Monitoring the National Road Safety Strategy:

Cost-Effectiveness of Road Safety Measures

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Title

MONITORING THE NATIONAL ROAD SAFETY STRATEGY: COST EFFECTIVENESS OF ROAD SAFETY MEASURES

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Abstract

This study reviewed what economic appraisals have been performed on road safety measures within the priority areas identified in the National Road Safety Strategy and Action Plan, and appraised their methodological soundness. The focus has been to establish the cost-effectiveness of measures, and to discuss the role of cost-effectiveness analysis in relation to the current reliance on cost-benefit analysis for resource allocation decisions.

Keywords

COST-EFFECTIVENESS, ROAD SAFETY STRATEGY

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List of Abbreviations

AIHW:	Australian Institute of Health and Welfare
AIS:	Abbreviated Injury Scale
ARRB:	Australian Road Research Board
BCR:	Benefit-cost ratio
BTCE:	Bureau of Transport and Communications Economics
CA:	crashes avoided
DOT:	Department of Transport
EtOH:	alcohol (ethanol)
FORS:	Federal Office of Road Safety
H&CS:	Health and Community Services
HC:	human capital
IA:	injuries avoided
km:	kilometre
LS:	lives saved
MEEM:	macro economic evaluation model
MUARC:	Monash University Accident Research Centre
NCHPE:	National Centre for Health Program Evaluation
NHMRC:	National Health and Medical Research Council
NHTSA:	National Highway Traffic Safety Administration
NISU:	National Injuries Surveillance Unit
NRSAP:	National Road Safety Action plan
NRSS:	National Road Safety Strategy
R&D:	research and development
NRTAC:	National Road Trauma Advisory Council
OECD:	Organisation for Economic Co-operation and Development
PYL or PYLL:	productive years of life lost
QALY:	Quality Adjusted Life Year
RACV:	Royal Automobile Club of Victoria
RARU:	Road Accident Research Unit
RBT:	Random Breath Test
RTA:	Roads and Traffic Authority
TAC:	Transport Accident Commission
TINS:	Traffic Infringement Notices
USDOT:	United States Department of Transport
WTP:	willingness to pay
WTPH:	willingness to pay, hedonic

Monitoring the National Road Safety Strategy: Cost-Effectiveness of Road Safety Measures

Key points

- Economic evaluation can provide guidance on resource allocation questions in road safety; both cost-benefit analysis and cost-effectiveness analysis of road safety programs can inform the process of priority ranking, decision-making, and policy development.
- Where the decision involves the comparison of projects with quite divergent outcomes (e.g. reductions in road trauma, versus reduced travel time, versus projects in rail or air transport, etc.), cost-benefit analysis should be considered the most favoured method of economic appraisal, but its usefulness is weakened by the debate on the 'value of statistical life'.
- Where the decision involves programs the results of which can be captured in a single measure of outcome, cost-effectiveness analysis is an appropriated technique. The results, which are framed in terms of cost per life year saved or cost per injury avoided, are easier to communicate among decision makers and to the wider community.
- The reliability of both cost-effectiveness analysis and cost-benefit analysis depend, among other things, on the certainty of the benefits predicted, and hence on the precision and accuracy of program effectiveness evaluation. Current practice in this area (as evidenced by the published studies) requires improvement. In order to assist in decision making a greater effort to standardise methods in the evaluation of road safety measures should be made with greater attention to study design and consistent choice of cost and outcome categories.
- Some program areas have few published economic evaluations and it is very difficult on efficiency grounds to determine which road safety program areas should be expanded or contracted.
- It is clear however that some particular projects are cost effective on any measure and therefore if we are deciding how to use extra resources it is possible to save injury at a relatively low cost with the expansions of these programs. For example many of the

road engineering , speed and alcohol reduction programs appear to offer value for money.

- There seems to be a publication bias in favour of programs which have been implemented and it is open to question whether new untested programs would be more cost effective. There are for example few studies of cost-effectiveness in the area of education and licensing, or vehicle safety. In the absence of good data on the costs and the effectiveness of interventions a great deal can be achieved by modelling the likely impact on safety and costs using best estimates combined with sensitivity analysis. While sensitivity analysis should not be used as an excuse for poor data collection, it can also be used to determine when a more detailed study is warranted;
- If the objective is to minimise injury at least cost then the use of ratio measures (benefit to cost or cost-effectiveness) to rank programs is a good rule of thumb, but a more appropriate technique is the use of simple mathematical programming. This can be done using standard spreadsheet programs on a microcomputer

Executive Summary

This study reviewed what economic appraisals have been performed on road safety measures within the priority areas identified in the National Road Safety Strategy and Action Plan, and appraised their methodological soundness. The focus has been to establish the cost-effectiveness of measures, and to discuss the role of cost-effectiveness analysis in relation to the current reliance on cost-benefit analysis for resource allocation decisions.

Methodology

A literature search was conducted of Australian and international transport research and related databases, using university and transport sector library networks. The search keywords were framed in terms of road safety, road trauma prevention, effectiveness, evaluation, economic appraisal, cost-effectiveness and cost-benefit analysis. The aim was to identify effectiveness and cost-effectiveness studies that could be utilised in road safety priority settings. Inclusion criteria also extended to studies which presented sufficient effectiveness and cost data to construct a meaningful cost-effectiveness analysis.

Despite the comprehensiveness of the literature search, only a few genuine cost-effectiveness studies of road safety programs were found. As in the transport sector generally, the methodology used by the majority of economic appraisals, and in effectiveness studies that included economic analysis, was cost-benefit analysis. These varied in the strength of effectiveness evidence, and in those most concerned with program planning or funding proposals, the effectiveness was often only a crude estimate.

There was an extensive literature on the effectiveness of road safety programs, but mostly without an economic appraisal component. Again these studies varied widely in the quality of their design, their data, and analysis. Due mainly to the time constraints of this consultancy, it was decided to confine our analysis to only those studies which had an economic component and that were, or could be converted to, cost-effectiveness analysis. A full review of road safety effectiveness studies is probably warranted, but would be a major undertaking, and beyond the scope of this study.

A cost-effectiveness approach was applied to those studies where there was sufficient data for the analysis (i.e. studies which included both effectiveness information, even if only an estimate, and cost data). Convertable studies were compiled on a database (MS Access®2) using an economic analysis framework developed for this study. The total number of studies so treated was 48. Specific configurations of the database are presented in table form in the report.

Field consultations were conducted with representative interstate road safety stakeholders, with face to face meetings taking place in Melbourne, Canberra, Sydney, and Adelaide Advice was sought from the perspectives of NRTAC, state road safety managers, road trauma researchers, insurance offices and road user representatives Project time-line constraints prevented a wider direct consultation, but there was some indirect feedback on preliminary findings from an Austroads meeting held towards the end of the consultancy.

Overview of Findings

Cost-effectiveness analysis of road injury interventions is a useful supplementary form of analysis to cost-benefit analysis . For some research questions, it may be the preferred form of analysis. It seems clear that it is possible and meaningful to calculate the cost-effectiveness of road safety programs on the basis of cost per injury consequence. It is also possible to rank programs on the basis of their cost per injury consequence. Cost-effectiveness analysis has the strong advantage that it is more transparent in its decision rule, and easier to communicate to interested parties It allows the decision maker to adopt a benchmark figure for the value of an injury or fatality and say that a particular program has a cost per injury or fatality prevented less or more than they are prepared to pay If a program cost more than $5 million per life saved, for example, it may be rejected if the benchmark was $3 million

Cost-effectiveness analysis seems to provide similar absolute values for programs to cost-benefit analysis, where conventional benchmarks are used. That is to say, programs with a benefit-cost ratio (BCR) in excess of an accepted level of say 3.1, tend to have a cost per life year saved of less than $30,000, which is less than many common health care interventions which have been evaluated While cost-effectiveness analysis may provide similar guidance to cost-benefit analysis on broad notions of economic worth, it does produce different rankings of programs, especially where minor injury is a large component, and depending on how cost savings are treated in the benefit-cost ratio

The key limitations on the use of published cost-benefit studies of road safety interventions, are that the underlying data on the effectiveness of the programs is most often weak, and that the available techniques of evaluation are often not rigorously applied Many cost-benefit studies had flaws in design which were inconsistent with the theory and practice of the cost-benefit approach. There is little use of good experimental designs to establish efficacy and too much evaluation is based on intuitive guesswork, often without any supporting sensitivity analysis. Similarly, the lack of appropriate current data on the predicted outcomes of interventions would limit the use of cost-effectiveness analysis for resource allocation across program areas Consistency in the application and reporting of economic appraisal methods would improve the quality of information available to assist decision making.

Many of the published economic studies were for a group of initiatives at a particular level of expenditure. This makes it very difficult to evaluate the cost-effectiveness of future initiatives at perhaps different levels of expenditure. We might have evaluated a program to improve road conditions at 40 black spot locations, but this might tell us little about the cost-effectiveness of the 41st or another 20 elsewhere. There is a need for studies to evaluate the marginal cost and outcomes for interventions and to consider the transportability of the results. Only one study which we looked at (Cameron, 1993) had sufficient detail to allow a marginal cost-effectiveness analysis to be carried out. In many ways this study was a good example of an evaluation with a valid study design and containing sufficient detail to allow transportability

In the short term decisions have to be made and we would continue to recommend the use of economic evaluation methods. In the longer term we would recommend an effort to improve the standard and consistency of evaluation methods. In this context it is important to note that, where the safety budget is constrained, there are dangers in the simple application of rankings from cost-benefit or cost-effectiveness ratios. That is to say a simple league table of interventions ranked by these ratios can be a misleading guide to efficiency. There may be an important role for mathematical programming and associated techniques in determining the optimal profile of programs and the level of each program when utilising cost-benefit analysis or cost-effectiveness analysis results in the presence of a budget constraint.

In principle cost-effectiveness analysis could be used to assist in resource allocation decisions at all levels of decision making in road safety. It could be used to determine the optimal mix of programs within a priority area as well as to determine which broad area warrants extra investment. Data requirements are a barrier to each of these tasks, but particularly the latter In order to determine the best place for additional investment we need to know the cost-effectiveness of the marginal project in each priority area. We have identified only a small number of published studies overall which can provide reliable evidence on both effectiveness and costs, and a very small number of studies in some areas. It would be dangerous, therefore, to rely too heavily on current economic knowledge to allocate resources between priority areas. On the other hand, given a longer time frame, it should be possible to frame research in this way. In the meantime, cost-effectiveness analysis can be used within some broad program areas where there is sufficient reliable data. This seems to be the case, for example, in road environment programs where unpublished data may be available on the expected costs and outcomes of particular investments. In the absence of perfect data a great deal can be done with the use of informed views of the likely effectiveness of interventions and their likely costs. When used with sensitivity or threshold analysis it is possible to show which programs are likely to be cost effective, and which will not be even under the most optimistic assumptions. In this case the choice of economic analysis type is not likely to be important. In these cases the economic worth of a project is likely to be robust no matter the assumed economic value of intangibles such as lives saved or pain and suffering avoided. Where more detailed marginal choices have to be made, however, for example on program expansion, it is not only necessary to have good knowledge of the marginal effectiveness of a program, but also of the impact of the program on the relevant budget. In other words what safety interventions have to be given up in order to expand a particular program.

Conclusions

The major conclusions of this study are as follows:

- economic evaluation can provide guidance on resource allocation questions in road safety; both cost-benefit analysis and cost-effectiveness analysis of road safety programs can inform the process of priority ranking, decision-making, and policy development;

- where the research question involves the comparison of projects with quite divergent outcomes (eg reductions in road trauma, versus reduced travel time, versus projects in rail or air transport, etc.) Cost-benefit analysis should be considered the most favoured method of economic appraisal, but its usefulness is weakened by the debate on the 'value of statistical life';

- where the research question involves projects, the outcome of which can be encapsulated in a single physical measure (such as lives saved), cost-effectiveness analysis could be the preferred technique, or at least a very useful adjunct to cost-benefit analysis;

- the reliability of both cost-effectiveness analysis and cost-benefit analysis depend, among other things, on the certainty of the benefits predicted, and hence on the precision and accuracy of program effectiveness evaluation. Current practice in this area (as evidenced by the published studies) requires improvement;

- in the absence of good data on the costs and the effectiveness of interventions a great deal can be achieved by modelling the likely impact on safety and costs using best estimates combined with sensitivity analysis While sensitivity analysis should not be used as an excuse for poor data collection it can be used to determine when a more detailed study is warranted;

- the main advantages of cost-effectiveness analysis in road safety decision making are that:

(1) the value of a project is not influenced by the value of a statistical life;
(2) cost-effectiveness analysis can be adapted to suit a number of policy arenas, e g. it can be used to compare road safety programs with other types of programs which result in the same benefits, such as health or emergency services, or even air pollution control;
(3) cost-effectiveness analysis enables a transparent, yet systematic approach to program budgeting, that is easier to communicate to decision makers and the general public e.g. cost per crash avoided, cost per fatality prevented;

- the principal disadvantages of cost-effectiveness analysis in road safety decision-making are that:

(1) cost-effectiveness analysis does not provide a means of explicitly weighing safety effects against the other beneficial and harmful effects of decisions;
(2) costs and benefits are not valued in the same units, hence cost-effectiveness analysis does not enable comparison with other transport sector programs,
(3) the interpretation of cost-effectiveness analysis is unfamiliar to road safety management. Despite the unfamiliarity of the approach, the idea of cost effectiveness analysis has appeal to Australian road safety managers - especially in that the results of cost-effectiveness analysis are easy to communicate;

- while there is evidence of rigorous well designed economic appraisals, overall the standard is very variable, and steps need to be taken to improve the quality and consistency in the conduct and reporting of studies;

- one category of potential cost saving from road safety initiatives that is ignored or poorly measured at present, is long term disability from road accidents;

- if cost-effectiveness analysis is favoured as an appropriate form of appraisal to undertake, then careful thought needs to be given to the choice of outcome measures, including the combination of mortality effects and morbidity effects through a measure such as the Quality Adjusted Life Year (QALY);

- there are a number of programs which appear to offer good value for money. Many programs in the field of road engineering , alcohol and speed reduction appear to offer good value for money. This suggests that expansion of these programs should be considered.

Recommendations

Recommendations arising out of this study are:

(1) That methodological guidelines for the evaluation and economic analysis of road safety countermeasures be developed by the national peak road safety organisations in order to generate a national 'pool' of research results that could be shared by all stakeholders; ensure consistency of cost and effectiveness information; and enable greater comparability of road safety program evaluations.

(2) That road safety managers consider cost-effectiveness analysis a useful adjunct to decision-making and priority setting for road safety projects.

(3) That a small investment in recording and costing long-term disability from road accidents be made in order to enhance the measurements of benefits achievable from road safety.

(4) That road safety stakeholders work towards adopting the Quality Adjusted Life Year (QALY) approach in deriving the most appropriate standard of outcome measure for road safety cost-effectiveness analyses. Such a measure would need to combine both fatal and non-fatal disabling outcomes and do so in a way that reflects their relative seriousness. Failing this, that the Potential Years of Life Lost (PYLL) measure be used.

(5) That preliminary economic evaluation of new programs be done using current best information combined with sensitivity analysis. Where necessary, a full economic appraisal be undertaken consistent with standard methodology

1. Introduction

1.1. Priority areas

For the purposes of this study the priority areas have been arranged into groups and sub-groups, as shown in *Table 2.2.* It is clearly not possible to assemble all of the priority areas into mutually exclusive categories, but such an arrangement serves as a framework for this cost-effectiveness review.

Table 1: Priority Areas of the National Road Safety Strategy

General Areas	Specific Areas
ROAD USER ISSUES: Enforcement and Public Education (including supporting community actions)	Speed Drink driving: (RBT + Public Education/Low alcohol beer) Drugs and Driving Bicycle helmets Pedestrian behaviour Motorcyclists Red light cameras Fatigue
SCHOOL BASED EDUCATION	Programs aimed at immediate goals Programs aimed at long term goals School curricula: health & personal development
DRIVER TRAINING & LICENSING NOVICE/DEFENSIVE/ ADVANCED	National training curriculum for novice drivers and riders Competency requirements and standards
ROAD ENVIRONMENT	Blackspot treatments Road construction/maintenance (e.g. divided highways, edgelining, shoulder sealing etc) Road safety audits
VEHICLE SAFETY	Design (Occupant protection/ other issues e.g anti-lock brakes) In-service vehicle safety & roadworthiness standards
HEAVY VEHICLE SAFETY	Vehicle safety Fatigue management measures Public education
TRAUMA CARE	Rehabilitation services Delivery of trauma treatment

2. Objectives of the Study

This study reviewed what economic appraisals have been performed on road safety measures within priority areas identified in the National Road Safety Strategy and Action plan, and appraised their methodological soundness. The focus has been to establish the cost-effectiveness of measures, and to discuss the role of cost-effectiveness analysis in relation to the current reliance on cost-benefit analysis for resource allocation decisions.

The following specific objectives directed the study:

- to survey state, national and international literature for studies on the effectiveness of road safety interventions as identified in the National Road Safety Strategy and addressed in the National Road Safety Action Plan;
- to examine economic literature on effectiveness and cost-effectiveness of road safety programs;
- to apply a methodology for cost-effectiveness that is suitable for the Australian road safety context (only studies which were convertable by this method were included);
- to develop and apply a ranking/ratings matrix based on cost-effectiveness measures that will enable better judgement in decisions about investments in road safety programs, i.e. allocative efficiency in road safety;
- to undertake field consultations with road safety administrators and researchers in order to identify assessment criteria and standards that are current in the sector;
- to produce a report which identifies the road safety programs (or their elements) by cost-effectiveness, in a way that is amenable to incorporation into policy and planning

2.1. Methodology

2.1.1. Economic Evaluation

'Cost-benefit analysis is a procedure for comparing alternative courses of action by reference to the net social benefits that they produce' (Department of Finance, 1991).

The fundamental approach in economics to the evaluation of any social program is to ask the question; will the social benefits exceed the opportunity costs of the resources used to implement the program? There are three main analytical techniques within this general approach which have been used in the evaluation of policies, projects, and programs involving safety. These are *cost-benefit*, *cost-effectiveness*, and *cost-utility* analysis.

The key methodological strength in such an approach is that it requires the perspective of the analysis to be defined, and as a consequence , clarifies which costs and benefits should in theory be included. Benefits and costs are regarded as social rather than only private, and are usually weighted equally irrespective of the people to whom they accrue. A more restricted perspective than societal could be taken (eg. funder, provider, recipient, etc) but would need to be clearly stated in the research question. Equity could also be explicitly considered, however the net benefit approach is the simplest and the most common.

2.1.2. Cost-Benefit Analysis

An immediate question is how such resource costs and benefits should be valued. The conventional economic approach is based on the value judgment that social values should be based on an aggregation of individual preferences. The theory of demand in economics suggests that the inverse demand function for goods and services relates preferences to money values. That is to say the willingness-to-pay for a commodity is a measure of preference or welfare obtained from that commodity at the margin. Thus it is argued that individual values of resources and benefits are reflected in the price individuals are willing to pay. Cost-benefit analysis then is an appraisal technique in which all real costs and consequences of a technology are expressed in money. Cost-benefit analysis proceeds *as if* market prices existed (Department of Finance, ibid.).

In the context of road safety cost-benefit analysis could be used in the following contexts:

- accepting or rejecting a project;
- choosing projects from a number of possible projects;
- choosing the appropriate scale of a project;
- choosing one of a number of mutually exclusive projects; and

- all of the above, subject to a resource constraint

Two immediate problems arise in the evaluation of road safety programs: -

- Some commodities are not traded and therefore there is no observable price or willingness to pay (e.g. the natural environment, health, personal freedom). In such cases valuations need to be made on the basis of complementary markets or experimental techniques.

- Some commodities are subsidised, regulated or publicly provided because of a social judgment that supply should not be based on willingness to pay. (e g. health care)

Cost-benefit analysis as currently practiced in the evaluation of road safety, while in general compatible with economic theory, has a number of theoretical and practical problems.

1. The value of physical risk and safety, and therefore the money value of the consequences of road safety programs, is difficult to assess with any degree of confidence. Studies have used either contingent valuation and hedonic price techniques (Miller & Guria, 1991; Viscusi, 1993). These studies confound the valuation of life *per se* with the value of risk. Willingness-to-Pay for changes in risk at different absolute levels of risk will undoubtedly vary casting doubt on the generalisability of the results. This is one reason for the wide range of values produced by such studies.

2. Even if we could establish individual willingness-to-pay for safety it is not clear that the average values produced would reflect the community willingness to pay for death and injury prevention. Certainly in the area of health care services most countries including Australia have explicitly rejected the idea of relying on market generated willingness to pay as the mechanism for allocating health care resources They tend to favour a social decision making mechanism with a greater emphasis on equity.

3. The widely used alternative means of valuing life in the cost-benefit analysis road safety interventions is the human capital approach. Human capital is a measure of the value of potential output. As a measure of the social value of death and injury reduction it has no basis in economic theory. As a measure of productive output. there are also several problems, including that earnings forgone may be a poor measure of lost production (does not adequately reflect the firm's response, labour market conditions, etc) and that earnings may not accurately reflect one's ability to produce. Further it has the same unacceptable equity implications as willingness to pay insofar as those who have greater potential income would receive greater safety.

4 In addition to the value of life itself cost-benefit analysis has problems in valuing other so called intangible costs. Many road safety projects have multiple outcomes few of

which have market values. These include effects on the natural and built environment, with potential health and aesthetic impacts. They may also include (through legislation or promotion) impacts on personal liberties. Cost-benefit analysis has difficulty in encapsulating such effects within the money metric Thus it must be acknowledged that cost-benefit analysis (and other forms of economic appraisal) can offer only partial appraisal of a project While this is true of all forms of economic appraisal, the attempt to reduce the results of the analysis to a single figure of a net present value or a cost-benefit ratio can hide the fact that important costs and benefits may have been excluded. Thus a gross bias can be created in favour of projects for which the direct program costs are low, but intangible costs may be high. This is a characteristic of legislative solutions to road safety problems.

These problems have led to the development of other economic appraisal tools which do not constrain benefits to those which can be measured in terms of money

2.1.3. Cost-Effectiveness Analysis

Cost-effectiveness analysis is an appraisal technique for evaluating two or more alternatives in which inputs are measured as economic costs, but at least some consequences are valued in a single physical unit (lives saved, injuries avoided, casualty crashes avoided). Its major advantage is that it relaxes the assumption that all benefits have to be valued in monetary terms. It can be used to rank road safety interventions in terms of cost per crash consequence.

Two main problems arise with cost-effectiveness analysis. These are:

- The presumption in using a single measure of effectiveness is that the analysis has captured the predominant category of benefit. Thus if injuries avoided is used as the objective on which to compare two road safety projects the presumption is that there are no major differences in outcomes of other benefits. For example, mandatory bicycle helmets may save as many injuries as a road alignment modification project, while the latter may also prevent property damage and a greater number of fatalities. Thus, one must be careful that the measure of effectiveness is a good proxy for all of the important categories of benefit.

- To some extent this measurement issue can be reduced by converting some benefits into negative money costs. For example, property damage averted could be included as a cost saving in an evaluation of a road crash program. This raises the danger of changing the value of a cost-effectiveness ratio (and the ranking of programs) by including or excluding certain benefits solely on the grounds of convenience of measurement in money terms.

Unlike cost-benefit analysis, which calculates a net present value, cost-effectiveness analysis provides no absolute criterion for accepting or rejecting projects. It can however rank projects. Where there exists a benchmark value for the outcomes in a cost-benefit analysis then this provides an absolute criterion. However, the existence of a benchmark value implies a social value of life and injury. That is to say, if we reject a program with a cost per life year saved of $10,000, this implies a social value of a life year lost is less than $10,000

Cost-effectiveness analysis does not let us escape from the issue of choice, but it does make more explicit the trade-offs which are being made. The decision maker given a choice of doing a marginal project with say a cost per life saved of $50,000 is clear in her mind what the trade-off is. A rejection of a project with a benefit to cost ratio of say 3:1 is less obvious. While the net present value criterion can be translated into its impact on welfare directly and road safety decision makers may easily learn to do that translation (a benefit to cost ratio of 3:1 may be regarded as good) it is nevertheless less amenable to communication to others outside that circle. Cost-effectiveness analysis has the advantage of being more transparent and understandable and can be used both to underpin decisions and to communicate their rationale.

As discussed above cost-effectiveness analysis is limited by the assumption of a uni-dimensional outcome. Road crashes involve a range of health outcomes from very temporary minor pain, through weeks of pain and suffering of injury and treatment, including short or long term disability, and finally to death. Cost-benefit analysis could in principle capture all of these morbidity and mortality impacts in a single measure (willingness to pay). We have discussed some of the problems with this approach in relation to mortality reduction and the problems would be similar if the technique were extended to morbidity gains. Cost-effectiveness analysis of road safety interventions can consider the various dimensions of morbidity reduction in two ways. First, the cost of treatment and caring for those affected can be included as a cost saving associated with a program which reduces crashes. Second, the various outcomes can be listed and separate cost-effectiveness ratios calculated. This is the approach taken in this study. We have calculated the cost per death avoided, the cost per life year saved, the cost per serious injury avoided, and the cost per all injuries avoided. This approach, while extending the analysis beyond mortality measures does not provide any means for directly comparing programs which have different profiles of deaths and injury.

The major advantages of cost-effectiveness in this respect is that cost-effectiveness analysis enables a transparent, yet systematic approach to program budgeting, and it can be applied in different policy environments. In other words, according to the choice of output of a cost-effectiveness study (such as cost per crash averted, cost per life saved, or cost per life year gained), such information can be used to inform a wide range of participants in the road safety debate, or cost per quality adjusted life year saved. Such terms can be readily understood in forums with community groups, within the transport bureaucracy, and across government sectors such as police and health.

2.1.4. Cost-Utility Analysis

A possible solution to the problem of multiple health consequences is to construct an index of health related welfare. Cost utility analysis is an appraisal technique which measures costs in monetary terms, and measures consequences in terms of their social value to the community or "utility". It has been used in the evaluation of health related programs (Richardson, J. 1991).

Cost utility analysis eliminates the problem of obtaining individual monetary/market valuation of consequences, while allowing a wider spectrum of health consequences to be considered. It allows a weighting of consequences, not by money, but by a direct welfare measure. It does so at the expense of empirical issues of valid utility measures. It has not been used as yet in the field of road safety evaluation except in an illustrative sense, however it has the potential to offer an enhanced cost-effectiveness analysis of programs, particularly where consequences include long term disability. (Shiell and Smith (1993).

2.2. On The Measurement Of Effects In Economic Appraisal

All of the above techniques rely on good evidence on the relationship between a safety program and final outcomes for crash victims. The link between a particular road engineering project, for example, and any reduction in the number of deaths, short term or long term personal injury, disability must be clear Unfortunately there are many links in this chain and knowledge is fragmented. For example, there is some evidence on the effectiveness of interventions in reducing different types of crash, e.g. rear end versus side-on. There is better evidence on the relationship between crash type and resultant injury treatment (Andreassen, 1992b) There is little evidence linking casualty status (AIS score for example) and temporary or permanent health outcomes, aside from length of stay (Hendrie et al 1994) or insurance payouts (Oxley and Fildes, 1993). This is a major gap in the literature which may bias the results of economic evaluation It may be that insufficient weight is being paid to those types of crashes which are more likely to result in long term disability through head or spinal injury.

2.2.1. Methodology: Ranking Of Interventions

The current study uses cost-effectiveness to analyse a number of road safety interventions. It aims to provide a ranking by program area (and within program area) using the data from a number of published cost-effectiveness and cost-benefit studies It compares the rankings obtained with the original cost-benefit studies. We also demonstrate the effects of a budget constraint on efficient program selection

Cost-effectiveness ratios have been calculated as the ratio of net costs to three measures of consequences.

- Cost per life saved
- Cost per life year saved
- Cost per death and injury avoided

We have re-analysed a number of published studies and present cost-effectiveness ratios These are used to rank programs The rankings are compared with the position in the ranking derived from the original benefit to cost or cost-effectiveness ratios. The rankings might be different for two main reasons First. the methodology in the original study may not conform with the approach to cost-effectiveness analysis used here For example, studies may have only included government costs and excluded private costs, or they may have double counted costs. Second, cost-benefit analysis which uses a high value of life will ensure higher net benefits for programs which reduce a relatively small number of fatalities as opposed to those projects which eliminate a large number of minor injuries. cost-effectiveness analysis, based on the cost per injury avoided, may give a different ranking to cost-benefit analysis in this case.

The rule of thumb decision criteria in cost-effectiveness analysis is that independent programs should be arrayed from the lowest ratio of cost to consequences to the highest, and the programs chosen from the top of the list down until a threshold value is reached. This criterion seems to be the standard used in road safety resource allocation decisions. In the presence of a resource or budget constraint, however, and with indivisible programs, this can be a misleading rule. We demonstrate this by comparing the rankings using cost-effectiveness ratios with the optimal choice of programs in presence of three constrained budgets. The optimal choice is a set of programs which minimises the consequences of crashes for a given budget.

2.2.2. Assumptions Used In The Analysis

Published studies were re-analysed using the assumptions set out below.

A consistent set of costs was included for each program Costs included were the capital and recurrent costs of the program appropriately discounted at 5% to a present value. 5% represents the real return on 10 year government bonds (a risk free return). Capital costs are assumed to occur at the beginning of the year. All costs were converted to 1992 Australian dollars. Cost offsets for each crash avoided included only hospital and medical savings and property damage. The value of hospital and medical savings per crash type was taken from Andreassen (1992b) table 4.8 (ARR 217, p. 15). Where the study did not provide the number of injuries but only the number of crashes, the distribution of the number and severity of injury by crash type was taken from Andreassen (1992b) tables 4.1 and 4.2. The cost of injury assumed is given in *Table 2* below.

Costs were generally those reported in individual studies. Where these were not in 1992 $AUD they were appropriately converted. These generally included only the direct costs of the intervention (i.e., staff, maintenance, and materials). Where appropriate, the cost to individuals was also included. An example is the purchase of bicycle helmets by cyclists in a program encouraging or requiring the wearing of bicycle helmets. Travel and time (or productivity) costs were excluded from the analysis in order to standardise across studies. However, in few of the studies reviewed was this an issue.

***Table 2: Money value of cost savings used** (adapted from Andreassen, 1992)*

Cost saving types	*Cost of treatment*
Fatality	$3,812
Hospitalised injury	$9,261
Medical treatment injury	$700
Property damage	$4,462

Years of life saved were calculated as the expected number of years of life at the median age by road user type of accident fatality for the year 1993. (Road Fatalities Australia, 1994) These years of life were discounted at 5%. Thus the average life expectancy of a driver who died in a car accident at the median age of 30 is 78. The years of life lost are 48 which if discounted at 5% is 18 years. This double discounting is not intuitively obvious and indeed there has been some controversy in the literature on the issue of discounting life years (Olsen, J.A. 1993). This is largely because of the difficulties of conceiving of a trade-off between years of life now and in the future. This difficulty would evaporate if we could place value on life and use the traditional arguments for discounting. The problem then is not so much one of should we discount life years but how do we value life years. If we make the initial assumption that an extra life year has the same value no matter who gets it then there is some intuitive logic in the further assumption that society would prefer to give an extra year of life to 10 people today than give one year to 10 people each over the next ten years, or give 10 years to one person Note that this process counteracts some of the implicit bias in cost-effectiveness analysis against the elderly.

The resulting cost-effectiveness equation is

$$\frac{\delta C}{\delta E} = \frac{\delta C_{rx} - \delta C_{morb} - \delta C_{mort} - \delta C_{property}}{\delta M_{mort} + \delta M_{morb}}$$

Where δC_{rx} is the change in program costs

δC_{morb} is the change in the cost of morbidity treatment

δC_{mort} is the change in the treatment cost of a fatality

$\delta C_{property}$ is the change in the cost of property damage

δC_{mort} is the change in the number of fatalities

δC_{morb} is the change in the number of injuries

Any data, whether dollar costs or outcomes, which was not presented in a one year time frame was adjusted to an equivalent year's effect before any conversions were attempted.

Some interventions involved a decrease in the rate of one crash type and an increase in the rate of another crash type. In these cases the net effect in terms of outcomes calculated (e.g., lives saved and lost), was used to calculate the effects on outcomes overall.

Where costs and benefits were expected to occur over more than 12 months these were discounted by 5% for a period either specified in the original study, or as per a judgment made regarding the likely life of the project. This ranged from anywhere between 2 and 10 years. In calculating cost-effectiveness ratios, where costs and benefits had been discounted, then outcomes (*i.e.*, lives saved, injuries avoided) were also discounted over the relevant time period and also at a 5% discount rate.

2.2.3. Effectiveness

Where studies used effectiveness data (i.e., life years saved, injuries avoided) that was drawn from another study, the effectiveness of the intervention was unquestioned. Where the effectiveness data was that reported by the study itself, and a range of effectiveness estimates were provided, the lowest of these were used for the calculation of dollar benefits and cost-effectiveness ratios Where no range was presented then a judgment was made regarding the strength of the effectiveness results and these were adjusted accordingly before dollar benefits were calculated.

2.3. Criteria For Inclusion Of Studies

2.3.1. The Literature Search Strategy

A literature search in the field of road safety program effectiveness was conducted. A more or less complete and up-to-date overview of the published literature in the national and international spheres was achieved. The project team was able to survey recent literature and documentation which described, analysed, and evaluated road safety programs in terms of effectiveness. Attention was directed to those which were in National Road Safety Strategy priority areas, or which showed potential for extension and/or improvements in implementation, and those that were likely to produce significant and measurable gains in the short to medium term. Those programs that demonstrated sound needs assessment, planning processes, appropriate implementation strategies, and which address the issues of cost-effectiveness and sustainability were particularly sought.

A detailed literature search was conducted, looking for studies, both Australian and from overseas, on the economic evaluation of different options in the priority areas as outlined in the National Road Safety Action Plan The methodology for the search was as follows:

(i) A detailed computerised literature search and review was initiated using the IRRD, Medline, ROAD, LASORS, Engineering and Applied Science (RMIT), Econlit and overseas databases to determine available studies This activity was continued throughout the project Other data sources were explored, during the project to ascertain the most up-to-date information e.g. Government reports, studies undertaken in key centres such as the Australian Road Research Board (ARRB), the NHMRC Road Accident Research Unit, Adelaide (RARU), Monash University Accident Research Centre (MUARC), the Australian Institute of Health and Welfare (AIHW) and the National Injuries Surveillance Unit (NISU).

Key words used in the search included the following terms either singly or in combination.

> road safety; road trauma, injury prevention, road accidents, speed management; driver training; drink-driving; economics, cost and cost analysis, economic evaluation; cost-effectiveness analysis; cost-benefit analysis; health promotion; trauma prevention; effectiveness

The aim was to identify effectiveness and cost-effectiveness studies that could be applied in road safety priority setting Inclusion criteria also extended to studies which presented effectiveness and cost data sufficient to construct a meaningful cost-effectiveness analysis.

Despite the comprehensiveness of the literature search, only a few genuine cost-effectiveness studies were found applied to road safety programs. As in the transport sector generally, the majority of economic studies used cost-benefit methodologies These varied in the strength of effectiveness evidence, and in those most concerned with program planning or proposals, the effectiveness was usually only a crude estimate

There was an extensive literature on the effectiveness of road safety programs, but without economic evaluation. Again these studies varied widely in the quality of their design, their data, and analysis Due mainly to the time constraints of this consultancy, it was decided to confine our attention only to those studies that were, or could be converted to, cost-effectiveness analysis

A selection of convertable studies that represented the widest range of programs possible were compiled on a database (MS Access ²2) using an economic analysis framework developed for this study. The total number of records so treated was

48. Specific configurations of the database were output into table form for illustrative purposes.

(ii) A written overview of the evidence relating to the cost-effectiveness and cost-benefit analysis of the included studies is presented in a hard-copy format of the master database (available as separate document)

2.3.2. Other Documentation

Many road safety programs are not published in the literature. Their details appear in government technical reports, or in conference proceedings. The NCHPE already had a collection of such documents pertaining to the area of road safety. The project team reviewed relevant annual reports and recent conference program abstracts. Contact was made with those individuals and organisations whose programs indicate they have addressed some or all of the issues of:

- developing priorities;
- cost-effectiveness;
- quality of program delivery;
- evaluation, particularly that which is useful and actionable.

2.3.3. Inclusion Criteria

Two inclusion criteria were used to decide which studies were converted to cost-effectiveness analysis using the methodology above

1. Studies needed to identify a change in road trauma outcomes e.g., lives saved or injuries avoided, in order to allow for the recalculation of benefits and/or the (re)calculation of cost-effectiveness ratios.

2. The costs associated with the intervention needed to be identified within the study itself. This generally limited the studies available for conversion from cost-benefit analysis to cost-effectiveness analysis to those which separately identified the outcome data. Some studies only reported the money value of outcomes and these had to be excluded. Only 9 cost-effectiveness analysis studies were located in the literature search and only 7 were able to be adjusted to fit the methodology used in this report. Sixty-nine (69) cost-benefit analysis studies were identified of which 41 could be converted using our methodology.

2.4. Cost-Effectiveness Ranking Versus Cost-Benefit Ranking

We have converted all studies into cost-effectiveness ratios and compared the ranking with the original cost-benefit or cost-effectiveness ratios. The rankings might be different for two main reasons.

1. The methodology in the original study may not conform with standard approaches to cost-effectiveness analysis. For example, studies may have only included government costs and excluded private costs
2. Cost-benefit analysis which uses a high value of life will ensure higher net benefits for programs which reduce a relatively small number of fatalities as opposed to those projects which eliminate a large number of minor injuries. Cost-effectiveness analysis, based on the cost per injury avoided, may give different ranking to cost-benefit analysis in this case. We have compared these two approaches in the Table A4.3 in *Appendix 4*.

2.5. Other Issues

Few Australian studies on the economic evaluation of road safety interventions have been undertaken and this project has incorporated the appraisal of overseas studies. Where possible these appraisals have been assessed for applicability to the Australian context. Most of the studies relating to road trauma prevention programs have focused on the three most important prevention measures - road user issues, engineering, and legislative components. Limited information is available on the costs and benefits of community-wide road safety intervention programs that aim to modify multiple risk factors in the population.

In *Appendix 1* is a description of theoretical frameworks that may ultimately be used in measuring the effectiveness of road safety measures.

In Australia there are a number of key participants representing a range of individual and organisational viewpoints in the field of road safety. There is a wide range of opinion about road safety program effectiveness and how it should be measured Usually the approach to the analysis of an intervention or program can be largely dependant upon the process that the research is informing

3. Results

3.1. The Presentation of the Results

Tables A4.1 - A4.4, provided at *Appendix 4*, summarise the results of the analysis. The studies have been arranged by national priority areas. Each of these tables shows the present value of the total cost of the program and the present value of the net cost (total cost less estimated cost savings). Where the cost savings exceed the cost of the program, net costs are negative (in brackets). Most of the cost savings have been estimated using methodology discussed above. Some studies, however, did not allow this and the net costs are those reported in the original study. This is the case for the heavy vehicle study and for most of the vehicle safety studies.

Table A4.1 shows the benefit cost ratio from the original study along with the ratio of net costs to consequences for four measures of outcome. Ratios are shown as the cost per "life saved", "life years saved", "serious injuries avoided" and "all injuries avoided". Where net costs are negative no ratios have been calculated. Not all studies reported the 4 measures of consequences. There are 31, 31, 32 and 33 studies with the 4 measures respectively.

Table A4.2 shows the ranking of the interventions by four cost-effectiveness ratios: the ratio of net costs to lives saved, life years saved, life and serious injury saved, and all injuries saved.

Table A4.3 shows the ranking of a sub-set of studies by benefit cost ratio, and the four cost-effectiveness ratios. There were only 25 studies from which comparable ratios could be derived.

Table A4.4 shows the ranking by lives saved and by all injuries avoided of those studies which had net savings.

3.2. Results Of Ranking Differences

Table A4.2 suggests that the ranking of programs by cost-effectiveness ratio is sensitive to the measure of consequences. The ranking of some programs vary according to whether mortality or morbidity is used as an outcome measure. This is notwithstanding some bias towards uniformity imposed by the way in which the data was constructed In just over half of the studies data was available on the actual distribution of casualties, and many of the analyses used a fixed distribution of injury severity per casualty crash. Thus the choice of outcome measure could be very important in determining the choice of the program. There are no differences between cost per life saved and cost per life year saved because the data did not allow us to differentiate consequences by age However in principle, these could give different rankings, for example, for child safety harnesses and cycle helmets. A large number of studies had net savings and were therefore not amenable to ranking by cost-effectiveness analysis. Strictly speaking they should all be done. However since in reality some ranking may be necessary two approaches are used

First, Table A4.4 shows the ranking of those programs with net savings by lives saved and by all injuries avoided. The rational is that we cannot choose between a large saving and one which is close to zero then let us assume that they are all close to zero and choose on the basis of outcomes. The resulting ranking in Table A4.4 is interesting insofar as the more expensive programs are not necessarily the ones which save more lives or injury. The analysis is limited however by the assumption that the level of saving is unimportant. However as a generalisation within the set of programs with net savings those with the highest expenditure tended to have both the highest absolute net saving and the highest level of injury reduction This is what you would expect if no account is taken of the rate of return from the constrained money expenditure As with table A4.3, the ranking was different depending on whether the focus was on lives saved or injuries prevented

Second, we examine explicitly the issue of a constrained budget in section 3 5 below

3.3. Results Of Rankings Across Program Areas

In principle cost-effectiveness analysis is capable of making statements about the efficiency of resource allocation across program areas. In practice in this context the limited number of studies within each priority area prevents any conclusions being drawn regarding the cost-effectiveness of investments between program areas. There seems to be some bias in the number and quality of studies conducted in each area. Road engineering projects are particularly over represented and almost all have net benefits and therefore rank at the top in a cost-effectiveness framework. In addition, the road engineering appraisals are all *ex post* and are likely to have undergone preliminary screening and appraisal. They also contain better evidence of effectiveness and are, therefore, less uncertain in their impact This is not to say that future investment in road safety should be directed toward road engineering, but rather that these particular completed programs have represented efficient use of resources. Future investment priorities are informed by this only to the extent that they provide part of the benchmark of what might be expected of an efficient program. Within the other priority areas, however, programs range from the top to the bottom of the rankings. This in part reflects uncertainty on the part of analysts of the likely effectiveness of the programs, most of which are based on modeling rather than actual effectiveness data

3.4. Results Of Rankings Within Program Areas

It is difficult to generalise about the implications of the cost-effectiveness analysis within the priority areas. Only the road user issues area contain enough studies with a range of rankings to allow comparisons. There is some suggestion here that some programs focusing on speed are less cost effective than others which focus on alcohol or cyclists. However, it is also clear that there are counter examples within these categories It should be noted that even within the studies re-analysed the results were sensitive to the assumptions made and although every effort was made to ensure consistency, a certain amount of discretionary judgement was inevitable. Where the data was taken directly from the studies the extent of sensitivity to the assumptions made is unknown.

3.5. Results Of Using A Programming Technique To Rank In The Face Of Budget Constraint

As previously discussed, choosing which programs to implement solely on the basis of cost-effectiveness ratios is not appropriate if there is budget constraint facing the agency and programs are not perfectly divisible (i.e. you cannot do 25% of a program or 3 times a program). In this case, it if you want to maximise an objective subject to a resource constraint, one approach is to use some form of mathematical programming. *Table A4.5* shows the results of a simple computer programming iterative solution to such an optimisation analysis. The assumed aim in this example is to maximise the number of lives saved by adopting projects with a given cost to the agency subject to an overall budget constraint. Three budget constraints have been used. $3 million, $7 million, and $50 million. The programs are listed in order of their agency investment cost per life saved. That is to say, the costs are not offset by savings to other agencies or individuals. Thus the initial ranking in *Table A4.1* is different from *Table A4.5.* With a budget of $3 million the first and the third ranking projects could not be done. A decision maker might be tempted to undertake the 2nd and 4th programs however, if he was proceeding to base decisions purely on the ranking in a league table of results. This would not maximise lives saved for $3 million expenditure. Rather the analysis suggests that projects 2,5,6, and 7 should be done, as this saves 82 lives with an expenditure of $2,911,530 With a budget of $7 million the decision is much more straightforward, and conforms with the ranking by cost-effectiveness ratio after excluding the first program. The budget constraint of $50 is much more complex. While it suggests including the first 9 highest ranking programs on cost-effectiveness ratios and excluding the 9 lowest ranking programs, the pattern of accept and reject from the remaining 11 programs is not obvious by inspection. By choosing the appropriate mix of programs it is possible to save 2,591 lives at a budget cost of $49,986,226.

This suggests that while simple cost-effectiveness ratios (and cost-benefit ratios) will provide a good rule of thumb in determining the optimal use of resources to achieve a given objective, other rules are necessary in the presence of a resource constraint Where the optimal combination is not obvious from inspection of the costs and outcomes of the programs, some form of mathematical programming can be used.

4. Discussion

4.1. Literature Review: The Approach Taken In Other Studies

The three main evaluation techniques used in road safety are cost-benefit, cost-effectiveness and multi-criteria evaluation. Some major cost-effectiveness reviews were made about 15-20 years ago (see Downs & Larkey; OECD, 1981). Since then, apart from mention in texts such as Jones-Lee et al(1987), reference to cost-effectiveness techniques has declined, and cost-benefit seems to be the method of choice used for economic analysis by road safety researchers. This is particularly evident in the Australian literature. The reasons for this trend are not apparent, but may have something to do with the appeal of assigning a set monetary cost for a death or serious injury to the denominator. Apart from being easy, this approach also looks authoritative. In reality, however, this hides a lot of the assumptions that are involved in arriving at the value of a statistical life (see above, under Methodology), which can lead to distortions in the priority setting process.

4.2. Cost-Effectiveness Analysis And Priority Setting

Cost-effectiveness analysis of road injury intervention is a viable alternative to cost-benefit analysis. It seems clear that it is possible and meaningful to calculate the cost-effectiveness of road safety programs on the basis of cost per injury consequence. It is also possible to rank programs on the basis of their cost per injury consequence Cost-effectiveness analysis seems to provide similar absolute values for programs where conventional benchmarks are used. That is to say programs with a benefit cost ratio in excess of the accepted level of say 3;1, tend to have a cost per life year saved less than $30,000, which is less than many common health care interventions which have been evaluated. However cost-effectiveness analysis may produce different rankings of programs especially where minor injury is a large component and depending on how cost savings are treated in the benefit cost ratio.

The limitation on the use of published cost-benefit analysis studies of road safety interventions is that the underlying data on the effectiveness of the programs is most often weak. Techniques of evaluation are often not rigorous. There is little use of good experimental designs and too much evaluation is based on intuitive guesswork. In the short term decisions have to be made and we would continue to recommend the use of economic evaluation, however in the longer term we would recommend an effort to improve the standard and consistency of evaluation. Consistency in the area of economic evaluation would also improve the quality of information for decision making. Many cost-benefit analysis studies had flaws in design which were inconsistent with the theory and practice of the cost-benefit approach A lack of the use of sensitivity analysis was also apparent

Cost-effectiveness analysis has the strong advantage that it is more transparent in its decision rule That is to say it allows the decision maker to adopt a benchmark figure for the value of an injury or fatality and say that a particular program has a cost per injury or fatality less or more than they are prepared to pay (eg. if a program cost more than $50,000 per life year saved it may be rejected.) However the lack of appropriate current data on the predicted outcomes of interventions limits the use of cost-effectiveness for resource allocation across program areas.

Many of the evaluations have been done for a group of initiatives at a particular level of expenditure. This makes it very difficult to evaluate the cost-effectiveness of future initiatives at perhaps different levels of expenditure. We might have evaluated a program to improve road conditions at 40 black spot locations but this might tell us little about the cost-effectiveness of the 41st or another 20 elsewhere. There is a need for studies to evaluate the marginal cost and outcomes for interventions and to consider the transportability of the results. Only one study which we looked at (Cameron, 1993) had sufficient detail to allow a marginal cost-effectiveness to be carried out. In many ways this study was a good example of an evaluation with a valid study design and containing sufficient detail to allow transportability.

Where the safety budget is constrained there are dangers in the simple application of ranking costs effectiveness ratios. There may be a role for mathematical programming techniques in determining the optimal profile of programs and the level of each program.

4.3. An Example of Decision Making Using Economic Data

Let us take a practical example of a program decision. We want to decide whether to implement a program of fatigue edge lining which would include a publicity campaign (Road Safety Priorities Program, 1994) The total cost of the program is $1,000,000, the net savings are $229,556, and the number of injuries avoided is 91. If we compare the ratio of benefits to costs with other programs this one has a BCR of 4 and ranks 12th. Since it has net savings it is ranked at the top of the program list using cost-effectiveness analysis. In terms of lives saved it is ranked 7th; in terms of net cost it is ranked 14th and in terms of all injuries it is ranked 15th i.e. a quarter to a half way down our list. The cost to the investing agency per life saved is $76,982. If the agency who funds this program is only interested in its own expenditures, and has a budget of at least $3m then this is one of the projects that it should do The decision of whether to do this program depend therefore on whose perspective we take, what is our measure of safety, and of course what else competes for the budget. In this case the program seems cost effective since it has net savings, is in the top 25% of programs in terms of injuries avoided, and it would be chosen by an agency with a small budget who wished to maximise injuries avoided

4.4. Effectiveness Evaluation

4.4.1. Study Design Adopted To Evaluate These Road Trauma Prevention Programs

It is self-evident that the design of evaluation studies of road trauma prevention programs will be shaped by the particular characteristics of such road trauma programs and to a lesser extent by the nature of road injury, as distinct from disease For example, prevention programs based on road engineering or mass media are not usually amenable to randomised control trials in which individuals are allocated on a random basis to study and control groups, as is preferred in the evaluation of health programs In addition the more ready availability of routinely collected data on road injury (for police or insurance purposes) means that road trauma researchers are not forced to use expensive, purpose designed data collection systems that other health program evaluators are often obliged to use in their studies.

Nevertheless, there are some common desirable features that should occur in program evaluation of all types, road trauma prevention programs included. These concern the selection of the most appropriate and rigorous study designs. It was apparent that this did not always occur in the conduct of the economic appraisal papers reviewed. It is likely that these shortcomings are not unique to the economic appraisal literature but are shared by the literature on the effectiveness of road trauma prevention programs more generally.

For example there were instances where the most appropriate control group was not chosen. In the Black Spot Treatment study (Motha, 1991), the control program (or group of roads) consisted of the full range of prevention measures introduced on all roads in the relevant states (which consequently included the black spot treatment sites as well). A truer control program would be those state-wide measures as they impacted on Black-Spot sites that shared the same characteristics as the treatment sites, but were not treated. This is because the two groups of sites share as similar characteristics as possible except for the fact that only one group has been treated. It may be that the impact of general prevention measures differ on untreated Black-Spot sites and all roads. If this is so then 'all roads' do not constitute an appropriate control group and a study based on them may understate or overstate the impact of Black-Spot treatment. This is perhaps an example where the availability of road injury data from routine sources disadvantages the road trauma program evaluator since routinely collected data is not collected with regard for that evaluator's particular requirements for the most rigorous, best possible design for their study.

Furthermore, it may be that even after selecting the most suitable control programs that differences remain in the circumstances and characteristics of drivers at the study and control sites. The acquisition of additional, specially collected data may be necessary to adjust for the effect of these confounding variables operating at the two different groups of sites.

Another problem encountered was the use of raw numbers rather than rates of injuries. This can produce very misleading conclusions about the value of programs. For example, the Iowa seat belt study (Nelson et al, 1993) was based on the proportion of road injury victims in casualty departments in Iowa, having particular characteristics in terms of wearing seat belts and the severity of their injuries. Differences in the proportions of belted and unbelted victims dying or having serious injury among victims may however not be the same as differences between belted and unbelted drivers

4.4.2. Desired Features

In general it is desirable that economic appraisal studies use locally collected and contemporaneous data on health outcomes If this is done, one can be more confident that effectiveness, if demonstrated, is real rather than just hypothesised on the basis of data collected at another time and place and in different circumstances. If the latter is used it may be that the results are not generalisable to the local site being studied It will be essential in such circumstances to use Sensitivity Analysis in order to test the effect of varying these hypothesised levels of effectiveness.

Furthermore, as argued above, it is desirable that the most appropriate control program is used and that all known confounding variables are identified and controlled where possible. This will require that the most suitable study design is chosen As well as a suitable control group, this is likely to incorporate *before and after* measurements In some circumstances this may involve repeated measurements of both (the Interrupted Times Series Design). In other circumstances, particularly when multiple factors are operating for variable but discrete periods of time, a Times Series Analysis may be appropriate. The evaluation of the TAC television advertising (Cameron, 1993) in Victoria is an excellent illustration of the use of this latter technique

4.4.3. The Form Or Aim Of These Evaluation Programs

Economic appraisal studies, by their nature lend themselves to so-called summative evaluation studies. The purpose of such studies is to make some definitive assessment of the program being studied, the consequence of which is that funding for such programs is either expanded or curtailed. Nevertheless, it is possible that such studies may have as their focus so-called formative evaluation. This means that, at least in part, these studies are being conducted to determine if these programs can be modified or improved so that if they were subject to economic appraisal in the future, this would be more favourable than currently. For such a study to be conducted, it will be necessary to collect additional data. This will particularly involve driver and victim reaction to the program in circumstances of normal driving, near accidents or actual accidents when relevant

4.4.4. Measures Adopted to Assess Health Outcome

Issues associated with monetising health outcomes in cost-benefit analysis road trauma prevention programs are discussed elsewhere in the document. These are, however, additional issues concerned in the measurement of health outcomes in the context of cost-effectiveness analysis which will be discussed here.

It is essential in cost-effectiveness analysis studies that there be one global measure of outcome, rather than several indicators of outcome. Preferably such a global measure should be sufficiently broad so that it makes possible a comparison of the cost-effectiveness of programs that do not constitute alternatives eg mass media and edge lining. Global measures of this nature should desirably assess impact of a program on longevity or survival from the injury but also the quality of life experienced by the victim after the injury. This is most simply expressed by the presence and level of long-term disablement resulting from the injury. Further it should combine and weight these longevity and quality of life impacts in a way that expresses the relative importance of these to injury victims. This is usually reflected in terms of Quality Adjusted Life Year (QALY) saved. While indices measuring QALYs exist, none are probably sufficiently well developed and validated to be useful to the task being considered. It is relatively simple to derive such measures if death and disability numbers, after appropriate weighting, are combined.

The best alternative to QALYs is Potential Years of Life Lost (PYLL). This expresses the impact of death from road injury on longevity by estimating years of life lost based on age at death from road injury and age at death from all causes. PYLL does not capture Quality of Life effects resulting from non-fatal injury or indeed levels of non-fatal injury, as distinct from death, generally. The choice of one effectiveness measure in the cost-effectiveness of road trauma prevention programs is currently either death alone (best captured by PYL or a combined measure of death/serious disabling injury. The latter has the advantage that it does not ignore injury and that it generates larger numbers than death alone - a fact useful in the statistical analysis of outcomes It has the disadvantage that currently it weights death and serious injury equally and that it may not be applied in a standard way by different investigators whose definition of serious disabling injury may differ. Neither of the two measures at the current time have compelling advantage and can not be recommended for use over the other. In this study cost-effectiveness of programs are ranked using both measures, where they are available.

4.4.5. Morbidity Measures - Long-Term Disability

The adoption of the QALY approach, as outlined above, requires the categorisation, measurement and costing of long-term disability states. There is a lack of data on the causes, frequency, and expense of these types of injury, the most costly in human and economic terms.

At the moment the evaluation of effectiveness, cost-benefit analysis, and cost-effectiveness analysis all suffer from lack of data in this area. It is likely that current data collection and costs restrictions do not capture the full effect of these types of injury and that marginal increases in precision here would dramatically improve the quality of road safety evaluation more than by any other improvement.

4.4.6. What Could Road Safety Managers Ask of Their Researchers?

The reliability of both cost-benefit and cost-effectiveness analysis depends on the certainty of the benefits ascribed to the intervention. This in turn depends on the precision and accuracy of the evaluation of program effectiveness, and these issues have been covered earlier. Some other common problems that were encountered in existing economic appraisals of road safety programs looked at in this study are in the following areas:

- lack of attention to time frames;
- lack of rigour in interpreting effectiveness/efficacy measurements;
- cost categories,
- discount rates,
- lack of sensitivity analysis;
- comparator not specified.

These are some of the issues, together with a more rigorous collection of effectiveness data, that could well be addressed in the design of road safety studies. A more precise identification of the specific kinds of data and analysis that would be ideal is, however, beyond the scope of the present study.

5. Conclusions

Cost-effectiveness analysis can be used as a tool in resource allocation decisions with regard to road safety interventions. At the present time, however, there are insufficient numbers of studies of acceptable quality to allow definitive judgements to be made about priority setting across broad areas of road safety interventions Nevertheless cost-effectiveness analysis could be used to determine allocations within program areas if sufficient information was available. Where data are uncertain, formal statistical, or informal sensitivity analysis, could be used to inform decisions about particular budget allocations.

The perspective of cost-benefit analysis and cost-effectiveness analysis is usually a societal one. While financial appraisal from the point of view of a single agency could be used to supplement the societal perspective, there are dangers in restricting either costs or benefits to one agency or sector because important linkages could be lost.

Broadly speaking, both cost-effectiveness analysis and cost-benefit analysis identify valuable safety programs. The ranking of these programs may change due to the different weights being placed on the outcomes. Given the arbitrary nature of the 'value of life' weights being used, we would recommend a closer look at the impact of these values on the relative merits of programs. If continued use is to be made of cost-benefit analysis studies, researchers should at least report the unweighted values of lives saved, life years saved, or injuries averted

The quality of published evaluation studies in the area of road safety has been questioned in this report. In particular, there are some common desirable features that should occur in all health program evaluations, road trauma prevention studies included These concern the selection of the most appropriate and rigorous study designs Unfortunately such features were absent from most of the studies reviewed.

In summary, the major conclusions of this study are as follows.

- the overarching guiding principle in the choice of evaluation approach, is that the appraisal methods should match the research question - the choice of the form of analysis; the viewpoint of the analysis, the identification, measurement, and valuation of cost and outcomes; should all reflect the research question;

- where the decision involves the comparison of projects with quite divergent outcomes (eg reductions in road trauma, versus reduced travel time, versus projects in rail or air transport, etc.) cost-benefit analysis should be considered the most favoured method of economic appraisal, but its usefulness is weakened by the debate on the 'value of statistical life';

- where the research question involves projects, the outcome of which can be encapsulated in a single physical measure (such as lives saved), cost-effectiveness analysis could be the preferred technique, or at least a very useful adjunct to cost-benefit analysis;

- both cost-benefit analysis and cost-effectiveness analysis of road safety programs can inform the process of priority ranking, decision-making, and policy development,

- the reliability of both cost-effectiveness analysis and cost-benefit analysis depend, among other things, on the certainty of the benefits predicted, and hence on the precision and accuracy of program effectiveness evaluation. While there is evidence of rigorous well designed economic appraisals, overall the standard is very variable, and steps need to be taken to improve the quality and consistency in the conduct and reporting of studies. Current practice in this area (as evidenced by the published studies) requires improvement;

- the main advantages of cost-effectiveness analysis in road safety decision making are that:

  (1) the value of a project is not influenced by the value of a statistical life,

  (2) cost-effectiveness analysis can be adapted to suit a number of policy arenas, e g. it can be used to compare road safety programs with other types of programs which result in the same benefits, such as health or emergency services, or even air pollution control;

  (3) cost-effectiveness analysis enables a transparent, yet systematic approach to program budgeting, that is easier to communicate to decision makers and the general public e.g. cost per crash avoided, cost per fatality prevented,

- the principal disadvantages of cost-effectiveness analysis in road safety decision-making are that:

  (1) cost-effectiveness analysis does not provide a means of explicitly weighing safety effects against the other beneficial and harmful effects of decisions;

  (2) costs and benefits are not valued in the same units, hence cost-effectiveness analysis does not enable comparison with other transport sector programs,

  (3) the interpretation of cost-effectiveness analysis is unfamiliar to road safety management. Despite the unfamiliarity of the approach, the idea of cost effectiveness analysis has appeal to Australian road safety managers - especially in that the results of cost-effectiveness analysis are easy to communicate

- One category of potential cost saving from road safety initiatives that is ignored or poorly measured at present, is long term disability from road accidents.

In principle cost-effectiveness analysis could be used to assist in resource allocation decisions at all levels of decision making in road safety. It could be used to determine the optimal mix of programs within a priority area as well as to determine which broad area warrants extra investment. Data requirements are a barrier to each of these tasks, but particularly the latter. In order to determine the best place for additional investment we need to know the cost-effectiveness of the marginal project in each priority area. We have identified only a small number of published studies overall which can provide reliable evidence on both effectiveness and costs, and a very small number of studies in some areas. It would be dangerous, therefore, to rely too heavily on current economic knowledge to allocate resources between priority areas. On the other hand, given a longer time frame, it should be possible to frame research in this way. In the meantime, cost-effectiveness analysis can be used within some broad program areas where there is sufficient reliable data. This seems to be the case, for example, in road environment programs where unpublished data may be available on the expected costs and outcomes of particular investments. In the absence of perfect data a great deal can be done with the use of informed views of the likely effectiveness of interventions and their likely costs. When used with sensitivity or threshold analysis it is possible to show which programs are likely to be cost effective, and which will not be even under the most optimistic assumptions In this case the choice of economic analysis type is not likely to be important. In these cases the economic worth of a project is likely to be robust no matter the assumed economic value of intangibles such as lives saved or pain and suffering avoided. Where more detailed marginal choices have to be made, however, for example on program expansion, it is not only necessary to have good knowledge of the marginal effectiveness of a program, but also of the impact of the program on the relevant budget. In other words what safety interventions have to be given up in order to expand a particular program.

6. Recommendations:

Recommendations arising out of this study are:

6.1. Development Of Evaluation Guidelines

- That methodological guidelines for the evaluation and economic analysis of road safety countermeasures be developed by the national peak road safety organisations, in order to:

  (1) generate a national 'pool' of research results that could be shared by all stakeholders;
  (2) ensure consistency of reporting; and
  (3) enable greater comparability of road safety program evaluations.

6.2. Cost-effectiveness

- That road safety managers consider the cost-effectiveness methodology as a useful adjunct to decision making and priority setting for road trauma prevention projects.

6.3. A Research Imperative

- That a small investment in recording and costing long-term disability from road accidents be made in order to greatly enhance the quality of evaluation achievable in road safety.

6.4. The Need To Determine A Common Outcome Measurement

- That road safety stakeholders consider adopting the Quality Adjusted Life Year (QALY) as the most appropriate standard of outcome measure for road safety cost-effectiveness. Failing this, that the Potential Years of Life Lost (PYLL) measure be used.

6.5. Resource Allocation Using Current Data

- That in the short run where data is less than ideal, decisions be based on an analysis whose methodology is consistent with economic principles, using best estimates of costs and consequences combined with sensitivity analysis.

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8. Appendices

8.1. Appendix 1: Conceptual Framework for Analysis

Before any firm conclusion can be made with respect to the prioritisation of resource allocation decisions for road safety (including the treatment of road trauma), there is a need to systematically appraise the wide range of interventions using primary costing data and epidemiological evidence from both Australia and overseas. The National Centre for Health Program Evaluation is currently developing two approaches to address priority setting - the "Economic Framework for Allocative Efficiency" model and the Macro Economic Evaluation Model (MEEM)

The first model is extensive and concerned with the development of a health planning framework for the achievement of allocative efficiency, by comparing the costs and effectiveness of programs across the whole health sector. The aim is to compare all possible health interventions for a specific disease state, grouping them by stages including primary prevention, early diagnosis, disease management, prevention of complications and end-stage care.

MEEM, a joint project between the NCHPE and the Australian Institute of Health and Welfare, is designed for impact costing, and resource allocation in the health promotion and illness prevention sector. It is essentially the construction of a ranking index from the systematic analysis of available data bases allowing the evolution of a broad-based framework for priority setting. The underlying rationale for MEEM is that judgements about priorities for health promotion and illness/injury prevention should be based on information about: the public health significance of the disease condition (e.g. as measured by cost-of-illness, morbidity and mortality indicators); the theoretical preventability (efficacy) and practical preventability (effectiveness) of the disease; and the relative cost-effectiveness (efficiency) of individual preventive measures aimed at achieving the potential for prevention.

While the scope and timing of the current project will not allow for a complete working of these approaches to fit the priority setting of road safety programs, the underlying principles of the above modelling approaches can be applied in the formulation of a matrix presentation of cost-effectiveness.

8.2. Appendix 2: Worked example of an entry in the cost-effectiveness database

Nguyen, Hodge and Hall (1987) is a good example of the application of the methodology used in this study. The following is a stepwise working which demonstrates the basic principles and approach used to develop the tables of results (Section 5)

Title: The road safety effectiveness of traffic signal installation at 4-leg intersections in Victoria.

Author: T Nguyen, G Hodge & K Hall.

Journal: N/a. Explanation. The study was an unpublished Road Traffic Authority (Victoria) report and therefore this category is not applicable (N/A).

Date: Jan 1987

Issue: N/a

Evidence of effectiveness: Yes Explanation: This study contained 'before and after' estimates of the effects of the signal installations on various categories of casualty accidents. It did not refer to another study

Intervention Description: Estimation of the effects on outcomes, benefits and costs, of traffic signal installations at 4-leg intersections in Victoria. Explanation: This study firstly calculated the effects of installing traffic signals at 4-leg intersections (two roads crossing each other) in terms of the different accident types (i.e., pedestrian, cross-traffic, right against), and secondly used these outcomes, and cost data, to calculate dollar benefits for the purpose of deriving a cost-benefit ratio.

Hypothesis Tested: That the installation of new traffic signals at 4-leg intersections reduce death and injury from the collision of turning vehicles with oncoming traffic, and yield net social savings. Explanation: The authors were interested in determining the effectiveness of the traffic installations in terms of accidents, and also in dollar terms

Comparator(s) description: Before the installation of new traffic signals. Explanation. The study compared before and after accidents rates of the sites treated.

Type of analysis: C/B. Explanation: The codes used here were cost-benefit analysis (C/B), and cost-effectiveness (C/E).

Benefit or outcome description: M. Explanation: The codes used here were: injuries avoided (IA); lives saved (LS); money (M); crashes avoided (CA); other (O).

Omitted categories from benefits in this type of analysis: No. Explanation: The study included all the benefits which are included in the methodology i.e., medical, hospital, and property damage savings.

How were money benefits calculated?: HC. Explanation: The codes here were human capital (HC), willingness to pay hedonic prices (WTPH), and not applicable (N/A)

Discount rate for benefits (%): 0. Explanation: This was the discount rate used by the original study. Equal to 0 indicates no discounting used, or not specified by study (NS).

Cost/price data year. Cost data; 1976. Explanation: This indicates whether the study used cost data or price data, and the year in which the data was.

Currency: $AUD. Explanation: This was the currency in which the values for benefits and costs were reported. The codes were Australian dollars ($AUD), and United States dollars ($US).

Incremental Cost: Yes Explanation: This was concerned with whether the costs calculated were for a marginal increase in the intervention. All studies were.

Program scale: 82 new traffic installation sites in Melbourne metropolitan area; $12,965,067. Explanation: This described the population size of the program, and the total cost of the program.

Duration of costs: 10 years. Explanation: This described the time period over which the program was assumed to incur benefits, and therefore costs as well.

Which costs included: Medical; hospital; productivity; program. Explanation: This described the which costs (including cost savings) the study included in its analysis using keywords.

Which costs excluded: None. Explanation: See previous explanation.

Discount rate for costs (%): 10. Explanation: The discount rate used by the study for its benefit calculations.

Sensitivity analysis: N. Explanation: This described the type of sensitivity analysis used in the study (if any) using codes: none (N); single parameter (S); and threshold analysis (T).

Summary of findings: Found cost-benefit ratios of between 7.4 to 5 using direct works costs and total costs, respectively. Explanation: The study calculated two cost-benefit ratios. One including the direct costs of the project and another using all costs associated with the traffic signal installations

Cost-benefit ratio (n:1): 5. Explanation: The lower of the 2 cost-benefit ratios are used for ranking purposes

Notes on benefit measurement: All benefits included; converted benefits were $8,753,863. Explanation: The study included all benefits which were required under the methodology. The present value of the converted benefits under the methodology is also reported

Notes on cost measurement: Authors include all likely costs of the program. Explanation: The study included all costs which were required under the methodology.

Cost to agency/government. $12,965,607. Explanation: This was the present value of the costs to government only, of undertaking the program.

Total cost: $12,965,067. Explanation: This was the present value of all costs incurred by the program. In this case all costs incurred by the program were borne by the government.

Net cost: $4,211,204 Explanation: This is the present value of the net of the converted costs and benefits. A bracketed figure indicates a negative net cost i.e., net benefits.

Lives saved: 29. Explanation: This was the present value of the lives saved (if any) by the intervention.

Life years saved: 528 Explanation. This was the present value of the calculated life years saved from the intervention This figure was based upon the life years saved.

Serious injuries avoided: 66. Explanation: This was the present value of the number of serious injuries (those requiring hospitalisations) avoided due to the intervention

All injuries avoided: 191. Explanation: This was the present value of the sum of serious injuries and other injuries (those requiring medical treatment only) avoided due to the intervention.

Cost per lives saved: $143,456. Explanation: This was the division of the present value of net costs by the present value of the lives saved due to the intervention

Cost per life years saved: $7,970. Explanation: This is the same as the previous calculation except the denominator is now the present value of the life years saved

Cost per lives and serious injuries saved: $44,198. Explanation: This is the same as the previous calculation except the denominator is now the present value of the sum of the lives saved and serious injuries avoided.

Cost per lives and all injuries: $19,109. Explanation: This is also the same as the previous calculation except the denominator is now the present value of the sum of lives saved, and serious injuries and other injuries avoided.

Private costs: $0. Explanation: This was the present value of any costs incurred by the intervention which were borne by individuals. In this case no non-travel, non-time costs were borne by individuals due to the intervention.

8.3. Appendix 3: List of Studies Examined but not Converted

The following table lists studies examined in the course of this project, which were not incorporated into the major database or results due to time constraints The lists includes reported cost-benefit ratios from the original studies, or cost-effectiveness ratios, depending on the nature of the study:

Record Number	Title	Author	Intervention Description	BCR (n:1)	Capital Cost/accident avoided ($)
1.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 3 median closures	N/a	14,259
2.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of new street lighting at 4 isolated intersections	N/a	5,329 *
3.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of upgrading street lighting at an isolated intersection	N/a	(14,733)#
4.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of installing additional lanes at 4 intersections without traffic lights	N/a	(13,561)#
5	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 8 modifications of channelisations	N/a	(11,524)#
6.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of a realignment of 3 short sections of road	N/a	45,323*
7.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 2 traffic signal co-ordination treatments	N/a	(8,525)#
8.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 20 new traffic signal and channelisation treatments	N/a	17,180
9.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 15 modified traffic signals and channelisation treatments	N/a	(12,579)#
10.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 62 street closures	N/a	5,285
11.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 3 roundabout installations	N/a	25,324

Record Number	Title	Author	Intervention Description	BCR (n:1)	Capital Cost/accident avoided ($)
12.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of installing 11 school pedestrian crossings	N/a	18,462
13.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of the installation of an additional lane	N/a	(680,829)#
14.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 3 installations of street lighting	N/a	29,261
15.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 2 parking control treatments	N/a	836
16	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of the installation of a rail crossing	N/a	127,186
17.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 30 new channelisations at signalised intersections	N/a	25,295
18.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 20 pedestrian refuge islands	N/a	14,601
19.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 8 new signals and channel modification treatments	N/a	41,380*
20.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 1 treatment to improve visibility	N/a	168,462*
21.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 1 zebra crossing	N/a	(3,052)*#
22.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 1 zebra crossing plus channels	N/a	(838,054)*#
23.	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 3 pedestrian protection treatments	N/a	45,825*
24	The evaluation of the effectiveness of low cost traffic engineering projects	Teale G	Estimates cost-effectiveness of 1 pavement marking	N/a	1,241*

Record Number	Title	Author	Intervention Description	BCR (n:1)	Capital Cost/accident avoided ($)
25.	Road user behaviour 1993	Road User Behaviour Working Party	Cost-benefit analysis of a fatigue project including: an education campaign; a road engineering project, and community action.	1 8	N/a
26	Road user behaviour 1993	Road User Behaviour Working Party	Cost-benefit analysis of a program involving 3 motorcycle counter-measures including: training, education, and legislation	10	N/a
27.	Road user behaviour 1993	Road User Behaviour Working Party	Cost-benefit analysis of continuing an anti-drink driving campaign	2.5	N/a
28	Road user behaviour 1993	Road User Behaviour Working Party	Cost-benefit analysis of continuing a restraint wearing project	6 5	N/a
29.	Road user behaviour 1993	Road User Behaviour Working Party	Cost-benefit analysis of a bicycle project involving: education, and enforcement; legislation	9.7	N/a
30	Evaluation of mid-block accident black spot treatments	Tziotis M	Cost-benefit analysis of mid-block 'black spots' treatments	7.59	N/a
31	Benefit/cost analysis of road trauma countermeasures: Rural road and traffic engineering programs	Ogden KW	Cost-benefit analysis of road and traffic engineering programs on rural roads	2.9	N/a

8.4. Appendix 4: Tables of Results

Table A4.1: Cost effectiveness of programmes: cost per life saved, cost per life year saved, cost per serious injury avoided and cost per injury avoided

Intervention Description *(reference)*	Total cost[1]	Net cost[2]	BCR (n:1)[3]	Net Cost per life saved	NetCost per life year saved	Net Cost per life and other serious injuries saved	Net Cost per life and all other injuries saved
Driver Training and Licensing:							
Night time curfew for drivers in the first year *(Torpey et al)*	$1,400,000	$560,000	5	$150,000	$8,000	$12,444	$6,000
Heavy Vehicle Safety:							
Installation of seat belts in school buses*† *(Begley et al)*	$71,307,644	$54,946,195	0.3			$197,661	$197,661
Road Environment:							
Traffic signal installations at 4-leg intersections* *(Nguyen et al)*	$12,965,067	$4,211,204	5	$143,456	$7,970	$44,198	$19,109
51 black spot projects* *(Motha)*	$7,032,292	$4,941,176	1			$71,101	$13,059
46 accident blackspot treatments* *(Richardson G)*	$5,443,260	($2,249,103)	56				
Installing 16 new pedestrian traffic signals* *(Teale)*	$536,010	($2,624,142)					
44 new channelisations* *(Teale)*	$2,759,082	($600,190)					
Converting 20 cross intersections to T-junctions* *(Teale)*	$497,459	($1,476,255)					
46 projects involving installation of safety bars along roads* *(Teale)*	$149,579	($899,223)					
Installing 57 new traffic signals* *(Teale)*	$3,715,494	($14,830,424)					
Installing 53 roundabouts* *(Teale)*	$1,498,487	($3,902,181)					
Modifying 49 traffic signals* *(Teale)*	$1,754,960	($4,445,381)					
Road User Issues:							
Mandatory bicycle helmet use legislation in Israel† *(Ginsberg & Silverberg)*	$23,358,503	($36,757,571)	3				
Legalising footpath cycling *(Torpey et al)*	$1,250,000	$3,120,000	43	$192,593	$10,898	$2,452	$2,452

Table A4.1: Cost effectiveness of programmes: cost per life saved, cost per life year saved, cost per serious injury avoided and cost per injury avoided

Intervention Description *(reference)*	Total cost[1]	Net cost[2]	BCR (n:1)[3]	Net Cost per life saved	NetCost per life year saved	Net Cost per life and other serious injuries saved	Net Cost per life and all other injuries saved
A bicycle safety publicity campaign *(RSPP)*	$50,000	($36,140)	11 3				
Promotion of wearing of protective headgear by passenger motor vehicle occupants *(Torpey et al)*	$14,500,000	$12,450,000	1.2	$2,150,000	$115,000	$74,923	$75,000
Zero blood alcohol limit for all motorcyclists *(Torpey et al)*	$2,300,000	$1,770,000	3	$280,000	$15,000	$3,485	$3,500
A package of alcohol counter-measures* *(RSPP)*	$1,500,000	$617,461	8	$77,183	$4,270	$8,344	$8,344
Fitting of an ignition interlock as a condition of relicencing for all convicted drink drivers for 6 years *(Torpey et al)*	$29,300,000	$26,810,000	1.5	$1,080,000	$60,000	$127,959	$128,000
A television and other media advertising campaign* *(Cameron et al 1993)*	$5,173,056	($4,336,584)	3 9				
Training for responsible serving of alcohol in licenced premises *(Torpey et al)*	$13,960,000	$8,750,000	5	$210,000	$12,000	$20,000	$20,147
Increasing the legal drinking age from 18 to 21 years *(Torpey et al)*	$2,100,000	$560,000	7	$80,000	$4,000	$7,487	$2,500
A fatigue edge lining project including: a publicity campaign; seminar/research on sleep apnea, fatigue monitors; and edge lining/tactile edge lining *(RSPP)*	$1,000,000	($229,556)	4				
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway *(RSPP)*	$5,000,000	($10,525,133)	3 5				
A package of motor cycle counter-measures *(RSPP)*	$278,000	($68,827)	13.9				
A package of redlight camera counter-measures* *(RSPP)*	$2,200,000	$1,017,750	3 9	$360,393	$19,937	$10,635	$10,635
A speed camera program with publicity and enforcement, targeting drivers exceeding the speed limit by 25km/h or more *(Torpey et al)*	$67,500,000	$48,860,000	12	$613,049	$33,318	$56,644	$23,106
A speed management program involving publicity to support enforcement and inform on speed zoning review *(Taylor)*	$48,646,930	($39,374,128)	2 3				

Table A4.1: Cost effectiveness of programmes: cost per life saved, cost per life year saved, cost per serious injury avoided and cost per injury avoided

Intervention Description *(reference)*	Total cost[1]	Net cost[2]	BCR (n:1)[3]	Net Cost per life saved	NetCost per life year saved	Net Cost per life and other serious injuries saved	Net Cost per life and all other injuries saved
The 55 mph speed limit in US† *(Kamerund)*	$1,739,340,554	($38,351,740,475)					
A package of speed counter-measures* *(RSPP)*	$1,150,000	($148,465)	11 6				
Vehicle Safety:							
A $20 rebate to encourage the purchase of child seats *(Torpey et al)*	$1,000,000	$970,290	0.65	$2,420,000	$120,000	$358,065	$70,000
A seatbelt warning device *(MUARC CR100)*	$14,929,656	($46,281,934)	4 1				
The promotion of retrospective fitting of high mounted rear brake lights *(Torpey et al)*	$6,700,000	$4,110,000	1 8	$1,550,000	$84,329	$64,764	$8,220
Regulation to forbid carriage of passengers of persons not seated in approved car seats in load areas *(Torpey et al)*	$2,450,000	$1,530,000	3	$690,000	$38,000	$37,195	$13,500
Vehicle knee bolsters *(MUARC CR100)*	$33,058,524	($62,811,196)	2.9				
Improved lower vehicle panels *(MUARC CR100)*	$26,660,100	($21,328,080)	1.8				
An energy absorbing wheel *(MUARC CR100)*	$10,664,040	($23,460,888)	3 2				
Improved seatbelt geometry and seats *(MUARC CR100)*	$4,265,616	($26,873,381)	7 3				
A seatbelt webbing clamp *(MUARC CR100)*	$22,394,484	($2,239,448)	1.1				
A shoulder-based seatbelt pretensioner *(MUARC CR100)*	$61,318,230	$30,659,115	0.5				
A seat-based seatbelt pretensioner *(MUARC CR100)*	$61,318,230	$12,263,646	0.8				
An electro-mechanical facebag assuming minimum benefits *(MUARC CR100)*	$213,280,800	$89,577,936	0.58				
An electro-mechanical facebag assuming maximum benefits *(MUARC CR100)*	$213,280,800	$4,265,616	0 98				
An electro-mechanical fullsize passenger airbag *(MUARC CR100)*	$234,608,880	$192,379,282	0.18				

Table A4.1: Cost effectiveness of programmes: cost per life saved, cost per life year saved, cost per serious injury avoided and cost per injury avoided

Intervention Description ***(reference)***	**Total cost[1]**	**Net cost[2]**	**BCR (n:1)[3]**	**Net Cost per life saved**	**NetCost per life year saved**	**Net Cost per life and other serious injuries saved**	**Net Cost per life and all other injuries saved**
An electro-mechanical fullsize driver airbag *(MUARC CR100)*	$24,340,888	($3,651,133)	1 15				
An electronic fullsize driver airbag *(MUARC CR100)*	$354,579,330	$81,553,246	0 77				
Padded upper vehicle areas *(MUARC CR100)*	$44,255,766	$30,979,036	0.3				
Vehicle inspections in New Jersey*† *(Loeb & Gilad)*	$170,972,266		1 24				
* *Non-Australian studies*							
† *Contains evidence of effectiveness in original study*							

Notes
1. Only programs with identified outcomers have been ranked;
2 Total costs are the direct public and private costs of the program;
3 As benefit cost ratio in original study

Table A4.2 Ranking of programs by cost effectiveness[1]

Intervention Description *(reference)*	BCR (n:1)[2]	(Rank) Net Cost per lives saved [3]	(Rank) Net Cost per life years saved [5]	(Rank) Net Cost per lives and serious injuries saved [5]	(Rank) Net Cost per lives and all injuries saved [6]
Driver Training and Licensing:					
Night time curfew for drivers in the first year of driving *(Torpey et al)*	5	22	22	23	21
Heavy Vehicle Safety:					
Installation of seat belts in Texas school buses*† *(Begley et al)*	0.3			32	33
Road Environment:					
Traffic signal installations at 4-leg intersections in Victoria* *(Nguyen et al)*	5	21	21	26	27
51 black spot projects * *(Motha)*	1			29	25
46 accident blackspot treatments* *(Richardson G)*	5.6	1	1	1	1
Road User Issues:					
Mandatory bicycle helmet use legislation in Israel† *(Ginsberg & Silverberg)*	3	1	1	1	1
Legalising footpath cycling *(Torpey et al)*	43	1	1	1	1
A bicycle safety publicity campaign *(RSPP)*	11.3	1	1	1	1
Promotion of wearing of protective headgear by passenger motor vehicle occupants *(Torpey et al)*	1.2	30	30	30	30
Zero blood alcohol limit for all motorcyclists *(Torpey et al)*	3	24	24	19	20
A package of alcohol counter-measures* *(RSPP)*	8	18	20	21	23
Fitting of an ignition interlock as a condition of relicencing for all convicted drink drivers for 6 years *(Torpey et al)*	1.5	28	28	31	32
A television and other media advertising campaign* *(Cameron et al 1993)*	3.9	1	1	1	1

Table A4.2 Ranking of programs by cost effectiveness[1]

Intervention Description *(reference)*	BCR (n:1)[2]	(Rank) Net Cost per lives saved [3]	(Rank) Net Cost per life years saved [5]	(Rank) Net Cost per lives and serious injuries saved [5]	(Rank) Net Cost per lives and all injuries saved [6]
Training for responsible serving of alcohol in licenced premises *(Torpey et al)*	5	23	23	24	28
Increasing the legal drinking age from 18 to 21 years *(Torpey et al)*	7	20	19	20	19
A fatigue edge lining project including: a publicity campaign; seminar/research on sleep apnea, fatigue monitors, and edge lining/tactile edge lining *(RSPP)*	4	1	1	1	1
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway *(RSPP)*	3.5	1	1	1	1
A package of motor cycle counter-measures *(RSPP)*	13.9	1	1	1	1
A package of redlight camera counter-measures* *(RSPP)*	3.9	25	25	22	24
A speed camera program with publicity and enforcement, targeting drivers exceeding the speed limit by 25km/h or more *(Torpey et al)*	12	26	26	27	29
A speed management program involving publicity to support enforcement and inform on speed zoning review *(Taylor)*	2.3	1	1	1	1
The 55 mph speed limit in US† *(Kamerund)*	na	1	1	1	1
A package of speed counter-measures* *(RSPP)*	11.6	1	1	1	1
Vehicle Safety:					
A $20 rebate to encourage the purchase of child seats *(Torpey et al)*	0.65	31	31	30	31
The promotion of retrospective fitting of high mounted rear brake lights *(Torpey et al)*	1.8	29	29	28	22
Regulation to forbid carriage of passengers of persons not seated in approved car seats in load areas *(Torpey et al)*	3	27	27	25	26
Vehicle knee bolsters *(MUARC CR100)*	2 9				

Table A4.2 Ranking of programs by cost effectiveness[1]

Intervention Description *(reference)*	BCR (n:1)[2]	(Rank) Net Cost per lives saved [3]	(Rank) Net Cost per life years saved [5]	(Rank) Net Cost per lives and serious injuries saved [5]	(Rank) Net Cost per lives and all injuries saved [6]
Improved lower vehicle panels *(MUARC CR100)*	1.8				
An energy absorbing wheel *(MUARC CR100)*	3.2				
Improved seatbelt geometry and seats *(MUARC CR100)*	7.3				
A seatbelt webbing clamp *(MUARC CR100)*	1.1				
A shoulder-based seatbelt pretensioner *(MUARC CR100)*	0.5				
A seat-based seatbelt pretensioner *(MUARC CR100)*	0.8				
An electro-mechanical facebag assuming minimum benefits *(MUARC CR100)*	0.58				
An electro-mechanical facebag assuming maximum benefits *(MUARC CR100)*	0.98				
An electro-mechanical fullsize passenger airbag *(MUARC CR100)*	0.18				
An electro-mechanical fullsize driver airbag *(MUARC CR100)*	1 15				
An electronic fullsize driver airbag *(MUARC CR100)*	0 77				
Padded upper vehicle areas *(MUARC CR100)*	0 3				
Vehicle inspections in New Jersey*† *(Loeb & Gilad)*	1.24				

† *Non-Australian studies*

* *Contains evidence of effectiveness in original study*

Notes.
1. Only programs with identified outcomers have been ranked, 2. Net costs are total costs less cost savings from the program. Where there are net savings the figure is in brackets;
3. Programs with net savings have been ranked as 1 of 31; 4 Programs with net savings have been ranked as 1 of 31;
5. Programs with net savings have been ranked as 1 of 32, 6 Programs with net savings have been ranked as 1 of 33

Table A4.3 Comparison of the ranking of selected programs by benefit cost ratio and by cost effectiveness ratios

Intervention Description *(reference)*	(Rank) BCR (n:1)	(Rank) Net Cost per life saved	(Rank) Net Cost per life years saved	(Rank) Net Cost per life and serious injury saved	(Rank) Net Cost per life and other injury saved
Legalising footpath cycling *(Torpey et al)*	1	1	1	1	1
A package of motor cycle counter-measures *(RSPP)*	2	1	1	1	1
A speed camera program with publicity and enforcement, targeting drivers exceeding the speed limit by 25km/h or more *(Torpey et al)*	3	17	17	19	21
A package of speed counter-measures* *(RSPP)*	4	1	1	1	1
A bicycle safety publicity campaign *(RSPP)*	5	1	1	1	1
A package of alcohol counter-measures* *(RSPP)*	6	11	11	13	15
Increasing the legal drinking age from 18 to 21 years *(Torpey et al)*	7	12	11	12	11
46 accident blackspot treatments* *(Richardson G)*	8	1	1	1	1
Night time curfew for drivers in the first year of driving *(Torpey et al)*	9	14	14	15	13
Traffic signal installations at 4-leg intersections in Victoria* *(Nguyen et al)*	9	13	13	18	19
Training for responsible serving of alcohol in licenced premises *(Torpey et al)*	9	14	14	16	20
A fatigue edge lining project including a publicity campaign; seminar/research on sleep apnea, fatigue monitors; and edge lining/tactile edge lining *(Torpey et al)*	12	1	1	1	1
A television and other media advertising campaign *(Cameron et al 1993)*	13	1	1	1	1
A package of redlight camera counter-measures *(RSPP)*	13	16	16	14	16
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway *(RSPP)*	15	1	1	1	1

Table A4.3 Comparison of the ranking of selected programs by benefit cost ratio and by cost effectiveness ratios

Intervention Description *(reference)*	**(Rank) BCR (n:1)**	**(Rank) Net Cost per life saved**	**(Rank) Net Cost per life years saved**	**(Rank) Net Cost per life and serious injury saved**	**(Rank) Net Cost per life and other injury saved**
Mandatory bicycle helmet use legislation in Israel† *(Ginsberg & Silverberg)*	16	1	1	1	1
Zero blood alcohol limit for all motorcyclists *(Torpey et al)*	16	15	15	11	12
Regulation to forbid carriage of passengers of persons not seated in approved car seats in load areas *(Torpey et al)*	16	18	18	17	18
A speed management program involving publicity to support enforcement and inform on speed zoning review *(Taylor)*	19	1	1	1	1
The promotion of retrospective fitting of high mounted rear brake lights *(Torpey et al)*	20	20	20	20	14
Fitting of an ignition interlock as a condition of relicencing for all convicted drink drivers for 6 years *(Torpey et al)*	21	19	19	24	24
Promotion of wearing of protective headgear by passenger motor vehicle occupants *(Torpey et al)*	22	21	21	22	22
51 black spot projects* *(Motha)*	23			21	17
A $20 rebate to encourage the purchase of child seats *(Torpey et al)*	24	22	22	23	23
Installation of seat belts in Texas school buses*† *(Begley et al)*	25			25	25

Table A4.4: Ranking of those programs with net savings: ranked by lives saved, all injuries averted, and net costs

Intervention Description *(reference)*	Total cost	Net cost	Rank by lives saved	Rank by net cost	Rank by all injuries saved
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway *(RSPP)*	$5,000,000	($10,525,133)	1	4	5
Mandatory bicycle helmet use legislation in Israel *(Ginsberg & Silverberg)*	$23,358,503	($36,757,571)	2	2	1
A speed management program involving publicity to support enforcement and inform on speed zoning review *(Taylor)*	$48,646,930	($39,374,128)	3	1	8
Installing 57 new traffic signals *(Teale)*	$3,715,494	($14,830,424)	4	3	2
Legalising footpath cycling *(Torpey et al)*	$1,250,000	($3,120,000)	5	8	4
A television and other media advertising campaign *(Cameron et al 1993)*	$5,173,056	($4,336,584)	6	6	3
A fatigue edge lining project including: a publicity campaign; seminar/research on sleep apnea; fatigue monitors; and edge lining/tactile edge lining *(RSPP)*	$1,000,000	($229,556)	7	14	15
Modifying 49 traffic signals *(Teale)*	$1,754,960	($4,445,381)	8	5	6
Installing 53 roundabouts *(Teale)*	$1,498,487	($3,902,181)	9	7	7
A package of speed counter-measures* *(RSPP)*	$1,150,000	($148,465)	10	15	14
46 accident blackspot treatments in Victoria *(Richardson G)*	$5,443,260	($2,249,103)	11	10	12
44 new channelisations *(Teale)*	$2,759,082	($600,190)	12	13	9
Installing 16 new pedestrian traffic signals *(Teale)*	$536,010	($2,624,142)	13	9	10
Converting 20 cross intersections to T-junctions *(Teale)*	$497,459	($1,476,255)	14	11	11
46 projects involving installation of safety bars along roads *(Teale)*	$149,579	($899,223)	15	12	13
A package of motor cycle counter-measures *(RSPP)*	$278,000	($68,827)	16	16	16
A bicycle safety publicity campaign *(RSPP)*	$50,000	($36,140)	17	17	17

Table A4.5: Choice of project with a constrained budget for the agency : cost-effectiveness ratios versus programming solution with three levels of budget

Intervention Description ***(reference)***	**Cost to agency/ government**	**Lives saved**	**Agency cost per life saved**	**With a budget of $3m maximum lives saved 82**	**With a budget of $7m maximum lives saved 146**	**With a budget of $50m maximum lives saved 2,591**
				Inclusion of programs indicated		
Vehicle inspections in New Jersey*† *(Loeb & Gilad)*	$30,930,717	2,347 41	$13,177	no	no	yes
Mandatory bicycle helmet use legislation in Israel† *(Ginsberg & Silverberg)*	$825,520	57	$14,483	yes	yes	yes
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway *(RSPP)*	$5,000,000	73.6	$67,935	no	yes	yes
46 projects involving installation of safety bars along roads* *(Teale)*	$149,579	2.11	$70,891	no	yes	yes
A fatigue edge lining project including: a publicity campaign, seminar/research on sleep apnea; fatigue monitors; and edge lining/tactile edge lining *(RSPP)*	$1,000,000	12.99	$76,982	yes	yes	yes
Installing 16 new pedestrian traffic signals* *(Teale)*	$536,010	6.36	$84,278	yes	no	yes
Promotion of wearing of protective headgear by passenger motor vehicle occupants *(Torpey et al)*	$550,000	5.79	$94,991	yes	no	yes
Installing 57 new traffic signals* *(Teale)*	$3,715,494	37.34	$99,504	no	no	yes
The 55 mph speed limit in US† *(Kamerund)*	$1,739,340,554	15,443 47	$112,626	no	no	no
Converting 20 cross intersections to T-junctions* *(Teale)*	$497,459	3 97	$125,305	no	no	yes

Table A4.5: Choice of project with a constrained budget for the agency : cost-effectiveness ratios versus programming solution with three levels of budget

Intervention Description *(reference)*	Cost to agency/ government	Lives saved	Agency cost per life saved	With a budget of $3m maximum lives saved 82	With a budget of $7m maximum lives saved 146	With a budget of $50m maximum lives saved 2,591
				Inclusion of programs indicated		
A package of speed counter-measures* *(RSPP)*	$1,150,000	8.38	$137,232	no	no	yes
Installing 53 roundabouts* *(Teale)*	$1,498,487	10 87	$137,855	no	no	yes
Modifying 49 traffic signals* *(Teale)*	$1,754,960	12 48	$140,622	no	no	yes
A package of motor cycle counter-measures *(RSPP)*	$278,000	1,97	$141,117	no	no	yes
A package of alcohol counter-measures* *(RSPP)*	$1,500,000	8	$187,500	no	no	yes
Fitting of an ignition interlock as a condition of relicencing for all convicted drink drivers for 6 years *(Torpey et al)*	$4,680,000	24.77	$188,938	no	no	no
Training for responsible serving of alcohol in licenced premises *(Torpey et al)*	$9,247,000	40.7	$227,199	no	no	no
Regulation to forbid carriage of passengers of persons not seated in approved car seats in load areas *(Torpey et al)*	$550,000	2.16	$254,630	no	no	yes
Increasing the legal drinking age from 18 to 21 years *(Torpey et al)*	$2,000,000	7.2	$277,778	no	no	no
A bicycle safety publicity campaign *(RSPP)*	$50,000	0.13	$384,615	no	no	yes

Table A4.5: Choice of project with a constrained budget for the agency : cost-effectiveness ratios versus programming solution with three levels of budget

Intervention Description *(reference)*	Cost to agency/ government	Lives saved	Agency cost per life saved	With a budget of $3m maximum lives saved 82	With a budget of $7m maximum lives saved 146	With a budget of $50m maximum lives saved 2,591
				Inclusion of programs indicated		
44 new channelisations* *(Teale)*	$2,759,082	7	$394,155	no	no	no
Night time curfew for drivers in the first year of driving *(Torpey et al)*	$1,400,000	3.33	$420,420	no	no	no
Traffic signal installations at 4-leg intersections in Victoria* *(Nguyen et al)*	$12,965,067	29	$447,071	no	no	no
A $20 rebate to encourage the purchase of child seats *(Torpey et al)*	$232,000	0.36	$644,444	no	no	no
46 accident blackspot treatments* *(Richardson G)*	$5,443,260	8	$680,408	no	no	no
Zero blood alcohol limit for all motorcyclists *(Torpey et al)*	$2,300,000	3 3	$696,970	no	no	no
A package of redlight camera counter-measures* *(RSPP)*	$2,200,000	2.82	$780,142	no	no	no
A speed management program involving publicity to support enforcement and inform on speed zoning review *(Taylor)*	$48,646,930	54	$900,869	no	no	no
A television and other media advertising campaign* *(Cameron et al 1993)*	$18,000,000	15.59	$1,154,586	no	no	no

* *Non-Australian studies*

† *Contains evidence of effectiveness in original study*