Research to improve the accuracy of economic evaluations in road safety

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ABSTRACT

Selection of road engineering safety schemes is generally based on prioritisation involving an economic evaluation of the costs to implement and maintain the scheme, and the expected benefits that will be derived. Inaccurate information used in this process can lead to the selection of inappropriate or less deserving schemes. Given the limited budget available for road safety improvements, any information that can be provided to practitioners to improve this evaluation will help maximise the benefits from limited resources.

This paper discusses recent Austroads funded research to improve the accuracy of economic evaluations for road safety engineering treatments. Research conducted at ARRB includes:

- improvements in the accuracy of the expected crash reduction benefit from various safety treatments
- information on calculating the cumulative effect of using more than one treatment at a location
- an investigation of treatment life
- provision of information on treatment costs.

Results from each of these projects is discussed, and information provided on how prioritisation and selection of safety schemes can be improved based on this research.

INTRODUCTION

All road and traffic authorities need to direct their funding wisely to road safety treatments that ensure the most cost-effective returns in crash and injury reductions. Prioritisation is typically based on a calculation of the benefit-cost ratio (BCR), or the benefits that derive from the project (mainly from reductions in injury) divided by the cost of the project (including costs associated with the implementation and ongoing maintenance). Details on performing an economic evaluation can be found in the Austroads Guide to Project Evaluation (see Tsolakis, Preski & Patrick, 2005), while examples of evaluation in the road safety environment can be found in Austroads (2004).

In order to determine costs and benefits for road safety projects, accurate information is required on the expected benefits of safety treatments in terms of casualty reduction, as well as the costs of treatments and how long they are expected to provide a benefit. In addition, it is typical that more than one safety measure is implemented at a location, so it is important that any assessment take account of the combined benefit of multiple treatments.

ARRB Research has been involved in Austroads funded research on road safety risk assessment (see Turner & Bennett, 2005 for an overview). This project has identified shortcomings in the information currently available on all of these issues. As a consequence, it is likely that decisions about the appropriate projects to fund will result in less than optimal use of road safety funding. This paper provides information on each of these issues, and suggests ways in which economic evaluation of safety schemes can be improved to provide better use of available funding.

CRASH REDUCTION FACTORS

A large amount of investment has been made by road authorities and road safety researchers to identify the crash reduction expected from the implementation of various road safety treatments. There are a number of sources of information on this topic that either provide an expected overall crash reduction (e.g. Elvik and Vaa, 2004; Ogden, 1996; Turner, 2007) or the crash reduction that would be expected for specific movement types (e.g. for head-on crashes, see Austroads, 2004). ARRB has now reviewed a number of road safety treatments (see Table 1 for examples) resulting in the development of around 90 crash reduction factors. This research has been based on extensive review of local and international research which was assessed and adapted for use in the Australian and New Zealand context (see Turner & Imberger, 2005 for further details of the methodology used).

Table 1: Example treatment types for which crash reduction estimates were derived

Accesses	Pavement markings - centreline
Clear zones	Pavement markings - edgeline
Delineation - RRPMs	Pavement markings - words and symbols
Grade separation	Pedestrian/cyclist treatments
Guide posts	Railway crossing improvements
Intersection - advanced warning	Road surface improvements
Intersection - left turn lane	Roundabouts
Intersection - linked signals	Safety barriers
Intersection - red light camera	Sight distance improvements
Intersection - right turn phase	Signs - advisory
Intersection - right turn lane	Signs - regulatory
Intersection - right turn lane (extend length)	Street lighting
Intersection - signal visibility	Speed change (in limit and change in mean speed)
Intersection - signal timing	Staggered junctions
Intersection - splitter and median islands	Superelevation

Line marking - profile edge line	Traffic calming
Median crossovers	Traffic signals
Median retrofit	Widen or seal shoulders
Midblock turning provision	Work zones
Overtaking lanes	

Where possible, the expected reduction in different road environments (e.g. rural, urban, intersection, midblock) has been determined.

As part of this research large discrepancies were often identified in the crash reduction values provided by different studies for the same treatment type. Often this was a result of differing environment type (e.g. between the countries where the studies occurred), but in many cases it may have been due to differences in the methodology used. A large number of studies were of low methodological quality, with many not including a basic control group to account for changes other than that produced by the treatment being assessed. In order to allow a synthesis of information from across numerous studies, a rating scale was developed to determine the methodological robustness of the research identified. The study rating system (see Table 2) was developed as a tool in assessing the quality of research, and in determining how much weight to apply to each study that contributed to the final reduction figure (to date this has only been used to qualitatively weight results).

Table 2: Study rating system

Study type	Descriptive statistics only	Simple statistical analysis	Complex statistical analysis
Simple study – no controls, no traffic volume	1	1	(not likely)
Study without control group but traffic volume	2	2	(not likely)
Study using comparison group/all crashes etc. to control for general crash trends	3	4	5
Study controlling for general crash trends and the regression-to-the-mean effect, generally using controls based on similar sites	3	4	5
Study using matched comparison group, based on crash rates controlling for general trends and regression-to-the-mean	3	4	5

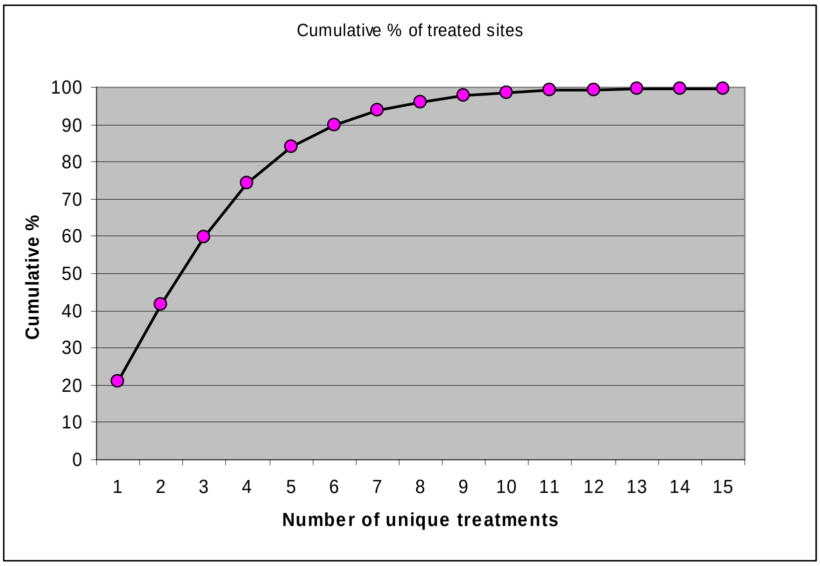
Once information from relevant studies was assessed and a crash reduction value calculated, an overall assessment was made as to the level of confidence in this value (based on the rating system, as well as the number of studies, the country of origin and the age of the research). Out of all of the crash reduction values identified through this research, only 7% of these were identified as having a high level of confidence. For 43% of values there was a medium level of confidence, while the remaining 50% were attributed a low level of confidence. Examples of crash reductions and their associated confidence levels are provided in Appendix 1. Despite this, these estimates are based on the best available information, and should be considered by practitioners when estimating crash reductions for these treatment types.

Caution should be used when encountering information on crash reduction factors, as the method used to obtain this information may be of low quality. Use of such information could lead to an inaccurate evaluation of the benefits of that treatment type.

Note that the research undertaken by ARRB has concentrated on the overall expected benefit of treatments, and not on the reduction expected for individual movement types (e.g. head-on crashes). There is even less robust information available on this issue. Research currently being conducted by ARRB for the BTRE is aimed at improving knowledge on this topic.

EFFECT OF USING MULTIPLE COUNTERMEASURES

As identified in Turner & Tziotis (2006), it is typically the case that more than one treatment is used at the same location. For example, where there is a problem at a rural bend with vehicles leaving the road, attempts may be made to improve delineation through the use of signs and line markings, to increase the width of the shoulder, and to make improvements to the skid resistance of the road surface. Based on an analysis of New Zealand data it was found that multiple treatments were used at around 80% of crash locations (see Figure 1).



Even where it appears from records that a single treatment has been used, this is often not the case. Hanley et al. (2000) report that what may initially appear to be single treatments may actually be multiple treatments on closer inspection. They reviewed sites where project descriptions generally indicated single treatments. However, they also assessed 'as built' plans and project reports of these same sites and found that for many of the sites, multiple treatments had been used.

Although in some cases there will be a clear primary treatment (one treatment that will provide the main crash reduction benefit), in other cases the treatments may act together to improve safety (as in the example above). There is currently limited guidance on how to calculate the benefit of using more than one treatment.

A review of literature revealed several commonly used equations that attempt to account for the diminishing benefit from using multiple treatments. Most took the following form (or a variation of this):

$$CRF_t = 1-(1-CRF_1)(1-CRF_2)(1-CRF_3) + \ldots.$$

where: CRF_t = total crash reduction
CRF_x = individual crash reductions.

As an example, if three treatments are being considered in one location, with respective reductions of 40%, 25% and 20%, the results would be as follows:

$$CRF_t = 1-(1-0.4)(1-0.25)(1-0.2)$$
$$= 1- (0.6 \times 0.75 \times 0.80)$$
$$= 0.64, \text{ or a 64\% reduction in crashes.}$$

A 64% reduction in crashes is obviously less than the 85% reduction that would be calculated if each reduction was added together.

However, of the equations identified in the literature, none appear to have been validated. An attempt at validation was made based on New Zealand crash monitoring data. An analysis was undertaken on the crash reduction effectiveness of several single treatments, and this information was compared with the effect when using these same treatments in combination.

The results showed that existing equations over-estimate the combined benefits of treatments. Based on the results of this analysis, it is recommended that crash reduction estimates derived using these equations be multiplied by 0.66 to provide a more accurate estimate of actual reduction (in the example above, instead of a 64% reduction, a 42% reduction should be used). It was also recommended that attempts be made to prioritise the combinations of treatments that are most commonly used, and then a program of research undertaken to identify crash reductions from these combinations.

Use of the above guidance will allow a more accurate assessment of the expected crash reduction at sites with multiple treatments.

TREATMENT LIFE

Most recent attention appears to have been targeted at identifying appropriate crash reduction factors, and although there are large gaps in knowledge on this issue, even less information is available on other parts of the economic evaluation performed to identify an appropriate BCR. One important aspect that has been overlooked is the ‘life’ over which an evaluation should be performed. Current advice differs markedly across New Zealand and Australia. A review of this guidance was undertaken as part of the Austroads research. This identified that some jurisdictions provide no guidance on this issue, while the guidance that does exist appears to have little empirical basis. As an example, the expected life of a roundabout in one jurisdiction was 10 years, while in another it was 20 years. Doubling the period over which project benefits can be accrued dramatically changes the BCR of a project if all other factors are held equal (although not doubling the BCR because of discounting of benefits over time). Although differences in treatment life could be expected in some circumstances (due for instance to climate, traffic volumes, materials available for construction or the changing nature of the road environment), it was concluded that this difference was at least in part due to a lack of information on this topic.

A literature review was undertaken on the expected treatment life of various road safety treatments. Some overseas guidance on this issue was identified (e.g. Iowa Department of Transport, 1998; Minnesota Department of Transport, 2002; Virginia Department of Transport, 2006) but much of this appeared to be based on subjective assessment. Literature reviews were performed on a number of specific treatment types, but little information was identified of relevance (information was available on pavement surfacing, pavement markings, signs, raised pavement markers and profile edgelines).

Asset managers (through the Austroads Assets Task Force) were also surveyed to determine what values they thought would be appropriate for different treatment types. The information they provided was thought to be a maximum that an asset would last before losing its safety benefit. However, it was also noted that in many situations, that asset might be replaced for reasons other than maintenance, particularly in areas where traffic volumes were increasing. As an example, a roundabout installed in a newly developed area with a rapidly growing population may need to be replaced well before it started to deteriorate, as with increasing traffic volumes it may need to be redesigned to cope with the changing traffic environment.

Table 3 summarises the results from each of these sources of information (treatment life values currently used in safety, the review of literature, and the information from asset managers), and provides a maximum treatment life value for each treatment.

These figures need to be used with caution, as treatment life may be different in specific situations, depending on issues such as traffic volumes, climate, and likelihood of change in conditions. The values provided are generally higher than those currently used in road safety programs. Values for some treatments have increased by a greater amount in proportion to others, while some are less than currently used. This means that there may be a need to place a greater emphasis on some treatment types (i.e. they will now provide a relatively higher BCR than other treatment types). Additionally, as these figures are generally higher than those already used by safety practitioners, it is likely that BCRs could be higher for these schemes, because the ratio of benefits to costs is greater than previously anticipated.

Table 3: Possible maximum treatment life (years)

Treatment type	Safety survey	Literature review	Asset survey	Possible maximum
Grade separation	20	n/a	45	50
Realign curve	20	n/a	30	30
Stagger or realign intersection	20	n/a	30	30
Roundabout	20	n/a	25	25
Shoulder sealing or widening	20	n/a	25	25
Add or widen lane (including overtaking lane)	20	n/a	25	25
Provide acceptable superelevation	15	n/a	25	25
Median barrier	15	n/a	25	20
Railway level crossing barriers	15	n/a	20	20
Median island (or other island)	15	n/a	25	20
Guardrail (roadside)	15	n/a	20	20
Street lighting	15	n/a	30	20
Remove roadside hazard (trees, pylons, etc.)	20	n/a	10	20
New traffic signals (hardware and/or software)	15	n/a	20	15
Improve sight distance by removing impediment on main road	15	n/a	10	10
Edge marker posts (guideposts)	10	n/a	10	10
Skid resistant surface	5	n/a	10	10
Signs (advisory, warning, parking, speed limit, etc.)	10	1-20 years, but generally 10 years or less	15	10
Linemarking (paint and thermoplastic)	5	1-5 years	5	3 and 5
Raised reflectorised pavement markers	5	1.5-5 years	10	3

TREATMENT COST

The cost of a treatment also plays a significant role when calculating the BCR and in determining whether a treatment will be implemented. This cost depends on both the initial treatment cost and the associated maintenance costs. The Austroads research identified that errors are likely based on the costs of treatments (both at implementation and for maintenance). Based on an analysis of cost data from New Zealand for safety schemes (comparing the expected treatment cost with the actual cost to implement a scheme) it was calculated that the average cost estimate error across sites was relatively low (around $4,000), but that this value masks some quite large estimate errors. In fact, around a third of the total sites demonstrated an underestimate cost error, with a mean value of approximately $20,000 (a doubling of the project value). Approximately two-thirds of the sites demonstrated an overestimate cost error, similarly with a mean value of around $20,000 (around a third of the actual value).

One interesting finding from the analysis was that the most commonly used treatments tended to result in an over-estimate of cost, while less commonly used treatments produced an under-estimate.

Data from the study of treated sites in New Zealand, as well as guidance provided in Australia (e.g. from Victoria and Western Australia on implementation costs; and from Victoria, Western Australia and New South Wales on maintenance costs) provide useful information about possible costs, but can only ever act as guides. Further work is required to provide more reliable results, most likely based on the actual costs of treatments.

SUMMARY AND RECOMMENDATIONS

The calculation of a BCR appears on the surface to be an accurate science. However, closer examination reveals that there are a number of sources of potential error in making this calculation. Useful guidance is emerging from Austroads research on this issue, particularly in relation to more accurate crash reduction factors. Limited guidance is also available on an appropriate treatment life and cost. Improvements in the calculation of project benefits and costs would lead to better selection of the most deserving schemes, thereby maximising the value gained from finite resources dedicated to road safety improvements. At the very least, acknowledgement needs to be made of likely sources of error. It is therefore recommended that greater use be made of sensitivity testing (e.g. calculating the BCR using various scenarios) when calculating the economic benefit of road safety schemes.

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Appendix 1: Crash reduction factors and associated confidence in these values

Treatment category	Environment / treatment type	% Reduction	Confidence
Channelisation at intersections – splitter and median islands	Splitter island – all environments	40%	Low
	Splitter island – rural	35%	Low
	Splitter island – urban	40%	Low
	Splitter island – T intersection	45%	Low
	Splitter island – X intersection	40%	Low
	Median island – mountable	15%	Low
	Median island – non-mountable	25%	Low
Delineation – RRPMs	All environments	5%	Medium
Intersection – left turn provision	All environments	30%	Low
Intersection – linked signals	Linking of existing signals	15%	Medium
Intersection – red light camera	All environments	6%	High
Intersection - right turn lane	All environments	35%	Medium
	At signalised intersections	35%	Low
	At unsignalised intersections	35%	Low
	Urban	30%	Low
	Rural	35%	Low
	Painted	30%	Low
	Protected	35%	Low
Line markings – profile edge lines	Shoulder	23%	Medium
Midblock turning provisions	All environments	34%	Medium
Overtaking facilities	All environments	23%	Medium
Pavement markings – centreline	All environments	30%	Low
Pavement markings – edge line	All environments	19%	Low
Sight distance	Rural environments and intersections – based on an improvement in sight distance	30%	Medium
Signs – advisory	Advisory speed signs	25%	Low
	Curve warning signs	25%	Low
	Chevron warning signs	30%	Low
	Bridge warning signs	30%	Low
	Guidance signs	15%	Low
	Variable message signs	15%	Low
	Vehicle activated signs	34%	Medium
Street lighting **	Improve lighting – all environments	30%	Medium
	Improve lighting – midblock	30%	Low
	Improve lighting – intersections	40%	Low
	Install lighting – all environments	35%	Medium
	Install lighting – intersections	50%	Medium
	Install lighting – midblock	40%	Medium
	Install lighting – rural	30%	Low
	Install lighting – rural intersection	40%	Medium
	Install lighting – urban	30%	Low
** Note: These are % reductions expected in night crashes only	Install lighting – urban intersection	20%	Low