Evaluation of Road Safety Benefits with Paramics

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Introduction

This paper discusses the evaluation of road safety impacts in traditional road user cost benefit analyses of road projects. It shows that road safety benefits are underestimated because we do not usually evaluate the delays that accidents cause to other road users. Using **Paramics**®, a microscopic simulation modelling package, the delays to vehicles caused by incidents on the road system have been estimated for comparison with the costs usually calculated.

The paper is laid out as follows:

- Current methods of cost benefit analysis are described, in particular the accident cost component.
- A method of estimating the delays that road accidents cause to other road users is presented.
- The implications for road safety measures are discussed.

Cost Benefit Analysis

In most road agencies, road user cost benefit analysis is used to calculate the **benefit-cost ratio**, which is used as an indicator of a project's economic viability. Road user costs are usually identified as having three components:

- Vehicle operating costs;
- Person-hour costs; and
- Accident costs.

The cost-benefit analysis usually involves estimating these three components for a 'base case' and a 'do-something' scenario (i.e the project), and subtracting one from the other to give the economic benefits. These costs are streamed over a period representing the economic life of the project, and discounted to a common base year as 'net present values'.

The usual approach to accident benefit analysis is to assess the likely change in accident occurrence attributable to a project, and assign accepted dollar values to the change. The result is expanded to annual levels and spread over the evaluation period (typically 30 years for a road infrastructure project) and discounted to a base year to give the 'present value' of accident benefits.

The dollar values assigned to accidents vary between jurisdictions. The RTA in NSW recommends a range of values in its Economic Analysis Manual, reproduced in Appendix A.

Some important things to note from the RTA's analysis are as follows:
- Accident costs include vehicle repair, insurance administration, accident investigation/reporting, legal costs, and alternate transport, but exclude any other property damage costs.
- No account is taken of delays to other road users caused by incidents on the road system.
- No account is taken of the pain, grief and suffering element of accidents.

A similar approach is used for evaluation of low-cost road safety improvements, where the economic benefits from accident savings are usually the only benefits (unless the project also provides time savings, for example).

Road Safety Benefits

In the writers' experience, for most significant road improvement schemes, road safety benefits are seldom more than about 25% of the total road user economic benefits. This is for two main reasons:
- Most road investment projects involve significant capacity or operating speed improvements at the same time; safety benefits are generally not the main reason for road investment, although they do figure highly in the priorities of road agencies and decision makers, probably rightly so.
- As will be shown, road safety benefits are significantly underestimated by current methods.

There are of course some situations in which investment is directed purely at road safety improvements – often called 'low-cost road safety measures', possibly because the relatively low value placed on accidents cannot of itself justify larger investments.

A case in point is the Pacific Highway in New South Wales – well known as one of the country's more notorious stretches of road, and tragically the scene for a number of the fatal accidents in NSW over the last Christmas/New Year holiday period. Major investment is under way to upgrade the Highway, similar to the treatment that the Hume Highway received in the 1980s and 1990s. Funds were committed partly because of several bad accidents involving buses and a number of fatalities some years ago, although in most cases the areas where these crashes occurred were subjected to some improvement, and accident statistics for more recent years do not look so bad.

As any user of the Pacific Highway will know, several sections of it get very busy during holiday periods and if an accident occurs it can result in major detours. An accident involving fuel spillage from a tanker some years ago near Murwillumbah necessitated closure of the Highway and a 30-kilometre detour along narrow roads to the west for over three hours. Although this incident happened at night it still resulted in considerable extra time and driving distance for a significant number of vehicles. It wouldn't take too many of these events in a year to add significantly to the economic costs of the incident, thus increasing the justification for doing something about it.

The fundamental question is, how do we get a reasonable estimate of the delays to traffic caused by accidents on the road network?

Effects of Accidents on Traffic Flow

More road accidents tend to occur on busier roads than on lightly-trafficked roads, except perhaps in non-urban areas, where road geometry, driver fatigue or vehicle problems are the major causative factors. This is quite well understood and will not be explored further here.

Most accidents are at or close to intersections where vehicles are turning or conflicting with each other's movements in some way. A typical accident, involving moderately serious vehicle damage and/or personal injury, might take about 30 minutes to clean up. If such an accident blocks a lane of traffic and results in additional 5-minute delays to about 5,000 vehicles, a total of over 400 vehicle-hours is lost – or (at a typical average vehicle occupancy of 1.2) 550 person-hours, in round numbers. If this time is worth $12.87 an hour ($15.44 per vehicle hour (RTA, 1999) divided by typical car occupancy of 1.2) we get $7,100 worth of lost time per accident. The average cost of an accident is around $16,300 (RTA, 1999), so the delays to traffic in this simple example would increase the economic cost of the accident by about 43%.

A more serious accident could involve greater delays and more traffic; if a partial or total road closure is required, the delays can soon build up to 15-20 minutes per vehicle. However these more serious accidents involve more damage or injury and would be more costly in other ways, so the proportional increase could well be similar.

Estimation of Delays

To get a better handle on the amount of delay caused by road accidents, it is best to find a reasonably efficient way of estimating the actual delays incurred by drivers trying to get past an accident scene.

One particularly interesting tool for doing this is called **Paramics**®, a traffic simulation modelling package that, amongst many other things, enables the user to specify incidents as interruptions to traffic flow, monitor the resulting queueing and measure the delays to traffic. **Paramics**® represents a new generation of simulation software in that it displays the behaviour of vehicles on-screen, at the same time as generating a detailed simulation of traffic moving through a road network using car-following and gapacceptance criteria. It is flexible enough to model any kind of intersection layout, and can simulate the movement of all vehicle types.

Paramics® is an example of a micro-simulation model, which analyses traffic on a vehicle by vehicle basis. Instead of using aggregate relationships like saturation flows (as used by SIDRA), micro-simulation models are concerned with the behaviour of individual vehicles, reaction times, acceleration rates and deceleration rates. Although many aspects of micro-simulation have a long history of research, such as vehicle following behaviour, practical micro-simulation has only been possible since the advent of far more powerful computers over recent years.

A striking feature of the **Paramics**® model is the realistic animation of the movement of individual vehicles on a road network. This enables decision-makers, who may not have a background in traffic engineering analysis, to appreciate the consequences of alternative traffic schemes.

In recent years they have often been applied to congested road networks particularly in downtown areas with coordinated traffic signal controls, roundabouts and give-way junctions. The **Paramics**® model is a simulation model; many inputs have a random or stochastic component such as the driver characteristics for individual vehicles, and the number of vehicles that arrive over short periods of time. This means that the model will output slightly different results, such as queue lengths, every time it is run.

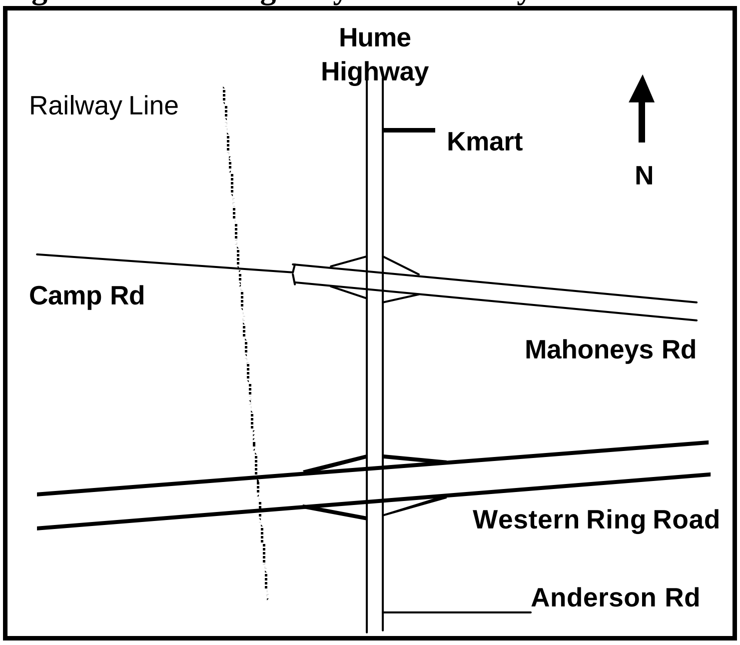
Hume Highway Example

Paramics® was applied to a busy and dangerous arrangement of intersections along the Hume Highway on the northern outskirts of Melbourne. The study area is shown in Figure 1.

The **Paramics**® model of this area was built to examine a particular problem; eastbound traffic exiting the Western Ring Road at Hume Highway queues back up the off-ramp and causes congestion on the freeway, because of the capacity constraints at the intersection of the off-ramp with Hume Highway. This problem is exacerbated by the intersection to the north, between Hume Highway and Camp Road/Mahoneys Road. Traffic queueing back from this intersection affects the Western Ring Road/Hume Highway intersection, reducing its capacity to discharge traffic from the Western Ring Road off-ramp.

The area is also notorious for a high number of accidents involving heavy vehicles. There is a high proportion of trucks in the traffic stream, but an inordinately high incidence of accidents involving trucks. This is thought to be due to a number of factors, including the high travel speeds of trucks as they enter Melbourne's built-up area (most of the accidents occur southbound on the Hume Highway).

Figure 1. Hume Highway Model Study Area



For the purpose of investigating the traffic delays caused by accidents, we took the **Paramics**® Hume Highway model and applied 'incidents', represented by a vehicle stopping and blocking a traffic lane for 5 minutes (minor incident) or 30 minutes (significant incident). The incidents were modelled at two different locations (at the Camp Road/Hume Highway intersection, and at the Western Ring Road/Hume Highway intersection).

The simulation was run a number of times and average delays compared between the four incidents and a base case with no incidents. The results are shown in Table 1.

Table 1 Results of Paramics® Incident Simulations

	Total modelled vehicle-hours	Diff from Base Case
Base Case (no incident)	9934.4	N/A
Camp Road/Hume Highway intersection		
5-minute incident	10173.1	238.7
30-minute incident	10482.8	548.4

Western Ring Road/Hume Highway intersection		
5-minute incident	10165.6	231.2
30-minute incident	10454.0	519.6

The 5-minute incident simulation gave rise to an additional 230 vehicle-hours of travel, whilst the 30-minute incident gave rise to about 520-550 hours (the Camp Road incident created more delay than the Western Ring Road one).

Addition to the Cost Benefit Analysis

At $12.87 an hour, traffic delays with the 5-minute incident would add nearly $3,000 to the cost, increasing to nearly $7,000 for the 30-minute incident.

Compared to the average accident cost of $16,300, the 30-minute incident adds about 42% in traffic delays – remarkably close to the simple example discussed earlier.

The important thing about the **Paramics®** model approach is that real incidents can be simulated and traffic delays estimated in specific conditions.

Conclusions

Most cost-benefit analysis procedures ignore the effects of road accidents on traffic flow. A simple worked example, and a more sophisticated simulation of these effects, suggest that, if taken into account, the economic costs of road accidents (and hence the benefits of reducing them) could increase by about 40%.

At locations where there are a lot of minor incidents (for example, minor collisions at busy intersections), it is not inconceivable that the traffic delay component of accident costs would be greater than the costs currently used in economic appraisals.

The advent of user-friendly and powerful traffic simulation tools like Paramics® make it relatively easy to develop estimates of traffic delays that are tailored to the specific situations being considered. Low-cost road safety project evaluations could benefit from this, as the cost of doing the simulation itself is much lower. It is relatively easy to build a simulation of an entire day’s traffic activity, with and without a typical range of incidents, and provide a detailed and reproducible assessment of the delays caused.

Another possibility would be to use Paramics models to develop a range of typical values (eg. delays per vehicle in given traffic flow conditions) which could then be applied to accident statistics to provide a proxy for the detailed simulation of each situation. A set of ‘look-up’ tables could be developed to provide typical delays per vehicle across the likely range of incident types, locations and traffic levels.

In any event it is important that future evaluations include the effect of accidents on traffic flow, because it is demonstrably significant and it could raise the priority of spending on road safety-related expenditure relative to other calls on funds.

Acknowledgments

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References

NSW Roads and Traffic Authority, 1999. Economic Evaluation Manual. Version 2, July 1999.

Sinclair Knight Merz, 2000. Hume Highway Paramics Report (unpub.)

APPENDIX A

EXTRACT FROM NSW ECONOMIC ANALYSIS MANUAL
(Version 2, 1999, Appendix B)

C) ACCIDENT COSTS

Table 7 provides estimates of casualty costs per person by casualty type in 1999.

TABLE 7
CASUALTY COSTS PER PERSON

Casualty Type	$
Fatality	771,800
Admitted Injury	131,800
Treated Injury	8,600
Non-treated Injury	1,010
Not Injured	390

Source: ARRB Preliminary costs for accident types, Research Report 217, 1992. Indexed using estimates of Average Weekly Earnings (AWE) for NSW, ABS Catalogue No. 6302.0

Table 8 provides the estimated generic costs per accident in 1999. Apart from tow-away accidents, these costs include an average **incident cost of $16,300 per accident**. Incident costs include vehicle repair, insurance administration, accident investigation/reporting, legal costs, and alternate transport, but exclude any other property damage costs. Tow-away accident costs include damage to cars as well as any ancillary costs.

TABLE 8
GENERIC COSTS PER ACCIDENT

DESCRIPTION	COST ($)
Fatal	937,000
Injury requiring hospital admission	175,000
Injury requiring medical treatment	27,000
Injury not requiring medical treatment	17,000
Tow-away	12,200

Source: Based on 1997 RTA NSW accident data and costs by casualty class from Andreassen D, *Costs for accident-types and casualty classes*, ARR 227, ARRB TR, 1992, updated to 1999 values.

A fatal accident is an accident where there is at least one fatality. An injury requiring hospital admission accident involves at least one person being admitted to hospital. An injury requiring medical treatment accident involves at least one person receiving medical treatment. An injury not requiring medical treatment accident involves at least one person being injured but not requiring medical treatment. A tow-away accident is one where at least one vehicle is towed away but no-one is killed or injured.

For an urban project assessment, estimated accident cost savings may need to be calculated separately and added on to the VOC and time cost savings. The average cost of a reported urban accident at January 1999 prices is **$36,400**.

Table 9 expresses average accident costs by road type in terms of cost per million vehicle kilometres of travel (mvkt).

TABLE 9
AVERAGE ACCIDENT COST BY ROAD TYPE 1999

	Av. Cost per mvkt ($)
Local/sub arterial	55,000
Arterial	40,000
Freeway	12,500
Weighted average cost per mvkt	45,000

Source: Based on ARRB TR paper ARR227, updated to 1999 values.

For the analysis of projects where specific accident costs by type of accident are required Table 10 below gives estimated figures for 1999.

TABLE 10
ACCIDENT COSTS BY ACCIDENT TYPE 1999

Accident Type Group			
Two vehicle types		**Urban**	**Rural**
Group Code	**Brief Description**	**$**	**$**
101-109	Intersection, from adjacent approaches	30,500	94,600
201	Head-on	79,800	176,200
202-206	Opposing vehicles; turning	31,900	106,000
301-303	Rear end	22,700	55,500
305-307	Lane change	32,500	51,800
308,309	Parallel lanes; turning	23,700	103,600
207&304	U-turn	26,600	79,700
407	Vehicle leaving driveway	23,900	52,100
503,506	Overtaking; same direction	38,900	21,300
601	Hit parked vehicle	27,100	195,900
903	Hit railway train	175,300	304,800
One vehicle types			
001-003	Pedestrian crossing carriage	88,100	122,700
605	Permanent obstruction on carriageway	18,100	12,200
609	Hit animal	26,700	26,300
701,702	Off carriageway, on straight	31,100	63,200
703,704	Off carriageway, hit object	39,500	65,200
705	Out of control on straight	47,600	98,600
801,802	Off carriageway, on curve	30,800	60,600
803,804	Off carriageway, hit object	40,700	74,100
805	Out of control on curve	49,100	77,600
	Other	48,300	119,600

Source: Based on ARRB TR paper ARR227 and updated by 1997 NSW accident data, and ABS NSW AWE.

It is recommended that when analysing road safety projects the method used in ARRB TR paper ARR 226, *A Guide to the Use of Road Accident Cost Data in Project Evaluation and Planning* (1992) be used.