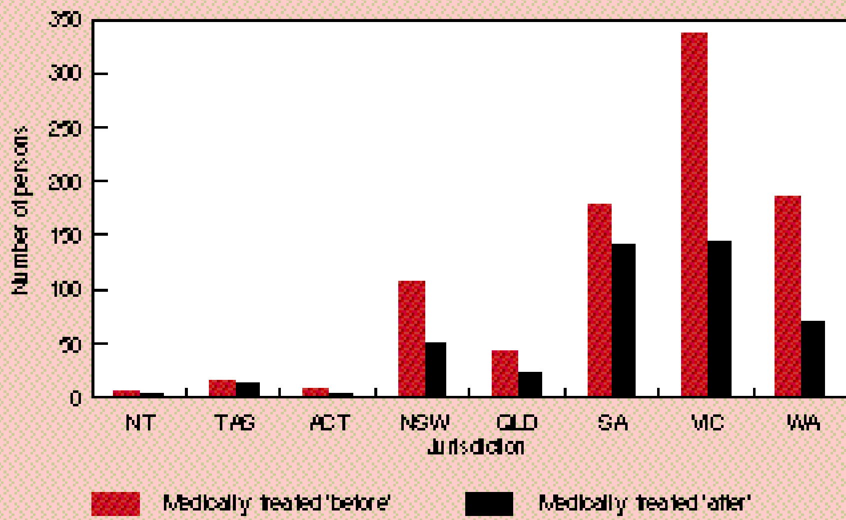


Note All jurisdictions: Seriously injured 'before' (317), Seriously injured 'after' (122).

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE 8.3 DISTRIBUTION OF MEDICALLY TREATED PERSONS BY JURISDICTION



Note All jurisdictions: Medically treated 'before' (881), Medically treated 'after' (447).

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

In 1992, injury crashes at the 254 sample sites fell by 46 per cent. In the context of comparisons of injuries outlined above, the treatments applied appear to have moderated the level of injury in the much smaller numbers of crashes which occurred after treatment. On the basis of the limited evidence from the sample sites treated during the first half of the Program, it appears that sites have been well chosen for remedial work and that appropriate treatments were applied.

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

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

Overall, the decrease in injury crashes at the sample sites was more than 2.5 times what could have been expected on the basis of general comparable crash trends 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 substantial success in reducing crashes involving death and serious injury.

PDO crashes

The mean number of PDO crashes at individual sites (except in Victoria) in each year prior to treatment was 11.9. The experience among the jurisdictions varied substantially. There were 1.6 crashes per site per year in Queensland, 2.9 in Tasmania, 4.1 in NSW, 10.2 in Western Australia, 14.2 in the Northern Territory, 17 in the ACT and 32.6 in South Australia. As explained in chapter 5, the criteria for recording crashes vary widely among the jurisdictions and what is recorded represents different proportions of PDO crashes that actually occur. These numbers are therefore not strictly comparable.

Of recorded PDO crashes between 1988 and 1990, 63 per cent were in South Australia, 18 per cent in Western Australia and 7 per cent in NSW. In 1992 the greatest proportions of PDO crashes at sample sites were 70 per cent from South Australia, 14 per cent from Western Australia, and 6 per cent from NSW.

While the South Australian crash experience therefore predominates in a comparison of overall crash numbers, the nature of the Tanner methodology for obtaining average crash reduction effects from a number of separate estimates (appendix VIII) precluded South Australian crash numbers from swamping the experience of other jurisdictions.

The 30 per cent overall decrease in PDO crashes at sample sites compares with falls of around 20 per cent in Western Australia between 1988–90 and 1992, some 15 per cent in NSW, and less than 10 per cent in the territories, South Australia and Tasmania. There was a slight increase in Queensland over the same period.

Overall, the decrease in PDO crashes was more than triple what could have been expected on the basis of general comparable community trends.

The fact that treatments have led to more pronounced declines in injury crashes than in recorded PDO crashes, suggests that the Black Spot Program has had an impact not only on the frequency of collisions but also on their severity.

CRASH AND INJURY ANALYSIS FOR INDIVIDUAL TREATMENTS

New traffic signals (UH1)

New traffic signals were installed at 50 of the sample sites in six jurisdictions. Table 8.2 shows details of crashes and injuries at the 50 sites. At these sites, there was a mean of 2.4 injury crashes per site per year between 1988 and 1990. These sites (excluding those in Victoria) recorded a mean of 5.6 PDO crashes per year during this period.

The pre-treatment crash experience at sample sites where new traffic signals were implemented was therefore less severe than those for the sample as a whole. In view of the capital costs generally involved in installing new traffic signals, unless substantial reductions in crashes occurred after installation, BCRs would tend to be lower than for the Program as a whole.

TABLE 8.2 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: NEW TRAFFIC SIGNALS (UH1)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction* [a]
Injury crashes	**121**	**70**	**42 (30)**
PDO crashes[b]	225	145	36
Persons seriously injured	**38**	**13**	**66**
Killed	3	1	67
Hospitalised	35	12	66
Persons medically treated	125	54	57

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Excludes Victorian experience.

Source BTCE estimates based on data provided to FORS by states and territories.

Injury crashes

Figures 8.4 and 8.5 show the distributions of injury crashes and seriously injured persons respectively, by jurisdiction. Figure 8.6 shows the distribution of medically treated persons, by jurisdiction.

Among the jurisdictions, sites in Western Australia experienced a mean of 4.7 injury crashes per year before treatment and sites in Victoria experienced 4.0, but means elsewhere were between 1 and 2. The largest components of the injury crash mix prior to treatment came from Western Australia (35 per cent), Victoria (33 per cent) and Queensland (12 per cent). During the first post-treatment year, 1992, injury crashes fell by around 40 per cent and recorded PDO crashes by a little over one-third.

In Victoria, injury crashes at sample sites fell by 75 per cent. There were no hospitalisations or fatalities in 1992, and the number of people requiring medical treatment fell by 70 per cent. This performance compares with a reduction of nearly 30 per cent in injury crashes in all Victorian urban areas.

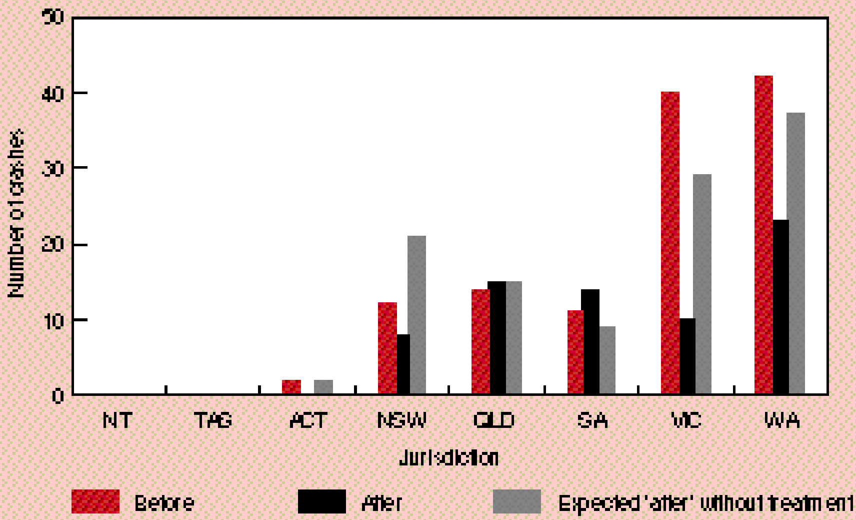
Western Australian injury crashes at sample sites fell by nearly one-half, compared with general urban-area reductions of around 10 per cent. The numbers of people killed or hospitalised and of those requiring medical treatment declined by about 60 per cent and 75 per cent respectively. Thus, as in Victoria, injury consequences in crashes which occurred at sites after treatment were somewhat less severe than they had been before treatment.

With much smaller crash numbers involved, the sample sites in NSW experienced injury crash reductions of about one-third. While the number of people hospitalised increased marginally, those requiring medical treatment fell by nearly 30 per cent. Queensland and South Australia both experienced increases in injury crashes.

Several years' further post-treatment data from the sites in NSW, Queensland and South Australia would be needed to assess whether these initial consequences represented an aberration, or whether there were problems in site selection or application of treatment. For instance, it is possible that the absence of a separate right-turn phase exacerbated crash potential in some locations.

Despite the uncertainties inherent in fairly small crash numbers, the good performance in Victoria and Western Australia described above

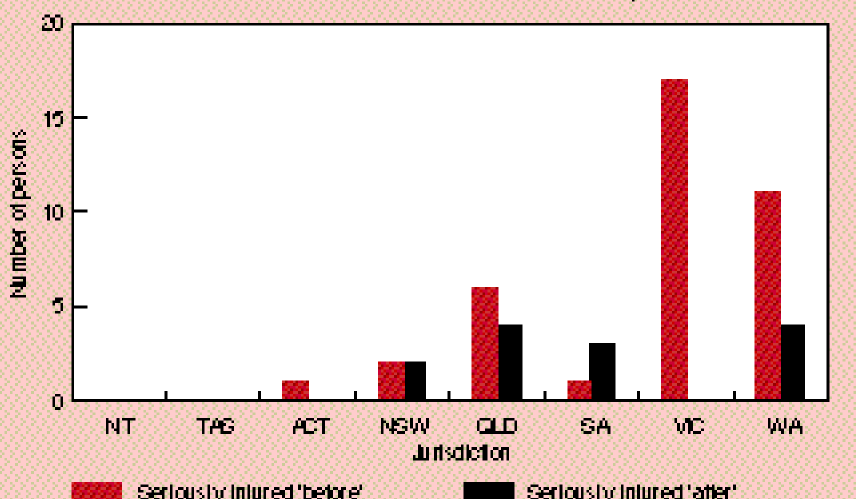
FIGURE 8.4 DISTRIBUTION OF INJURY CRASHES BY JURISDICTION[a]: NEW TRAFFIC SIGNALS (UH1)



Note All jurisdictions: Before (121), After (70), Expected 'after' without treatment (113).
a. In the sample, the Northern Territory and Tasmania had no UH1 treatments.
Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

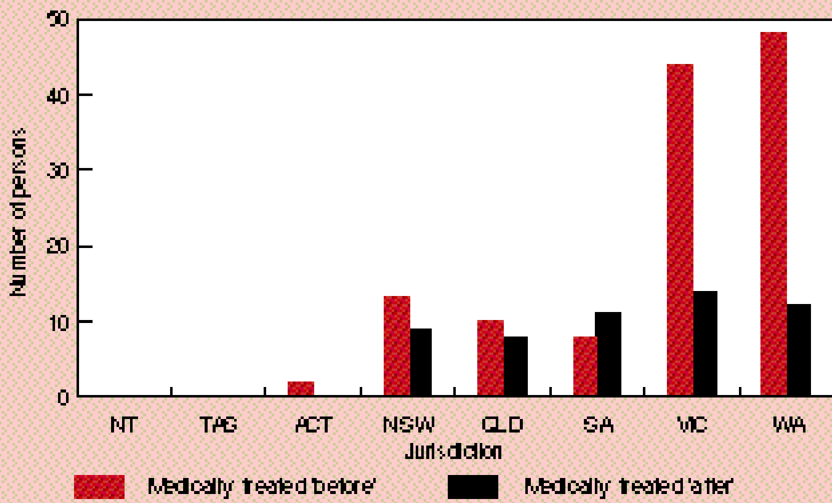
FIGURE 8.5 DISTRIBUTION OF SERIOUSLY INJURED PERSONS BY JURISDICTION[a]: NEW TRAFFIC SIGNALS (UH1)



Note All jurisdictions: Seriously injured 'before' (38), Seriously injured 'after' (13).
a. In the sample, the Northern Territory and Tasmania had no UH1 treatments.
Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE [illegible] DISTRIBUTION OF MEDICALLY TREATED PERSONS BY JURISDICTION[a]: NEW TRAFFIC SIGNALS (UH1)



Note All jurisdictions: Medically treated 'before' (125), Medically treated 'after' (54).

a. In the sample, the Northern Territory and Tasmania had no UH1 treatments.

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

means that overall injury crash reductions were 2.5 times what would have been expected on the basis of trends in individual jurisdictions. It appears that at sites where new traffic signals were installed, the major objective of the Black Spot Program in reducing serious injury was achieved.

PDO crashes

The greatest recorded numbers of pre-treatment PDO crashes at sites at which new traffic signals were installed were in South Australia (43 per cent), Western Australia (28 per cent) and NSW (14 per cent). There were substantial variations per site across jurisdictions, with the ACT averaging 18.3 PDO crashes per year, and South Australia 13.9, but elsewhere mean annual PDO crash numbers ranged between 1.2 and 7.0.

PDO crashes at sample sites in South Australia declined by about one-third, over five times the rate of general urban area reductions. In Western Australia, PDO crashes fell by almost 40 per cent compared with a drop of slightly under 20 per cent in urban areas. NSW sites had PDO crash reductions of over one-half, a rate nearly four times that experienced in urban areas of the state. The fall in PDO crashes of nearly 80 per cent in the ACT compared with a general trend decline of under 10 per cent. Queensland, with about the same number of PDO crashes in the control areas prior to treatment as after, recorded an increase of 60 per cent at the sample sites.

The one-third reduction in PDO crashes in the sample was 3.5 times what would have been obtained by applying control ratios in individual jurisdictions to the number of crashes occurring annually before treatment.

Overall, at sites where new traffic signals were installed, there appears to have been a substantial decrease in crashes as a result of treatment, and an appreciable amelioration in severity consequences where crashes did occur after treatment.

Modified traffic signals (UH2)

There were 59 of the sample sites in six jurisdictions at which traffic signals were modified. Details of crashes and injuries at these sites are set out in table 8.3. The impact of having separate right-turn phases could not be quantified, as often information about whether individual modifications had consisted solely of a right-turn phase or whether such a phase was part of a more extensive modification, was not conveniently available.

Between 1988 and 1990, the annual mean number of injury crashes per site was 5.4 nationally and the mean number of recorded PDO crashes excluding Victoria was 16.6. These levels were both somewhat higher than the means for the entire sample of sites. As capital costs associated with these projects were often modest, there was potential for rather high BCRs if substantial reductions in crashes eventuated.

Injury crashes

Figures 8.7 and 8.8 show the distributions of injury crashes and seriously injured persons respectively, by jurisdiction. Figure 8.9 shows the distribution of medically treated persons, by jurisdiction.

Among the jurisdictions, the greatest proportions of injury crashes prior to treatment were in Victoria (38 per cent), Western Australia (27 per cent) and South Australia (21 per cent). Mean annual injury crashes per site ranged from around 2 in the ACT and Queensland, to 6.4 in Victoria and 7.8 in Western Australia.

TABLE 8.3 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: MODIFIED TRAFFIC SIGNALS (UH2)

(Mean number per year, rounded to nearest integer)

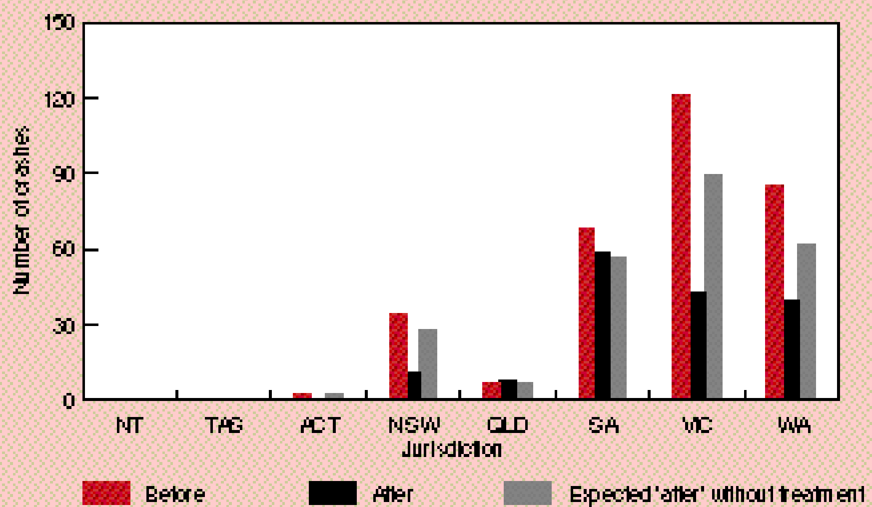
	Before (1988–90)	*After (1992)*	*Per cent reduction* [a]
Injury crashes	**316**	**159**	**50 (38)**
PDO crashes[b]	664	461	31
Persons seriously injured	**74**	**21**	**71**
Killed	5	1	80
Hospitalised	69	20	71
Persons medically treated	302	132	56

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Excludes Victorian experience.

Source BTCE estimates based on data provided to FORS by states and territories.

FIGURE 8.[illegible] DISTRIBUTION OF INJURY CRASHES BY JURISDICTION[a]: MODIFIED TRAFFIC SIGNALS (UH2)



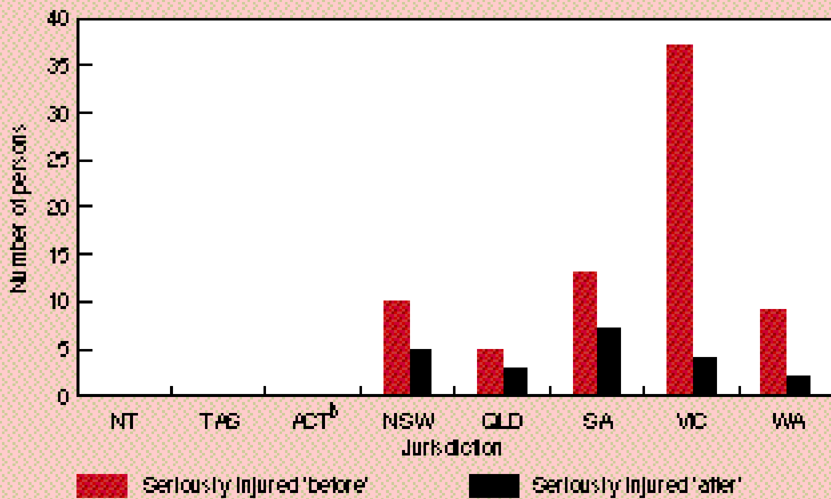
Note All jurisdictions: Before (316), After (159), Expected 'after' without treatment (244).

a. In the sample, the Northern Territory and Tasmania had no UH2 treatments.

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE 8.8 DISTRIBUTION OF SERIOUSLY INJURED PERSONS BY JURISDICTION[a]: MODIFIED TRAFFIC SIGNALS (UH2)



Note: All jurisdictions: Seriously injured 'before' (74), Seriously injured 'after' (21).

a. In the sample, the Northern Territory and Tasmania had no UH2 treatments.

b. In the ACT there were no seriously injured persons before or after treatment.

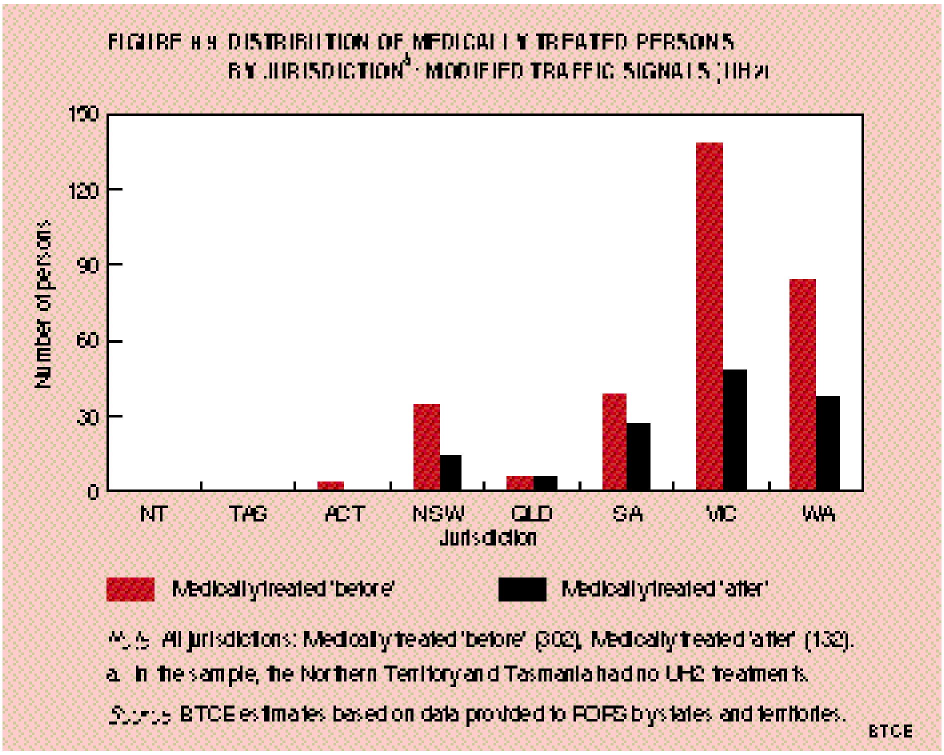
Source: BTCE estimates based on data provided to FORS by states and territories.

BTCE

Injury crashes fell from these levels by around one-half in 1992. NSW and Victoria both experienced decreases in injury crashes of about two-thirds, compared with community trend improvements of around 25 per cent in both states. Western Australia's injury crashes dropped by more than one-half, compared with a fall of around 10 per cent in the state's injury crashes in urban areas over this period.

The number of serious injuries at sample sites plummeted by 90 per cent and 80 per cent respectively in Victoria and Western Australia, and the number of people requiring medical treatment decreased in those states by about two-thirds and one-half respectively. In NSW, serious injuries fell by about 50 per cent, and the number of people requiring medical treatment by nearly 60 per cent.

South Australia's 15 per cent reduction in injury crashes was slightly less than the community-wide improvement in Adelaide in the same period. However, the number of people seriously injured fell by nearly one-half, and the number requiring medical treatment by around 30 per cent. This suggests that, as in most other jurisdictions, there was an



injury mitigating effect on the crashes that continued to occur after treatment.

On the other hand, even though rather small numbers were involved, Queensland had a slight rise in injury crashes, but had a fall of 40 per cent in PDO crashes. Data for several years after 1992 would be required to assess the impact of treatment work on injuries and crashes in Queensland.

Injury crash reductions at the sample sites where traffic signals were modified were 2.5 times what might have been expected on the basis of the general reductions in crashes occurring in urban areas within individual jurisdictions over the same period.

PDO crashes

Mean annual PDO crashes in the period before treatment at sites where traffic signals were modified ranged from 3.9 for Queensland and 5.1 for NSW to 20.2 in Western Australia and 23.0 in South Australia. South Australia had 48 per cent of recorded PDO crashes, Western Australia

33 per cent and the ACT (its single site averaged 53 such crashes each year) and NSW 8 per cent each.

In South Australia, as with injury crashes, the number of PDO crashes fell 15 per cent, more than double the improvement achieved generally throughout the Adelaide metropolitan area. PDO crashes fell by about one-half in Western Australia and by about 40 per cent in both NSW and the ACT, compared with general crash trend reductions in those jurisdictions of around 20, 15 and 10 per cent respectively.

The overall drop in recorded PDO crashes after treatment at sites where traffic signals were modified was nearly one-third. This drop was 2.8 times what the various individual community crash trends would have predicted.

In summary, modification of traffic signals appears to have had a major effect on both injury crashes and injuries, and also made a sizeable impact on recorded PDO crashes in most jurisdictions. Despite the problems mentioned above, the overall experience at these sites suggests that they were generally selected appropriately and treatments applied effectively.

Roundabouts (UH7)

All jurisdictions were represented in the 31 sites in the sample at which roundabouts were constructed. Details of crashes and injuries at these 31 sites are set out in table 8.4. At these sites, during the 1988–90 pre-treatment period, mean injury crashes were 2.5 per site per year and mean PDO crashes 4.0 per site per year (excluding Victoria).

Total numbers of crashes in the sample of sites prior to treatment were rather low. The rather low pre-treatment crash experience combined with the extensive capital outlays required for some projects, meant that very high reductions in crashes were necessary for high BCRs to be achieved.

Injury crashes

Figures 8.10 and 8.11 show the distributions of injury crashes and seriously injured persons respectively, by jurisdiction. Figure 8.12 shows the distribution of medically treated persons, by jurisdiction.

Over the period from 1988 to 1990, mean annual injury crash numbers per site ranged from 1.3 in Tasmania and 1.5 in NSW to 3.3 in both territories and 3.9 in Victoria. Only Victoria, Western Australia and

TABLE 8.4 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: ROUNDABOUTS (UH7)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction* [a]
Injury crashes	**77**	**9**	**88 (86)**
PDO crashes[b]	100	48	52
Persons seriously injured	**32**	**0**	**100**
Killed	2	0	100
Hospitalised	30	0	100
Persons medically treated	76	9	88

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Excludes Victorian experience.

Source BTCE estimates based on data provided to FORS by states and territories.

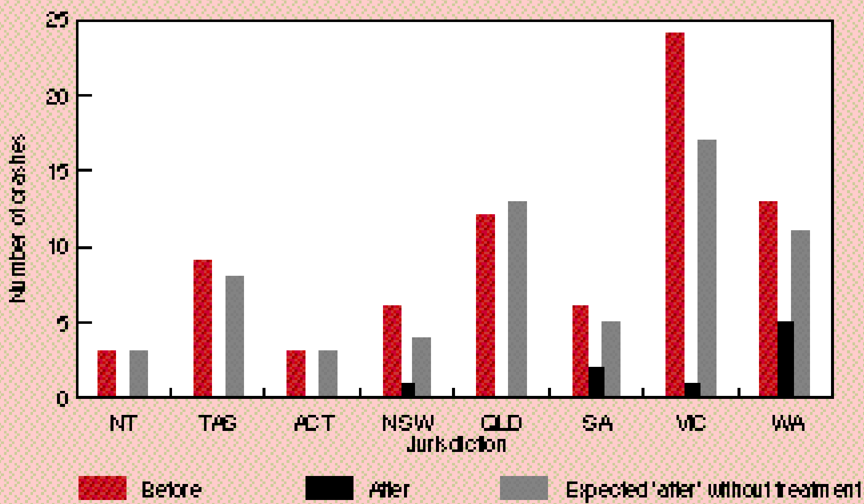
Queensland had more than 10 injury crashes at sample sites per year in the period before treatment, and of the remaining jurisdictions, Tasmania alone had a total of more than 25 crashes per year. Of injury crashes, 31 per cent were in Victoria, 17 per cent in Western Australia and 16 per cent in Queensland.

The post-treatment reduction in injury crashes at sample sites amounted to nearly 90 per cent, with both territories, Tasmania and Queensland not experiencing any injury crashes in 1992. In fact, there were no fatalities or injured persons requiring hospitalisation in other jurisdictions, compared with a national mean of 32 such instances in each year prior to treatment.

The number of people requiring medical treatment also fell by nearly 90 per cent. In other words, after the installation of roundabouts both injury crashes and injuries at the sample sites virtually ceased.

The remarkable decrease in injury crashes was over 5.5 times as much as community crash trends in the various jurisdictions would have suggested. Several more years of post-treatment data would be needed to establish whether these figures accurately reflect the impact of treatment or whether they were abnormally low in 1992 for some reason.

FIGURE 8.10 DISTRIBUTION OF INJURY CRASHES BY JURISDICTION: ROUNDABOUTS (UHA)

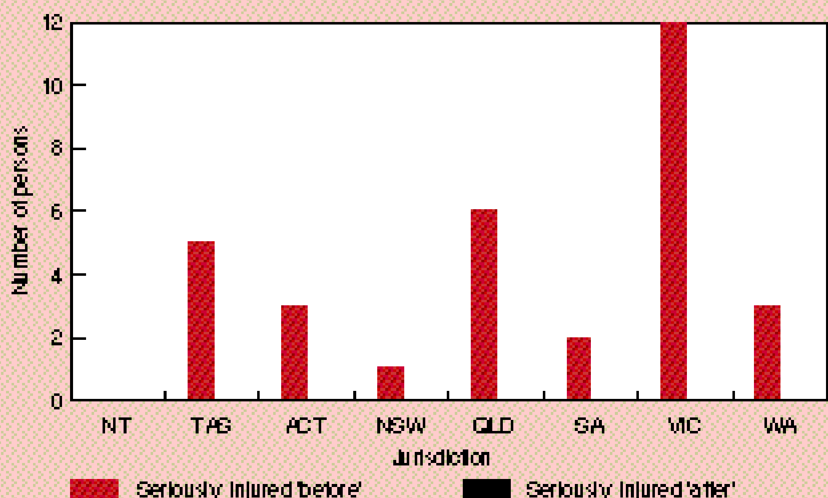


Note: All jurisdictions: Before (77), After (9), Expected 'after' without treatment (65).

Source: BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE 8.11 DISTRIBUTION OF SERIOUSLY INJURED PERSONS BY JURISDICTION[a]: ROUNDABOUTS (UHA)



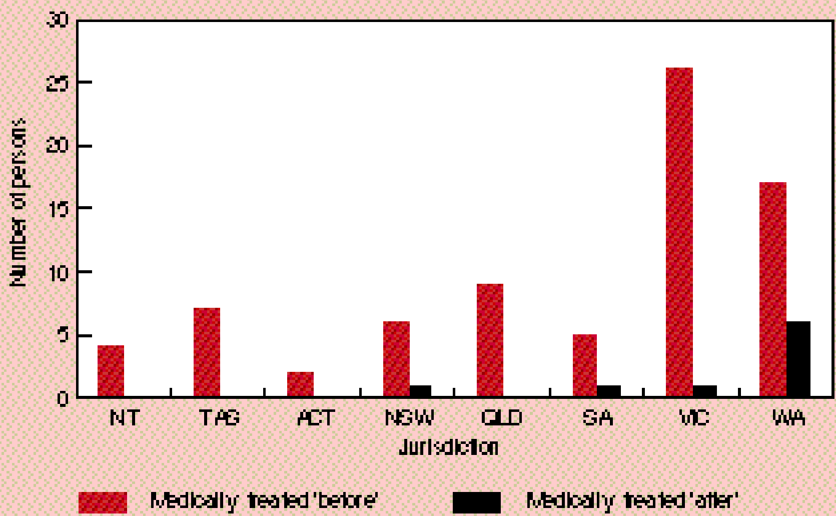
Note: All jurisdictions: Seriously injured 'before' (32), Seriously injured 'after' (0).

a. At all sample sites, there were no seriously injured persons after treatment.

Source: BTCE estimates based on data provided to FORS by states and territories.

BTCE

FIGURE H.12 DISTRIBUTION OF MEDICALLY TREATED PERSONS BY JURISDICTION: ROUNDABOUTS (UHA)



Note All jurisdictions: Medically treated 'before' (76), Medically treated 'after' (9).

Source BTCE estimates based on data provided to FORS by states and territories.

BTCE

PDO crashes

Among the states other than Victoria, the range of mean recorded PDO crashes per site per year ranged from 2.3 in NSW to 7.8 in South Australia. The two territory sites experienced the highest mean numbers of PDO crashes per site: 8.7 in the ACT and 14.7 in the Northern Territory.

Western Australia had 22 per cent of recorded PDO crashes, Tasmania had 18 per cent and South Australia, 16 per cent. These figures reflect the fairly even spread of sites and annual numbers of crashes among the different jurisdictions.

PDO crashes declined by just over one-half, with Queensland's reduction being over 90 per cent, and those of Tasmania and the Northern Territory around two-thirds, the ACT's about one-half, and those of South Australia and Western Australia over one-third. Queensland in fact experienced a slight increase in PDO crashes on all declared roads over the period in question. Tasmania had a slight decrease in PDO crashes, while falls of about 10 per cent were recorded in the territories and South Australia, 15 per cent in NSW, and 20 per cent in Western Australia.

The overall drop in PDO crashes was over six times what might have been expected on the basis of general crash trends in the individual jurisdictions.

Even allowing for the small numbers involved, the drop in crashes and injuries was dramatic across the board. Even the smallest impact of the construction of roundabouts, a fall in injury crashes in Western Australia of about 60 per cent and a decrease of around 40 per cent in PDO crashes, was rarely achieved overall for other treatments.

It appears that roundabouts at the sites chosen for treatment removed most of the potential for vehicle conflict and subsequent injuries. With a general reduction in speed occurring on approaches to roundabouts, the crashes which occurred after treatment were generally of a fairly minor nature. Many of these projects involved substantial capital costs: BCRs at other roundabout sites with modest capital costs may be relatively high.

Intersection channelisation (UH3)

There were 32 intersections in the sample at which channelisation was undertaken, with at least one in each jurisdiction. Table 8.5 shows details of crashes and injuries at sample sites. Over the period 1988–90 prior to treatment, the mean number of injury crashes per year at these sites was 4.3 and, excluding sites in Victoria, mean annual recorded PDO crashes numbered 13.9.

As comparatively high crash numbers at South Australian sites strongly influenced these means, without substantial crash reductions in South Australia, high BCRs would be difficult to achieve.

Injury crashes

South Australia's mean number of injury crashes per site per year in the period before treatment was 8.8, Victoria's 6.9 and the Northern Territory's 5.3. In other jurisdictions it varied between 0.7 and 3.2, and was mainly below 2. The overall composition of injury crashes at these sample sites was dominated by South Australia (38 per cent), Victoria (35 per cent) and Western Australia (14 per cent).

Injury crashes at the sample sites dropped by just over 40 per cent after treatment. The reduction in injury crashes was nearly two-thirds in

TABLE 8.5 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: INTERSECTION CHANNELISATION (UH3)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction* [a]
Injury crashes	**138**	**80**	**42 (28)**
PDO crashes[b]	348	233	33
Persons seriously injured	**32**	**14**	**57**
Killed	1	2	100[c]
Hospitalised	31	12	62
Persons medically treated	115	69	40

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Excludes Victorian experience.

c. Increase.

Source BTCE estimates based on data provided to FORS by states and territories.

Western Australia, just exceeded one-half in Victoria and was just short of 40 per cent in South Australia. These improvements compared with decreases of around 10, 30 and 20 per cent throughout the respective metropolitan areas used as controls for general community trends over this period.

In the ACT, NSW and Tasmania, there were slight increases in injury crashes but reductions of 50–60 per cent in PDO crashes. Because of the fairly small numbers involved, several more years' data would be necessary before any firm conclusions might be reached about the effectiveness of treatments in those jurisdictions.

The number of people killed or hospitalised fell by more than 60 per cent in South Australia and Victoria, and in those states the respective declines in the numbers of people requiring medical treatment were about 15 per cent and 55 per cent. In Western Australia the number requiring medical treatment decreased by 75 per cent.

Overall, injury crash reductions were more than double what might have been expected on the basis of decreases occurring in control areas in each jurisdiction. In South Australia and Victoria, as reductions in serious injuries were steeper than reductions in injury crashes, it appears that the selection of sites and application of treatments in those jurisdictions had a mitigating effect on the consequences of crashes which occurred after treatment.

PDO crashes

Over the 1988–90 pre-treatment period, South Australia had a mean of 42.8 PDO crashes annually at its six sample sites, and both territories each experienced more than 10 at their single sites. In other jurisdictions the mean per site was between 1.8 and 4.8. Of the recorded PDO crashes which occurred, 74 per cent were in South Australia and 13 per cent in Western Australia.

Total PDO crashes were reduced by about one-third. The reduction in PDO crashes was nearly 30 per cent in South Australia compared with a drop of around 5 per cent in the Adelaide metropolitan control area. The 40 per cent decrease in Western Australia was double that achieved throughout the whole metropolitan area, while the ACT and Northern Territory experienced decreases of around one-half and two-thirds respectively, compared with a drop of 10 per cent in each corresponding control area.

The overall decline in PDO crashes in the sample was over four times what could have been expected from general community crash trends.

Provision of medians (UH4)

There were 12 sites in the sample in four jurisdictions at which medians were constructed. Table 8.6 shows details of crashes and injuries at the sites. During the 1988–90 pre-treatment period, these sites had annual means of 13.7 injury crashes and 60.0 PDO crashes.

However, as well over 90 per cent of crashes and injuries occurred in South Australia, the overall experience closely mirrors what happened in that state. The six sites in South Australia, on stretches of road several kilometres long, had a mean of 26 injury crashes and 117 PDO crashes each year in the period before treatment, compared with 16 injury and 89 PDO crashes in the year after treatment.

Overall, injury crashes fell by around 40 per cent and PDO crashes by 25 per cent. The injury crash improvement was more than double what

TABLE 8.6 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: PROVISION OF MEDIANS (UH4)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction* [a]
Injury crashes	**164**	**100**	**39 (26)**
PDO crashes	720	538	25
Persons seriously injured	**34**	**16**	**53**
Killed	2	2	20[b]
Hospitalised	32	14	57
Persons medically treated	101	68	33

a. The number in brackets is the reduction from the number of crashes anticipated through application of appropriate control ratios to take account of general crash trends.

b. Increase from actual mean of 1.7.

Source BTCE estimates based on data provided to FORS by states and territories.

declining trends in various control areas would have suggested, while the decrease experienced in PDO crashes was about four times what general community trends indicated.

The number of serious injuries at sample sites fell by just over one-half and the number of those medically treated by about one-third, again indicating some mitigation in the consequences of the crashes which occurred after treatment.

Protected turning bays (UM2)

There were nine sites in the sample in five jurisdictions at which protected turns were implemented. Details of crashes and injuries at these sites are shown in table 8.7. These sites had means of 4.0 injury crashes and 11.8 recorded PDO crashes (excluding Victoria) per site per year during 1988–90. Victoria and Western Australia together accounted for over 90 per cent of injury crashes, and Western Australia and the ACT together contributed 85 per cent of all PDO crashes.

TABLE 8.7 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: PROTECTED TURNING BAYS (UM2)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction*
Injury crashes	**36**	**25**	**30**
PDO crashes[a]	71	36	49
Persons seriously injured	**10**	**6**	**42**
Killed	0	1	200[b]
Hospitalised	10	5	50
Persons medically treated	41	30	26

a. Excludes Victorian experience.

b. Increase from actual mean of one-third.

Source BTCE estimates based on data provided to FORS by states and territories.

After treatment, injury crashes at these sample sites fell by 30 per cent in 1992, the number of people seriously injured declined by over 40 per cent, and PDO crashes decreased by nearly 50 per cent.

In Western Australia, injury crashes fell by around one-half. There was an increase in serious injuries, involving very small numbers before and after treatment, but the number of those requiring medical treatment was halved. On the other hand, Victoria’s injury-crash improvement of less than 10 per cent compared with declines of around 30 per cent across the entire metropolitan area over this period. This combination meant that the fall in injury crashes was about 1.5 times what declines in relevant control areas would explain.

Western Australia’s number of PDO crashes dropped by about one-third after treatment, compared with reductions of around 20 per cent in the urban control area. PDO crashes fell by about two-thirds in the ACT (about four times the improvement in the control area), and by even more in NSW where rather small crash numbers were involved. Overall, PDO crashes fell at more than triple the rate expected on the basis of general urban trends in the various jurisdictions.

Victoria’s unusual experience compared with the success achieved at its sample sites for other treatments may warrant further examination.

Unless greater reductions are achieved in future years, physical examination of site works may be necessary to establish why treatments have not been particularly effective.

Shoulder sealing (RH1)

There were 15 sites in the sample in four jurisdictions at which shoulder sealing was carried out. Table 8.8 shows details of crashes and injuries at the sites. At these sites, there was an annual mean of 3.3 injury crashes per site over the period 1988 to 1990, and 4.6 recorded PDO crashes per site in the three states except Victoria.

Around 80 per cent of the injury crashes at sample sites occurred in Victoria and South Australia, and nearly 80 per cent of recorded PDO crashes were in South Australia. Consequently, the experience in those two states heavily influenced overall outcomes.

Injury crashes fell by 20 per cent overall, the number of people seriously injured decreased by about 25 per cent, and the number of people requiring medical treatment dropped by about 20 per cent. PDO crashes increased by about 10 per cent.

In Victoria, injury crashes dropped by one-third during 1992, a slight improvement compared with the experience in rural control areas. The number of people seriously injured dropped by one-half, and the number requiring medical treatment by 20 per cent, suggesting that shoulder sealing in Victoria had some success in mitigating the severity of crashes that occurred after treatment.

South Australia’s injury crashes decreased by 15 per cent, a slight improvement compared with the experience in the rural control area, but PDO crashes climbed by nearly one-quarter. Queensland had small increases in both injury and PDO crashes, while Tasmania experienced strong falls in both, although the numbers involved in both states were small.

The drop in injury crashes was about what experience in control areas would have predicted, while total PDO crashes increased. It is possible that these mediocre outcomes were due to poor selection of sites for treatment. In particular, the South Australian experience warrants further study as more data become available in future years.

TABLE 8.8 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: SHOULDER SEALING (RH1)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction*
Injury crashes	**49**	**39**	**20**
PDO crashes[a]	41	45	9[b]
Persons seriously injured	**32**[c]	**24**	**26**
Killed	4	4	8[d]
Hospitalised	29	20	30
Persons medically treated	40	33	18

a. Excludes Victorian experience.

b. Increase.

c. Persons killed and hospitalised do not add to persons seriously injured because of rounding.

d. Increase from actual mean of 3.7.

Source BTCE estimates based on data provided to FORS by states and territories.

Protected right turns (RH9)

There were six sites in the sample in NSW and South Australia at which protected right turns were constructed. Table 8.9 shows details of crashes and injuries at the sites. Both injury and PDO crashes had means of 6.8 crashes per site per year during the period 1988 to 1990. As over 85 per cent of both types of crashes occurred in NSW, what happened in that state effectively represented the overall sample outcome.

Both injury and PDO crashes in the sample fell by over 40 per cent. In NSW, the fall in injury crashes was about one-half, while the decrease in PDO crashes was about one-third. The numbers of people seriously injured or requiring medical treatment both fell by more than one-half in NSW. Very small numbers were involved in South Australia’s post-treatment increases in injury crashes and injuries, while no PDO crashes occurred there in 1992.

As serious injury crashes throughout rural areas in NSW fell by around 20 per cent in 1992, it may be possible to attribute substantial benefits to protected right turns after more data from future years become available.

TABLE 8.9 CRASHES AND INJURIES AT SAMPLE SITES BEFORE AND AFTER TREATMENT: PROTECTED RIGHT TURNS (RH9)

(Mean number per year, rounded to nearest integer)

	Before (1988–90)	*After (1992)*	*Per cent reduction*
Injury crashes	**41**	**23**	**43**
PDO crashes	41	23	43
Persons seriously injured	**32**	**16**	**50**
Killed	5	4	15
Hospitalised	27	12	56
Persons medically treated	36	19	48

Source BTCE estimates based on data provided to FORS by states and territories.

ASSESSMENT OF TREATMENT EFFECTS AND TREATMENTS

As outlined in chapter 6, an important part of the site selection process was to have large enough groups of particular treatments so that estimates of their crash reduction effects, and therefore BCRs, could be made.

On the basis of the pilot study experience of generally five to 10 crashes per site per year before treatment, at least 10, and perhaps even 20, sites with the same treatment would be necessary to draw firm conclusions. Only if relatively large numbers of crashes occurred at individual sites might a grouping of five projects where the same treatment was applied prove sufficient.

According to the site particulars recorded at the time the sample was chosen, there were six urban treatments and two rural ones applied to at least 10 sample sites. In the cases of shoulder sealing (RH1), selective roadside hazard modification (RH4) and protected turning bays (UM2) it proved impossible to gauge the extent of effectiveness of treatment from the limited data available. At the 14 RH4 sites finally in question there was a mean of around one injury crash per site per year prior to treatment and less than one PDO crash. Rural sites in Queensland tended to have very low numbers of crashes each year. As mentioned above, at the nine (following late notification of changes by the jurisdictions) UM2 sites, the lack of improvement in Victoria meant that no significant overall effects could be discerned. While the 15 RH1 sites averaged three injury crashes and over four PDO crashes (outside Victoria) each year before treatment, they showed little or no improvement immediately afterwards.

Three rural treatments and one urban treatment were applied at between five and nine sample sites in the original sampling. Of these, only the six (as it turned out) protected right-turn (RH9) sites had sufficient crashes in the pre-treatment period for some assessment to be attempted. However, the promising early reductions in NSW did not attain statistical significance.

RESULTS OF COST–BENEFIT ANALYSIS: CRASH-TYPE METHOD

Following the previous discussion of the crash numbers required for meaningful analysis of treatment effects, this section presents results of a completed cost–benefit analysis using the crash-type method for five urban treatments at a benchmark discount rate of 8 per cent. Results are also presented using alternative discount rates of 6 per cent and 10 per cent. Results are presented in terms on NPVs and BCRs. The benefits of treatments using the crash-type method have been tested for statistical significance using the method proposed by Tanner (1958) and described in appendix VIII.

Estimates by treatment

The eight treatments for which estimates are presented here or in appendix XIII (without testing for statistical significance) relate to 214 projects (out of a total of 254 in the sample) having a combined capital cost of $22.4 million. As outlined above, in urban areas new traffic signals were installed at 50 sites (at a cost of $5.8 million), traffic signals were modified at 59 sites ($5.7 million), 32 intersections were channelised ($2.7 million), and 12 stretches of medians ($1.1 million), 31 roundabouts ($4.1 million) and nine protected turning bays ($0.7 million) were constructed. In rural areas 15 shoulders were sealed ($1.5 million), and six protected right-turns were completed ($0.7 million).

The estimated lifetimes of these treatments range from 12 years for new and modified traffic signals to 20 years for treatments such as roundabouts and shoulder sealing. First year crash reduction benefits were assumed to continue unchanged for these periods. Box 8.1 displays the BCRs for the five treatments in the sample which were associated with the most crashes.

Table 8.10 sets out NPVs and BCRs for these five treatments at discount rates of 6, 8 and 10 per cent. The total NPV of the sample projects relating to these treatments was $92.7 million at an 8 per cent discount rate. By comparison, the NPVs at 6 per cent and 10 per cent discount rates were $107.3 million and $80.6 million respectively.

The highest BCR of 13.4 was for projects involving provision of medians. Sites where medians were built had falls in right-turn crashes of 48 per cent more than indicated by control areas, and falls in rear-end crashes of 27 per cent more.

The next highest BCR obtained was 6.8 for traffic signal modification. Right-turn crashes were reduced by 56 per cent more than what general community trends would explain, right-angle crashes by 30 per cent more and rear-end crashes by 21 per cent more. It was not possible to establish at how many sites separate right-turn phases had been introduced.

Roundabouts and channelisation projects had BCRs of 5.6 and 4.9 respectively. Although there were often major capital costs associated with roundabouts, right-angle crashes fell 72 per cent and right-turn crashes 88 per cent beyond what was predicted by the control ratios.

BOX 8.1 BCRs FOR SELECTED TREATMENTS: CRASH-TYPE METHOD

Provision of medians	13.4
Traffic signal modification	6.8
Roundabouts	5.6
Intersection channelisation	4.9
New traffic signals	2.6

Note BCRs are based on an assumed constant stream of benefits over project life, discounted at a rate of 8 per cent.

Source BTCE estimates.

TABLE 8.10 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY TREATMENT: CRASH-TYPE METHOD

Treatments	*Capital cost ($m)*[b]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[b]	*BCR*	*NPV ($m)*[b]	*BCR*	*NPV ($m)*[b]	*BCR*
New traffic signals (UH1)	5.8	50	12	12.0	2.6	14.0	2.8	10.3	2.4
Traffic signal modification (UH2)	5.7	59	12	35.3	6.8	39.9	7.5	31.3	6.2
Channelisation (UH3)	2.7	32	15	11.0	4.9	12.8	5.6	9.4	4.4
Provision of medians (UH4)	1.1	12	15	14.7	13.4	16.9	15.2	13.0	12.0
Roundabouts (UH7)	4.1	31	20	19.8	5.6	23.8	6.4	16.6	4.9
Protected turning bays[c] (UM2)	0.7	9	15						
Shoulder sealing[c] (RH1)	1.5	15	20						
Protected right turns[c] (RH9)	0.7	6	20						
Total[d]	22.4	214		92.7		107.3		80.6	

a. NPVs and BCRs 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 estimates.
d. Numbers may not add to totals due to rounding.

Source BTCE estimates based on data provided to FORS by states and territories.

Sites experiencing channelisation had reductions in right-angle and rear-end crashes of 37 per cent and 31 per cent beyond what community trends explained.

Projects involving installation of new traffic signals had a BCR of 2.6. Right-angle crashes at those project sites fell by 74 per cent more than could be expected, and rear-end crashes by 25 per cent more.

In the case of right-turn lanes, shoulder sealing and protected right-turns, there were insufficient crash numbers in the sample to make a definite assessment of their effectiveness.

Table 8.11 sets out the statistically significant crash reduction effects estimated for these treatments. In each case, Tanner's methodology (appendix VIII) was applied to determine which crash types had sustained reductions beyond what might be explained by the experience in control areas. Testing was undertaken on the basis that the natural logarithm of the ratio of observed crashes after treatment, to those expected after the application of state and territory control ratios, was approximately normally distributed. As this quantity had to be estimated from sample data, a one-sided t-test was applied at the 90 per cent significance level. A symmetric 90 per cent confidence interval was then also constructed. When this was converted to a confidence interval for the ratio itself, there was no longer symmetry about the point estimate.

The quantity $1-\kappa$ in table 8.11 can in each case be interpreted as a general percentage crash reduction factor attributable to a treatment after due allowance has been made for general community trends. It effectively represents the amount by which the actual number of crashes after treatment should be less than the number expected in the absence of treatment. As such, it provides a convenient estimate of the crash reduction potential of a particular treatment in terms of crash types when cost–benefit evaluations are being made of proposed safety measures.

Estimates by expenditure category

For the purpose of estimating wider Program benefits, sample projects were categorised on the basis of the amount of capital expenditure involved. This was also the manner in which the sample projects were selected 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). As discussed in chapter 6, characteristics of sample sites within each category closely matched those of all projects completed during the lifetime of the Program.

TABLE 8.11 STATISTICALLY SIGNIFICANT CRASH REDUCTION EFFECTS OF TREATMENTS: CRASH-TYPE METHOD

(per cent)

			90 per cent confidence interval	
Treatment	*Crash type with significant effect*[a]	*Crash reduction factor (1 - K)*[b]	*Lower limit*	*Upper limit*
New traffic signals (UH1)	Right-angle	74	57	85
	Rear-end	25	0[c]	47
Traffic signal modification (UH2)	Right-angle	30	0[c]	54
	Right-turn	56	0[c]	84
	Rear-end	21	0[c]	41
Channelisation (UH3)	Right-angle	37	3	59
	Rear-end	31	12	46
Provision of medians (UH4)	Right-turn	48	0[d]	74
	Rear-end	27	0[c]	47
Roundabouts (UH7)	Right-angle	72	21	90
	Right-turn	88	20	98

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 K represents the ratio of crashes after treatment to the expected number calculated using the relevant control ratios. Therefore, the value (1 - K) 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 (K = 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 - K) 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 K produced a confidence interval including the value of zero. Some of Tanner’s approximations may not be applicable in these cases (see appendix VIII).

Source BTCE estimates based on data provided by the states and territories.

Table 8.12 sets out NPVs and BCRs by expenditure category. The 254 projects in the sample had a total capital cost of $25.5 million. The project sample comprised 95 major ($18.4 million), 62 medium ($4.5 million), 63 small ($2.2 million) and 34 minor (0.4 million) projects. Mean project lifetimes in each category were used in the analysis.

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 total NPV at a 6 per cent discount rate was $97.8 million while at a 10 per cent discount rate the NPV dropped to $71.1 million.

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). While there were significant reductions in several types of crashes for medium and large projects, for small projects, only rear-end crashes (whose costs tend to be fairly low) fell significantly.

Some of these BCRs have possibly been underestimated because of the relatively small number of projects and short after-period examined. With a greater after-period and more projects for each treatment, it is likely that more crash types would show statistically significant crash reduction effects. As the composition of projects in each expenditure category is likely to vary substantially in future studies, no particular importance can be attached to the actual crash reduction factors based on expenditure categories found on this occasion and these have therefore not been reported.

Estimates for Program

Table 8.13 sets out the overall NPVs and BCRs for the Black Spot Program's projects from the Schedule of Acceptable Treatments. These estimates were obtained by expanding the estimates for the four capital expenditure categories by the ratios obtained from table 6.6 to obtain estimates for equivalent categories in the total population of Schedule black spot projects undertaken during the Program. These four individual estimates were then combined to generate an estimate of overall Program Schedule treatment benefits. In carrying out this expansion process it was assumed that the benefits of the treatments in each expenditure category of the sample were representative of the benefits in the corresponding category for the whole Program. This is quite likely as there was a reasonably close match between mean expenditures.

TABLE 8.12 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY EXPENDITURE CATEGORY: CRASH-TYPE METHOD

Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	18.4	95	15	50.2	3.5	59.5	3.9	42.6	3.1
Medium	4.5	62	15	30.3	6.8	35.0	7.6	26.4	6.1
Small	2.2	63	15	2.0	1.8	2.6	2.0	1.6	1.6
Minor	0.4	34	10	0.6	2.1	0.7	2.2	0.5	2.0
Total[d]	25.5	254		83.2		97.8		71.1	

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

TABLE 8.13 COST–BENEFIT ANALYSIS[a] OF ALL PROJECTS BY EXPENDITURE CATEGORY: CRASH-TYPE METHOD

Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*[d]	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	170.8	802	15	466.7	3.5	552.6	3.9	395.7	3.1
Medium	43.3	622	15	293.2	6.8	338.6	7.6	255.8	6.1
Small	23.3	721	15	21.5	1.8	27.5	2.0	16.5	1.6
Minor	7.4	813	10	10.4	2.1	12.1	2.2	8.9	2.0
Total[d]	244.7	2 958		791.8		930.8		676.9	

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance. Figures are also based on actual rather than approved expenditure, and are therefore different from the figures in chapter 2. This analysis was based on the data in table 6.6.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

On this basis, and using an 8 per cent discount rate, the major projects involving Schedule treatments produced an overall net benefit of $466.7 million, followed by the medium, small and minor projects with benefits of $293.2 million, $21.5 million and $10.4 million respectively.

Using the crash-type method, the net present value of benefits to society from the Black Spot Program's Schedule treatments was therefore estimated at $791.8 million at an 8 per cent discount rate and the overall BCR for the major part of the Program was estimated at 3.9. Further benefits arose from non-Schedule site treatments and road safety enhancement measures such as electronic speed cameras and breathalyser units.

RESULTS OF COST–BENEFIT ANALYSIS: CRASH-SEVERITY METHOD

In this section and appendix XIII, the results of the cost–benefit analysis, in terms of NPVs and BCRs, are presented for the crash-severity method for the same eight treatments examined previously under the crash-type method. A benchmark discount rate of 8 per cent was used and results are also presented using alternative discount rates of 6 per cent and 10 per cent.

Estimates by treatment

Box 8.2 displays the BCRs for the five treatments associated with the most crashes. Tanner's methodology has again been applied to establish which crash-severity categories had significant reductions.

Table 8.14 sets out NPVs and BCRs for the five urban treatments mentioned in the previous section, at discount rates of 6, 8 and 10 per cent. The total NPV of the sample projects relating to these treatments was $89.2 million at an 8 per cent discount rate. By comparison, NPVs at 6 per cent and 10 per cent discount rates were $104.2 million and $76.9 million respectively.

The highest BCRs obtained were 9.2 for roundabouts and 7.7 for traffic signal modification. Sites with traffic signal modifications required modest expenditure and experienced drops in serious injury crashes (involving fatalities and hospitalisation) about 60 per cent greater than indicated by control ratios. Although all types of injury crash reductions at roundabouts were at least 80 per cent more than control ratios could explain, large capital costs were incurred at a number of sites, and the average number of crashes per site was much lower than for sites where traffic signals were modified.

Medianisation and channelisation projects had BCRs of 5.0 and 6.5 respectively. New traffic signals had a very low BCR of 0.1. In the case of protected turning bays, shoulder sealing and protected right-turns, there were insufficient crash numbers in the sample to make a definite assessment of their effectiveness.

Table 8.15 sets out the statistically significant crash reduction effects identified for these treatments. In each case, Tanner's methodology (appendix VIII) was applied to determine which crash-severity classifications had experienced reductions beyond what was indicated by control areas. Testing was undertaken on the basis that the natural logarithm of the ratio of observed crashes after treatment, to those expected after the application of state and territory control ratios, was approximately normally distributed. As this quantity had to be estimated from sample data, a one-sided t-test was applied at the 90 per cent significance level. A symmetric 90 per cent confidence interval was also constructed. When this was converted to a confidence interval for the ratio itself, there was no longer symmetry about the point estimate.

The quantity $1-\kappa$ presented in table 8.15 in each case can be interpreted as a general percentage crash reduction factor attributable to a treatment after due allowance has been made for general community trends. It effectively represents the amount by which the actual number of crashes

BOX 8.2 BCRs FOR SELECTED TREATMENTS: CRASH-SEVERITY METHOD

Roundabouts	9.2
Traffic signal modification	7.7
Intersection channelisation	6.5
Provision of medians	5.0
New traffic signals	0.1

Note BCRs are based on an assumed constant stream of benefits over project life, discounted at a rate of 8 per cent.

Source BTCE estimates.

TABLE 8.14 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY TREATMENT: CRASH-SEVERITY METHOD

Treatments	*Capital cost ($m)*[b]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[b]	*BCR*	*NPV ($m)*[b]	*BCR*	*NPV ($m)*[b]	*BCR*
New traffic signals (UH1)	5.8	50	12	–7.2	0.1	–7.4	0.1	–7.1	0.1
Traffic signal modification (UH2)	5.7	59	12	40.9	7.7	46.1	8.5	36.4	7.0
Channelisation (UH3)	2.7	32	15	15.3	6.5	17.7	7.3	13.3	5.8
Provision of medians (UH4)	1.1	12	15	4.7	5.0	5.5	5.6	4.1	4.4
Roundabouts (UH7)	4.1	31	20	35.6	9.2	42.3	10.7	30.3	8.1
Protected turning bays[c] (UM2)	0.7	9	15						
Shoulder sealing[c] (RH1)	1.5	15	20						
Protected right turns[c] (RH9)	0.7	6	20						
Total[d]	22.4	214		89.2		104.2		76.9	

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance. Figures are also based on actual rather than approved expenditure, and are therefore different from the figures in chapter 2.

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 BTCE estimates based on data provided by states and territories.

TABLE 8.15 STATISTICALLY SIGNIFICANT CRASH REDUCTION EFFECTS OF TREATMENTS: CRASH-SEVERITY METHOD

(per cent)

Treatment	*Crash severity with significant effect* [a]	*Crash reduction factor (1 - K)* [c]	*90 per cent confidence interval* [b] *Lower bound*	*Upper bound*
New traffic signals (UH1)	First aid injury	158[c]	100[d]	510
	Medical injury	30	0[d]	61
Traffic signal modification (UH2)	Nil injury	21	6	33
	Medical injury	39	17	55
	Serious injury	60	17	81
Channelisation (UH3)	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 (UH4)	Nil injury	20	0[d]	45
Roundabouts (UH7)	Nil injury	47	8	69
	First aid injury	82	0[f]	99
	Medical injury	80	47	92
	Serious injury	100	e	e

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 K see table 8.11, 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 K produced a confidence interval including the value of zero. Some of Tanner's approximations may not be applicable in these cases (see appendix VIII).

Source BTCE estimates based on data provided to FORS by states and territories.

after treatment should be less than the number expected in the absence of treatment. As such, it provides a convenient estimate of the crash reduction potential of a particular treatment in terms of crash severities when cost–benefit evaluations are being made of proposed safety measures.

Estimates by expenditure category

As was done for the crash-type analysis, for the purpose of estimating Program Schedule treatment benefits, sample projects were categorised on the basis of the amount of capital expenditure involved. 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).

Table 8.16 sets out results by expenditure category. The 254 projects in the sample had a total capital cost of $25.5 million. The project sample comprised 95 major ($18.4 million), 62 medium ($4.5 million), 63 small ($2.2 million) and 34 minor (0.4 million) projects. Mean project lifetimes in each category were used in the analysis.

The total NPV for the 254 projects was $132.7 million at an 8 per cent discount rate 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. Total NPV at a 6 per cent discount rate was $153.4 million while at a 10 per cent discount rate the NPV fell to $115.5 million.

The highest BCR was for the minor projects (26.9) while the lowest was for small projects (0.8). The medium and major projects had BCRs of 6.1 and 5.6 respectively. Reductions in serious injury crashes were statistically significant except in the case of small projects. Although the fall beyond what control ratios predicted was actually highest for major projects, the impact of the capital expenditure incurred is felt in that BCR.

While the sample results indicate that minor projects, costing less than $20 000 each, tended to generate very high returns, caution should be exercised in light of the small numbers of crashes involved. An assessment based on several years' post-treatment data would be desirable.

TABLE 8.16 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY EXPENDITURE CATEGORY: CRASH-SEVERITY METHOD

Expenditure category[b]	*Capital cost ($m)[c]*	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)[c]*	*BCR*	*NPV ($m)[c]*	*BCR*
Major	18.4	95	15	92.3	5.6	107.3	6.3	80.0	5.0
Medium	4.5	62	15	26.8	6.1	31.0	6.8	23.3	5.5
Small	2.2	63	15	–0.5	0.8	–0.2	0.9	–0.7	0.7
Minor	0.4	34	10	14.0	26.9	15.4	28.9	12.8	25.1
Total[d]	25.5	254		132.7		153.4		115.5	

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

Estimates for Program

Table 8.17 sets out the overall NPVs and BCRs for Schedule treatments funded during the Black Spot Program. These estimates were obtained by expanding the estimates for the four capital expenditure categories by ratios derived from table 6.6 to obtain estimates for equivalent categories in the total population of Schedule black spot projects undertaken during the Program. These four individual estimates were then combined to generate an estimate of overall Program benefits where Schedule treatments were applied. With the same justification mentioned in the analysis by crash type, in carrying out this expansion process it was assumed that the benefits of the treatments in each expenditure category of the sample were representative of the benefits in the corresponding category of Schedule treatments for the whole Program.

The major projects produced an overall net benefit of $839.0 million, followed by the medium and minor projects with benefits of $259.3 million and $245.4 million respectively. The small projects produced a net loss of $4.9 million.

Using the crash-severity method, the NPV of benefits to society from Schedule treatments funded by the Black Spot Program 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

Estimates of BCRs based on the crash-severity and crash-type methods of estimating crash costs show some significant differences, indicating that the method of assessing first-year crash reduction benefits, which are then assumed to remain constant over the life of the project, plays a major role.

The range of BCRs for the crash-severity method (0.1 to 9.2) was less than for the crash-type method (2.6 to 13.4) for individual treatments. 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.

TABLE 8.17 COST–BENEFIT ANALYSIS[a] OF ALL PROJECTS BY EXPENDITURE CATEGORY: CRASH-SEVERITY METHOD

Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	170.8	802	15	839.0	5.5	975.0	6.2	726.5	4.9
Medium	43.3	622	15	259.3	6.1	300.0	6.8	225.6	5.5
Small	23.3	721	15	–4.9	0.8	–2.4	0.9	–6.9	0.7
Minor	7.4	813	10	245.4	26.9	269.9	28.9	224.1	25.1
Total[d]	244.7	2 958		1 338.7		1 542.4		1 169.2	

a. NPVs and BCRs are based on changes in crash numbers that have been tested for statistical significance. This analysis was based on data in table 6.6.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

When the entire sample of 254 projects was analysed by expenditure category, the crash-severity NPV exceeded the crash-type NPV by 60 per cent. The crash-severity NPV exceeded the crash-type NPV by 69 per cent once the sample estimates were extrapolated to the entire population of Schedule projects.

For medianisation projects the crash-severity BCR was 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 for crash severity (0.1). However, for roundabouts the crash-severity BCR (9.2) was much greater than the crash-type BCR (5.6). The BCRs using the two methods were reasonably close for traffic signal modification (7.7 and 6.8) and channelisation (6.5 and 4.9).

One reason for such wide variations in results is that the different approaches to valuing costs play a major role when only a small number of crashes are being assessed. In the crash-severity method there are fewer classifications for crashes, and if significant effects were found for serious injury crashes, the unit cost applied was around $170 000. In the analysis by crash type, more crash classifications may reduce the potential for establishing significant effects among small numbers. In any case, the unit costs to be applied for individual crash types are typically in the region of $20 000 to $60 000.

The two most common treatments implemented under the Black Spot Program were modified traffic signals (501 projects) and roundabouts (405 projects). In the first case, there were over 1 000 crashes at the sample sites in each year before treatment, and in the second, crashes almost ceased after treatment. The crash-severity approach produced the higher BCR in both instances.

Where there are very large numbers of crashes, there are better prospects that both methods will identify as significant essentially the same features, and through the laws of large numbers, value them in roughly the same manner. There were about five times as many crashes prior to treatment at all the sites in the sample at which traffic signals were modified as there were at roundabouts. Even though the crash-reduction factors experienced at roundabouts were greater than at modified traffic signals, under the crash-type approach the manner in which reduction benefits were valued was influenced more by the smaller number of crashes which occurred prior to treatment. Under the crash-severity approach, benefits at roundabouts were found to be greater than those at sites where traffic signals were modified.

Table 8.18 shows details of crashes per site before and after treatment for the sample projects by expenditure category. Reductions in total crashes per site ranged from 23 per cent for the small expenditure category and 33 per cent for the medium expenditure category, to 36 and 37 per cent respectively for the minor and major expenditure categories. On the other hand, decreases in serious injury crashes (fatal and hospitalisation) per site varied from 36 per cent for the small projects and 47 per cent for medium projects, to 68 per cent for minor projects and 70 per cent for major projects. Falls in numbers of minor injury crashes (first aid and medical treatment) ranged from about one-third for small projects, and two-fifths for both major and minor projects, to around one-half for medium projects.

Considering these proportions for crash reductions, it is not surprising that the small expenditure category produced the lowest BCR under the crash-severity method of analysis. Further, because the ratio of capital expenditure on major projects to crashes recorded before treatment was much higher than for other categories, even with the sharp reductions achieved in injury crashes, BCRs for major projects under both the crash-type and crash-severity approach were not as impressive as those for medium projects.

These comparisons illustrate the interplay between the relative levels of expenditure incurred and the relative levels of crash reductions achieved in the cost-benefit analytical approach. Very favourable safety outcomes may be overshadowed by the amount of expenditure required to obtain them.

Some studies (for example BTCE 1993; Andreassen 1992) have obtained crash-type BCRs substantially higher than those obtained using the crash-severity method. However, in this study the converse was often found to be the case. The main reason for the result by extent of expenditure is the marked drop in serious injury crashes and associated serious injuries, particularly hospitalisation injuries, at many treated sites.

The Black Spot Program had an impact not only on frequency of crashes but also in mitigating the injury consequences in those crashes which still occurred after treatment. The crash-severity methodology placed a higher value on these changes than did the crash-type approach because of the relative unit costs mentioned earlier.

On the other hand, when particular treatments were considered, the predominance of PDO crashes sometimes meant that the valuation

TABLE 8.18 MEAN EXPENDITURE AND CRASHES PER SITE PER YEAR FOR SAMPLE PROJECTS, BY EXPENDITURE CATEGORY

			Before[a]			*After*[b]		
Expenditure category[c]	*Number of sites*	*Mean expenditure ($)*	*PDO crashes*	*Injury crashes*[d]	*Total crashes*[e]	*PDO crashes*	*Injury crashes*[d]	*Total crashes*[e]
Major	95	193 000	13.9	5.6	19.5	9.4	2.9	12.3
Medium	62	72 000	9.4	4.0	13.3	6.8	2.1	8.9
Small	63	35 000	4.1	2.3	6.4	3.4	1.5	4.9
Minor	34	12 000	3.4	2.3	5.7	2.5	1.2	3.6

a. Mean number of crashes each year during 1988–90.

b. Number of crashes in 1992.

c. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

d. Fatal, hospitalisation, medical treatment and first aid crashes.

e. Numbers may not add to totals due to rounding.

Source BTCE estimates based on data provided by states and territories.

under the crash-type approach was much higher than that under the crash-severity approach.

The crash-type method, being based on more disaggregated data relating to vehicle movements prior to crashes, can usually be expected to capture the economic effects of changes in crashes with better precision than the crash-severity method. Indeed, if the crashes that were observed after treatment were to recur, the cost attached to them under the crash-type method would remain essentially the same. However, chance shifts in the number of fatalities and hospitalisations could result in major revisions of crash-severity estimates. The somewhat atypical results obtained in this study in regard to the relative magnitudes of crash-type and crash-severity BCRs should therefore not be construed as detracting from the advantage of the better precision of the crash-type method in studies involving the analysis of crashes.

CONCLUDING ASSESSMENT

This study provides illuminating perspectives on the results of an extensive black spot elimination program. Due to the limited time frame during which the study was carried out, and the considerable scope of the Program, the study of the sample of treated sites was constrained by data limitations.

There are generally a variety of confounding factors that plague before and after studies such as this, including site-specific factors and the regression-to-mean effect. Available data did not permit all of these factors to be assessed. A major factor—the influence of general community crash trends—was taken into account in the study. The impacts of other factors are not expected to be substantial compared with the overall reductions in crashes consequent to site treatment.

Another difficulty is the instability generally associated with small crash numbers. The reliability of the results of statistical tests tends to be affected by the presence of small crash numbers and in such cases the results have to be interpreted with caution. The effects of some treatments could not be determined because of the small crash numbers that were involved.

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 (the 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.

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

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 strongly suggests that this objective has been achieved.

APPENDIX I ROAD SAFETY (BLACK SPOT) PROGRAM NOTES ON ADMINISTRATION

These Notes on Administration are a guide to the administration of the Black Spot Program and should be read in conjunction with a copy of the Australian Centennial Roads Development Act 1990 *(ACRD). A reference to States in these Notes includes the Northern Territory and the Australian Capital Territory.*

1. GENERAL NOTES

1.1 OBJECTIVE

The objective of the legislation is to provide financial assistance to States as part of a Road Safety strategy to reduce the road toll.

The financial assistance program aims to improve the physical condition or management of locations noted for a high incidence of crashes involving death and serious injury, often termed ‘Black Spots’, and to encourage implementation of safety-related road management techniques that have proven road safety value.

The Black Spot Program provides a source of Federal funding towards road safety projects, distinctly separate from road funding under the ACRD Program.

The Program will commence operation on 1 July 1990 and run for 3 years.

1.2 ADMINISTRATION

The Program will be administered by the Federal Office of Road Safety (FORS), which should be the first point of contact.

1.3 APPLICATION

Funds under the Program are available for:-

- works on public roads, regardless of ownership or control
- capital expenditure on equipment having road safety improvement potential.

1.4 ELIGIBLE WORKS

The Program aims to fund cost-efficient safety-oriented projects. Submissions are expected to encompass locations or safety enhancement measures where the highest benefits can be achieved. Projects should have a benefit to cost ratio of at least 2, and a recorded history of fatalities or serious injuries.

Works eligible for funding may include any construction, alteration or remedial treatment at a demonstrable Black Spot. Specific sites or short lengths of road can be considered.

Up to 10% of the funds, as determined by the Minister, may be available for other tangible and visible road safety enhancement projects, including speed and alcohol limit control equipment, and bicycle and pedestrian safety projects. Examples of the types of projects that could be submitted for consideration are at Appendix 1A (*in this report the examples of road safety enhancement projects are in appendix II)*.

Works already under construction at 1 July 1990 are not eligible for the Program.

Where remedial works are extensive, consideration may be given to joint funding, using Black Spot Program funds to treat the core road safety problem(s), and funds from other Federal or State road programs for adjacent works that enhance the overall safety benefit.

1.5 INELIGIBLE WORKS

Monies are not available for the purchase of road-building plant or equipment, or for the operational or maintenance costs of any road safety enhancement projects that may be purchased or installed under this Program.

Road-based projects on declared National Highways are not eligible for Black Spot funding.

1.6 IDENTIFICATION TECHNIQUES

In preparing program submissions, States will be asked to provide a short outline of the methods used within their jurisdiction to identify Black Spots.

This requirement is to enable States to use suitable assessment methods while at the same time satisfying the objectives of the Black Spot program.

2. PROGRAM SUBMISSIONS

2.1 TREATMENT PARAMETERS

The Federal Office of Road Safety has prepared a Schedule of Treatments, which shows a range of cost-efficient minor traffic engineering works ranked in order of safety benefits. The Schedule is at Appendix 1 (*in this report the Schedule is in table 1.1*).

Based on their own data, States will identify problem sites/lengths. In seeking solutions, States may either choose a corrective action from the treatment types in the Schedule, or nominate some other form of treatment.

Treatments selected from the Schedule will be accepted in programs without further justification. Treatments not on the Schedule will require supporting argument.

Innovative treatments may be proposed. They will be administered as non-scheduled items.

Appendix 2 (*appendix III in this report*) should be used as a guide in providing information.

2.2 ENVIRONMENT

Federally funded projects are subject to the Environment Protection (Impact of Proposals) Act 1974, and the provisions of Section 30 of the Australian Heritage Commission Act 1975. All proposals with significant environmental or heritage implications shall comply with the provisions of this legislation.

2.3 COSTS

All costs directly associated with any approved project are eligible for funding. Ongoing running costs are not eligible for funding.

The approved project cost will be the limit of funding of that project under the Black Spot Program.

To achieve maximum effect from the Program, the emphasis will be on low-cost, high-return projects. Projects estimated to cost less than $200 000 should be given priority consideration when preparing submissions.

2.4 PROGRAMS

States should prepare a submission for the consideration of the Federal Minister listing proposed projects. The initial list of candidate projects should be submitted as soon as possible, and subsequent proposals by the end of March 1991 and 1992.

Information that should be provided in the submission is shown at Appendix 2 (*appendix III in this report*).

States must certify that the proposals conform or will conform with the requirements of Federal and State environmental legislation, as noted in 2.2 above.

As provided in the Act, the Minister may consider a Program made up of projects submitted by a State and other projects nominated by the Minister that meet the objectives of the Black Spot Program. The projects should be capable of completion within the time frame of the legislation.

The Minister may nominate Federal project priorities if the need arises.

The Minister may announce publicly his approval of a State Program at the same time as notifying the States.

2.5 CONDITIONS

States will observe conditions relating to funding arrangements set down by the Federal Minister. The conditions will include implementation of the ten-point road safety package as agreed to between the Commonwealth and the States.

3. FINANCIAL ARRANGEMENTS

3.1 NOTIFICATIONS

States shall provide half-yearly written notification to FORS of progress in implementing the safety package (see para 2.5)

States will provide written notification to FORS within 90 days from when a project reaches virtual physical completion. The notification will indicate the final cost of the project.

3.2 PAYMENTS

States will be advised of an annual indicative allocation for funding approved Programs. Within those advised allocations, payments will be made by equal quarterly instalments.

These payments will be made without a request from the State, subject to approval of a Program, availability of funds, evidence of satisfactory progress with work on projects, and satisfactory implementation of the road safety package.

3.3 STATEMENTS OF EXPENDITURE

Each State is required to submit to the Minister as soon as practicable after 30 June each year financial statements, in a form approved by the Minister, giving details of expenditure from amounts paid under the Act. In preparing statements, States should have regard to the various requirements and conditions specified in the Act.

The approved format for statements of expenditure is at Appendix 3 (*appendix IV in this report*) of these Notes. This format includes amounts expended or set aside during the financial year from amounts paid to the State under the Act. The limit of carry-over into a subsequent year shall be not greater than 10 per cent.

The following certificates and report will be required in respect to the statement:-

1. A certificate from the Chief Executive Officer or his delegate that: 'Expenditure in accordance with the itemised break-up shown is for works carried out in accordance with the Act and the Notes on Administration.'

2. A report by an 'appropriate person', as determined by the Act, which in the case of a State road authority is the Auditor General of the State, stating:-

- whether the statement is in the form approved by the Minister;
- whether, in the person's opinion, the statement is based on proper accounts and records
- whether the statement is in agreement with the accounts and records, and
- whether, in the person's opinion, the expenditure of money has been in accordance with the Act.

The statement should be completed and forwarded to the Department of Transport and Communications for Ministerial consideration no later than six (6) months following the end of the financial year for which expenditure is being reported.

4. PUBLIC INFORMATION

4.1 RECOGNITION

The Minister shall be responsible for publicity on approved projects funded from the Program. Publicity material prepared by a State is permissible where projects are at least equally funded by the Federal and State governments. In this case, States shall advise FORS of impending publicity relating to approved projects. Such publicity shall be cleared before release and acknowledge the Federal funding role.

4.2 SIGNPOSTING

States shall erect signposting at approved Black Spot work sites, except where the project cost is less than $100 000. Signs are to conform with wording and layout at Appendix 4 (*appendix V in this report*). In other cases when work is in progress, a temporary sign is to be erected. Signs shall remain in place for the life of the Program.

4.3 INFORMATION AND INSPECTIONS

Under the Act, the Minister may require any other information about the project or exercise the right to visit work sites at any time, as he sees fit, for himself or any officer connected with administration of the Program.

5. FOLLOW UP

There will be a follow-up to this Program to evaluate the actual effect of the road safety program on road crashes. States should monitor the global program effect, and be in a position to supply a simple evaluation of the effectiveness of individual treatments.

6. SUBMISSIONS

Submissions should be made to the Minister for Land Transport, Parliament House, Canberra ACT 2600

Two copies should also be sent at the same time to the First Assistant Secretary, Road Safety Division, Department of Transport and Communications, GPO Box 594, Canberra, ACT 2601.

Telephone contact number is (06) 274 7445.
The facsimile contact number is (06) 274 7922.

Material transmitted by facsimile should be confirmed by postal advice.

APPENDIX II ROAD SAFETY ENHANCEMENT PROJECTS

Bicycle helmet rebates

Electronic speed cameras

Radar equipment

Breathalyser units

Mobile breath test stations (excluding patrol cars)

Pedestrian safety control measures

APPENDIX III BLACK SPOT PROGRAM APPLICATION INFORMATION

FEDERAL OFFICE OF ROAD SAFETY: GPO BOX 594: CANBERRA ACT 2601
Contact Numbers- Telephone (06) 274 7445 Fax (06) 274 7922

BLACK SPOT PROGRAM APPLICATION INFORMATION

Authority submitting proposal...
Road name(s)...
LGA Name...
Location Description..
....
....

Crash History of Site/Length for last 3 years (*)

....
....
....

Problem Diagnosis

....
....

Treatment Proposed (Schedule Item #)
....
....

Estimated cost to BLACK SPOT Program $...........................
Any other source $...........................

Expected safety improvement from project: (*)

Estimated death/injury/crash reduction ..../Year
Estimated community savings $.................. /Year

<u>If not on Schedule</u>, expected ratio of benefits to costs..............and submission attached

Date expected to commence work ....
Date expected to complete work ....

Any environmental concerns with the proposal? YES/NO
If clearances are required, have they been obtained? YES/NO
If **YES**, please attach copies of Certificate(s)

Date of submission ..../............./..............
Name of contact officer ....Position...........................
Phone.........................Fax..................................

(*) A "crash" is where there has been death or serious injury at the site/length.

Use attachments/sketches where this will simplify your submission.

APPENDIX IV BLACK SPOT PROGRAM FINANCIAL STATEMENT

FINANCIAL STATEMENT

ROAD SAFETY (BLACK SPOT) PROGRAM

Australian Centennial Roads Development Act

Statement of Amounts Expended or Set Aside For Expenditure
From Monies Paid to the State of....................................

Line 1	Amount Received during year ended 30 June 199x	$............
Line 2	Amount Expended during year ended 30 June 199x	$............
Line 3	Amount Set Aside during year ended 30 June 199x	$............

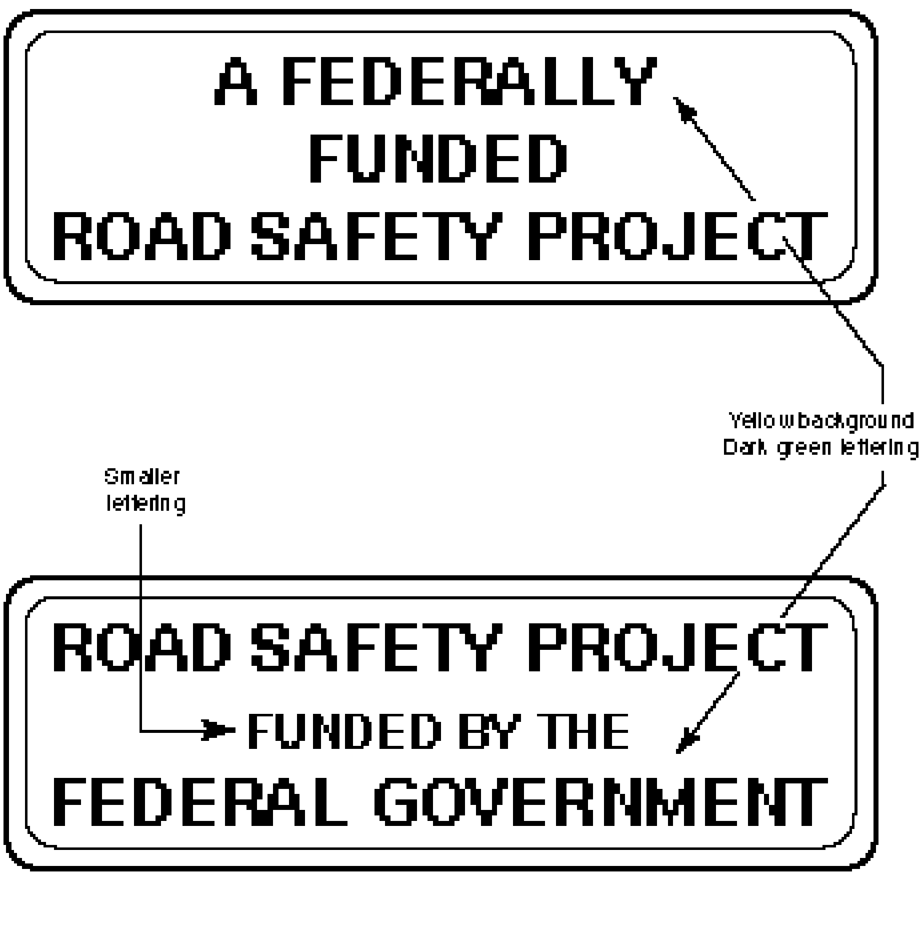
(Line 1 = Line 2 + Line 3)

(certificate of Chief Executive Officer)

(certificate of Auditor-General)

Dated.........../.........../...........

APPENDIX V ROAD SIGN TO BE USED AT BLACK SPOT SITES BEING TREATED



Size of sign approximately 1200 x 800 mm

APPENDIX VI REGRESSION-TO-MEAN EFFECT

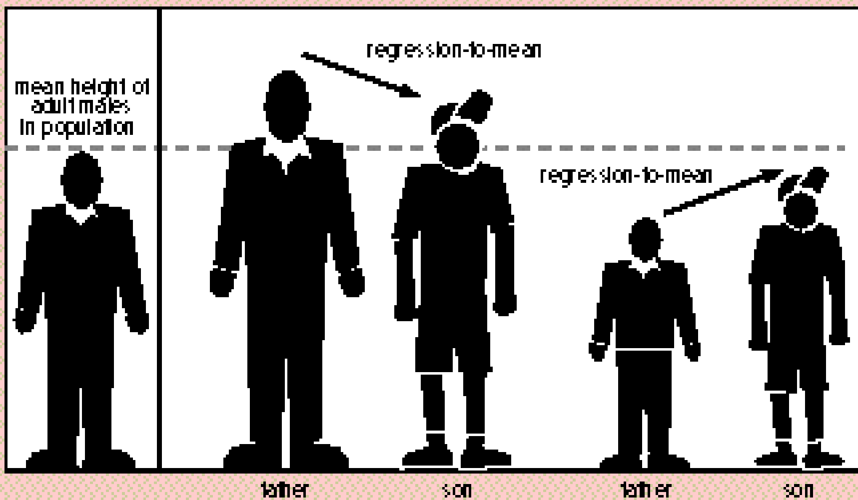
THE CONCEPT OF 'REGRESSION-TO-MEAN'

In his studies of physiological inheritance, Sir Francis Galton (1889) reported that the mean height of sons with tall fathers was less than the fathers' height when both heights were measured at adult ages. He also found conversely, that the mean height of sons with short fathers was greater than their fathers' height. Figure VI.1 illustrates the effect. Galton used the term 'regression' in the sense of the tendency of a variable to return or regress towards its mean value. Galton initially called the phenomenon 'regression toward mediocrity' and later replaced 'mediocrity' with 'mean' (Kotz and Johnson 1982).

The effect originally identified by Galton (often referred to as the 'regression' effect) has more recently been observed in various situations such as golf scores, traffic law violations and road crash counts (Hauer and Persaud 1983). In all these cases, as in Galton's study of inheritance, it was found that what happened in the 'after' period was, on average, different from what happened during the 'before' period.

Regression-to-mean (RTM) is a statistical phenomenon which occurs when two variables (such as the number of crashes that occur during two periods of time at a particular site) are associated with less than perfect correlation (Griffin et al. 1975). Assuming that the numbers of crashes at a site in two time periods are not highly correlated, an unusually high or low number of crashes in one period will tend to be associated with a number closer to the mean during the second period. The lower the correlation between two variables, the more pronounced is the RTM effect. In the case of zero correlation between two variables, irrespective of the value of the first variable, the most likely value or 'best guess' of the value of the second variable is the mean value.

FIGURE VI.1 GALTON'S FINDINGS ON THE RELATIONSHIP BETWEEN HEIGHTS OF FATHERS AND SONS



Note On average, sons of tall fathers tend to be shorter than their fathers, and sons of short fathers tend to be taller than their fathers. In both cases, the heights of the sons tend to 'regress' towards the mean height of males in the population.

Source BTCE.

BTCE

REGRESSION-TO-MEAN IN 'BEFORE AND AFTER' STUDIES

In assessing the effects of road safety treatments, the simple 'before and after' study is commonly used. This type of study compares the number of crashes during a period before treatment with the number during a period after treatment.

The rationale for the 'before and after' approach is as follows. To determine the effect of the treatment, it is necessary to compare the number of crashes that would have occurred in the 'after' period if the treatment had not been applied, with the number of crashes that actually occur after the treatment is applied. However, it is not possible to determine the number of crashes that would have occurred in the after period if the treatment had not been applied. Therefore, it is assumed that the number of crashes observed before the treatment was applied is a reasonable estimate of the number of crashes that would have occurred in the after period without the treatment. This critical assumption in the before and after study can be subject to systematic

RTM bias (other factors that can affect a before and after study are described in chapter 4).

Sites are usually selected for treatment because of their recently observed high crash experience. Due to random variation, it is more likely that sites with a high number of crashes in one period will have a lower number of crashes in the next period than an even higher number of crashes, and vice versa. As the bias arises due to the non-random or selective manner in which some entities (such as black spot sites) are chosen for a particular purpose (such as treatment), the RTM effect is also known as 'bias-by-selection'. However, Hauer (1986) points out that this bias is possible even if the sites are selected on a random basis: it only renders the bias subject to the vagaries of randomness. Under these conditions the bias may be positive or negative and of varying magnitude.

RTM can be easily observed in real crash data sets. Table VI.1 sets out actual crash data for 1 kilometre sections of highway in Ontario, Canada during two consecutive years (Hauer and Persaud 1983). The table shows that road sections which recorded a certain number of crashes in the first year had a lesser number of crashes on average in the second year, and road sections which recorded zero crashes in the first year registered an increase on average in the second year. The last column of the table shows the extent of the RTM effect.

Most statistical methods for correcting for the effect of RTM in before and after studies attempt to provide an unbiased estimate of the number of crashes that would have occurred at a site if it had not been treated. This estimate is then compared with the observed number of crashes in the 'after' period to determine the true effect of the treatment.

The following analysis of the RTM effect at a black spot site subjected to a treatment follows the approach and notation of Mountain and Fawaz (1991).

If m is the expected (that is, long-term mean) number of crashes at a site and x_A is the observed number of crashes after the site is treated, the effect, t, of the treatment is

$$t = \frac{x_A}{m} \qquad (1)$$

If the number of crashes falls after treatment, $t<1$; if it increases, $t>1$; and if the treatment has no effect, $t=1$.

TABLE VI.1 REGRESSION-TO-MEAN IN ONTARIO CRASH DATA[a]

Number of road sections in group	*Number of crashes in first year* [b]	*Mean number of crashes in second year* [c]	*Change (per cent) from first to second year*
12 859	0	0.404	[d]
4 457	1	0.832	–16.8
1 884	2	1.301	–35.0
791	3	1.841	–38.6
374	4	2.361	–41.0
160	5	3.206	–35.9
95	6	3.695	–38.4
62	7	4.968	–29.0
33	8	4.818	–39.8
14	9	6.930	–23.0
33	≥10[e]	10.39	–22.0

a. Crash data for 20 762 sections of highway, each 1 kilometre in length, in Ontario, Canada. The data are for two consecutive (unspecified) years. The mean number of crashes per kilometre during the first year was 0.707 and during the second year, 0.746. It is possible that several confounding factors were present in the second year, such as changes in road and environmental conditions and more stringent traffic law enforcement. However, it is unlikely that such effects can fully explain the magnitude and consistency of the observed regression effects at individual road sections.

b. The number of crashes at the corresponding group of road sections. For example, 12 859 road sections had no crashes during the first year.

c. The mean number of crashes at the corresponding group of road sections during the second year. For example, the 12 859 road sections which had no crashes in the first year, had a mean of 0.404 crashes during the second year.

d. Increase.

e. Mean of 13.33.

Source Hauer and Persaud (1983).

The percentage change, T, in crashes after treatment is given by

$$T = \left(\frac{x_A - m}{m}\right) \text{ 100 per cent} \quad (2)$$

It is possible to observe x_A, but m has to be estimated. If x_B is the number of crashes observed in the period before treatment, x_B is not a good estimator of m. As already noted, this is because sites are generally selected for treatment on the basis of an unusually high x_B. In other words, if the effect, t, of a treatment is estimated as t^*,

$$t = \frac{x_A}{x_B} \quad (3)$$

where the estimate t^* will be less than t so that T (the percentage change in crashes) will be overestimated. The error in the estimator t^* is the RTM effect. If r denotes the RTM effect, it can be expressed as

$$r = \frac{m}{x_B} \quad (4)$$

and $t^* = rt$

The percentage change in crashes due to the RTM effect, R, can be expressed as

$$R = \left(\frac{m - x_B}{x_B}\right) \text{ 100 per cent} \quad (5a)$$

or R=(r–1) 100 per cent (5b)

IMPLICATIONS OF REGRESSION-TO-MEAN IN ROAD SAFETY

Policy decisions based on the results of evaluation studies which have not accounted for RTM bias when there is a substantial likelihood of its presence can lead to a systematic misallocation of road safety resources.

In certain cases RTM effects can appreciably overstate the true benefits of treatments. Wright and Boyle (1987) indicate regression effects of the order of 5 to 30 per cent at sites with observed crash frequencies in the range normally considered appropriate for remedial treatment. Brude and Larsson (1982) observed regression effects of 50 to 60 per cent for injury crashes at unaltered rural road junctions in Sweden.

Nguyen (1986) estimated the effects of RTM in two samples of sites in Melbourne: a sample of 20 low-cost traffic signal treatment sites and a sample of 50 sites that were part of a traffic signal coordination program. Two methods of estimation were used: the non-parametric method of Hauer (1980a) and the Empirical Bayesian method of Abbess et al. (1981).[1] The estimated RTM bias for the low-cost traffic signal treatment was less than 1 per cent while for the signal coordination sample it was less than 2 per cent. It was also found that the signs of the biases for individual sites (positive for under-estimation and negative for an over-estimation of the apparent treatment effect) virtually cancelled out.

Nguyen recognises the highly resource intensive nature of the task of correcting for RTM bias. He concludes that whenever the criteria for selection of a road safety treatment are composite, such as often occurs when road safety is only one of a number of operational, strategic, political and other concerns, the estimation of the RTM bias may be given a low priority. Nguyen's results suggest that when studying a fairly large group of sites, the effects due to RTM at individual sites could be both positive and negative and the resulting net effect may be fairly small.

To minimise regression effects, it is necessary to choose sites for treatment which have high crash rates in the long-term rather than those whose observed high crash rates are due only to short-term random fluctuations. Crash data collected over a long period are likely to provide a good estimate of the underlying mean crash rate. However, the social and political pressure to treat sites with recent high crash rates often precludes the possibility of studying a site's crash history over a relatively long period. The process by which an agency selects a particular site for treatment is usually not straightforward and completely transparent, which means that the extent of any RTM bias is uncertain. However, to the extent that a black spot may indeed have an inherent engineering or environmental defect, the effect of RTM would be expected to be small.

METHODS FOR DEALING WITH REGRESSION-TO-MEAN

The simple 'before and after' study (a 'non-experimental' approach) does not attempt to identify or control for other possible causes (including the RTM effect) of the observed effect following a treatment.

1. Both methods are described in this appendix.

By contrast, methods for dealing with RTM include an experimental approach in which it is eliminated entirely, ‘quasi-experimental’ time series approaches which can determine if regression effects are plausible explanations for an observed change, and various statistical methods which attempt to calculate numerical adjustments or corrections.

The key to removing any RTM bias involves estimating the ‘expected’ number of crashes (that is, what the number of crashes would have been in the after period had there been no treatment). This is in fact what most statistical methods are designed to achieve. The following description of methods that could be used to deal with RTM classifies them according to their general methodological basis.

Experimental analysis

The ‘classical experiment’ involves the use of a ‘treatment’ group and a ‘control’ group. The control group should be similar in all respects to the treatment group. This is the best method for taking account of RTM effects.

Ideally, a group of similar sites which are candidates for treatment should be assigned randomly to a treatment group and a control group. Random assignment is intended to make the two groups similar in all respects except for the treatment. If regression effects are present, they should affect both groups in a similar manner.

However, good control groups are seldom found. If a site has an unusually high number of crashes and an appropriate treatment is available, deferring implementation of the treatment for research purposes is hard to justify on ethical grounds. Hauer (1986) has shown that there can be substantial random variation from year to year in the average number of crashes at small groups of sites. Therefore, even if suitable control groups are available, and if these groups are relatively small in number, the advantage of eliminating RTM bias can be counteracted by imprecision in the estimates of the treatment effect.

Time series methods

When full experimental control is not possible, a quasi-experimental design may be used to identify regression effects. A common method of doing this is to extend and make more reliable the simple before and after study by adopting a time series approach. The general methodology is 'quasi-experimental analysis' and the specific method of analysis is the 'interrupted time series design' (Campbell and Stanley 1966). Interrupted time series in this context differs from the time series in economics. In economic time series the exogenous causal variable is continuously present to different degrees, whereas in interrupted time series the 'causal' variable is examined as a specified intervention or shock at a point in time (Campbell and Ross 1968).

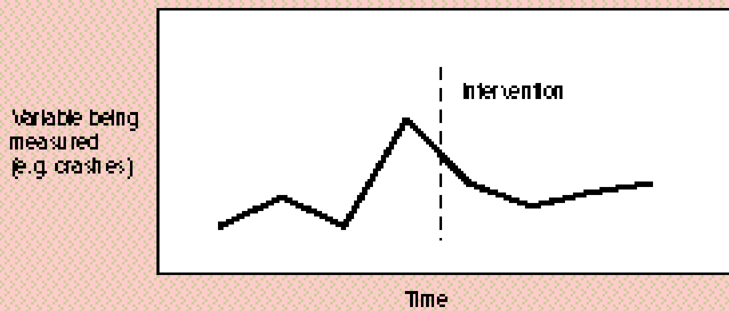
The quasi-experimental approach essentially posits that the observed effect following an intervention can be attributed to the intervention unless proven invalid and that the only invalidation is from plausible rival explanations for the effect. It is the obligation of the researcher to consider and assess all possible rival explanations (including regression) for the effect.

In the case of a black spot site, the interrupted time series design involves a series of observations of crashes at a site over time (with seasonal trends removed) interrupted by the treatment. The time series can indicate whether there was an abrupt change in the number of crashes after the implementation of the treatment. The interrupted time series method by itself cannot take account of all rival explanations for the observed effect, particularly a long-term trend. It can, however, be combined with other time series data (such as those for control areas) to provide multiple time series designs which can be used to assess the effect of the long-term trend and other factors.

The interrupted time series method assesses regression effects by determining whether the level of the series is normal or extreme at the time of the intervention. Various competing explanations for the change being studied, including regression, are associated with parts of the time series graph with characteristic shapes or slopes. As shown in figure VI.2, the part of the graph suggesting the presence of a regression effect would generally occur just after a sharp peak in the series, and be downward sloping with the slope decelerating with time (Ross 1973). The shape of the relevant part of the time series graph would enable an assessment to be made of the direction and significance of the regression effect.

Interrupted time series has been used in a few studies on road safety issues. Campbell and Ross (1968) studied the effects of a licence suspension system introduced to deter speeding in Connecticut, United States in 1955. They found that regression and instability were plausible explanations for much of the decline in fatalities that occurred shortly after the system was introduced. Ross (1973) used interrupted time

FIGURE VI.2 TIME SERIES SHOWING RTM EFFECT TO BE A REASONABLE EXPLANATION FOR AN INTERVENTION (for example, a black spot treatment)



Source: Adapted from Ross (1973).

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series analysis to investigate the deterrent effects of the *British Road Safety Act 1967* on drink driving. He concluded that regression was one of several implausible explanations for the change, and that the Act had in fact had the desired deterrent effect by causing a substantial reduction in casualties.

Techniques of intervention analysis have also been developed whereby external shocks or interventions can be modelled using appropriate dummy variables. One of the most powerful techniques for analysing fairly long time series (more than about 50 observations) is the autoregressive integrated moving average (ARIMA) model. Statistical techniques have been developed to test for possible rival explanations for a particular intervention. McDowall et al. (1980) describe procedures to model and assess whether intervention effects are abrupt, permanent; abrupt, temporary; or gradual, permanent. ARIMA models can be used to assess the impact of interventions such as road engineering treatments on time series data. In Australia, intervention analysis techniques have been applied by Bhattacharyya and Layton (1979) to assess the effectiveness of seat belt legislation in Queensland.

Another technique of intervention analysis that has been used to study road safety issues is based on structural time series modelling, which differs in significant respects from ARIMA modelling. The technique has been used by Harvey and Durbin (1986) to estimate the changes in casualty rates following the introduction of British seat belt legislation.

Time series models could not be applied meaningfully in this study because of the relatively small number of observations that were available.

Non-parametric method

Non-parametric (distribution-free) methods assume no knowledge about the distributions of the underlying populations. To estimate the expected number of crashes in the after period if the treatment had not been applied, it is necessary to know the number of crashes at the site in the before period. Because the site was chosen for treatment from a group of candidate sites, it is also necessary to know the number of crashes at the other candidate sites during the before period.

Using a non-parametric method, Persaud and Hauer (1984) derived a formula to estimate $a(k)$, the number of crashes expected to occur during the equivalent after period at the group of sites which had k crashes in the before period. This estimate is then compared with the observed number of crashes after treatment to provide an unbiased estimate of the treatment effect. The equation is:

$$a(k) = [(k+1)N_{k+1}]\,/N_k \qquad (6)$$

where N_k and N_{k+1} are the number of sites having k and $(k+1)$ crashes respectively in the period before treatment.

This method assumes that crashes at individual sites are Poisson distributed, but makes no assumptions about the distribution of crashes in the population of sites. The formula is convenient to use because only the crash history of the treated sites needs to be known. A disadvantage of the method is that it cannot deal with RTM at individual sites.

Bayesian methods

Conventional or frequentist statistical theory interprets probability objectively in terms of frequency. By contrast, the Bayesian approach combines sample information with other available prior information that may appear to be relevant. Bayesian methods assume that a parameter such as the number of crashes at a black spot can be regarded as a random variable having a particular prior probability distribution. The probabilities associated with this prior distribution are subjective probabilities because they incorporate a person's degree of belief. Researchers use individual knowledge and experience as the basis for specifying the subjective probabilities given by the prior distribution.

Bayesian techniques use the prior distribution and the sampling distribution to calculate the posterior distribution using Bayes Theorem. The posterior distribution consists of information from the subjective prior distribution and the objective sampling distribution, and indicates the researcher's degree of belief in the value of the parameter after the sample has been observed.

Bayesian methods are classified into Pure Bayesian and Empirical Bayesian methods. In Pure Bayesian methods, assumptions are made about the parameters of the prior distribution without any data, while in Empirical Bayesian methods the prior parameters are estimated using data. The Empirical Bayesian approach is a hybrid which incorporates the methods of conventional statistics and Bayesian methods (Maritz 1970). The Empirical Bayesian approach has been gaining increasing prominence in road crash data analysis because estimates obtained using the approach are not subject to RTM bias.

Abbess et al. (1981) propose an Empirical Bayesian method which requires crash data for the entire population of sites. It has been shown (Gipps 1980; Abbess et al. 1981) that if the number of crashes at a site is Poisson distributed about a constant true mean, and if the prior between-site variation in the true means can be described by a gamma distribution, the posterior distribution is also of gamma form. The parameters of this posterior distribution can be derived from the prior parameters and observed data. The mean of the posterior distribution represents a prediction of the number of crashes in a future period and takes account of RTM, assuming that the true crash rate remains constant.

If the true crash rates fit a gamma distribution, the observed number of crashes, which are assumed to be Poisson distributed about the various true means, will collectively fit a negative binomial distribution. Under the foregoing assumptions, if a total of s crashes is observed at a site in n years, the RTM effect for a site is given by the expression

$$[(\frac{s_0+s}{n_0+n})\frac{n}{s}-1]\times 100 \text{ per cent} \tag{7}$$

where s_0 and n_0 correspond to the shape and scale parameters respectively of the prior gamma distribution (for the derivation of this formula see Abbess et al. 1981).

Abbess et al. (1981) recognise that the best method for estimating s_0 and n_0 is maximum likelihood estimation. However, for practical purposes they propose the method of moments. If the mean number of crashes over the past year at all sites in the area is $\bar{a}$ and the variance is var(a), rough estimates $\hat{s}_0$ and $\hat{n}_0$ of s_0 and n_0 are:

$$\hat{s}_0 = \bar{a}^2 \ / \ [\text{var}(a) - \bar{a}\,] \qquad (8a)$$

$$\hat{n}_0 = \bar{a} \ / \ [\text{var}(a) - \bar{a}\,] \qquad (8b)$$

These results are consistent with a more general result derived by Hauer (1986) based on the work of Katz (1963). If the number of crashes in a population of similar sites to which the site belongs in a given period has mean $\bar{x}$ and var(x) and the site has x crashes in that period, then the expected number of crashes at that site in a similar subsequent period is given by

$$x + \bar{x}\,(\bar{x} - x) \ / \ \text{var}\,(x) \qquad (9)$$

This result is applicable in cases where the observed distribution of crashes at the sites is any one of several discrete probability distributions including the negative binomial, binomial and Poisson. The method is easy to use but is very sensitive to the manner in which the population of similar sites is defined (Elvik 1988b). Elvik showed that a wide range of estimates for the RTM effect can be generated by changing the definition of the population to which the site is supposed to belong.

Mountain and Fawaz (1991) propose that if the between-site variation in the true means can be described by a gamma distribution, the expected crash frequency at sites similar to the study site can be estimated using any of several existing prediction models such as those in the COBA manual (United Kingdom, Department of Transport 1981). Alternatively, regression methods may be used to establish prediction models. However, these models require large amounts of data. The more complex models relate crash frequencies by type to traffic flow and site geometry.

Mountain and Fawaz (1991) cite a study by Brude and Larsson (1987) in which the latter use prediction models to eliminate RTM effects. One of the difficulties in using existing prediction models is that the shape parameter of the gamma distribution cannot be directly estimated. Brude and Larsson assume an arbitrary range of values for the shape parameter, ranging from 1 to 25. Even if this range of values can be narrowed, as has been done by some researchers, considerable inaccuracies in the estimates of the actual treatment effect are possible.

A similar approach was suggested by Hauer (1992) who proposed a multivariate regression method based on the Empirical Bayesian approach. The method provides estimates of the expected number of crashes and its variance for an imaginary reference population whose characteristics are identical to the measured characteristics of the site being studied. The method uses a multivariate model which incorporates information about the characteristics (such as gender, age, traffic volume and site geometry) of the site being studied and information derived from the crash history of the site. The method can be used when large reference populations do not exist but there are sufficient data to construct a multivariate statistical model.

The EBEST (Empirical Bayes Estimate of Safety in Transportation) methodology was developed by Pendleton (1991) and Pendleton et al. (1991) for the US Federal Highway Administration. EBEST, which is available in the form of computer software, estimates the effect of a treatment and tests its statistical significance. The EBEST methodology uses the method of maximum likelihood in the estimation procedure and incorporates a measure of exposure (such as traffic volume or road section length) in the prior distribution, and this enables each site to be evaluated individually and weighted by its exposure.

The EBEST procedure uses both a reference and a treatment group to estimate the unknown parameters of the assumed gamma distribution of the site true mean crash frequencies. The reference group is the population of potential treatment sites. Exposure data is required for all the sites in the treatment and reference groups.

The use of EBEST requires certain assumptions to be satisfied. One of the critical assumptions is ‘exchangeability’. Exchangeability involves the assumption that the site true means are identically and independently distributed. This means that the sites in the reference group should be homogeneous with respect to factors that influence their safety such as traffic volume, site geometry and other site-specific factors. Put another way, there should be no a priori reason to know that one site’s true mean crash frequency is different from any of the others.

Regression method

A ‘two-period regression’ method has been proposed (Jarrett et al. 1988; Jarrett 1991) which is close to the original concept of RTM investigated and named by Galton (1889). The method involves fitting a regression equation to crash frequencies at untreated sites for two separate time periods. These time periods are chosen to be the same as the before and after periods at a treated site. The resulting equation can be used to predict the crash frequency which would have been expected if the site had not been treated, thereby making it possible to assess the real effect of the treatment. Jarrett et al. (1988) showed that the regression equation would be linear under fairly general conditions. If the before crash numbers are denoted by x and the after numbers by y, a line $\hat{y} = a + bx$ can be fitted to the data.

Ordinary least squares is not an appropriate approach for the estimation of the regression coefficients a and b in this case because the variance of y is not constant. Some form of weighted least squares is more appropriate. The approach does not require the assumption that the crash frequency at a site satisfies a Poisson distribution. It is sufficient to assume that the frequency has a distribution with variance proportional to the mean. It is also not necessary to assume that the mean crash frequencies of the sites conform to a gamma distribution.

Jarrett et al. (1988) argue that although the regression method gives less efficient estimates of the regression coefficients than approaches which require a negative binomial distribution to be fitted, it is valid under less restrictive assumptions and is therefore a more robust method.

METHODOLOGICAL ISSUES

The above discussion of the various methods that have been proposed to deal with the RTM effect suggest several practical difficulties associated with these methods. The experimental method for controlling for regression effects is impractical to apply. The quasi-experimental approach using interrupted time series analysis is generally capable of determining whether regression effects are a significant explanation for a particular change, but it cannot precisely quantify the effect. The method also requires data for fairly long periods before and after treatment.

The statistical methods that have been described rely on certain assumptions which are questionable. There has often been a general assumption that the number of crashes at an individual site in a given period of time is Poisson distributed about a constant true mean. Bayesian methods and the regression method assume a particular distribution of mean crash rates between sites.

Nicholson (1985) cites the work of Hauer (1978) who found that traffic conflict counts sometimes do not follow a simple Poisson distribution. Therefore, assuming that there is a close relationship between conflicts and crashes, crash counts would not be expected to follow a Poisson distribution. Nicholson (1985) also describes his own empirical study of crash counts at intersections in Auckland, New Zealand, the results of which reveal an inconsistency with the Poisson assumption. The statistical methods for correcting for RTM bias also assume that the underlying true crash rate at a site is constant over time. In reality, this rate may vary with time for each location (Nicholson 1988). The analysis of crash trends in Australia between 1988 and 1992 described in chapter 7 bears this out.

The Empirical Bayesian methods assume that if the between-site means fit a gamma distribution, the observed crash numbers would fit a negative binomial distribution. Nicholson (1988) notes that a good fit of the negative binomial distribution to observed crash count data does not mean that the Poisson and gamma distributions are appropriate assumptions. He further notes that the choice of the gamma distribution is one of mathematical convenience because it is the natural conjugate of the Poisson distribution.

Wright et al. (1988) found that the Empirical Bayesian methods of Abbess et al. (1981) and Hauer (1986) were not very sensitive to assumptions about the form of the distribution of mean crash rates between sites in the population. They found that various distributions which differed widely from the gamma distribution produced RTM effects of a similar order of magnitude to the gamma form, and they therefore expected estimates based on the gamma distribution to give reasonably accurate results. However, they noted that the gamma assumption could lead to substantial errors in estimating the RTM effect for sites close to the upper extreme of the distribution.

Commenting on the two-period regression method, Wright et al. (1988) observe that although the method can be applied to almost any form of data, the particular function chosen for the regression model implies an assumption about the nature of the distribution of site means. Jarrett et al. (1988) note that the standard errors of the regression coefficients produced by the method are relatively large even for moderate sample sizes, resulting in considerable uncertainty about the size of the RTM effect.

Most statistical methods for correcting RTM bias require crash data for the site being studied as well as crash data for similar untreated sites. The issue therefore arises of defining what ‘similarity’ means (Mountain and Fawaz 1991; Wright et al. 1988). The use of all sites in the area in which the sites being treated are located will produce biased estimates unless the treated sites are truly representative of the population. In practice, sites to be treated are unlikely to be representative of the population, as these sites will tend to have higher underlying mean crash rates than the population as a whole. It is therefore desirable to divide the population of sites into homogeneous sub-groups which are similar in terms of various observable factors such as crash history, traffic flow and site geometry. While attempting to ensure homogeneity within sub-groups, it is also important to ensure that the number of sites in each group are not too small, as this would affect the reliability of the estimates.

Some degree of judgment is inevitably required in grouping ‘similar’ sites. Hauer (1986) notes that it would be expected that entities are subjected to treatment not only on the basis of their crash history but also on the basis of a diagnosis of a fault which can be rectified. Hauer argues that if this is the case, the treated entities are almost certainly a different group from those that are untreated, and points out that the extent to which this difference affects estimation accuracy remains to be determined.

Apart from the problem of defining ‘similarity’ there is also the practical difficulty of identifying similar sites which have been left untreated. The Empirical Bayesian methods also require substantial amounts of data on the untreated sites, such as exposure, and these are not always available or up-to-date.

Wright et al. (1988) point out that none of the statistical methods have ever been tested against real data in a controlled experiment. The real test of the validity of the methods would be to use them to predict the RTM effect for a sample of sites which are identified for treatment. Treatment of these sites could then be suspended and the observed RTM effect compared with the predicted effect. As this is not likely to happen, the effectiveness of statistical methods for dealing with RTM effects will probably remain a matter of continuing debate.

APPENDIX VII ACCIDENT MIGRATION

THE CONCEPT OF 'ACCIDENT MIGRATION'[1]

The term 'accident migration', which occurs in the literature on road safety, normally refers to the observed increase in the number of crashes in the neighbourhood of a black spot site after it has been treated: there is an apparent migration of crashes from the treated site to surrounding sites. Spatial crash migration within a treated black spot is also possible: after treatment, crashes in one part of the black spot site decrease while crashes in another part increase.

If crash migration does indeed exist, it has important implications for road safety because the apparent benefits of black spot treatments will be counteracted wholly or partly by increases in crashes in other areas of the road network. An associated issue which has implications for the selection of treatments for black spot sites is whether different types of treatment cause different degrees of migration. The possible existence of migration also has important implications for the manner in which the road area is defined in evaluation studies which adopt the 'before and after' analytical approach. Restricting the analysis to the before and after crash experience at hazardous sites or road sections which have been treated will preclude the investigation of possible migration effects beyond the bounds of the treated areas.

Crash migration in the spatial sense is one type of migration. Other types of migration are also possible. These include migration by type of crash (a treatment reduces the crash type it was intended to reduce, but increases certain other crash types); and migration by injury severity

1. The term 'accident migration' has been used to introduce the subject because it is well-established in the literature. As explained in box 1.1, the preferred term used in this report is 'crash' rather than 'accident' and hence 'crash migration' has been used extensively in this appendix and elsewhere in the report.

(there may be an overall increase or decrease in the average severity of crashes that occur at a black spot after it is treated).

There is some empirical evidence that crashes migrate by type and severity. Some studies of crashes at signalised intersections have reported a significant change in crash types after signalisation. For example, a before and after study of 31 signalised intersections by Short et al. (1982) found little or no overall change after signalisation in the number of crashes and in their severity as measured by property damage only equivalent (PDOE). A significant decrease of 34 per cent in the number of right-angle crashes was accompanied by a significant increase of 37 per cent in rear-end crashes (including side-swipes) and a significant increase of 41 per cent in 'other'(head-on, vehicle / bicycle, fixed-object etc. crashes.

Adams (1988a) suggested that crashes can migrate over time as well as space. He cited the anecdotal evidence of an operator of mixed fleet buses in Ontario, Canada. The operator had seen older children, who for many years had been transported in school buses (which had flashing lights when stopped to make it obligatory for traffic in both directions to stop to let the children cross the road), step off a charter bus and cross the road without looking. There is as yet no empirical evidence for temporal crash migration.

RESEARCH ON CRASH MIGRATION

The first empirical study on crash migration was conducted by Boyle and Wright (1984). They studied a sample of 133 sites treated between 1975 and 1978 in 16 London boroughs. The results showed that, after treatment, there was a 22 per cent decrease in crashes at the treated sites over the three-year period, accompanied by a 10 per cent increase in crashes at the links and nodes in the immediate surrounding areas. This apparent migration of crashes into the surrounding area was adjusted to take account of secular trend. For the 16 boroughs as a whole, after deducting crashes at treated sites, there was a 0.6 per cent rise in crashes over the same period. The researchers concluded that the observed 10 per cent increase in crashes in the areas surrounding the treated sites was highly significant.

Boyle and Wright (1984) offered what is essentially a 'risk compensation' explanation for crash migration. An untreated black spot has a higher number of crashes than an average location on the road network and is therefore also likely to have a higher than average number of near misses or conflicts. Some proportion of drivers leaving an untreated black spot would have experienced some type of conflict and are therefore likely to drive more cautiously. The higher level of caution displayed by these drivers will artificially depress the number of crashes in the surrounding area. After the black spot is treated, the proportion of drivers displaying cautious behaviour will decrease, causing the number of crashes in the surrounding area to increase to its 'natural' level.

The study by Boyle and Wright attracted considerable criticism on methodological grounds. A key criticism by Stein (1984), amplified by McGuigan (1985), was that the possible effect of 'regression-to-mean' (RTM) (see appendix VI) had not been taken into account in the study as the effect could also apply in reverse to neighbouring untreated sites. According to this argument, sites which had higher than expected crash numbers would tend to show a reduction in crashes in the near future, while nearby sites with lower than expected crash numbers would tend to show an increase. This combination of events could lead to the erroneous conclusion that crashes had 'migrated'. McGuigan's study involved an analysis of a set of crash data relating to the Lothian Region in the United Kingdom and concluded that at least some, and possibly a major part, of the apparent crash migration identified by Boyle and Wright was due to a reverse RTM effect.

Boyle and Wright (1985) did not concede that the reverse RTM effect could account for their results. They pointed out that McGuigan's analysis assumed that all sites in the study area with more than a given number of crashes are black spots which will be treated during the study period, whereas in practice only a small proportion of them will be treated. As many of the untreated sites adjacent to the treated black spots will have high crash rates, they argued that a reverse RTM effect of the magnitude necessary to account for their results would not be expected at these untreated sites.

Persaud (1987) cites a study by Ebbecke (1976) which examined the safety effect of converting 222 one-street stopped intersections in Philadelphia to all-way stop control from 1968 to 1972. Ebbecke concluded that while conversion of these particular intersections to all-way stop control reduced crashes by about 50 per cent, the crashes over the total area were rearranged rather than reduced. Persaud argued that because the intersections selected for conversion in Ebbecke's study were chosen on the basis of public pressure, they may have been associated with unusually high crash rates. Ebbecke's conclusion may therefore have been influenced by his study not accounting for the possible effects of RTM.

Persaud used Ebbecke's data set and calculated unbiased estimates of the expected number of crashes at the treated intersections by using data for a group of untreated intersections. Despite this refinement, Persaud found that most of the crashes saved at the converted intersections had apparently migrated to the unconverted ones. Persaud considered that the explanation for this phenomenon is bounded by two possibilities: drivers try to maintain a target level of risk consistent with 'risk homeostasis theory' (see p.259) or drivers adapt to the changes in a complex manner which has little to do with maintaining a target level of risk. Persaud reasoned that his empirical results favour the second possibility. He argued that this adaptive behaviour on the part of drivers could take different forms, such as choice of route resulting in traffic redistribution, incorrect anticipation of the behaviour of other drivers, and changes in speed distribution. According to this hypothesis, real or perceived risk is traded against other attributes of travel without attempting to maintain it at some target level.

Maher (1987) took McGuigan's RTM explanation of crash migration further by proposing a probabilistic hypothesis. Maher argued that crash migration and RTM both arise from the same cause: bias-by-selection. A key ingredient in Maher's explanatory model is that of 'spatial correlation' of crash rates: there is positive correlation (similarity) between the underlying crash rates at adjacent sites. To support this argument he cited research studies which have found that the primary explanatory variable for the crash rate at a site is traffic flow or exposure. As there are continuous flows of vehicles passing through the road network, Maher argued that flow levels at adjacent sites will tend to be similar, thereby leading to a similarity in their crash rates.

Maher's hypothesis can be explained in symbolic terms as follows. Let y be the observed crash frequency in the before period and m be the underlying or true crash frequency. Assume that sites are identified for treatment on the basis that the observed number of crashes is greater than some critical value k ($y>k$). Therefore, a neighbouring site has to meet two conditions: its y value must be less than or equal to k and it must be adjacent to a treated site.

At a treated site m will tend to be high because to be selected for treatment its y must be high. At a neighbouring site y must be low (because it does not qualify for treatment) but m will be high (because of spatial correlation: it is adjacent to a treated site which has high *m*). In the period following the treatment, the expected crash frequency at the neighbouring site will be *m* and the apparent proportional change in the crash rate will be

$$\frac{m-y}{y} \quad (1)$$

Following from the foregoing reasoning, the sign of expression (1) is likely to be positive, indicating an increase in the crash rate at the neighbouring site and thereby explaining the apparent 'migration' effect. Table VII.1 clarifies the theory.

Using simulated data sets, Maher showed that the apparent crash migration effects found by Boyle and Wright could be explained by his probabilistic model. This research suggests that attempts to explain crash migration should account for RTM effects as well as spatial correlation between neighbouring sites.

TABLE VII.1 PROBABILISTIC EXPLANATORY MODEL OF CRASH MIGRATION

	Treated site	*Untreated neighbour*
Number of crashes before treatment	$y>k$ high m	$y \le k$ high m
Proportional change in observed number of crashes after treatment	$(\frac{k_1 - y}{y})$ negative $k_1 < y$	$(\frac{m - y}{y})$ positive $k_1 < y < m$

Note The expected crash frequency (underlying or true crash frequency) at a site is represented by *m*. Assuming that there is spatial correlation between the treated and untreated sites, both sites will have similar high values of *m*. The observed number of crashes is represented by *y*. The decision to treat a site is assumed to be based on *y* being greater than a certain critical number of crashes *k*. After the site is treated, it is assumed that the crash frequency falls to k_1 which is less than *k*. The proportional change in crash frequency is negative for the treated site and positive for the nearby untreated site, creating the illusion that crashes have migrated.

Source BTCE interpretation of probabilistic hypothesis of crash migration proposed by Maher (1987).

In a subsequent paper, Maher (1990) acknowledged the limitations of the simulation approach and again attempted to explain the migration effect in purely probabilistic terms. In this instance he used a bivariate negative binomial model incorporating spatial correlation between the true mean crash rates of sites. The assumption of spatial correlation used in Maher's probabilistic models is based on established relationships between crash frequency and traffic flow and the continuity of flows within the road network. However, the extent of such correlations is not yet determined and further work is required to estimate them. Despite this limitation, Maher showed that the numerical properties of the bivariate negative binomial distribution indicate that it could provide a feasible alternative to the behavioural explanation of migration.

Kahrmann (1988) reported the results of an analysis of crashes in Berlin–Charlottenburg in Germany where a number of measures were introduced between 1980 and 1981 to achieve area-wide traffic restraint. The method of investigation was a before and after analysis of crashes using untreated areas as control groups. The study found that the traffic restraint measures had led to a decrease in crashes in the area of investigation without causing an increase in crashes in the adjacent areas.

Levine et al. (1988) undertook two case studies to assess the safety effects of projects involving re-striping and reconstruction which added a non-standard mixed-flow lane to a freeway by elimination of an interior shoulder in Los Angeles and Orange County in the United States. In the Los Angeles case study they found a statistically significant crash migration effect, while no such effect was identified in the Orange County case study. They concluded that if crash statistics for portions of roadway influenced by the lane are not included in such studies, partial and potentially misleading effects will be observed.

Mountain and Fawaz (1989) studied the area-wide effects of engineering work carried out at a number of sites on principal roads in Cheshire, England, between 1977 and 1987. Using crash data for the sample sites, and predictive models, they estimated the expected number of crashes at each of the treated and neighbouring sites and compared them with the observed number of crashes at those sites during the period after treatment. Their results, albeit of a preliminary nature, indicated a net increase in crashes on the road network studied, following the application of engineering measures. They also found substantial RTM effects which in all cases exceeded 10 per cent. Mountain and Fawaz recognised the need for additional data and further work to test the validity of their results. They also stressed the more general need in evaluation studies to consider changes in crash frequencies over a wider area than at the treated sites only.

Loveday and Jarrett (1991) attempted to test Maher's probabilistic hypothesis in two ways. One method involved testing the magnitude of spatial correlation in a number of different data sets. Using simulation studies they found that although it was plausible that spatial correlation could account for the apparent migration effects observed by Boyle and Wright, there was no clear relationship between the magnitude of the spatial correlation and the magnitude of the migration effect in the actual data sets used by Boyle and Wright.

Loveday and Jarrett's second approach was more direct. They reasoned that if Maher's hypothesis was correct, crashes should appear to migrate from a site with a high crash frequency to adjacent sites whether or not the site had been treated. The approach involved analysing crash data for two consecutive time periods to measure the apparent migration effect from untreated high-crash sites. The migration effect was then compared with the apparent migration from treated sites. This was done using data from two outer London boroughs, Barnet and Brent. Loveday and Jarrett found some inconclusive evidence of crash migration from treated black spots in Brent. They recognised several limitations in their study and concluded that there was a clear need for a large scale study if the issue of crash migration was to be resolved.

Mountain and Fawaz (1992) conducted a rigorous analysis of crash migration effects using the same data set used in their 1989 study. The neighbours of the treated sites were considered to be the 500-metre sections of the network adjacent to the treated sites. In this study, they adjusted for the possible effects of year-to-year fluctuations in crash totals. Boyle and Wright's hypothesis implied that an increase in crashes would only be expected at locations near treated sites at which crashes had been reduced. Mountain and Fawaz recognised that, by implication, if crash frequencies increased at treated sites, there may be a decrease at adjacent sites. If no distinction is made between sites where treatment is followed by an increase or decrease in crashes, changes in crash frequencies at adjacent sites may counterbalance each other, reducing the apparent magnitude of the overall effect. They investigated this possibility by analysing the sites after splitting them into two groups of what they considered to be successfully and unsuccessfully treated sites.

Mountain and Fawaz found that although some amount of migration can be attributed to RTM effects, these effects did not completely account for the degree of migration found in their study. A key conclusion of the study was that migration does occur because of treatment. They considered that although the average annual increase in crashes in the area surrounding an individual treated site was not large (about 0.2 crashes per site per year), it was large enough to be practically significant, especially when the effect is aggregated over a number of sites. They also found that the effect of engineering treatments varied with time. In the first year after treatment increases in crashes were concentrated in the 0–200 metre region adjacent to treated sites. In the first two years after treatment, increases in crashes occurred over the full 500-metre region, implying that the migration effect could extend beyond that area in subsequent years.

EXPLANATIONS FOR CRASH MIGRATION

The literature on crash migration suggests several possible explanations for the phenomenon. One set of explanations suggests that crash migration is not related to treatment and occurs in spite of it, while the other set implies that it is related to treatment and occurs because of it (Mountain and Fawaz 1992). These two sets of explanations are summarised below.

Reasons for crash migration unrelated to treatment

- A statistical artefact arising from a simple reverse RTM effect. In a ‘before’ period, treated sites have an unusually large number of crashes, while crash experience at adjacent non-treated sites is comparatively low. In the ‘after’ period, the expectation is that independent of treatment, crashes at the treated sites decrease, while those at the adjacent non-treated sites increase.
- A statistical artefact caused by spatial correlation between the mean crash frequencies at adjacent sites. This means that the underlying or true mean crash frequencies at sites adjacent to treated black spots are higher than those at other untreated sites. Therefore, the increase in crashes due to the reverse RTM effect is larger than at other non-adjacent untreated sites.
- A deterioration of road and environmental conditions of adjacent sites, such as a decline in the condition of the road surface (an implausible explanation considering the magnitude of migration observed in the various studies).

- The increase in crashes at sites surrounding treated black spots is part of a rising trend in crashes that would occur even if the treatments had not been implemented (most empirical studies have taken account of crash trends and found that they do not explain the amount of observed migration).

Reasons for crash migration related to treatment

- Drivers have a target level of risk which they seek to maintain. The reduced risk from safety benefits of the treatments are therefore exactly compensated for by drivers increasing their risk elsewhere. The overall time-averaged crash rate therefore remains constant. This is the 'risk homeostasis' explanation (see below).

- Treatment of a site can reduce drivers' level of awareness, and this persists for some time, causing an increase in crashes at neighbouring sites. Alternatively, driver response to a safety measure may be complex, involving the trading of crash risk against other attributes of travel such as travel time or driving pleasure. For example, a driver forced to reduce speed at a roundabout may thereafter increase speed, and therefore risk, to compensate for lost travel time. This is the 'risk compensation' explanation.

- The treatment can cause an increase in crash exposure at adjacent sites. This occurs as a result of the treatment redistributing the flow of vehicles and / or pedestrian traffic, thereby causing changes in the volume and / or composition of the flow.

Risk compensation and risk homeostasis[2]

Adams (1988) claims that there is abundant evidence for the existence of risk compensation and cites as an example the tendency of motorists

2. The term 'homeostasis' was coined in 1932 by W.B. Cannon, an American physician, who used the term to describe the concept of feedback as a basic physiological principle. For example, Cannon explained the regulation of body temperature by processes such as perspiring when the body becomes too hot and shivering when it becomes too cold. In this process the equilibrium of the body is regarded as being maintained by feedback signals from what is required by the body, to how what is required can be obtained. The term is commonly used to describe a mechanism which maintains a certain parameter at a relatively constant level.

to slow down when they come to a sharp bend. Risk compensation theory suggests that drivers consume safety benefits such as better brakes or safer roads at least partly in the form of performance benefits such as increased speed. In the case of treated black spots, this compensatory mechanism is supposed to operate by lowering the vigilance or level of preparedness of drivers causing an increase in their response times, leading to a more dispersed pattern of crashes.

Wilde (1982) has proposed a much-criticised theory that drivers behave in accordance with a homeostatically controlled self-regulation process by which they tend to maintain a certain target level of risk independent of external conditions. At any moment in time, the level of risk experienced is compared with the level the individual wishes to take and decisions to change behaviour will be made whenever there is a discrepancy between these two levels. Whether the individual's consequent behaviour will have the desired result of re-establishing equilibrium between the target level and the experienced level of risk is supposed to depend on three types of skills: perceptual (the extent to which subjective risk corresponds to objective risk); decisional (the ability to decide what should be done to provide the desired adjustment); and executional (whether the driver can effectively carry out what should be done).

Wilde argues that the level of performance attributable to these skills may be improved by such measures as driver education, licensing standards and improved road geometry but that such improvements are unlikely to have a permanent effect on the crash rate. According to risk homeostasis theory, such 'non-motivational' safety measures may decrease the crash rate per kilometre, but they will have no effect on the rate per unit time of exposure or per capita. The implications of the theory for black spot remedial work are therefore not encouraging: it predicts that the crash rate per unit of driver exposure is invariant regardless of road geometry. Wilde cites the results of several before and after studies on the installation of three-phase traffic lights at urban intersections which indicate that following installation, fewer right-angle but more rear-end, left-turn and side-swipe crashes occurred, while the total frequency and the average severity rate remained the same.

The theory of risk homeostasis suggests that lasting crash reduction per unit time of exposure or per capita cannot be achieved by providing road users with more opportunity to be safe but only by measures that increase their desire to be safe. The latter can supposedly be achieved by reducing their target level of risk by the use of 'motivational' safety measures. Wilde postulates four broad groups of motivational safety measures or tactics by which target risk levels can be lowered and suggests examples for each strategy. These tactics (with one example of each tactic in brackets) are: decreasing the expected benefit of risky behaviour (abolish any financial benefits that truck drivers receive for driving long distances in short periods of time); decrease the expected costs of cautious behaviour (subsidise public transportation between and within cities); increase the expected benefit of cautious behaviour (reduce insurance premiums for crash free driving); and increase the expected cost of risky behaviour (increase enforcement and penalties for unsafe driving).

Among the various criticisms of the theory of risk homeostasis is its seeming lack of coherence (Haight 1986; McKenna 1988). In regard to traffic risk, the theory posits that when people are made to take less risk in one way, they will take more risk in another. McKenna (1988) notes that in the exposition of risk homeostasis theory, Wilde appears to switch between the view that risk homeostasis acts at the individual level and that it acts at the level of society. In regard to road safety, this means that on the one hand individual road users offset any benefit to themselves from safety measures by compensatory behaviour, and on the other hand that there is a compensatory shift in risk from one category of road user to another following the introduction of safety measures. McKenna (1988) argues that these two explanations cannot coexist: a ‘shift in risk’ explanation is not consistent with the view that road users maintain their own levels of crash risk at a constant level.

Wilde (1982) even believes that the theory may apply across behaviour domains, and cites limited empirical evidence suggesting that following a reduction in cigarette smoking, the decrease in smoking-related deaths is fully compensated by an increase in deaths due to alcohol consumption, road crashes, and other causes.

Statistical evidence on whether conventional safety measures (such as black spot elimination and vehicle design improvements) will have no effect on per capita crash rates as predicted by risk homeostasis theory, is not clear cut. Trends in road crash fatality rates per 100 000 persons for Australia and some other countries show reductions between 1970 and 1990 (Anderson et al. 1993). However, in the case of the United States for instance, the overall road crash fatality rate per 100 000 persons has not shown a substantial change in trend over the period 1930 to 1990 (Baker et al. 1992). Alderson (1981) has published international mortality tables which include per capita mortality data expressed as standardised mortality ratios for all kinds of violent and accidental death in 31 countries (including Australia) from 1900 to 1975.[3] Wilde (1986) presents a graphical exposition of this data which shows a fairly constant pattern across the countries as a whole. He observes that the data may suggest that people collectively have a more or less stable 'risk budget' which is spent one way or another.

Evans (1986) examined seven types of crash rates (including crash rates on different types of roads and crash rates of individuals) based on United States data. The crash rate trends appeared relevant to risk homeostasis theory. Evans reports that his findings contradict predictions about these trends that would appear to follow from the theory. He concludes that risk homeostasis theory should be rejected because there is no convincing evidence supporting it and much evidence refuting it. Citing road crash data for the United States, Evans (1991) observes that average driver risks are different on different roads and that risks change over time. He further argues that risk also changes by large amounts during a particular trip—the risk is much higher at intersections than between intersections—and although most drivers would be aware of this there is little they can do to equalise the risk.

Knott (1994) analysed road crash trends in NSW during the period 1881–1991. He concludes, in accordance with the predictions of risk homeostasis theory, that specific improvements in road traffic engineering and vehicle design have had no measurable effect on the long-term trend in the fatality rate per vehicle. However, Knott observes that factors directly affecting road user behaviour appear to have had a beneficial effect and cites as examples the statistically significant correlation between the fall in the fatality rate per vehicle that followed both the introduction of random breath testing and the public outcry in the wake of the Grafton and Kempsey bus crashes. Knott argues that for a road safety measure to be effective, its central aim must be the improvement of road user behaviour and / or the lowering of their risk tolerance.

Despite the apparent problems involving the credibility of risk homeostasis theory, conclusive evidence is elusive because target levels of risk, if they exist at all, are perceptual and therefore cannot be measured. In fact, Evans (1991) argues that the use of the word 'theory' to describe the notion of risk homeostasis is without justification because a scientific theory must be capable of being experimentally refuted.

3. In calculating standardised mortality ratios, adjustments are made for differences in mortality within the same country over time and between countries at any one time, associated with variance in the proportion of persons in particular age brackets.

Risk compensation likewise is very difficult to test because it would require measurement techniques able to detect very small changes in behaviour.

Some road safety researchers (for example, Wright and Boyle 1987) have expressed the view that the occurrence of some degree of risk compensation, with a significant impact on crashes, is plausible but that the compensation is not complete (that is, it is not homeostatic).

AN ASSESSMENT OF CRASH MIGRATION

Crash migration is a controversial issue and is not yet well understood. The findings of most of the studies previously described tend to tilt the balance of empirical evidence in favour of crash migration being a real, as opposed to a statistical, phenomenon, but the evidence is not conclusive.

If the existence of crash migration is confirmed, determining the reason for its occurrence will provide an even more formidable challenge for research. There appears to be considerable evidence which does not support risk homeostasis theory but the theory cannot be empirically tested. Risk compensation on the other hand has some plausibility which derives from both common experience and some empirical evidence. However, the degree and type of risk compensation that may occur with individual drivers defies measurement.

The possibility of crash migration has potentially serious implications for road safety policy because some part of the apparent benefits of crash reduction flowing from engineering treatments might be illusory. Further, if in order to measure the reduction in crashes at treated sites, untreated sites in the vicinity of these treated sites are used as controls, there is the possibility that the reduction at the treated sites will be overestimated.

A definite verdict on crash migration will have to await further research. The likelihood of identifying a particular effect with a high degree of confidence is related to the size of the sample studied: a relatively weak effect will require a large sample. There is also a need for proper control areas and good exposure data in traffic studies of this nature. Planned, area-wide studies on the effects of safety measures using large data sets will therefore be required if more light is to be shed on whether crash migration is definitely more than a figment of statistical fancy.

The investigation of crash migration in this study would have considerably extended its scope and would have required detailed additional data on a large number of untreated sites. A serious investigation of crash migration would require a planned data gathering exercise on an area-wide basis, carried out in conjunction with black spot remedial works. However, Evans (1991) is pessimistic about the possibility of investigating crash migration empirically. He notes that even the worst black spots have only a handful of crashes per year, and that given the many other factors involved in crashes, it would be almost impossible to find convincing evidence of migration.

APPENDIX VIII PROCEDURE FOR TESTING STATISTICAL SIGNIFICANCE OF CHANGES IN CRASH NUMBERS

As discussed in chapter 4, the change in the number of crashes at a site after treatment may be due to several factors other than the treatment itself, acting individually or in combination. One such factor is statistical instability inherent in observed crash numbers. After the influence of other factors has been accounted for, it is necessary to determine if any observed reduction in crash numbers following a treatment is very much more likely to be due to treatment than to chance.

In this study, the influence of factors external to the treated sites has been accounted for by the use of control ratios based on crash experience in urban and rural areas in each jurisdiction. The methodology proposed by Tanner (1958) has been adapted and used to test whether observed reductions in crashes (whether classified by severity or type) have been statistically significant. Following is a summary of the methodology. Details of derivation of equations are found in Tanner (1958).

N is the number of sites from which data are to be combined.
b_i is the number of crashes in the before period at site i (i = 1, 2, ...N)
a_i is the number of crashes in the after period at site i (i = 1, 2, ...N)
$n_i = a_i + b_i$
When used in this appendix, the summation sign ∑ denotes summation over sites from i = 1 to i = N.

C_i is the ratio of crashes after to before in the control area for site i.

Then

$$k_i = \frac{a_i}{(b_i C_i)}$$

measures the apparent effect of the change at site i. It is the ratio of crashes after to the number that would have been expected if the treatment had no effect. A value of k_i greater than unity denotes an increase compared with the control area, while a value less than unity denotes a decrease.

The methodology does not make any assumptions about the distributions of crashes at individual sites, groups of sites, or sites in different jurisdictions. However, it is assumed that a_i and b_i are drawn from a binomial distribution:

$$\left[\frac{1}{1+\kappa_i C_i} + \frac{\kappa_i C_i}{1+\kappa_i C_i}\right]^{n_i}$$

in which n_i is regarded as fixed and κ_i is the ‘true’ value of k_i that is, the value that k_i would take if a_i and b_i took their expected values.

The method of maximum likelihood is used to estimate κ the common value of $\kappa_1, \kappa_2, \ldots\ldots \kappa_N$

The estimate k of κ satisfies

$$\sum \frac{a_i - k b_i C_i}{1 + kC_i} = 0 \qquad (1)$$

which can be re-written as

$$\sum \frac{n_i}{1 + kC_i} = \sum b_i \qquad (2)$$

The left hand side of this equation may then be calculated for suitable trial values of k until a sufficiently accurate approximation to the solution is obtained. Concentration on the largest expected value as well as 0.5, 0.8 and 1.0 was found to lead quickly to solutions after one or more interpolations.

Tanner shows that the sampling distribution of log k is more nearly normal than that of k itself. Therefore, confidence limits and significance tests would be better based on the assumption of a normal distribution of log k. By a general property of maximum likelihood estimates, log k is the maximum likelihood estimate of log κ.

If all the κ_i were equal to a common κ, then the variation between the sample estimates

$$k_i = \frac{a_i}{(b_i C_i)}$$

would arise solely from the binomial distributions to which a_i and b_i are subject. This means that a χ^2 test for variations between the κ may be used based on the statistic

$$\chi^2 = \sum \frac{\left(a_i - kb_iC_i\right)^2}{kC_i n_i}$$

where k is the maximum likelihood estimate given by equation (2). The corresponding expression with κ instead of k is distributed as χ^2 with N degrees of freedom. Replacing κ by the efficient estimate k reduces the degrees of freedom to N–1.

Tanner uses a power series expansion technique to obtain an estimate k of the average population (rather than just the sample) effect κ and its sampling variance. Equation (2) provides a reasonably satisfactory estimate of κ at least when the variations between the κ_i are fairly small. Provided the error of k as an estimate of κ is sufficiently small,

$$\operatorname{var}\log k = \frac{\operatorname{var} S(\kappa)}{\left(\dfrac{dS(x)}{d\log x}\right)^2_{x=\kappa}} \tag{3}$$

where

$$S(x) = \sum \frac{a_i - xb_iC_i}{1 + xC_i} \tag{4}$$

This assumes that over a sufficient range of x, $S(x)$ is linearly related to x.

The simplification of formulae yields the following estimate of the sampling variance of log k

$$\operatorname{var}\log k = \frac{\left(1+\phi\right)\left(1 + \dfrac{2}{\sum n_i}\right)}{\sum \dfrac{\kappa C_i n_i}{\left(1+\kappa C_i\right)^2}} \tag{5}$$

where

$$\phi = \left(\frac{\chi^2}{N-1} - 1\right)\frac{N\sum n_i^2}{\left(\sum n_i\right)^2} \tag{6}$$

The term (1 + ø) can be omitted if there is no firm evidence that κ_i varies from site to site, and the term

$$\left(1+\frac{2}{\sum n_i}\right)$$

can be omitted for reasonably large values of $\sum n_i$.

κ may be replaced by the sample estimate when the standard error is required and by unity when it is required to test whether κ = 1.

Therefore, as the sampling distribution of log *k* approaches the normal distribution as the sample size becomes large

$$\frac{\log k}{\sqrt{\operatorname{var}\log k}}$$

can be taken to come from a t-distribution with N–1 degrees of freedom. If confidence intervals for log κ are made symmetric about the point estimate, those for κ will not be symmetric. If a treatment effect is significant,

$$\log\ k \pm t_{N-1,0.05}\ \sqrt{\operatorname{var}\log k}$$

gives one set of 90 per cent confidence limits for log κ. These confidence limits can be converted into a non-symmetric confidence interval for κ. However, as reductions in crashes can be expected, a one-tailed test is more appropriate for testing significance.

Tanner's formulae rely on various conditions for approximations to be valid. In some cases it was found that a treatment effect was significant but that the subsequent revision of sample variance estimates could produce a confidence interval for log κ including zero.

Estimates of 1– κ are presented in chapter 8. The number 1– κ can be interpreted as the crash reduction factor attributable to a treatment after allowance has been made for general community trends. It therefore provides a convenient estimate of crash reduction effects likely to follow the implementation of a particular treatment and may be used in cost–benefit evaluations of proposed treatments.

The appearance of the value 0 in confidence intervals for 1– κ is most commonly due to the fact that a number of treatment effects were significant at the 90 per cent level but not at the 95 per cent level.

APPENDIX IX STANDARDISED CRASH COSTS

This appendix provides crash costs by crash type for each state and territory. Person costs have been calculated using injury profiles for 1992. Incident costs were derived from ARRB (1992d) and adjusted to 1992 dollar values. ARRB's estimates of incident costs were based on one-vehicle and two-vehicle crashes. Aggregate data obtained for the present study indicated that, for some crash types, the mean number of vehicles per crash was greater than two. An adjustment was therefore made to ARRB's incident cost estimates to take account of differences in the mean number of vehicles involved in some crash types. In making this adjustment, only the vehicle repair cost and insurance administration component of ARRB's incident costs was increased in proportion to the mean number of vehicles actually involved in crashes.

TABLE IX.1 COSTS OF URBAN CRASHES BY CRASH TYPE AND 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	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	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

TABLE IX.1 COSTS OF URBAN CRASHES BY CRASH TYPE AND JURISDICTION[a] (TWO-VEHICLE CRASHES) (continued)

($)

Crash type (two-vehicle)	*ACT*	*NSW*	*NT*	*QLD*	*SA*	*TAS*	*VIC*	*WA*
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

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 among jurisdictions.

b. Tasmania's coding system incorporates both right-angle and right-turn crashes within an 'angle crash' category.

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

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

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE IX.2 COSTS OF URBAN CRASHES BY CRASH TYPE AND JURISDICTION[a] (ONE-VEHICLE CRASHES)

($)

Crash type (one-vehicle)	*ACT*	*NSW*	*NT*	*QLD*	*SA*	*TAS*	*VIC*	*WA*	*Incident cost,[b] all jurisdictions*
Person cost									
Pedestrian	68 092	60 758	84 303	109 202	60 512	44 487	77 879	46 260	6 492
Off straight	1 116	18 629	48 368	67 670	2 379	28 304	49 880	35 811	12 791
Off straight hit object	12 771	17 905	91 610	38 551	12 620	22 421	76 590	25 592	10 262
Straight lost control	9 028	35 110	40 086	26 833	24 533	12 347	31 487	22 764	10 254
Off curve	na	23 460	7 121	25 325	32 417	28 304	58 108	65 893	12 497
Off curve hit object	na	23 574	6 180	72 294	17 741	22 421	86 308	19 955	10 573
Off curve lost control	na	32 383	35 572	108 647	51 665	12 347	43 430	21 123	10 994
Standardised total cost									
Pedestrian	74 584	67 250	90 795	115 694	67004	50 979	84 371	52 752	
Off straight	13 907	31 420	61 159	80 461	15 170	41 095	62 671	48 602	
Off straight hit object	23 033	28 167	101 872	48 813	22 882	32 683	86 852	35 854	
Straight lost control	19 282	45 364	50 340	37 087	34 787	22 601	41 741	33 018	
Off curve	na	35 957	19 618	37 822	44 914	41 095[c]	70 605	78 390	
Off curve hit object	na	34 147	16 753	82 867	28 314	32 683[c]	96 881	30 528	
Off curve lost control	na	43 377	46 566	119 641	62 659	22 601[c]	54 424	32 117	

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

a. Caution must be exercised when comparing cost figures among jurisdictions because crash recording arrangements and coding systems vary among jurisdictions.

b. For one-vehicle crashes, there was no need for an adjustment for the greater mean number of vehicles involved as in the case of two-vehicle crashes, and therefore the incident cost is the same for all jurisdictions.

c. As Tasmania's coding system does not differentiate between crashes off a straight road or a curve, the same estimates are used for these crash types.

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE IX.3 COSTS OF RURAL CRASHES BY CRASH TYPE AND JURISDICTION[a] (ONE- AND TWO-VEHICLE CRASHES)

($)

Crash type	*NSW*	*QLD*	*SA*	*TAS*	*VIC*	*Incident cost, all jurisdictions*
Person cost						
Rear-end	25 212	28 655	3 882	15 858	61 815	8 400
Head-on	156 795	273 376	45 269	156 916	240 088	13 532
Off straight	38 607	47 723	15 014	50 936	67 790	11 535
Off straight hit object	50 407	59 023	27 034	80 281	99 763	9 006
Straight lost control	46 242	69 046	34 620	21 827	56 107	8 998
Off curve	36 613	51 558	16 146	50 936	73 445	11 241
Off curve hit object	48 439	63 851	18 198	80 281	92 693	9 317
Off curve lost control	38 777	47 344	24 287	21 827	72 276	9 738
Standardised total cost						
Rear-end	33 612	37 055	12 282	24 258	70 215	
Head-on	170 327	286 908	58 801	170 448	253 620	
Off straight	50 142	59 258	26 549	62 471	74 325	
Off straight hit object	59 413	68 029	36 040	89 287	108 769	
Straight lost control	55 240	78 044	43 618	30 825	65 105	
Off curve	47 854	62 799	27 387	62 471[b]	73 901	
Off curve hit object	57 756	73 168	27 515	89 287[b]	102 010	
Off curve lost control	48 515	57 082	34 025	30 825[b]	82 014	

a. Rural figures were not available at all for the ACT and the Northern Territory. Costs were not estimated for Western Australia because all sample projects were in urban areas. There was no need for an adjustment for the greater mean number of vehicles involved in two-vehicle crashes as was done for urban areas, and therefore the incident cost is the same for all jurisdictions. Caution must be exercised when comparing cost figures among jurisdictions because crash recording arrangements and coding systems vary among jurisdictions.

b. As Tasmania's coding system does not differentiate between crashes off a straight road or a curve, the same estimates are used for these crash types.

Source BTCE estimates based on data provided to FORS by states and territories.

APPENDIX X MEASURING THE ECONOMIC VALUE OF PROJECTS

Evaluating a project involves relating its inputs or costs to its outputs or benefits, and thus determining its economic value. Several measures of the economic value or effectiveness of projects are available. The net present value (NPV) is the most reliable indicator in evaluating projects. The NPV, and other measures which provide supplementary information, are described below. These other measures, which have some intuitive appeal and provide additional information, are the first year rate of return (FYRR), benefit–cost ratio (BCR), internal rate of return (IRR) and payback period. However, these measures have certain drawbacks, especially when used to compare and rank different projects, and should therefore be interpreted in conjunction with the NPVs.

In the BTCE (1993) pilot study, NPVs, BCRs, IRRs and payback periods were reported. Given the relatively greater interpretive value of NPVs and BCRs compared with the other measures described in this appendix, only these two measures have been reported in the present study.

First year rate of return (FYRR)

The FYRR is a relatively crude and limited measure of the economic value of projects, but is simple and straightforward to apply. The FYRR is the net monetary value of the reductions in crashes and other benefits and costs (such as changes in travel time and maintenance costs) during the first year following completion of the project, expressed as a percentage of its total capital cost.

$$\text{FYRR (per cent)} = \frac{\text{Net first year benefits}}{\text{Capital costs}} \times 100$$

If changes in costs and benefits due to factors other than crash reduction (for example, changes in travel time and site maintenance costs) are ignored,

$$\text{FYRR (per cent)} = \frac{\text{Crash reduction benefits}}{\text{Capital costs}} \times 100$$

The FYRR is a crude guide to the short-term value of a project. However, if the benefits and costs of a project are expected to extend over time, the use of FYRR would be an inappropriate measure.

The FYRR should be greater than the discount rate used in the NPV calculation. If the first year rate of return is less than the discount rate the project would benefit by postponement.

Net present value (NPV)

This is the difference between the present value of benefits and the present value of costs. The NPV can be expressed mathematically as follows.

$$NPV = (B_0 - C_0) + \frac{(B_1 - C_1)}{(1+i)} + \frac{(B_2 - C_2)}{(1+i)^2} + \ldots\ldots\ldots + \frac{(B_n - C_n)}{(1+i)^n}$$

or

$$NPV = \sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+i)^n}$$

where

B_0 and C_0 are benefits and costs in year 0 (the base year)
B_1 to B_n are benefits in years 1 to n
C_1 to C_n are costs in years 1 to n
i is the annual discount rate
n is the number of years of project life

If the present value of benefits exceeds the present value of costs, that is, if the NPV is positive, it means that the project yields a rate of return greater than the discount rate which was applied to it. Conversely, if the NPV is negative it means that the rate of return is less than the discount rate. The NPV has to be related to a definite period of time.

At the end of that period of time it must either be assumed that the investment has no further value, or it may be assigned a residual value representing its recoverable monetary value at that time, and this must be treated as a benefit in the final time period. The methodology used in this study assumes a zero residual value. The NPVs of projects were calculated with a discount rate of 8 per cent (Department of Finance 1991) and the results tested for sensitivity at discount rates of 6 and 10 per cent.

Benefit–cost ratio (BCR)

In contrast to the NPV, which measures a project's economic benefits in absolute terms, the BCR measures its relative benefits. The BCR is the ratio of the present value of benefits to the present value of costs. A BCR greater than 1 implies a positive NPV. It therefore follows that for a project to be acceptable, the BCR should be greater than 1.

The use of the BCR in comparing different projects can give an incorrect ranking if the projects differ in size. The BCR is also sensitive to the manner in which costs and benefits are defined. For example, disbenefits of projects could be added to the stream of costs or subtracted from the stream of benefits.

As in the case of the NPV, BCRs have been calculated at 8 per cent discount rate and tested for sensitivity at discount rates of 6 per cent and 10 per cent.

Internal rate of return (IRR)

This is the percentage rate of interest that equates the present value of benefits to the present value of costs so as to give a zero NPV. It is therefore a measure of the break-even rate of return of a project because it represents the highest rate of interest at which the project makes neither a profit nor a loss. If the IRR is greater than the discount rate used in the analysis, it indicates that the project is profitable and the converse applies if it is smaller.

As the IRR is the internal discount rate of a project, its estimation does not depend on a predetermined discount rate. One problem with using the IRR is that in certain circumstances a project may have more than one discount rate which produces a zero NPV. Also, incorrect rankings could result when projects of different sizes or lifetimes are compared.

Payback period

The payback period is the period of time required to recover the initial cost of the project. The payback period can be calculated conventionally or by discounting the flows of costs and benefits.

The conventional method involves calculating the number of years it takes for cumulative benefits or cash flows to equal the initial investment. The discounted method requires that the cash flows be discounted using the required rate of return before they are added up to equal the initial investment.

If the discounted method is used, the calculated payback period is the number of years from the beginning of a project that it takes until the sum of the discounted benefits equals the discounted costs. The payback period is a relatively crude measure of project performance as it does not take account of the benefits and costs over the whole life of the project. The conventional method has the additional disadvantage of not taking into account the time profile of the flow of benefits and costs and generally produces lower values than the discounted method. In general, the shorter the payback period, the more acceptable the project.

APPENDIX XI PROJECT LIFETIMES AND MAINTENANCE COSTS

Data on project lifetimes and annual maintenance costs for various treatments were provided by the states and territories. The tables below present upper and lower bounds of project lifetimes and annual maintenance costs for the range of values provided by the states and territories. The modal value (the value suggested by the majority of states and territories) is also presented for each treatment. These data were supplemented by information obtained from the literature (where appropriate). Judgment was then exercised in choosing a final estimate for use in the cost–benefit analysis.

For the analysis by level of expenditure, annual maintenance costs were obtained as a percentage of total capital costs by each level of expenditure (major 1.1 per cent, medium 2.0 per cent, small 2.4 per cent and minor 4.3 per cent). These same proportions were assumed to apply when wider Program estimates were made.

TABLE XI.1 ESTIMATES OF LIFETIMES OF TREATMENTS

(Years)

Treatment	*Lower bound*	*Upper bound*	*Mode*	*Final estimate*
New traffic signals (UH1)	10	20	10	12
Traffic signal modification (UH2)	5	30	10	12
Channelisation (UH3)	10	30	20	15
Provision of medians (UH4)	10	30	20	15
Roundabouts (UH7)	15	30	20	20
Protected turning bays (UM2)	10	30	20	15
Shoulder sealing (RH1)	10	25	20	20
Protected right turns (RH9)	20	30	25	20

Source BTCE estimates based on data provided to FORS by states and territories.

TABLE XI.2 ESTIMATES OF ANNUAL MAINTENANCE COSTS OF TREATMENTS

($ per project per year)

Treatment	*Lower bound*	*Upper bound*	*Mode*	*Final estimate*
New traffic signals (UH1)	1 000	7 000	5 000	5 000
Traffic signal modification (UH2)	400	2 000	400	800
Channelisation (UH3)	100	7 000	500	400
Provision of medians (UH4)	100	300	na	400
Roundabouts (UH7)	700	7 000	1 000	800
Protected turning bays (UM2)	750	5 000	750	750
Shoulder sealing (RH1)	500	8 000	2 000	2 500
Protected right turns (RH9)	0	30	na	700

na not available

Source BTCE estimates based on data provided to FORS by states and territories.

APPENDIX XII SAMPLE PROJECT PARTICULARS

APPENDIX XII SAMPLE PROJECT PARTICULARS

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
UH1 (50)						
A0003/22	ACT	HUME	MONARO HWY	314 996	1-Sep-91	1-Nov-91
N0006	NSW	LAKEMBA	PUNCHBOWL RD	80 000	na	29-Oct-91
N0012	NSW	ENGADINE	PRINCES HWY	134 667	1-Mar-91	1-May-91
N0027	NSW	GORDON	PACIFIC HWY	97 000	na	6-Oct-91
N0047	NSW	RAYMOND TERRACE	PACIFIC HWY	128 677	15-May-91	30-Jun-91
N0048	NSW	TOUKLEY	NORAHVILLE RD	27 000	1-Jul-90	16-Nov-90
N0072	NSW	CAMPBELLTOWN	APPIN RD	80 000	30-Sep-90	31-Oct-91
N0077	NSW	CARLINGFORD	JENKINS RD	102 000	na	30-Aug-91
N0079	NSW	MERRYLANDS	PITT ST	70 000	na	10-Aug-91
N0082	NSW	ST ANDREWS	CAMPBELLTOWN RD	155 000	30-Sep-90	31-Oct-90
N0196	NSW	NEWCASTLE	DARBY ST	40 000	15-May-91	30-Jun-91
Q0002	QLD	CURRUMBIN WATERS	CURRUMBIN CREEK RD	128 735	1-Jan-91	30-Apr-91
Q0004	QLD	MERRIMAC	GOLD COAST SPRINGBROOK RD	107 830	1-Jan-91	11-Apr-91
Q0006	QLD	BEENLEIGH	BEAUDESERT-BEENLEIGH RD	122 528	1-Jun-91	3-Nov-91
Q0025	QLD	CABOOLTURE	BURPENGARY-CABOOLTURE RD	85 000	1-Nov-90	30-Dec-90
Q0028	QLD	CALOUNDRA	CALOUNDRA-NOOSA RD	43 791	30-Sep-90	31-Jan-91
Q0049	QLD	BURLEIGH HEADS	GOLD COAST HWY	49 573	1-Jul-91	17-Jul-91
Q0060	QLD	WOODRIDGE-KINGSTON	BRISBANE-BEENLEIGH RD	90 642	1-Aug-91	30-Sep-91
Q0062	QLD	MACKAY	MACKAY-SLADE POINT RD	64 275	6-Jun-91	30-Jun-91
Q0068	QLD	BUDERIM	BUDERIM-MOOLOOLABA RD	91 724	1-Oct-90	30-May-91
Q0174	QLD	CAPALABA	CAPALABA-VICTORIA POINT	36 511	1-Nov-91	31-Dec-91
Q0176	QLD	WATERFORD WEST	CHAMBERS FLAT	200 000	2-Sep-91	22-Oct-91
Q0191	QLD	PARK RIDGE	MOUNT LINDSAY HWY	104 718	1-Jun-91	31-Aug-91
Q0222	QLD	CAIRNS CITY	SPENCE ST	126 545	1-Aug-91	31-Oct-91
S0038	SA	ENFIELD	LOWER NORTH EAST RD (RN5221)	109 084	na	1-Dec-91
S0039	SA	WEST LAKES SHORE	MILITARY RD (RN5827)	142 812	1-Oct-90	18-Dec-90
S0069	SA	ADELAIDE	GREENHILL RD	126 337	1-Sep-90	21-Nov-90
S0078	SA	SOUTH BRIGHTON	SEACOMBE RD (RN6613)	135 819	1-Apr-91	6-Jun-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
S0030	SA		BEACH RD (RN6735)	61 513	1-Jul-90	5-Sep-90
S0034	SA	HOPE VALLEY	GRAND JUNCTION RD (RN5218)	69 879	1-Sep-90	19-Dec-90
S0091	SA	ADELAIDE	WEST TERRACE	90 000	1-Aug-91	9-Sep-91
V0087	VIC	THOMASTOWN	HIGH ST	49 432	1-Aug-90	1-Feb-91
V0088	VIC	COBURG	BELL ST	107 580	1-Aug-90	1-Oct-90
V0099	VIC	CHELTENHAM	WARRIGAL RD	127 431	1-Aug-90	1-Jun-90
V0103	VIC	MT ELIZA	NEPEAN HWY	130 652	1-Aug-90	1-Oct-91
V0109	VIC	CRANBOURNE NORTH	THOMPSON RD	360 433	1-May-91	30-Sep-91
V0118	VIC	MULGRAVE	POLICE RD	35 652	1-Nov-90	1-Jun-91
V0165	VIC	SOUTH MELBOURNE	FERRARS ST	111 252	1-Jan-91	1-Jun-91
V0178	VIC	WARRNAMBOOL CITY	PRINCES HWY	199 602	1-May-91	1-Sep-91
V0204	VIC	WARRNAMBOOL	PRINCES HWY	156 715	1-May-91	1-Sep-91
V0210	VIC	SPRINGVALE SOUTH	SPRINGVALE RD	257 501	1-Jan-91	31-Jul-91
W0002	WA	MANDURAH	ANSTRUTHER RD	96 000	31-Jul-91	23-Sep-91
W0003	WA	BIBRA LAKE	STOCK RD	129 658	18-Mar-91	21-Jun-91
W0019	WA	CAREY PARK	PARADE RD	121 882	3-Dec-90	19-Dec-90
W0020	WA	WANGARA	PRINDIVILLE DR	168 549	20-Mar-91	17-Apr-91
W0021	WA	SPEARWOOD	ROCKINGHAM RD	69 566	9-Nov-90	16-Jan-91
W0037	WA	BANJUP	NICHOLSON RD	218 863	13-May-91	30-Jul-91
W0044	WA	MALAGA	BEECHBORO RD	57 403	23-Apr-91	24-May-91
W0052	WA	CALISTA	CHISHAM AVE/GILMORE AVE	53 652	6-Aug-91	2-Oct-91
W0055	WA	COTTESLOE	CURTIN AVE	145 655	15-Jul-91	18-Sep-91
UH2 (59)						
A0001/20	ACT	ARANDA	BELCONNEN WAY	117 097	na	1-Jul-91
N0007	NSW	PENSHURST	FOREST RD	73 310	22-Feb-91	22-Mar-91
N0023	NSW	CREMORNE	GERARD ST	78 000	na	25-Jul-91
N0028	NSW	CROWS NEST	WILLOUGHBY RD	16 108	1-Jun-91	15-Jun-91
N0029	NSW	TURRAMURRA	COMENARRA PARKWAY	56 674	5-Feb-91	19-Feb-91
N0085	NSW	CAMPBELLTOWN	CAMPBELLTOWN RD	299 535	14-Sep-90	15-Oct-90

Project Reference	*Jurisdiction*	*Suburb*	*Road*	*Project cost ($)*	*Start date*[a]	*Finish date*
N0087	NSW	GLENBROOK	GREAT WESTERN HWY	60 000	na	15-Dec-91
N0093	NSW	LIVERPOOL	HUME HWY	97 742	2-Oct-90	2-Nov-90
N0096	NSW	BLACKTOWN	PATRICK ST	110 000	15-May-91	15-Jun-91
N0097	NSW	MINTO	PEMBROKE RD	30 169	na	20-Jun-91
N0323	NSW	FIGTREE	PRINCES HWY	34 000	1-Oct-91	31-Dec-91
N0325	NSW	WAGGA WAGGA	EDWARDS ST	180 000	1-Nov-91	31-Dec-91
Q0026	QLD	CABOOLTURE	BURPENGARY-CABOOLTURE RD	37 155	1-Nov-90	30-Dec-90
Q0066	QLD	NAMBOUR	NAMBOUR-BLI BLI RD	34 837	30-Sep-90	31-Oct-90
Q0096	QLD	TOWNSVILLE	UNIVERSITY RD	60 315	1-Nov-90	30-Jun-91
S0031	SA	EDWARDSTOWN	SOUTH RD (RN6203)	47 600	1-Sep-90	28-Nov-90
S0040	SA	SALISBURY	SALISBURY HWY (RN5406)	104 542	na	30-Apr-91
S0043	SA	WEST TORRENS	ANZAC HWY (RN6212)	179 156	1-Jun-91	4-Aug-91
S0047	SA	WINDSOR GARDENS	NORTH EAST RD (RN4489)	18 851	1-Mar-91	8-May-91
S0048	SA	HAPPY VALLEY	MAIN SOUTH RD (RN6203)	282 675	1-May-91	25-Jun-91
S0049	SA	O'HALLORAN HILL	MAIN SOUTH RD (RN6203)	339 173	1-Mar-91	25-Jun-91
S0050	SA	GLYNDE	PAYNEHAM RD (RN5221)	48 102	1-Oct-90	21-Oct-90
S0056	SA	BURNSIDE	PORTRUSH RD (RN6033)	11 633	1-Apr-91	1-May-91
S0064	SA	ELIZABETH DOWNS	MAIN NORTH RD (RN7200)	151 396	1-Oct-91	12-Nov-91
S0070	SA	SALISBURY HEIGHTS	MAIN NORTH RD (RN7200)	173 451	na	1-Nov-91
S0071	SA	ELIZABETH EAST	MAIN NORTH RD (RN7200)	99 262	1-Dec-90	13-Jan-91
S0072	SA	BEDFORD PARK	SOUTH RD (RN6203)	54 897	1-Nov-90	2-Jan-91
S0073	SA	HECTORVILLE	ST BERNARDS RD	105 861	1-Sep-90	13-Sep-90
S0074	SA	WOODVILLE EAST	WEST LAKES BLVD	149 554	1-Jul-90	31-Aug-90
V0048	VIC		PRINCES HWY WEST 1	235 305	1-May-91	31-Aug-91
V0049	VIC		HAMILTON HWY 1	76 351	1-Nov-90	1-Jun-91
V0086	VIC	PRESTON	BELL ST	33 063	1-Apr-91	1-May-91
V0095	VIC	KERRIMUIR	MIDDLEBOROUGH RD	27 686	1-Jan-91	1-Jun-91
V0098	VIC	MONT ALBERT	WHITEHORSE RD	34 127	1-Apr-91	1-Jun-91
V0105	VIC	RINGWOOD	MAROONDAH HWY	113 883	1-Apr-91	31-Jul-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
V0112	VIC	DONCASTER EAST	DONCASTER RD	155 311	1-May-91	30-Dec-91
V0117	VIC	GLEN WAVERLEY	SPRINGVALE RD	518 817	1-Nov-90	1-Jun-91
V0127	VIC	BAYSWATER	CANTERBURY RD	74 194	1-Dec-90	1-Jun-91
V0133	VIC	BAYSWATER	WANTIRNA-SASSAFRAS RD	67 192	1-Jan-91	1-Apr-91
V0149	VIC	NUNAWADING	MAROONDAH HWY	3 615	1-Apr-91	1-Jun-91
V0150	VIC	VERMONT SOUTH	BELL-SPRINGVALE HWY	112 055	1-Mar-91	31-Oct-91
V0153	VIC	HEIDELBERG	BANKSIA ST	21 690	1-Jan-91	1-May-91
V0167	VIC	SANDRINGHAM	BLUFF RD	58 332	1-Jan-91	1-Aug-91
V0172	VIC	ORMOND	NORTH RD	6 664	1-May-91	1-Jun-91
V0183	VIC	BRIGHTON EAST	HAWTHORN RD	14 452	1-May-91	1-Jun-91
V0184	VIC	TOTTENHAM	SUNSHINE RD	18 939	1-Oct-91	30-Nov-91
V0194	VIC	MALVERN	TOORAK RD	18 376	1-May-91	1-Jun-91
V0368	VIC	BELMONT	PRINCES HWY	24 101	1-Dec-91	1-Dec-91
W0010	WA	APPLECROSS	CANNING BEACH RD	35 592	5-Sep-91	20-Sep-91
W0014	WA	KALGOORLIE CENTRAL	HANNAN ST	25 649	9-Oct-91	9-Oct-91
W0016	WA	KARRINYUP	HUNTRISS RD	51 053	28-Mar-91	5-Apr-91
W0031	WA	GLENDALOUGH	HARBORNE ST/JON SANDERS DR	248 654	28-Feb-91	5-Apr-91
W0032	WA	KEWDALE	HORRIE MILLER DR/ KEWDALE RD	215 702	5-Jun-91	5-Dec-91
W0042	WA	KEWDALE	ABERNETHY RD	119 928	9-Sep-91	7-Nov-91
W0043	WA	ARMADALE	ALBANY HWY/S.W. HWY	34 631	5-Oct-91	14-Nov-91
W0066	WA	KARDINYA	NORTH LAKE RD	44 195	11-Nov-91	17-Dec-91
W0067	WA	BIBRA LAKE	PHOENIX RD	167 085	3-Sep-91	20-Nov-91
W0117	WA	RIVERTON	HIGH RD	14 984	1-Sep-91	4-Sep-91
W0135	WA	WANGARA	WANNEROO RD	120 000	27-Sep-91	11-Nov-91
UH3 (32)						
A0009	ACT	WODEN	MELROSE DR	27 177	1-Feb-91	1-May-91
N0106	NSW	LANSVALE	HUME HWY	85 000	20-Sep-90	21-Oct-90
N0157	NSW	NEWPORT	GRANDVIEW DR	37 000	1-Jul-91	31-Aug-91
Z0010	NT	ALICE SPRINGS	GAP RD	195 500	1-May-91	1-Oct-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
Q0051	QLD	ASHMORE	NERANG-SOUTHPORT RD	50 000	1-Jul-91	18-Sep-91
S0008	SA	SALISBURY PARK	MAIN NORTH RD (RN7200)	60 399	4-Jul-90	20-Jul-90
S0010	SA	PORT BROUGHTON	KADINA (RN3680)	28 200	1-Dec-90	31-Dec-90
S0051	SA	PLYMPTON	ANZAC HWY (RN6212)	9 054	1-Oct-90	30-Nov-90
S0076	SA	BRAHMA LODGE	MAIN NORTH RD (RN7200)	120 849	1-Dec-90	19-Feb-91
S0077	SA	UNLEY	GREENHILL RD	131 675	1-Nov-90	8-Jan-91
S0087	SA	SEACLIFFE PARK	OCEAN BLVD (RN6604)	25 168	1-Sep-91	31-Oct-91
T0034	TAS	STH LAUNCESTON	CANNING ST	4 747	6-Oct-91	15-Oct-91
T0044	TAS	ULVERSTONE	VICTORIA RD	11 249	15-Nov-91	17-Dec-91
T0070	TAS	GLENORCHY	ELWICK RD	20 805	1-Nov-91	29-Nov-91
T0083	TAS	DEVONPORT	WILLIAM ST	11 751	15-Aug-91	1-Sep-91
V0043	VIC	KYNETON	CALDER HWY 1	22 354	1-Jun-91	1-Jun-91
V0096	VIC	CANTERBURY	MONT ALBERT RD	180 750	1-Feb-91	1-Jun-91
V0102	VIC	FRANKSTON NORTH	FRANKSTON FREEWAY	80 749	1-Nov-90	28-Feb-91
V0106	VIC	MONTROSE	MT DANDENONG TOURIST RD	41 502	1-Jan-91	1-Jun-91
V0136	VIC	BLACKBURN	CANTERBURY RD	176 344	1-Oct-90	30-Jun-91
V0141	VIC	FERNTREE GULLY	NAPOLEON RD	309 959	1-Apr-91	1-Dec-91
V0185	VIC		CALDER HWY	19 855	1-Mar-91	1-Jun-91
W0004	WA	LOCKRIDGE	BENARA RD	166 978	15-Nov-91	15-Jan-92
W0029	WA	ROCKINGHAM	FLINDERS LANE	11 400	26-Jul-91	6-Sep-91
W0035	WA	MYAREE	MCCOY ST	75 161	9-Aug-91	9-Nov-91
W0036	WA	EAST VICTORIA PARK	MILLER ST	247 688	30-Aug-91	20-Nov-91
W0045	WA	CLOVERDALE	BELMONT AVE	139 913	19-Aug-91	15-Oct-91
W0048	WA	CRAWLEY	BROADWAY	40 391	12-Aug-91	13-Sep-91
W0068	WA	FREMANTLE	QUEEN VICTORIA ST	206 053	12-Aug-91	4-Oct-91
W0075	WA	SOUTH PERTH	MILL POINT RD	31 800	2-Aug-91	6-Dec-91
W0092	WA	WEMBLEY	CAMBRIDGE ST	25 112	11-Nov-91	20-Nov-91
W0136	WA	WILLETTON	WILLERI DR	81 690	5-Aug-91	4-Dec-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
UH4 (12)						
A0005	ACT	DICKSON	ANTILL ST	31 116	1-Feb-91	1-May-91
N0019	NSW	WARRIEWOOD	TURIMETTA ST	74 930	30-May-91	30-Jun-91
N0212	NSW	BAULKHAM HILLS	OLD NORTHERN RD	135 000	na	31-Aug-91
N0365	NSW	TWEED HEADS	WHARF ST (SH 10)	46 000	1-Nov-91	20-Dec-91
S0018	SA	SEATON	GRANGE RD (RN5851)	206 599	1-Dec-90	28-Feb-91
S0020	SA	HINDMARSH	MANTON ST	71 951	1-Sep-90	31-Oct-90
S0022	SA	MITCHELL PARK	MARION RD	60 855	1-Aug-91	30-Sep-91
S0027	SA	MALVERN	UNLEY RD	138 440	1-Sep-90	30-Nov-91
S0112	SA	SEATON	TAPLEYS HILL RD	176 880	1-Jul-91	1-Oct-91
S25-116	SA	ATHOL PARK	GRAND JUNCTION RD (RN5218)	159 011	1-Mar-91	30-May-91
T0037	TAS	CHIGWELL	MAIN RD	15 562	20-Nov-91	20-Dec-91
T0042	TAS	LATROBE	FRANKFORD RD	26 418	12-Dec-91	30-Dec-91
UH5 (2)						
N0117	NSW	NARELLAN	CAMDEN VALLEY WAY	15 000	na	15-Dec-91
W0040	WA	MENORA	WALCOTT ST	101 662	29-Aug-91	29-Nov-91
UH6 (2)						
A0018	ACT	MANUKA	FLINDERS WAY	36 477	1-Mar-91	1-Jul-91
N0158	NSW	CROMER	WAROON RD	5 000	na	27-Sep-91
UH7 (31)						
A0004/23	ACT	CALWELL	JOHNSON DR	218 066	1-Mar-91	1-Jul-91
N0016	NSW	WEST RYDE	ANZAC AVE	44 000	na	28-Feb-91
N0017	NSW	RYDE	BUFFALO RD	30 097	26-Jan-91	26-Feb-91
N0133	NSW	NORTHMEAD	HAMMERS RD	62 700	1-Nov-90	20-Jan-91
N0136	NSW	GREENACRE	NOBLE AVE	75 000	21-Nov-91	6-Feb-92
Z0011	NT	DARWIN	DALY ST	245 129	1-May-91	1-Sep-91
Q0080	QLD	THORNLANDS	CLEVELAND-REDLAND BAY RD	218 000	1-Jan-91	31-May-91
Q0122	QLD	MACKAY	BRIDGE RD	80 000	14-Jan-91	18-Mar-91

Project Reference	*Jurisdiction*	*Suburb*	*Road*	*Project cost ($)*	*Start date*[a]	*Finish date*
Q0164	QLD	ROCKHAMPTON	ALEXANDRA ST	30 000	1-Mar-91	30-Jun-91
Q0211	QLD	BIRKDALE	BIRKDALE RD	200 000	1-Jul-91	30-Nov-91
S0094	SA	NORTH BRIGHTON	KING GEORGE AVE	42 000	1-Sep-90	5-Nov-90
S0097	SA	WHYALLA	MCDOUALL STEWART AVE	48 000	1-Aug-91	1-Sep-91
T0041	TAS	STH LAUNCESTON	BALFOUR ST	10 017	25-Aug-91	15-Sep-91
T0045	TAS	WYNYARD	AUSTIN ST	10 503	17-Oct-91	5-Nov-91
T0055	TAS	DEVONPORT	STEELE ST	68 983	15-Oct-91	1-Dec-91
T0063	TAS	NEW NORFOLK	LYELL HWY	52 786	1-Oct-91	30-Nov-91
T0073	TAS	BRIDGEWATER	EAST DERWENT HWY	128 535	1-Oct-91	30-Dec-91
T0077	TAS	NEWTOWN	MONTAGU ST	13 118	4-Feb-91	28-Feb-91
T0081	TAS	BLACKMANS BAY	BLACKMANS BAY MAIN RD	45 075	1-Oct-91	28-Oct-91
V0011	VIC	SOLDIERS HILL	MIDLAND HWY	738 643	1-Jan-91	30-Jun-91
V0077	VIC	MANSFIELD	MAROONDAH HWY	333 549	1-May-91	1-Nov-91
V0122	VIC	FRANKSTON	MOOROODUC RD	75 313	1-Jan-90	30-Sep-91
V0129	VIC	SOMERVILLE	ERAMOSA RD WEST	294 531	1-Dec-90	1-Apr-91
V0132	VIC	LYNDHURST	DANDENONG-HASTINGS RD	591 478	1-May-90	1-Dec-91
V0216	VIC	EPPING	CHILDS RD	67 047	1-Jan-91	1-Feb-91
W0005	WA	NORANDA	BENARA RD	103 153	23-Sep-90	15-Oct-91
W0009	WA	BOULDER	BURT ST	51 713	18-Mar-91	26-Apr-91
W0018	WA	BASSENDEAN	OLD PERTH RD	35 453	15-Nov-90	20-Dec-90
W0046	WA	BULL CREEK	BENNINGFIELD RD	59 778	13-May-91	26-Jul-91
W0049	WA	NEDLANDS	BROADWAY	63 600	12-Aug-91	13-Sep-91
W0056	WA	GOSNELLS	DOROTHY ST	40 739	1-Oct-91	2-Dec-91
UH8 (4)						
T0066	TAS	NEWTOWN	BROOKER HWY	49 005	1-Apr-91	30-Jun-91
V0094	VIC	KENSINGTON	DYNON RD	679 640	1-Aug-90	1-Jun-91
V0119	VIC	BORONIA	WANTIRNA-SASSAFRAS RD	119 141	1-Dec-90	1-Jun-91
V0215	VIC	MILL PARK	PLENTY RD	90 142	1-May-91	1-Jun-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
UM1 (2)						
Q0192	QLD	TOOWOOMBA	TOOWOOMBA - MILLMERRAN RD	128 699	1-Jun-91	31-Dec-91
T0079	TAS	HOBART	SOUTHERN OUTLET	31 575	10-Jan-91	13-Jan-91
UM2 (9)						
A0010	ACT	WESTON	HINDMARSH DR	68 997	1-Mar-91	1-Jul-91
N0024	NSW	GYMEA	PRINCES HWY	200 000	na	19-Sep-91
N0046	NSW	KARUAH	PACIFIC HWY	46 445	1-Oct-90	28-Feb-91
S0029	SA	WOODVILLE WEST	FINDON RD	5 000	7-Sep-90	24-Sep-90
V0110	VIC	BULLEEN	MANNINGHAM RD	205 225	1-Mar-91	1-Sep-91
V0174	VIC	FOOTSCRAY	WESTERN HWY	18 704	1-Sep-91	31-Oct-91
V0211	VIC	KNOXFIELD	BURWOOD HWY	71 471	1-Dec-90	1-Jul-91
W0059	WA	ORANGE GROVE	KELVIN RD	22 260	1-Jul-91	27-Sep-91
W0064	WA	PADBURY	MARMION AVE	52 020	28-Oct-91	13-Dec-91
UM5 (2)						
Q0016	QLD	MT GRAVATT	SOUTH EAST FREEWAY	109 000	1-Apr-91	30-Jun-91
Q0017	QLD	UNDERWOOD	SOUTH EAST FREEWAY	218 000	1-Jan-91	31-Mar-91
RH1 (15)						
Q0014	QLD	BARCALDINE-GEERA SID	CAPRICORN HWY	200 182	3-Oct-90	30-Jun-91
Q0032	QLD	CAIRNS (ELLIS BEACH)	CAPTAIN COOK HWY	26 500	1-May-91	30-Jun-91
Q0043	QLD	ESK	ESK-HAMPTON RD	30 850	1-Aug-91	30-Sep-91
Q0053	QLD	RAVENSHOE	KENNEDY HWY	60 885	1-Jun-91	31-Oct-91
S0014	SA	NOARLUNGA	VICTOR HARBOR (RN4760)	96 454	21-Nov-90	5-Dec-90
S0015	SA	NOARLUNGA	CAPE JERVIS (RN4763)	71 793	1-Jan-91	28-Feb-91
S0075	SA	RENMARK	STURT HWY	188 433	1-Feb-91	31-Jul-91
S12-106	SA	HAHNDORF	BURNSIDE-BALHANNAH (RN6039)	265 046	1-Jun-91	31-Aug-91
T0075	TAS	HOWRAH	ROKEBY MAIN RD	97 098	1-Aug-91	30-Oct-91
V0005	VIC		BASS HWY	49 200	1-Aug-90	1-Feb-91
V0006	VIC		PRINCES HWY	135 786	1-Sep-90	1-Jan-91
V0067	VIC		GOULBURN VALLEY HWY 1	189 367	1-Feb-91	30-Jun-9
V0082	VIC		BUFFALO RIVER RD	33 914	1-Nov-90	1-Jun-91

Project Reference	*Jurisdiction*	*Suburb*	*Road*	*Project cost ($)*	*Start date*[a]	*Finish date*
V0166	VIC	SHEPPARTON	GOULBURN VALLEY HWY	34 324	1-Mar-91	1-Jun-91
V0171	VIC		PRINCES HWY(270.5-272.8KM)	68 850	1-Oct-91	1-Dec-91
RH2 (2)						
S0166	SA	HACKHAM WEST	SOUTH RD	27 232	1-Nov-91	3-Dec-91
V0147	VIC	GISBORNE	CALDER HWY	16 199	1-May-91	1-Jun-91
RH4 (14)						
Q0022	QLD	INJUNE	CARNARVON DEVELOPMENT RD	41 498	1-Feb-91	30-Apr-91
Q0035	QLD	SHARPERS CREEK	CAPRICORN HWY	20 995	1-Feb-91	19-Sep-91
Q0057	QLD	INGLEWOOD	CUNNINGHAM HWY	7 505	1-Nov-90	30-Jun-91
Q0079	QLD	QUILPIE	DIAMANTINA DEVELOPMENT RD	54 626	1-Mar-91	30-Jun-91
Q0143	QLD	EAGAN'S HILL	BURNETT HWY	34 454	1-Jun-91	30-Sep-91
Q0169	QLD	BILOELA	OXLEY AVE	19 000	1-Mar-91	30-Jun-91
Q0170	QLD	MT GLORIOUS	MT GLORIOUS RD	78 369	9-Jul-91	22-Sep-91
Q0214	QLD	SHELDON	DUNCAN RD	40 000	1-Mar-91	31-May-91
V0009	VIC		SOUTH GIPPSLAND HWY	39 113	1-Jul-90	1-Sep-90
V0010	VIC		STRZLECKI HWY	23 189	1-Aug-90	1-Oct-90
V0025	VIC		SUNRAYSIA HWY	57 840	1-Sep-91	30-Sep-91
V0029	VIC		MIDLAND HWY 1	14 460	1-Sep-91	30-Sep-91
V0040	VIC		BALLARAT-MARYBOROUGH RD	38 677	1-May-91	31-May-91
V0072	VIC		MELBA HWY	321 224	1-Nov-90	31-May-91
RH5 (2)						
Q0086	QLD	MOONIE	MOONIE HWY	15 620	1-Feb-91	30-Jun-91
Q0134	QLD	GLADSTONE/BILOELA	GLADSTONE-BILOELA	7 188	1-Aug-91	30-Nov-91
RH6 (4)						
Q0013	QLD	WESTMAR	MOONIE HWY	14 877	1-Mar-91	30-Jun-91
Q0064	QLD	SMITHFIELD	KENNEDY HWY	36 726	27-May-91	14-Jun-91
Q0078	QLD	PROSERPINE	PROSERPINE-SHUTE HARBOUR RD	5 940	30-Apr-91	30-Apr-91
Q0097	QLD	GOONDIWINDI	BARWON HWY	14 863	1-Mar-91	30-Jun-91

Project Reference	Jurisdiction	Suburb	Road	Project cost ($)	Start date[a]	Finish date
RH9 (6)						
N0044	NSW	BULAHDELAH	PACIFIC HWY	131 000	1-Apr-91	31-Jul-91
N0159	NSW	MOORLAND	PACIFIC HWY	81 000	1-Apr-91	31-Jul-91
N0160	NSW	BALLINA	PACIFIC HWY	250 000	30-Apr-91	27-Sep-91
N0178	NSW	BANGALOW	PACIFIC HWY	3 539	1-Oct-90	31-Oct-90
S0004	SA		NOARLUNGA-CAPE JERVIS (RN4763)	169 276	14-Dec-90	20-Feb-91
S0007	SA	ELIZABETH PARK	MAIN NORTH RD (RN7200)	38 407	14-Aug-90	21-Aug-90
RM4 (1)						
S0003	SA		NOARLUNGA-CAPE JERVIS (RN4763)	150 712	1-May-91	30-Jun-91
RM6 (5)						
A0002/21	ACT	GINNINDERRA	BARTON HWY	122 139	1-Mar-91	1-Jul-91
N0294	NSW	RAYMOND TERRACE	PACIFIC HWY	160 000	1-Sep-90	28-Feb-91
N0297	NSW	KARUAH	PACIFIC HWY	80 889	20-Jan-91	30-Apr-91
Q0147	QLD	BENARABY	GLADSTONE-BENARABY	79 547	1-Apr-91	31-Jul-91
V0181	VIC		MIDLAND HWY SEC 3	16 923	1-Mar-91	1-Apr-91

na not available

a. May include preliminary work.

Source Data sumbitted to FORS by states and territories.

APPENDIX XIII RESULTS OF EVALUATION WITHOUT TESTING FOR STATISTICAL SIGNIFICANCE

The NPVs and BCRs presented in the following tables are based on changes in crash numbers before and after treatment and have not been tested for statistical significance.

TABLE XIII.1 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY TREATMENT: CRASH-TYPE METHOD

				Discount rate 8%		*Discount rate 6%*		*Discount rate 10%*	
Treatments	*Capital cost ($m)[b]*	*Number of projects*	*Lifetime (years)*	*NPV ($m)[b]*	*BCR*	*NPV ($m)[b]*	*BCR*	*NPV ($m)[b]*	*BCR*
New traffic signals (UH1)	5.8	50	12	2.3	1.3	3.2	1.4	1.5	1.2
Traffic signal modification (UH2)	5.7	59	12	38.4	7.3	43.4	8.1	34.2	6.6
Channelisation (UH3)	2.7	32	15	14.4	6.2	16.7	7.0	12.5	5.5
Provision of medians (UH4)	1.1	12	15	19.1	17.1	21.8	19.3	16.8	15.3
Roundabouts (UH7)	4.1	31	20	24.7	6.7	29.5	7.8	20.8	5.9
Protected turning bays (UM2)	0.7	9	15	3.9	6.2	4.5	7.0	3.4	5.6
Shoulder sealing (RH1)	1.5	15	20	–0.8	0.6	–0.7	0.7	–0.9	0.5
Protected right-turns (RH9)	0.7	6	20	12.9	15.8	15.1	17.7	11.1	14.1
Total[c]	22.4	214		114.8		133.6		99.4	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.
b. In 1992 dollars.
c. Numbers may not add to totals due to rounding.

Source BTCE estimates based on data provided by states and territories.

TABLE XIII.2 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY EXPENDITURE CATEGORY: CRASH-TYPE METHOD

Expenditure category[b]	Capital cost ($m)[c]	Number of projects	Lifetime (years)	Discount rate 8%		Discount rate 6%		Discount rate 10%	
				NPV ($m)[c]	BCR	NPV ($m)[c]	BCR	NPV ($m)[c]	BCR
Major	18.4	95	15	66.5	4.3	77.9	4.8	57.0	3.9
Medium	4.5	62	15	35.2	7.7	40.6	8.6	30.8	7.0
Small	2.2	63	15	9.8	4.7	11.5	5.2	8.5	4.2
Minor	0.4	34	10	9.7	18.8	10.6	20.2	8.8	17.6
Total[d]	25.5	254		121.3		140.6		105.2	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. In 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

TABLE XIII.3 COST–BENEFIT ANALYSIS[a] OF ALL PROJECTS BY EXPENDITURE CATEGORY: CRASH-TYPE METHOD

Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	170.8	802	15	617.7	4.3	723.9	4.8	529.9	3.9
Medium	43.3	622	15	341.2	7.7	393.0	8.6	298.4	7.0
Small	23.3	721	15	103.3	4.7	120.4	5.2	89.2	4.2
Minor	7.4	813	10	169.1	18.8	186.2	20.2	154.2	17.6
Total[d]	244.7	2 958		1 231.3		1 423.4		1 071.7	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. In 1992 dollars. Only projects in the Schedule of Acceptable Treatments are included.

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

Source BTCE estimates based on data provided by states and territories.

TABLE XIII.4 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY TREATMENT: CRASH-SEVERITY METHOD

Treatments	*Capital cost ($m)*[b]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[b]	*BCR*	*NPV ($m)*[b]	*BCR*	*NPV ($m)*[b]	*BCR*
New traffic signals (UH1)	5.8	50	12	0.6	1.1	1.4	1.2	0.02	1.0
Traffic signal modification (UH2)	5.7	59	12	40.7	7.7	45.9	8.5	36.3	7.0
Channelisation (UH3)	2.7	32	15	15.3	6.5	17.7	7.3	13.3	5.8
Provision of medians (UH4)	1.1	12	15	19.2	17.2	21.9	19.4	16.9	15.3
Roundabouts (UH7)	4.1	31	20	35.6	9.2	42.3	10.7	30.3	8.1
Protected turning bays (UM2)	0.7	9	15	4.1	6.5	4.8	7.3	3.6	5.9
Shoulder sealing (RH1)	1.5	15	20	6.8	4.6	8.2	5.2	5.7	4.1
Protected right-turns (RH9)	0.7	6	20	8.2	10.4	9.7	11.7	7.0	9.3
Total[c]	22.4	214		130.6		151.9		113.1	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.

b. In 1992 dollars.

c. Numbers may not add to totals due to rounding.

Source BTCE estimates based on data provided by states and territories.

TABLE XIII.5 COST–BENEFIT ANALYSIS[a] OF SAMPLE PROJECTS BY EXPENDITURE CATEGORY: CRASH-SEVERITY METHOD

				Discount rate 8%		Discount rate 6%		Discount rate 10%	
Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*	*Lifetime (years)*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	18.4	95	15	92.6	5.6	107.6	6.3	80.3	5.0
Medium	4.5	62	15	31.7	7.1	36.6	7.9	27.7	6.4
Small	2.2	63	15	11.1	5.2	12.9	5.7	9.6	4.7
Minor	0.4	34	10	15.0	28.7	16.5	30.8	13.7	26.8
Total[d]	25.5	254		150.5		173.6		131.3	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. In 1992 dollars.

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

Source BTCE estimates based on data provided by states and territories.

TABLE XIII.6 COST–BENEFIT ANALYSIS[a] OF ALL PROJECTS BY EXPENDITURE CATEGORY: CRASH-SEVERITY METHOD

Expenditure category[b]	*Capital cost ($m)*[c]	*Number of projects*	*Lifetime (years)*	*Discount rate 8%*		*Discount rate 6%*		*Discount rate 10%*	
				NPV ($m)[c]	*BCR*	*NPV ($m)*[c]	*BCR*	*NPV ($m)*[c]	*BCR*
Major	170.8	802	15	860.6	5.6	999.5	6.3	745.8	5.0
Medium	43.3	622	15	307.1	7.1	354.3	7.9	268.1	6.4
Small	23.3	721	15	116.4	5.2	135.2	5.7	100.9	4.7
Minor	7.4	813	10	262.5	28.7	288.7	30.8	239.8	26.8
Total	244.7	2 958		1 546.7		1 777.7		1 354.5	

a. NPVs and BCRs are based on changes in crash numbers that have not been tested for statistical significance.

b. Major, $100 000 and over; medium, $50 000 to less than $100 000; small, $20 000 to less than $50 000; and minor, less than $20 000.

c. In 1992 dollars. Only projects in the Schedule of Acceptable Treatments are included.

Source BTCE estimates based on data provided by states and territories.

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Abbreviations

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AGPS	Australian Government Publishing Service
ARRB	Australian Road Research Board
BTCE	Bureau of Transport and Communications Economics
DoT	Department of Transport
DoTC	Department of Transport and Communications
FORS	Federal Office of Road Safety
NAASRA	National Association of Australian State Road Authorities
NSW	New South Wales
OECD	Organisation for Economic Cooperation and Development
PIARC	Permanent International Association of Road Congresses
RACV	Royal Automobile Club of Victoria
RTA	Roads and Traffic Authority (NSW)
SWOV	Institute for Road Safety Research (Amsterdam)

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ABBREVIATIONS

AADT	annual average daily traffic
AAT	annual accident total
ABS	Australian Bureau of Statistics
ACRD	Australian Centennial Roads Development (Act)
ACT	Australian Capital Territory
ADT	Average daily traffic
ALTD	Australian Land Transport Development (Act)
ARIMA	autoregressive integrated moving average
ARRB	Australian Road Research Board
ASD	Adelaide Statistical Division
BCR	benefit–cost ratio
Blvd	Boulevard
BTCE	Bureau of Transport and Communications Economics
CATI	computer assisted telephone interview
CBA	cost-benefit analysis
CBD	central business district
DCA	definitions for classifying accidents
EAN	equivalent accident number
EBEST	empirical bayes estimate of safety in transportation
EMD	equivalent material damage
EPDO	equivalent property damage only
FORS	Federal Office of Road Safety
FYRR	first year rate of return

GIS	geographical information system
GPO	general post office
HI	hazardousness index
Hwy	highway
IRR	internal rate of return
LATM	local area traffic management
LGA	local government authority
MAAP	Microcomputer Accident Analysis Package
MAB	Motor Accidents Board (Victoria)
MDO	material damage only
MI	minor injury
NAASRA	National Association of Australian State Road Authorities
NPV	net present value
NRMA	National Roads and Motorists' Association
NSW	New South Wales
NT	Northern Territory
OECD	Organisation for Economic Cooperation and Development
PAAR	planning annual accident reduction
PAR	potential accident reduction
PC	personal computer
PDO	property damage only
PDOE	property damage only equivalent
PEAC	Planning Evaluation and Audit Committee
PEP	portfolio evaluation plan
Pers. comm.	personal communication
PIARC	Permanent International Association of Road Congresses
QLD	Queensland
RACV	Royal Automobile Club of Victoria
Rd	road

RH	high potential rural
RM	medium potential rural
RTA	Roads and Traffic Authority (NSW)
RTM	regression-to-mean (or regression-to-the-mean)
RUM	road user movement
SA	South Australia
Sec	section
St	street
TAC	Transport Accident Commission
TARP	Traffic Accident Remedial Program
TAS	Tasmania
TRL	Transport Research Laboratory (United Kingdom)
UCL	upper control limit
UH	high potential urban
UM	medium potential urban
VIC	Victoria
WA	Western Australia