Economic Development Committee

<u>Inquiry into the road safety benefits of fixed speed cameras</u>

Submission 21

MONASH University
Accident Research Centre

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8 April 2010

Ms Lyndel Bates
Research Director
Economic Development Committee
Parliament House, George Street
Brisbane QLD 4000

Dear Ms Bates

INQUIRY INTO THE ROAD SAFETY BENEFITS OF FIXED SPEED CAMERAS

I refer to your call for submissions to the above Inquiry. Monash University Accident Research Centre (MUARC) has conducted extensive research on the road safety benefits of fixed speed cameras. An international literature review has examined the effects of fixed spot-speed cameras and point-to-point average-speed camera systems, but regrettably we have been unable to find reliable scientific evaluation of combined red-light and speed cameras. The results of our literature review and our evaluations of mobile speed cameras in Victoria and Queensland have been used to provide strategic advice on future speed enforcement programs in Western Australia and Queensland.

Our reports on speed enforcement strategies for Western Australia have been released by the WA Office of Road Safety and form part of this submission. MUARC report 270 (September 2006) covers the then-available evidence on fixed speed cameras in chapter 3 (and expanded upon in sections 6.6 and 6.7). MUARC report 277 (May 2008) was a later supplement to report 270 and contains further evidence on point-to-point speed camera systems in chapter 2. These two reports are summarised in the paper "Speed enforcement - Effects, mechanisms, intensity and economic benefits of each mode of operation" (by M. Cameron and A. Delaney) in the Proceedings, Joint Australasian College of Road Safety and Queensland Parliamentary Travelsafe Committee conference, *High Risk Road Users - Motivating behaviour change: what works and what doesn't work?*, Parliament House, Brisbane, September 2008. A copy of this paper also forms part of this submission.

During 2008-2009, Queensland Transport (now Department of Transport and Main Roads) commissioned MUARC to undertake research on the development of strategies for speed camera enforcement in Queensland. MUARC's final report (June 2009) covered the road safety benefits of fixed speed cameras, including the estimated effects of combined red-light and speed cameras based on assumptions about the individual effects of the two formats. Our report has not yet been released by the Department of Transport and Main Roads.

I hope that this information and the supporting documents are useful to your inquiry. For further information, please contact Professor Max Cameron on telephone 0417 331 762 or the following email address: max.cameron@muarc.monash.edu.au

Yours sincerely

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DEVELOPMENT OF STRATEGIES FOR BEST PRACTICE IN SPEED ENFORCEMENT IN WESTERN AUSTRALIA

FINAL REPORT

by

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September, 2006

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
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Title and sub-title: Development of strategies for best practice in speed enforcement in Western Australia: Final report

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Abstract:
The objective of this research is for the results and recommendations to be utilised to enhance speed enforcement strategies in WA, by assisting the WA Police in developing formal business cases for the deployment of enforcement technology (what, where and how) and the purchasing of enforcement technology (number, mix and type).

A package of speed enforcement programs was defined for the WA road environment which recognises its relatively unique characteristics of vast size and light traffic density, except in Perth. Evidence of the effects on speeds and road trauma in other jurisdictions due to speed camera systems and manual speed enforcement was reviewed and synthesised to provide strategic understanding of their mechanisms. For some key speed enforcement operations, it was possible to calibrate the road trauma reductions against the operational levels.

From this research base, it was possible to define a suitable speed enforcement method for each part of the WA road system and calculate the road trauma reductions and economic benefits if operated at each level. The recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes per annum.

The package is estimated to provide a saving of at least $186 million in social costs per annum. The total cost to produce these savings is estimated to be $18.6 million per annum. Thus the benefit-cost ratio of the package is estimated to be at least 10. The expected fine revenue from speeding motorists detected by the recommended speed enforcement operations, at least in the short term, is estimated to be $204 million per annum. Thus the estimated cost to operate the recommended package would initially be less than 10% of the fine income. In the longer term, the operational cost is not expected to exceed 20% of the expected diminishing fine income as speeding behaviour improves and detected offenders reduce in response to the escalated speed enforcement activity.

Key Words:
Traffic enforcement
Speeding

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Preface

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EXECUTIVE SUMMARY

Tasks and objectives

The principal tasks of the project were to:

- Conduct an analysis of current Australian and international activity, research and literature in relation to best practice in speed enforcement strategies and technology;
- Develop recommendations on the implementation of best practice in speed enforcement specifically for the WA setting; and
- Develop a detailed implementation plan in order to move from the current situation to what has been recommended.

The main objective is for the results and recommendations from the research to be utilised to enhance enforcement strategies in WA. Specifically, to assist the WA Police in developing formal business cases for:

- The deployment of enforcement technology (what, where and how);
- The purchasing of enforcement technology (number, mix and type); and
- Funding options and service delivery models for the purchase and support of the future enforcement technologies and activities.

Current Australian and international activity and research

The substantial body of research about speed camera systems in the Australian states, New Zealand and Great Britain was summarised in terms of the operational method used, deterrence mechanism, and effects on speeds and road trauma. The diversity of speed camera operations in these jurisdictions is shown below.

	Overt operations	Covert operations
Fixed installations, usually signed (fixed cameras)	New South Wales Great Britain	
Known fixed sites - "accident black spots" (mobile cameras)	New South Wales Western Australia South Australia Great Britain	
Fixed sites, randomly allocated cameras (mobile cameras)	Queensland	
Signed speed camera zones (mobile cameras sometimes)	New Zealand	New Zealand hidden camera trial (1998-2000)
Unsigned sites or zones (mobile cameras)		Victoria (also some unsigned fixed cameras since 2000)

The summary included research from Victoria about the crash reduction effects of moving mode (mobile) radar units, which are most suitable for use on rural undivided roads, and hand-held laser speed detectors, which are suitable for use in urban areas where there are difficulties with other modes of speed enforcement. Point-to-point speed camera systems measuring average speeds over a road section were also reviewed, but the evidence of their road trauma effects were found to be unclear at this stage.

No crash-based evaluation of WA's Multanova speed camera program could be found. Surveys of on-road speed behaviour at a representative sample of the WA road system had been implemented in the year 2000. These surveys did not indicate substantial improvements in speed behaviour since that time, including in rural WA although speed camera hours and vehicles monitored increased substantially during 2004, at least in some rural regions.

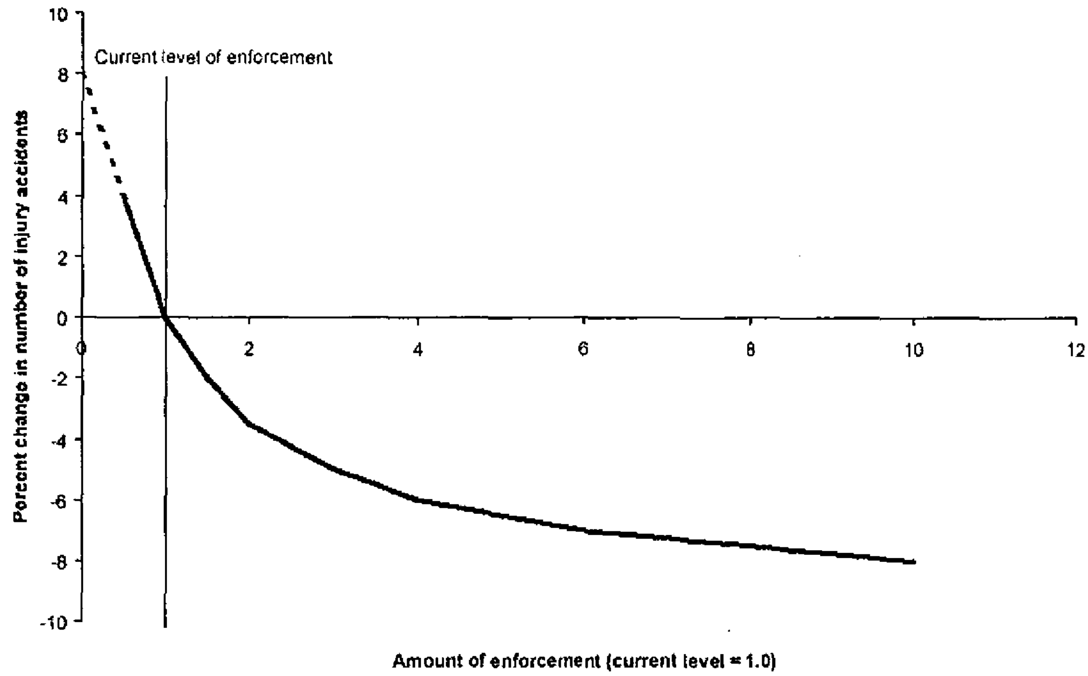
Options for speed enforcement in WA

The options for speed enforcement in the WA road environment were defined, recognising its relatively unique characteristics of vast size and light traffic density, except in Perth. The options covered:

- Covertly-operated car-mounted mobile speed cameras on urban arterial roads, based on experience in Victoria
- Overtly-operated mobile speed cameras randomly scheduled in time and space to sites covering a high proportion of crash locations within 2 km, based on experience in Queensland
- Covert operation of mobile speed cameras within the publicly announced routes (following current WA practice), based on experience in New Zealand from their trial of hiding their usually overtly-operated speed cameras within the designated camera zones
- Covert and overt mobile radar units on rural undivided highways and rural local roads, based on experience in Victoria with unmarked car and mixed marked/unmarked car operations
- Overtly-operated laser speed detectors on urban local roads, based on experience in Melbourne with low- to medium-intensity enforcement over multiple "black spot" sites
- Overt fixed speed cameras on Perth freeways, based on experience in the UK and New South Wales
- Point-to-point speed camera systems on highly-trafficked rural highways, however the evidence of their effects from the UK was too limited to allow further consideration.

Recommended speed enforcement package

The evidence of the effects on road trauma in other jurisdictions due to the speed camera systems and manual speed enforcement methods has been used to undertake an economic analysis of each of the speed enforcement options in those parts of the WA road system where they were considered suitable. In the case of some key speed enforcement operations, it has been possible to calibrate the road trauma reductions against the operational levels. The relationships were each of the diminishing-returns form found by Elvik (2001):



General relationship between traffic enforcement and crashes identified by Elvik (2001)

Such relationships were calibrated for the speed camera programs in Victoria and Queensland, and the mobile radar operations in Victoria, and then used to recommend levels of operation if similar speed enforcement methods were used in WA.

The recommended package of speed enforcement programs, together with the recommended level of program input (usually operational hours per month), is shown in the tables below. The second table shows the crash savings per month, by severity of crash, which derive from the percentage crash reductions if the program is implemented in that part of the WA road system. The social cost savings have been calculated from the crash savings using the Federal government's road trauma cost figures (BTE 2000), indexed to 2005 prices.

The recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction in crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes per annum over the whole of WA.

The package is estimated to provide a saving of at least $186 million in social costs per annum. The total cost to produce these savings is estimated to be $18.6 million per annum. Thus the benefit-cost ratio of the package is estimated to be at least 10. The expected fine revenue from speeding motorists detected by the recommended speed enforcement operations, at least in the short term, is estimated to be $204 million per annum. Thus the estimated cost to operate the recommended package would initially be less than 10% of the fine income. In the longer term, the operational cost is not expected to exceed 20% of the expected diminishing fine income as speeding behaviour improves and detected offenders reduce in response to the escalated speed enforcement activity.

Speed Enforcement Program	Speed Enforce-ment Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9000	90000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1025	3413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**8.01**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3000	30000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15000	11250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads			**9.98**	**9.0%**	**12.3%**	**26.0%**

Speed Enforcement Program	Crash savings per month			Social Cost Saving per month ($'000)	Program Cost per month ($'000)	Fine Revenue per month ($'000)
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3,974.64	634.1	9,000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1,551.51	51.9	341.3
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.27	59.4	3,561.3
Total for urban roads	**17.0**	**6.1**	**1.3**	**5,967.42**	**745.4**	12,903
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5,673.94	154.5	3,000
Mobile radar units on rural local roads	6.2	4.9	0.62	3,864.00	653.5	1,125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9,537.93**	**808.0**	4,125
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15,505.4**	**1553.3**	17,027.6

Implementation of the speed enforcement package

The best economic return would be achieved if the programs in the package are chosen in order of their individual benefit-cost ratios. However, this implementation strategy needs to be tempered in the WA context by the desire of the WA Government to have the maximum impact on serious road trauma in the short term. On this basis, the recommended order of implementation of the programs included in the speed enforcement package is:

1. Overt mobile speed cameras randomly scheduled on rural highways

2. Covert mobile speed cameras on urban highways (mainly Perth arterial roads)

3. Mobile radar units on rural local roads

4. Laser speed detectors at black spot sites on urban local roads (mainly Perth local streets)

5. Overt fixed speed cameras on Perth freeways.

To achieve this package, 43 additional vehicle-mounted speed cameras will be required, assuming that the existing 14 operational Multanova cameras can be used in this way. An additional 88[1] mobile radar units will be required, but the existing number of laser speed detectors is more than twice the number required for operations in Perth's local streets. In addition, 24 fixed camera installations will be required.

Operation of this enforcement technology, and processing of the estimated 2.043 million speeding tickets per year from the recommended package, will require a substantial increase in police personnel as well as about $4 million capital investment in the back-office infrastructure to triple its offence processing capacity. All costs except the capital cost of the expanded back-office have been included specifically in the economic analyses outlined above, but there may be issues associated with manufacturer's abilities to supply the enforcement equipment and, perhaps more critically, with the WA Police Service's ability to recruit and train an adequate number of personnel to expand the speed enforcement program at an adequate rate.

There is a danger, during a period when a jurisdiction is escalating its speed enforcement activity to levels much higher than previously, that inadequate attention will be given to risk management. Speed enforcement systems, especially camera-based, can create dilemmas for population at large which can cause social controversies of various types. However, the dilemmas and controversies which have arisen in other jurisdictions have been documented comprehensively. It is recommended that careful attention be given to this experience and that risk management be an essential ingredient of the implementation program.

The capital costs and on-going funding of the operations of the speed enforcement package are likely to be substantial issues for the WA Government. During the period of rapid expansion in speed cameras in the UK since 2000, a Cost Recovery mechanism has been in effect whereby the agencies operating the camera systems have been able to recover their costs from the central government fund receiving the fine revenue. The use of fine revenue in this way has not attracted public controversy.

[1] Additional to the 176 mobile radar units existing in 2004, some of which have recently been purchased.

It is recommended that the Western Australian Government give consideration to funding the operational costs of the speed enforcement package recommended here in a similar way. A transparent system whereby it is recognised that the costs of providing an effective system to reduce road trauma and social costs are met from the fines paid by speeding motorists should have broad public acceptance. From the Government's point of view, the impact on the fine revenue should be no more than 20%. The surplus revenue may also be the basis of Government investment in other effective road safety programs addressing problems other than speeding.

1 INTRODUCTION

Previous research has established a clear link between changes in travel speed and crash involvement risk, especially for crashes resulting in death or serious injury (Kloeden et al., 1997 and Nilsson, 1984). Therefore, speed enforcement that is able to reduce speeds generally, and excessive speeds in particular, should operate to reduce the incidence and severity of casualty crashes.

Travelling at unsafe speeds remains a common contributor to road trauma both in Australia and internationally. Speed has been estimated to be a factor in approximately one-third of all fatal crashes and around one-quarter of hospitalisations in Western Australia. In NSW between 1999 and 2003, the total cost to the community of speed related crashes was in excess of $6.2 billion (ARRB, 2005) with a total of 1,171 people killed and 23,999 seriously injured as a result of speed related crashes. Similarly, in the US, speeding is estimated to be a contributing factor to approximately one-third of all fatal crashes (NHTSA, 2003). Clearly there remains scope to reduce the incidence of speed related crashes and the associated financial and social costs.

Currently speed enforcement programs operate in a variety of forms internationally with associated variation in the nature and extent of the impact upon speeds and crashes. To optimise the effectiveness of speed enforcement operations in a given jurisdiction it is useful to review the variety of enforcement programs that operate internationally and determine the mode(s) of operation that collectively are likely to generate the greatest reductions in casualty crash frequency and severity. Therefore, it is necessary to examine existing practices in key Australian states and overseas jurisdictions to inform the development of recommendations that will optimise the safety impact of speed enforcement in WA.

1.1 PROJECT TASKS AND OBJECTIVES

The principal tasks of the project are to:

- Conduct an analysis of current Australian and international activity, research and literature in relation to best practice in speed enforcement strategies and technology;

- Develop recommendations on the implementation of best practice in speed enforcement specifically for the WA setting; and

- Develop a detailed implementation plan in order to move from the current situation to what has been recommended.

The main objective is for the results and recommendations from the research to be utilised to enhance enforcement strategies in WA. Specifically, to assist the WA Police in developing formal business cases for:

- The deployment of enforcement technology (what, where and how);

- The purchasing of enforcement technology (number, mix and type); and

- Funding options and service delivery models for the purchase and support of the future enforcement technologies and activities.

This research also aims to achieve the following objectives:

- To identify the most appropriate type, mix and level of speed enforcement practices for the WA setting;

- Identify the optimum number, type, and combination of speed enforcement technology for the WA setting eg speed cameras, laser/radar or other such equipment;

- To obtain a sufficient level of information to enable a fully costed business case to be developed regarding the purchase and/or implementation and ongoing support of future speed enforcement strategies and technology in WA. (The development of the business case is the next stage of the process and is not part of this project);

- To research current Australian and international best practice in speed enforcement technology and ensure that it is being applied to the road network in WA;

- To identify the most appropriate speed enforcement strategies in WA to contribute to the target of a 5% reduction in urban travel speeds as part of the current road safety strategy and a 10% reduction beyond this period; and

- To identify the road safety benefits and level/type of enforcement needed to ensure that 85th percentile speeds on all roads are no higher than the posted speed limit (ie ensuring that the travelling speed of 85% of the population is at or below the posted speed limit).

1.2 BACKGROUND TO CURRENT SPEED ENFORCEMENT ACTIVITIES

There are a number of variables that likely influence the outcome of the enforcement operations. In particular, an enforcement program may operate overtly or covertly, use fixed or mobile technology and may be directed at treating black-spot locations or addressing problem behaviour across the entire road network. In examining existing enforcement operations in later material each of the relevant program characteristics will be identified where possible, and the estimated influence on road safety outcomes discussed. Therefore a brief explanation of the principles surrounding these modes of operations follows. In addition, the key mechanisms through which enforcement operations are thought to operate are identified.

- *Overt vs covert*: enforcement programs are generally classified as either overt or covert in nature. It is the intention of overt operations to be highly visible to road users and in doing so increase the perceived risk of detection, thus altering the behaviour of road users immediately in time and space. Conversely, covert operations are not intended to be seen by road users and road users should be unaware of the location and timing of such enforcement operations. Effective covert operations will create a perception that detection may occur at any location and at any time.

- In general, speed enforcement technology can be either fixed or mobile. Fixed devices, such as the safety cameras located in the Burnley and Domain tunnels in Victoria, are located permanently at one site. In contrast, technologies such as slant radar speed cameras, are portable and tend to operate at one site for only a short period of time. This technology, along with others that can be moved from site to site, is referred to as mobile technology.

- In some circumstances, the location of safety cameras, whether fixed or mobile, may be chosen to affect a known problem of high crash risk or the risk of particularly severe crashes in a defined area. Such treatments are referred to as black spot treatments. Where the increased risk relates to a particular route or area the treatment can be spread across this black route or area. In general, black spot or black route programs are intended to have the greatest effect at the black spot site or along the black route and are rarely aimed at treating speed across the road network.

The choice between overt or covert, mobile or fixed and black spot or network wide operations may be dependent on a number of factors and this is reflected in the variety of enforcement programs operating in different jurisdictions. Some common factors that likely influence the nature and extent of speed enforcement operations are the level of resources available (e.g. equipment, staff, back office processing facilities), the road type to be enforced, the prevalence of speeding behaviour prior to enforcement and public attitudes towards the use of automated or semi-automated enforcement technologies. These issues will be discussed in more detail in the formulation of the optimum mix of speed enforcement operations presented in a later document. Nevertheless these factors, insofar as they impact upon the mode of enforcement, will also determine the mechanisms through which the enforcement achieves its effect.

The two primary mechanisms through which speed enforcement may effect positive behaviour change are general deterrence and specific deterrence. The key reasoning behind these processes relies on utility theory as described by Ross (1981). In general, this assumes that road users will decide whether on not to commit a traffic offence based on a rational analysis of the benefits and risks associated with committing the offence. It is noted, that it is the *perceived* risks and benefits of committing the offence that determines the utility of the action. Therefore, where the perceived benefit of committing an offence outweighs the perceived risks of detection and punishment, an individual will elect to commit the offence. Similarly, where the perceived risks of committing an offence are greater than the perceived benefits, a rational individual will elect not to commit the offence.

Although both the general and specific deterrence mechanisms are based on an assumption of rational behaviour, there are considerable differences in the operation of the two mechanisms.

- *General deterrence* is a process of influencing a potential traffic law offender, through his fear of detection and the consequences, to avoid offending (Cameron & Sanderson, 1982). Therefore, operations employing general deterrence mechanisms necessarily target all road users irrespective of whether they have previously offended. It follows that general deterrence programs have the potential to influence the behaviour of all road users.

There are thought to be three key elements that influence the effectiveness of a general deterrence program; the perceived risk of detection, the severity of punishment and the immediacy of punishment. The higher the perceived risk of detection the less likely a road user is to commit an offence. The actual risk of detection is less relevant given that it is most often unknown by the driver. The severity of punishment is also relevant although it is it is not the primary mechanism of general deterrence. However, past research has concluded that where the perceived risk of detection associated with an activity is low, severe punishment of the offence will have little impact (Ross, 1990). Similarly, two studies examining the effect of increases in penalties for speeding found no associated changes in driver behaviour (Arberg et al, 1989, and Andersson, 1989). It has therefore been suggested that it is the existence of a penalty rather than the size of the penalty that provides the general deterrence (Bjørnskau & Elvik, 1990). Finally, the swiftness of punishment impacts on the effectiveness of enforcement operations relying on the general deterrence mechanism. Unfortunately, there is little conclusive research evidence detailing the optimal timing of punishment (Zaal, 1994).

- *Specific deterrence* is a process of encouraging an apprehended offender, through his actual experience of detection and the consequences, to avoid re-offending (Cameron & Sanderson, 1982). Therefore, the potential impact of a specific deterrence program is more limited than that of a program relying on the general deterrence mechanism. Enforcement programs relying solely on the mechanism of specific deterrence have the potential to influence only those offenders who have previously been detected and punished for committing offences. It follows that the magnitude of the penalty, especially that applying if subsequent offences are committed, is of particular importance. The choice of penalty, whether it be a warning letter, a fine, demerit points on a licence or some combination of these, is likely to affect the recurrence of offending behaviour.

2 MOBILE SPEED ENFORCEMENT

2.1 COVERT OPERATIONS

2.1.1 Victorian Mobile Speed Camera Program

Since the inception of the mobile speed camera program in Victoria in 1989, the use of mobile speed cameras has become a pivotal component of speed enforcement operations in Victoria. Early evaluations of the effectiveness of the mobile speed camera program showed significant reductions in casualty crash frequency and severity (Cameron et al., 1992). In particular, from December 1989 to March 1990, there was a statistically significant 15% reduction in low alcohol hour[2] casualty crashes on arterial roads. This coincided with low levels of both speed camera enforcement and speed related publicity. During the period April 1990 to June 1990, when the publicity campaign was launched but prior to extensive enforcement operations, low alcohol hour crashes were reduced by 34% on Melbourne arterial roads and 21% in country towns. Reductions in the severity of injuries sustained in these crashes were also found in Melbourne during this period.

Following the high levels of both publicity and enforcement experienced from July 1990, low alcohol hour casualty crashes were reduced on arterial roads in Melbourne, country towns and on rural highways by 32%, 23% and 14% respectively. The injury severity of these crashes was also found to have decreased, principally in Melbourne. The effect of the speed camera enforcement program on high alcohol hour crashes is less clear.

Since these early evaluations the mobile speed camera program has continued to grow and in recent times some operational changes have been made. In particular, between 2000 and 2002, the number of operating hours increased from 4200 to 6000. Other changes to the program involved the introduction of flashless cameras during daytime hours and reducing the speeding offence detection threshold in three stages. These changes were complemented by a program of speed-related advertising carried out by the Transport Accident commission (TAC). It is the effect of the increase in mobile speed camera operating hours that is of particular relevance here. A recent study of the changes to the mobile speed camera program considered casualty crash and severity effects over the period 1998 to 2003 on a monthly basis (Bobevski et al., 2004). The analysis was appropriately structured to consider the effects across Police regions and time and the effects of individual changes to the mobile speed camera program. The results of the analysis are presented as elasticities and the appropriate interpretations are provided below.

In general, the analysis revealed that on average a 1% increase in mobile speed camera hours is significantly associated with a 0.09% decrease in casualty crash frequency. When applied to the total increase in mobile speed camera hours from 4200 to 6000 hours over the period 2000 to 2002, this equates to an estimated 3.25% reduction in casualty crash frequency. Similar estimates of program effects were estimated for the odds of a fatal outcome in these crashes. In that case the results indicate that every 1% increase in camera hours was significantly associated with a 2.03% reduction in the risk of a fatal outcome in a casualty crash. When applied to the total increase in hours this equates to an estimated 51.44% reduction in the risk of fatal outcome in a casualty crash.

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[2] Low-alcohol hours are times of the week when alcohol related crashes are less likely to occur, whereas high-alcohol hours of the week are those periods when alcohol related crashes are more likely to occur.

Area of operation

Given these estimates of program effectiveness it is useful to consider the area in which the mobile speed camera program operated to achieve these effects. Previous evaluations of the mobile speed camera program in Victoria have demonstrated that the impact of camera operations extends beyond camera operating sites (reference). Therefore, in defining the length of road which may be influenced by mobile camera operations it is necessary to consider all road types on which these cameras may operate effectively. Previous research has indicated that mobile, speed cameras are most effective in urban areas (Cameron et al., 2003). Therefore, streets and roads with speed limits up to 80 km/h in Melbourne and rural Victoria may be considered the most suitable targets as well as rural highways with speed zones of 60 and 70 km/h located in towns. The ability to identify the length and traffic volumes of such roads would provide reliable information about potential areas that would likely benefit from mobile speed camera operations.

Recent, accurate information describing the Victorian road network is not readily available. However, by using more dated information relating to road lengths and traffic volumes and appropriately scaling the data to reflect traffic and infrastructure growth, it is possible to estimate the area and kilometres travelled potentially affected by mobile speed camera operations. In 1996, the National Road Transport Commission published a Mass Limits Review (NRTC, 1996) that included information regarding the Victorian road network. Roads are divided by location (urban/rural) and type (national highways, arterials (high volume) and arterials (low volume)). This data, after appropriate scaling, will be used to establish estimates of mobile speed camera program per unit area per hour of enforcement as part of the development of the speed enforcement strategy.

In addition to the general (network wide) effects of the mobile speed camera program there is some evidence that the program also has a localised effect at mobile speed camera sites (Rogerson et al., 1994 and Newstead et al., 1995). In particular for the period from July 1990 to December 1991 during the two weeks following the receipt of Traffic Infringement Notices (TINs) by offending motorists, a statistically significant 10% reduction in *high* alcohol hour casualty crashes was experienced on arterial roads within one kilometre of the camera site. However, there was no reliable evidence of casualty crash reductions within one kilometre of the camera site during the week immediately following a speed camera enforcement session. In addition, no localised reductions in *low* alcohol hour casualty crashes or the severity of crashes were found during this period. Analysis of the mobile speed camera program during the period from July 1990 to December 1993 evaluated the localised effects of speed camera enforcement in rural towns and metropolitan Melbourne separately (Newstead et al., 1995). In metropolitan Melbourne but not in rural towns, the speed camera program was estimated to results in statistically significant casualty crashes reductions following enforcement operations or the receipt of TINs. The influence of TINs was evident during the three weeks following their receipt and was greatest on all roads during high alcohol hours. An 8.92% reduction in casualty crashes was experienced in high alcohol hours, on all roads, during the week following the receipt of TINs. These potential, additional localised effects would need to be accounted for in any estimation of the effectiveness of mobile speed camera per unit area per hour of enforcement.

2.1.2 The Netherlands

As part of a new regional enforcement program in the Netherlands first introduced in January 1998, speed enforcement using inconspicuous mobile speed cameras on rural roads in the Dutch province of Friesland was conducted. The enforced road sections contained signage warning drivers of the potential for speed enforcement activity. However, the enforcement operations may be classified as semi-covert as the enforcement itself was conducted from inconspicuous cars on the roadside. A comprehensive review of the speed and crash effects of the enforcement has been published (Goldenbeld and van Schagen, 2005). The program involved the enforcement of approximately 116km of 80km/h and 100km/h single carriageway rural roads with a history of high numbers of casualty crashes. On average each road length was enforced for between one and two hours each week. The enforcement program was supported by extensive publicity and information campaigns.

The evaluation of the enforcement program considered crash and speed effects over the five-year period following commencement of the program (1998-2002). Enforcement levels varied over this period ranging from 5,486 hours in 1998 to 14,439 hours in 2001. Further, from 2000 onwards, a number of modes of enforcement were adopted. These included the mobile speed camera described above, hand-held laser devices, radar devices located on hidden tripods outside police cars and other surveillance mechanisms. However, the majority of enforcement continued to be undertaken by inconspicuous mobile speed cameras. No information on enforcement hours was available for 2003.

The impact of the enforcement program on all casualty crashes and serious casualties was estimated separately by the authors. A 21% reduction in both all casualty crashes and serious casualties was estimated over the five year period. A number of cautionary notes are issued by the authors for those interpreting the results. In particular, the effect may be over-estimated due to regression to the mean effects and the influence of road engineering measures was not considered. Nevertheless the results of the study are consistent with those of other studies examining similar enforcement efforts on rural roads. Therefore, these results must be considered the best estimates of crash reductions due to the new speed enforcement program.

2.2 OVERT OPERATIONS

2.2.1 Queensland Speed Camera Program

The use of speed cameras in Queensland can generally be described as overt in nature as cameras operate from marked vehicles and signs advising motorists of the presence of camera operations are posted within 10 meters of them. The speed camera program first commenced in May, 1997 at which time cameras were deployed to 500 sites located only on state controlled roads where a speed limit review had been completed. Speed camera zones were chosen on the basis of crash history and were approved by Traffic Advisory Committees. The operation of cameras at particular sites was determined using a randomised scheduling procedure with some scope for variation. By December 2003, the number of speed camera sites in use had grown to over 2,900. An alternative measure of the intensity of the speed camera program is the number of speed camera operating hours achieved per month. In line with the increase in speed camera sites, there has been a substantial increase in the number of mobile speed camera hours per month, particularly during 2003.. Over this period mobile speed camera hours have shown a general increasing trend, however growth in hours has not been smooth with peaks and troughs in operating hours evident over the period which display no distinct pattern. On average over the period 1998 to 2002, mobile speed cameras operated 2,017 hours per month, but this increased to 5,993 hours per month during 2003.

The effectiveness of the camera program has been evaluated in terms of crash reductions by crash severity (Newstead and Cameron, 2003 and Newstead, 2004). Estimates of crash reductions by crash severity were calculated for each year after program implementation using a quasi-experimental treatment and control design and divided into three separate annuli, 0km to <2 km, 2km to <4km and 4km to <6km from approved camera sites. The results show that the crash reductions experienced are greatest nearest the camera sites particularly at higher severity levels (fatal or medically treated crashes). Further, crash reductions attributable to the speed camera program appear to have increased over time. This is expected as the number of speed camera sites defined in the treatment operational speed camera sites has also steadily increased over that period.

Specific results from the study estimate reductions in the order of 35% for combined fatal, hospital and other medically treated crashes within 2km of the speed camera site. Whilst this is an average effect the impact of the speed camera program was estimated to increase over the five years of the evaluation. The estimated impact of the speed camera program on other injury and non-injury crashes within 2km of the speed camera sites in the later years of the program was around 20% or less. These results were considered unlikely to be affected by other road safety initiatives in operation during the evaluation period in particular the Random Road Watch program described below. It was expected that the Random Road Watch program would have the same influence on crashes within both the treatment and control areas used in the speed camera evaluation.

Other interesting results from the study refer to the relationship between crash effects and the intensity, coverage and scheduling of the enforcement identified through analysis of the crash effects by police region. In particular, increased coverage of the crash population, increased density of enforced areas per crash and strict adherence with the randomization process were all associated with increased crash reductions.

2.2.2 Queensland Random Road Watch Program

Prior to the introduction of the speed camera program in Queensland, the Random Road Watch program (RRW) of traffic policing was in operation. The program was first introduced in the rural areas of the Southern Police Region December 1991. Since that time the program has been extended to operate throughout the State. The program aims to allocate enforcement resources in a random way so as to maximise road safety benefits. The approach is implemented by using the existing Police structure of regions and districts to select a number of road segments (approximately 40) that will be the subject of enforcement. These road segments are chosen to ensure that roads covering over 50 percent of all road crashes are included in the program. The central aims of this approach are to decrease the ability of road users to predict the location and timing of enforcement activities and to enable the police to cover larger parts of road network than would be the case with conventional policing.

The RRW program has been evaluated in terms of the effect of its implementation on crash frequency over the period of December 1991 to July 1996 (Newstead and Cameron, 1999). The analysis indicated that for all non-metropolitan areas of Queensland the RRW program resulted in statistically significant crash reductions at all severity levels. The crash reductions increased as the severity level of the crash increased. Examining crash reductions for rural and urban areas separately produced some interesting results. In rural areas, there was a statistically significant 34.3% reduction in fatal crashes but reductions in other crash categories were not statistically significant. On the other hand, urban areas experienced crash reductions for all categories except fatal crashes. However, the failure to identify statistically significant reductions in fatal crashes may be due to insufficient data.

In addition to the variations between metropolitan and rural areas, the outputs and crash effects of the program differed across Police regions. The relationship between the outputs of the program, such as the number of hours of enforcement, and the crash effects of the program in each region was investigated with the aim of determining the mechanisms that drive the program. Significant variations in the offences detected per crash treated and enforcement hours per crash treated were identified across regions. Treated crashes are defined as crashes in the year prior to the introduction of RRW on routes and in time bands enforced by RRW. It was found that the crash coverage of the program (i.e. the percentage of previous crashes in the region covered by the program) was positively related to both the total number of crashes saved and the percentage of crashes saved in the region. The analysis also indicated that total crashes saved and the percentage crash savings are positively related to offences detected and hours enforced, however, these associations were not statistically significant.

The effects of the program over time have also been analysed. The results show that the effect of the RRW program on all crash types except those involving fatalities has increased over time. The effect of the program on fatalities appears to be fairly consistent across the three years immediately following the implementation of the scheme.

Due to data insufficiency it proved difficult to produce conclusive results on the effect of the RRW program in the Metropolitan South Police region that forms part of metropolitan Brisbane. However, in general terms the overall effects in this region appear to be consistent with those experienced in the rest of Queensland. That is, reductions in overall crashes were experienced along with reductions within each year of the programs operation and within each of the crash severity crashes.

In conjunction with the results of the Queensland speed camera program described in section 2.2.1, these results suggest that optimum program effect can be achieved through the randomisation of enforcement scheduling and coverage of a large proportion of the crash population. Finally, it is noted that similar programs have been conducted in other jurisdictions and although the outcomes of these are not conclusive they indicate that reductions in crash frequency can be achieved by implementing randomly scheduled police enforcement.

2.2.3 New Zealand

The introduction of mobile speed cameras in New Zealand commenced in late 1993. The operation of the cameras was restricted to roads classified as 'speed camera areas' based on a record of speed related crashes. Entrances to these roads were clearly sign posted to ensure that motorists were aware of the potential presence of the speed cameras. Further, the majority of speed cameras were mounted on police cars and operators were prohibited from hiding the cameras. In urban areas, limited use was made of fixed position speed cameras mounted on poles, however, these were subject to the same signage requirements as the mobile camera operations. In total, 13 fixed and 31 mobile cameras have been operating in New Zealand since 1993. Prior to July 2000, the enforcement threshold was set at the 85th percentile speed for each site as determined by speed surveys of that site. Financial penalties (but no demerit points) were imposed where vehicles were detected travelling at or above the enforcement threshold. However, since 1 July 2000 a flat 10 km/h enforcement threshold has been in operation.

An evaluation of the effect of the speed camera program described above, found that fatal and serious crashes on roads with speed limits of 70 km/h or less were reduced by an estimated 13% during low alcohol times of day (Mara et al., 1996). In speed camera areas, the reduction in fatal and serious low alcohol hour crashes was 23.3%. Less substantial reductions in all injury crashes were experienced in speed camera areas on roads with speed limits of 100 km/h. No effect on crashes was identified on these roads when non-speed camera areas were included in the analysis.

Christchurch

A further evaluation of the speed camera program described above was conducted for the city of Christchurch only (Gunarta, S and Kerr, G). As the study was undertaken many years after the introduction of the speed camera program, the study considers the difference in speeds at speed camera sites and speeds measured at sites without a speed camera in operation. It was not possible to examine the crash impacts of the program directly. The comparison of speeds was conducted on minor 50km/h arterial or collector roads with 2-way traffic and 2 traffic lanes.

On average across the speed camera sites, mean speeds were 1.7km/h lower than at non-speed camera sites. The speed differences measured were greater in conditions involving wet roads (3.2km/h) or poor visibility (2.37km/h). In conditions of both wet roads and poor visibility the estimated mean speed reduction was 3.82km/h. Whilst the authors were not able to directly estimate the crash reductions attributable to the speed camera program in Christchurch they approximate the anticipated reductions using the relationship between injury accidents and speeds established by Andersson and Nilsson (1997). Using these relationships they estimate that in normal conditions the speed camera operations reduce casualty crashes by approximately 6% and fatal crashes by approximately 12% in the area surrounding the camera sites. These estimates appear similar to those obtained in the study by Mara et al described above for roads with speed limits of 70km/h. In conditions of poor visibility and wet roads, casualty crashes were estimated to be reduced by approximately 15% and fatal crashes by 28%.

2.3 MOBILE RADAR SPEED DETECTORS (MOVING MODE RADAR)

Between 1995 and 1996 a total of 73 mobile radar units (moving mode radar) became operational in Victoria. The mobile radar devices were used primarily in rural areas on two-way, undivided, 100 km/h speed limit roads and involved police intercepting vehicles travelling above the speed limit and issuing an on the spot fine. During this enforcement program all rural Police Districts in Victoria and some Police Districts covering outer metropolitan areas were issued with the mobile radar units. The devices were used on both marked and unmarked patrol vehicles. In particular, during the 1995/96 period, 81% of the operational hours were completed by marked patrol cars. This decreased slightly to 72% during the 1996/97 period. In November 1996 the TAC launched a television advertisement specific to the enforcement program. This advertisement was shown in both rural and metropolitan areas of Victoria. During the same period other advertisements relating to speeding generally were also shown in both rural and metropolitan areas.

For the period from July 1995 to June 1996, 48 mobile radar units were in operation for a total of approximately 902 hours per week. That is, a total of 47,136 hours of operation were achieved over the 12-month period. This number increased to 904 hours per week during the July 1996 to June 1997 period when the number of devices in operation increased to 73.

The enforcement program and associated publicity was evaluated in terms of its effect on casualty crashes on undivided roads in 100 km/h speed zones in Victoria (Diamantopoulou et al 1998). The preliminary analysis found no change in the number of casualty crashes in outer metropolitan regions where the mobile radar devices were used. Therefore, the following results relate to casualty crashes in rural Victoria only.

The analysis determined that the enforcement program had a positive effect on casualty crashes in rural Victoria for a period of approximately four days following the enforcement. The effect of the program diminished after this period. In addition, the effect of the program varied with the level of public awareness of the two advertising campaigns.

The most noticeable effect on casualty crashes occurred when there were high levels of awareness of the specific mobile radar publicity. This corresponded to the period of November 1996 to June 1997. During this period a 28% net reduction in casualty crashes was observed one to four days after the enforcement was present. However, this reduction was only marginally statistically significant. The net reduction found for casualty crashes occurring on the same day as the enforcement was not statistically significant. Further, when there was low public awareness of the specific mobile radar advertising no evidence of casualty crash reductions was found.

Similarly, during the period July 1996 to June 1997 there were weeks of high-level awareness of general speed-related publicity (including mobile radar publicity) and the strongest effect on casualty crashes was found during the four days after the enforcement was present. However, the effect was not as strong as that experienced when the publicity was specific to mobile radar activity. In fact, the 11% reduction in casualty crashes that occurred during this period was found not to be statistically significant.

The results for the combined period from July 1995 to June 1997 also indicate that the strongest effect occurred when awareness of the general speed-related enforcement was high. However, the 8% reduction in casualty crashes detected was found not to be statistically significant. A comparison with high awareness levels of specific mobile radar publicity over the full two-year period cannot be made given that this type of publicity was only introduced in November 1996.

Finally, the results detailed above should be considered as somewhat conservative given a number of technical decisions that were made relating to the evaluation (Diamantopoulou et al., 1998).

2.4 HAND-HELD LASER SPEED DETECTION DEVICES

The use of laser speed detection devices was introduced in Victoria in 1996 to overcome the difficulties associated with enforcement in busy traffic areas such as arterial roads. The laser devices were operated overtly and aimed to increase the risk of detection rather than the number of speeding vehicles detected. The research conducted on the effectiveness of laser speed detection devices relates to three main areas: the overall effect of enforcement on crashes, the effect of different enforcement levels on crashes and the effect of enforcement activities on crashes on different road types. Each of these will now be discussed in turn.

The laser speed enforcement program has been found to have a positive overall impact on the number of casualty crashes occurring (Fitzharris et al. 1999). A statistically significant 8.28% reduction in all casualty crashes was found during 1997 in the areas where laser speed detection devices were used. In addition, the similar crash reductions found for the two categories of casualty crash suggest that the enforcement program affected the number of crashes rather than the severity of crashes.

In terms of the intensity level of enforcement, the laser speed enforcement program was apparently effective in reducing casualty crashes only for low and medium levels of enforcement. It is noted that, low enforcement is defined as up to three hours of enforcement activity at a given site during the year whereas medium intensity enforcement was defined as more than three but no more than fifteen hours of enforcement at a given site per year.

The final set of results relate to the type of road on which the enforcement activity was carried out. The three road types were defined as freeways, arterial roads and other roads. The laser enforcement program led to a statistically significant 8.23% reduction in all casualty crashes on arterial roads only. The crash reductions on other types of roads were similar in magnitude but not statistically significant. However, the analysis for freeways and other roads was based on relatively few observations and may therefore have statistical power problems.

Finally, it is noted that the results presented in terms of the intensity level of enforcement and road type may have some interaction with each other. In 1997 enforcement intensity was highest on freeways and lower on arterial and other roads. Therefore, the analysis of the effect of laser speed enforcement as it relates to road type will be affected by the differing intensity levels of enforcement for each road type. Similarly, the analysis in respect of the intensity of enforcement will be affected by the road type on which the enforcement took place. Separating these effects has not been possible to date. However, given that the aim of using the laser devices was to provide more effective enforcement in busy traffic areas it was considered more appropriate to focus on the results as distinguished by road type, in particular the results for arterial roads.

2.5 COMPARISON OF OVERT AND COVERT MOBILE OPERATIONS

The second key issue in relation to the operation of mobile speed cameras is the contrast between overt and covert operations. There has been little research directly comparing the impact of the mode of operation on the effectiveness of a mobile enforcement program. However, some evidence does exist and is discussed below.

2.5.1 New Zealand

As detailed above the operation of mobile speed cameras in New Zealand is conducted in a highly visible manner. However, from mid-1997 to mid-2000 a trial of the covert use of speed cameras was conducted in one of the four police regions in New Zealand on roads with speed limits of 100 km/h. This involved adding to existing signage an indication to motorists that hidden cameras may operate in the speed camera areas. In addition to the extra signage, there were high levels of newspaper and radio publicity relating to the trial prior to its commencement. It is also noted that in the first year of operation there was a 26% increase in the operational hours of speed cameras in the trial region. In the second year of operation, the number of operational hours decreased by 13% from the first year level. There were no changes in the operation of speed cameras during the trial period in other areas of New Zealand. In particular, on all roads in non-trial speed camera areas, speed camera operations remained overt. Further, on roads with speed limits of 70 km/h or less in the trial region, speed cameras were operated overtly.

An evaluation of the hidden camera trial in terms of vehicle speeds and reportable crashes demonstrated that during the first two years of the trial, improved road safety outcomes were experienced (Keall et al., 2002). First, average speed in the trial regions decreased by an estimated 1.3 km/h over the first two years of the trial. The speed below which 85 percent of vehicles travelled in the trial region fell by an estimated 4.3 km/h. In addition, reportable crashes in the trial region fell by 11% in comparison to reportable crashes in the control regions. Further, it was found that the number of casualties in the trial region fell by 19% in comparison to casualties in the control regions. The number of casualties per crash fell by 9% on open roads in the trial region compared to open roads in the control regions. It is noted that these results relate to reductions across the treated region and not only at camera sites. This indicates that the covert mobile operations were able to generalise the effect of the New Zealand program beyond the speed camera sites.

Despite the above results it is difficult to draw conclusions from this study on the relative effectiveness of overt and covert automated speed enforcement programs. During the trial period, enforcement levels in the trial region were higher than in the non-trial regions. Further, the number of penalties issued in relation to incidents in the trial areas increased four fold (Keall et al., 2002). Therefore, based on previously established relationships between speed enforcement and crashes (Cameron et al., 1995), it is not unexpected that improvements in road trauma would occur as the level of enforcement increases. Nevertheless, the authors point to three factors which they believe together support the conclusion that the introduction of covert speed cameras influenced the casualty crash reductions. First, the fall in the frequency of casualty crashes coincided with the introduction of the covert program. Second, mean and high percentile speeds fell significantly during the trial. Finally, the reduction in the number of casualties per crash also confirms that speeds fell during the trial period.

2.5.2 Victoria

To clarify the comparative effect of covert and overt mobile speed enforcement operations, it is useful to examine some related Victorian research although it is noted that it does not relate directly to mobile speed cameras.

The effect of mobile (moving mode) radar speed detection devices on road trauma in rural Victoria has been examined in terms of the type of enforcement operation. That is, the effect of covert (unmarked car), overt (marked car) and mixed (marked and unmarked cars) mobile radar operations has been examined to identify any differences between the outcomes of different types of enforcement activity (Diamantopoulou and Cameron, 2001).

The analysis was conducted using crash data from July 1995 to June 1997 which was divided into two periods. These periods were July 1995 to June 1996 and July 1996 to June 1997 and corresponded with the use of 48 and 73 mobile radar devices respectively.

Analysis was also conducted on the two periods combined when up to 73 mobile radar device were in operation.

A net 20.7% reduction in casualty crashes occurring one to four days after a *covert* enforcement presence was identified during the period from July 1995 to June 1996. The presence of *overt* enforcement also had a positive effect on crashes occurring one to four days after enforcement however, the effect was less pronounced. During the period from July 1996 to June 1997, the largest reductions in casualty crashes occurred following mobile radar enforcement operations involving *both* marked and unmarked police cars. This effect was greatest on the day on which the enforcement activity took place (40.2% reduction).

The results of the combined period in which up to 73 mobile radar devices were in operation found that the most significant reductions in casualty crashes occurring one to four days after enforcement resulted from *covert* mobile radar enforcement. However, a mix of overt and covert enforcement was also found to be effective in reducing casualty crashes during this period.

It is noted that the crash reductions presented above are not statistically significant. Nevertheless the results are indicative of the likely relationships between overt, covert and mixed mobile radar enforcement and casualty crashes in rural Victoria.

3 FIXED SPEED CAMERAS

Fixed speed cameras operate extensively in a number of jurisdictions. In Australia, evaluations of the fixed digital speed camera program in NSW and fixed speed cameras on tollways operated by CityLink in Victoria have been conducted. Internationally, there have been several evaluations of the use of fixed speed cameras in the U.K. Each of these programs will now be considered in turn.

3.1 UNITED KINGDOM

Speed cameras were first introduced in the UK in 1992. Currently, speed camera operations in the UK are predominately fixed rather than mobile, however, the exact number of speed cameras currently in use is unclear. Regardless of the type of speed camera in use, speed cameras must be operated overtly with strict regulation surrounding the visibility of camera sites. Further, since April 2000, speed cameras and red-light cameras, collectively known as safety cameras, have been operated under cost recovery partnerships enabling local authorities to recover enforcement costs through fine revenue. The introduction of cost recovery partnerships enabled widespread, coordinated data collection and has led to the regular evaluation of the safety camera program. The most recent evaluation examines the first fours years of operation of the cost recovery partnerships including the impact of the safety camera program on both speeds and casualties at camera sites (Gains et al., 2005). The evaluation considers data from 38 participating partnerships that had been operational for at least one year at the time of the evaluation.

Examining the program in terms of casualty effects, there was an estimated 42% reduction in the number of people killed or seriously injured at the camera sites over and above that which might ordinarily be expected. Further, casualty crashes (where at least one participant was at least slightly injured), were estimated to have fallen by 22%. The authors state that the above reductions are slightly over-stated due to regression to the mean effects that resulted from the analysis method. Estimates of the extent of this effect indicate that, whilst it does account for some of the estimated casualty reduction, safety cameras still result in substantial improvements in casualty frequencies. Interestingly, the casualty and crash reduction experienced were greatest at fixed camera sites with somewhat lower reductions experienced at the mobile camera sites. This result is consistent with those found in earlier evaluations of the UK safety camera program (Gains et al., 2003). The earlier study also showed much greater reductions in the proportion of vehicles exceeding the speed limit at fixed camera sites compared to mobile camera sites which may help to explain the greater crash reductions experienced at these sites.

The program was estimated to have a similarly positive impact on speeds at the camera sites. Across the 38 partnerships a total of 20,000 speed surveys had been collected over the four year implementation period. Analysis of this data estimated an average speed reduction of 6% (2.2 mph) at new sites with the reduction being greater at site with speed limits of 30 or 40 mph (7%) compared to sites with higher speed limits (3%). Excessive speed (15 mph more than the speed limit) fell by an average of 51% at new speed camera sites with the effect being greatest at fixed camera sites (91%) and lowest at mobile camera sites (36%).

It is noted that the estimates of effect discussed above are attributable to a combined speed camera and red-light camera program.

Finally, in addition to the impact of the fixed speed camera program on casualty crashes at the camera sites, earlier studies of the program indicated that the effects of the overt cameras may generalise across the whole of the trial areas, with the average number of fatal and serious injuries in each trial area being 4% below the long-term trend in serious road trauma in the rest of Great Britain (Gains et al., 2003). While the camera sites were located in speed-related "accident hot spots", the density of their locations and/or their threat to speeding motorists appeared to be sufficient to produce a general effect which extends beyond the camera sites. This result has not been identified in the later evaluations of the UK safety camera program.

3.2 VICTORIA

Fixed speed cameras were first introduced in Victoria on CityLink and the Monash freeway in 2000. Since that time further fixed speed cameras have been positioned on other major freeways and highways in Victoria, however the operation of these cameras and their potential impact on crashes has not been evaluated in detail. Further, the effectiveness of the fixed speed cameras positioned on CityLink has been evaluated only in terms of the impact on vehicle speeds in the Domain tunnel (Diamantopoulou and Corben, 2001). The overall effect of the fixed-position speed cameras was to reduce the proportion of those drivers exceeding the speed limit and to reduce the average speed of vehicles in the tunnel. Average vehicle speeds fell from 75.05 km/h to 72.50 km/h. The proportion of drivers exceeding the 80 km/h speed limit fell by 66%. In addition, the proportion of drivers exceeding speeds of 90 and 110 km/h were also significantly reduced by 79% and 76% respectively. Previous research has highlighted the relationship between speed and casualty crash risk reductions .

3.3 NORWAY

Automatic speed enforcement was first introduced in Norway in 1988 and is operated in an overt manner. Photo radar units are mounted in roadside boxes and notification of their presence is by way of roadside signs on the enforced section of road. The speed cameras do not operate at all times, however, it is not possible for a driver to determine whether a camera unit is in operation when approaching or passing it. Since 1993 the selection of camera locations has been subject to three criteria relating to the crash rate, injury crash frequency per kilometre of road per year (crash density) and the mean speed at the enforcement site. Not all operational speed camera sites meet these three criteria. An evaluation of the effectiveness of this form of automated speed enforcement has been completed by Elvik (1997).

The evaluation considered 64 sections of road totalling 336.3 km in length. Due to the lack of available speed data the results are presented primarily in terms of crash reductions attributed to the automated speed enforcement and speed reductions are not considered in detail. Further the author was unable to determine those enforcement sites that met the criteria for selection on the basis of the mean speed at the site. The principal result of the analysis was that across all 64 road sections there was a statistically significant 20 percent reduction in the number of injury crashes. More detailed analysis was also conducted on the basis of compliance of the road section with the criteria for selection as a speed camera location. The results suggest that greater injury crash reductions are experienced at those speed camera sites meeting the criteria for selection as a speed camera site (26%) than at crash sites not meeting the criteria for selection (5%). That is, the greatest crash reductions were achieved at those sites experiencing higher crash frequencies and densities prior to the commencement of enforcement.

Unfortunately, as noted by Elvik no data was available concerning the frequency or duration of enforcement using these cameras. However, it is clear that the cameras did not operate at all times. Therefore, it is not possible to directly estimate the effectiveness of this type of overt speed camera enforcement per unit area per hour of operation.

3.4 NEW SOUTH WALES

Fixed digital speed cameras were first introduced in NSW in 1997 in the Sydney Harbour Tunnel. By 2005, the fixed digital speed camera program had grown to include at least 111 cameras (ARRB, 2005), all operating overtly with three signs advising of camera operations placed on approaches to speed camera locations. Sites for fixed digital speed cameras are selected on the basis of crash rates, crash severity and travel speeds at the camera location and the digital technology used enables the cameras to operate up to 24 hours a days (RTA, 2006).

An evaluation of the crash effects of the fixed digital speed camera program was conducted using a representative sample of 28 fixed digital speed camera sites (ARRB, 2005). The authors used a quasi-experimental before and after, treatment and control design. The analysis estimated that across the 28 camera sites examined there was a 22.8% statistically significant reduction in casualty crash frequency along the camera road length (usually 1-3 kilometres surrounding the camera site). When estimating the crash effect across both the camera road length and adjacent road lengths there was a non-statistically significant casualty crash reduction of 7.8%. All casualty crash reductions were estimated for the two years following the installation of the fixed digital speed cameras. Statistically significant estimates of fatal crash reductions were also calculated (89.9% on camera road lengths) however the associated confidence limits were wide (22.1-98.7%). Nevertheless, the result was statistically significant and indicates that the fixed digital speed cameras did reduce the incidence of fatal crashes occurring on the speed camera road lengths with the best estimate of the reduction being 89.9%. Marginally statistically significant fatal crash reductions were also estimated for the combined camera and adjacent road lengths.

3.5 POINT-TO-POINT SPEED CAMERAS

Point-to-point speed cameras operate to measure a drivers' average speed across a length of road and/or the spot speed at individual camera sites along the road length. A number of cameras are mounted at staged intervals along a particular route and are linked to measure the time taken to travel between at least two given points. The distance between two camera sites may vary from as low as 300 meters to up to tens of kilometres and an enforcement threshold may be implemented in a similar manner to mobile or fixed speed camera operations.

To date, few evaluations of point-to-point speed camera enforcement have been published. Indeed, it is believed that within Australia, point-to-point speed camera enforcement is operating on a trial basis only. However, in the U.K., point-to-point camera technology, using digital imaging, was installed on Nottingham's main link road from the M1 Motorway in July 2000, as part of a trial program of additional speed cameras in eight Police areas. Two cameras were mounted along the enforced 40 mph road length approximately 0.5 kilometres apart.

The evaluation of the trial found that fatal and serious injuries fell by 31% at camera sites in the Nottingham area, and that the results from the point-to-point camera site were not significantly different from the general effect (Gains et al., 2003). In a comparison with traditional wet-film spot-speed fixed cameras, Keenan (2002) found that reported casualty crashes at the Nottingham digital camera site fell from 33 during the year before installation to 21 during the year after, a reduction of 36%. In addition, both mean and 85th percentile speeds were below the 40 mph speed limit along the 0.5km road length enforced by the two cameras. In contrast, crashes at the spot-speed camera sites studied appeared to increase, but not statistically significantly so.

Commenting on the relative merits of the new technology, Keenan (2002) noted that the spot-speed fixed cameras have a site-specific effect whereas the point-to-point camera system has a link-long influence on drivers and their speeds despite enforcement being visible only at the start and end of the enforced road length. Further, Keenan (2002) noted from his study that "around the [spot-speed camera] sites a significant proportion of the drivers observed manipulated their behaviour in close vicinity to the installations, suddenly applying their brakes 50 metres before the camera and then promptly accelerating away from it. Most alarming was the fact that the accident statistics at some of the [spot-speed camera] sites had worsened since the camera installation". While the crash data were probably too few for Keenan to claim that the situation had worsened, it is possible that any speed and crash reduction benefits at the overt fixed spot-speed camera sites were eroded by some drivers behaving in the way Keenan suggests. However, given the policy in the U.K. of making fixed camera sites conspicuous and the placing of advance camera warning signs a requirement of the scheme, there should be less likelihood of drivers being taken by surprise. This effect may be even less likely to be a significant consequence of the point-to-point camera systems.

4 SUMMARY OF SPEED ENFORCEMENT IMPACTS

4.1 OVERVIEW OF EFFECTIVE ENFORCEMENT OPERATIONS

All modes of speed enforcement discussed above have led to at least some positive impact on either casualty crash frequency, crash severity or driver behaviour (as measured by speed). In most cases this effect has been significant. However, whilst many of the enforcement programs share similar traits, there are also some significant differences in the programs. These differences centre around the technology used, whether the operations are overt or covert, the intensity of operation and the target crash population. It is suggested that it is some of these differences that influence the effectiveness of the enforcement programs in the road environments in which they operate. In this context the research suggests the following conclusions:

- The covert operation of mobile speed cameras is effective in reducing casualty crash frequency on arterial roads metropolitan areas and country towns and, to a lesser extent, on highways in rural areas. These devices are also effective in reducing crash severity in metropolitan areas.
- The overt operation of mobile speed cameras is also effective in reducing casualty crash frequency. The impact of the speed camera is greatest closest to the camera site and diminishes with distance from the speed camera site.
- The overt and semi-overt operation of fixed speed cameras has been shown to be effective in reducing casualty crashes in black-spot areas.
- Mobile radar devices are effective in reducing casualty crashes in rural areas on undivided roads in 100 km/h speed zones. Analysis of the effects of mobile radar devices in outer metropolitan areas was inconclusive.
- Hand-held laser speed detection devices are effective in reducing casualty crash frequency, but not severity, on arterial roads in metropolitan Melbourne.
- The Random Road Watch program is effective in reducing crashes of all severity levels in non-metropolitan areas. The effect of the program in metropolitan areas is unclear.
- Initial evaluation of point-to-point speed cameras measuring average speeds along a road length indicate the potential of this technology to effectively treat speeding issues along a road length.

The duration of the impact of speed enforcement is another important factor to consider in planning enforcement operations. The analysis of mobile speed cameras and mobile radar devices in Victoria has produced important results in this area as there are some key differences in the operation of these devices. First, the use of speed cameras in Victoria is largely covert and infringement notices issued as a result of speed camera operations are usually received one to two weeks after the offence occurs. In addition, speed cameras are able to detect large volumes of speeding motorists per enforcement hour. In contrast, an offender detected speeding by a mobile radar device is issued with an on-the-spot fine in a deliberately overt manner. Also, the volume of speeding motorists detected by mobile radar devices per enforcement hour is lower than that for speed cameras. Differences in the duration of the enforcement effects are also evident. Speed camera enforcement operations have been shown to impact upon casualty crash frequency during the two weeks after the infringement notices are received. The exact duration of the effect is unclear. On the other hand, mobile radar enforcement was found to have the greatest effect during the four days immediately following the enforcement operations.

Finally, fixed speed cameras generally operate on a continuous basis and where this is not the case, drivers are unable to determine whether a fixed camera is in operation. Therefore it is not reasonable to discuss the duration of the enforcement effects of fixed speed camera operations as the enforcement is never perceived to be removed.

Although it is unclear which of the differences between the mobile speed camera and mobile radar enforcement programs result in the different duration of the enforcement effects, it likely that the duration of the effect of overt speed enforcement programs resulting in visible issuance of on-the-spot fines issued at the time of the offence is likely to be more immediate but shorter than the effect generated by a delayed issuance of infringement notices resulting from covert operations which detect many offences per enforcement hour.

4.2 EFFECTS OF OVERT SPEED ENFORCEMENT

As with any form of enforcement program, the effectiveness of overt speed enforcement may be due to the effect of specific deterrence, general deterrence or some combination of the two. There appears to have been some conflict as to whether overt enforcement has a significant general deterrence effect. Given the extensive use of overt speed enforcement in many jurisdictions some discussion of this issue is necessary.

First it is noted that the initial introduction of the speed camera program in Victoria involving the overt use of mobile cameras had no overall impact on casualty crash frequency. In addition, some research indicated that no relationship between the amount of enforcement seen by drivers and a driver's perceived risk of detection could be found. These results indicate that overt speed enforcement operations may not have a general deterrence effect.

On the other hand, more recent research relating to laser speed detection devices found that the use of these devices resulted in a significant decrease in casualty crashes. This supports the proposition that overt enforcement activity can have a significant impact on casualty crashes and has a general deterrence effect that may be localised in space. Further, early evaluations relating to the overt use of fixed safety camera in the UK suggested that the influence of these cameras extended beyond the speed camera sites. It is noted that this effect has not been noted in more recent evaluations of the UK safety camera program.

In addition to the localised, general deterrence effect of overt speed enforcement, it has been suggested that some forms of speed enforcement have a specific deterrence effect. This effect is primarily used in the Victorian speed camera program where the receipt of TINs and has been shown to impact on subsequent speeding behaviour, and consequently on the number of casualty crashes occurring. Early research relating to the period from 1990 to 1993 showed that the receipt of TINs for speeding offences resulted in reductions in casualty crashes. However, similar analysis using data from 1994 to 1996 found evidence of reductions in crash severity but not crash frequency as a result of the receipt of TINs.

The change in the effect of the receipt of TINs suggests that the specific deterrence effect of speed camera enforcement may have declined over time. This decline may be in part due to changes in the public's attitudes towards receiving TINs. The public may have become accustomed over time to receiving TINs and consequently may no longer adjust their driving behaviour. Alternatively, the magnitude of the penalties may not have been sufficient to deter speeding behaviour. Further research into this area is required to determine whether speed enforcement programs continue to have adequate specific deterrence effects.

4.3 SUMMARY OF SPEED CAMERA OPERATIONAL MODES AND THEIR EFFECTS

The variety of modes of operation of speed cameras available in practice is a key issue for developing an effective speed enforcement strategy for WA. Table 1 shows the diversity of modes of operation of speed camera systems in the Australian states, New Zealand and Great Britain, most of which have been described in previous sections along with evidence of their effectiveness.

Table 1: Diversity of speed camera operations in Australasia and Great Britain

	Overt operations	Covert operations
Fixed installations, usually signed (fixed cameras)	New South Wales Great Britain	
Known fixed sites - "accident black spots" (mobile cameras)	New South Wales Western Australia South Australia Great Britain	
Fixed sites, randomly allocated cameras (mobile cameras)	Queensland	
Signed speed camera zones (mobile cameras sometimes)	New Zealand	New Zealand hidden camera trial (1998-2000)
Unsigned sites or zones (mobile cameras)		Victoria (also some unsigned fixed cameras since 2000)

Table 2 summarises the effects on crashes at different levels, and the effects on crash injury severity, which have been found in scientific evaluations of the speed camera systems in the above table. Speeding can affect both crash risk and the injury outcome, so many studies have measured two crash criteria reflecting this dual role of speed. A distinction is drawn between whether the research has found the crash effect to be localised around the speed camera site (local effect), whether the effect is generalised over the jurisdiction (general effect), or whether both effects have been evaluated.

Table 2: Measured effects of speed cameras on crashes and crash injury severity (percentage reductions in road trauma shown as negative values)

	OVERT OPERATIONS		COVERT OPERATIONS		
Type of site: **Effects On crashes:**	**Fixed installations, known fixed sites, signed sites/zones**	**Fixed sites, randomly allocated operations**	**Signed sites or zones**	**Unsigned sites or zones**	**Unsigned sites, "flashless" cameras, lower enforcement tolerance**
Jurisdictions operating automatic cameras in this way	Great Britain New Zealand New S. Wales W. Australia S. Australia	Queensland (3000 hours per month)	New Zealand **(hidden camera trial)**	Victoria to 2000/2001 (4000 hours per month)	Victoria 2001/2002 onwards **(50% incr. in hours)**
Serious casualty crashes	Local effect [GB]: - 65% (fixed cameras) -28% (mobile cameras)	Doubling camera hours (2003) - Added general effect: - 9%			
Serious casualty crashes	Local effect [NZ]: - 23% (mobile cameras). General effect: - 13%				
Casualty crashes		Local effect: - 35%. General effect: - 26%	Added general effect: - 11%	General effect: -21% (- 32% in Melbourne)	Added general effect: - 3.25% (due to incr. hours)
Casualties per casualty crash			Added general effect: - 9%		
Serious casualties per crash				General effect: - 21% (Melbourne)	
Fatalities per crash					Added general effect: - 51% (due to incr. hours)
Material damage crashes		Local effect: - 20%. General effect: ≈ - 10%			

Regrettably, no crash-based evaluation of the WA speed camera program, which has operated since the mid 1980's, has been found in the published literature. Cameron (1999) specified a number of evaluation criteria defining speed-related crashes and recommended that these be used to evaluate the effects of the speed camera program across the road system and specifically at camera sites. A recommendation for an annual survey of speeding behaviour at general locations on WA's roads was implemented by the Main Roads Department in 2000 (baseline survey) and has been replicated in 2003, 2004 and 2005 (Radalj 2006). This recommendation was made because speeding behaviour measured at speed camera sites, by the cameras themselves, was considered to be a biased and unreliable indicator of speeds generally (though the data measured by the cameras may provide Police evidence that enforcement should continue at the particular location).

The MRD speed surveys provide the best evidence of the effects of the WA speed camera program since the year 2000. During the period 2000 to 2004, the number of camera hours in metropolitan Perth was essentially constant (perhaps slightly decreasing), making their effects difficult to detect, whereas the annual camera hours in rural WA fluctuated substantially and increased by 67% between 2003 and 2004 (Palamara and Bosch 2005a). Related to the increased hours, the number of vehicles assessed for speed by the cameras increased by 130% between the two years, suggesting that the overt cameras were sited at more highly-trafficked locations and hence could have been expected to be noticed more and have a greater effect. In practice, the speed survey results for rural WA showed that the proportion of drivers exceeding speed limits by at least 10 km/h rose from 5.1% to 6.2% between 2003 and 2004. However, the survey results were not specifically focused on the areas where most of the increase in camera hours occurred (Bunbury and Peel).

While this indicative result does not represent definitive evidence of a weak effect of the WA speed camera program in rural areas, it does suggest that with the limited camera-based resources to enforce speeding in those areas (three Multanova units) it is difficult for the WA Police to make a substantial impact, at least under current operational conditions. This contrasts with the very positive results for programs in other jurisdictions (Table 2) and suggests that the WA speed camera program is not operating in a mode and/or intensity which represents best practice, at least for rural speed enforcement. As outlined above, it is not possible to comment on the effectiveness of the program in metropolitan Perth. Further discussion of the operational characteristics of the WA speed camera program is given in the following chapter.

4.4 QUALITY OF SPEED ENFORCEMENT RESEARCH

It is the aim of this study to examine existing practices in key Australian states and overseas jurisdictions to inform the development of recommendations that will optimise the safety impact of speed enforcement in WA. This requires detailed knowledge of the mode of operation and robust evaluations of the effectiveness of speed enforcement programs. This review identifies many studies relating to the effectiveness of speed enforcement operations conducted using a variety of technology, operational modes and intensity. Many estimate the casualty crash effects of the programs and some are able to estimate the specific effects on serious and/or fatal crashes. A discussion of the key implications of existing research as it relates to different enforcement modes is provided above.

However, to generate a comprehensive and robust speed enforcement strategy, there remains some important missing information in many of the studies examined above. In particular, it has been difficult to gain sufficient information to enable the consistent estimation of enforcement effects per unit area per time unit of operation. Where sufficient information is available to enable this calculation, the information has had to be gathered from a variety of sources that are not necessarily compatible in time. The lack of this information in relation to all modes of speed enforcement will necessitate a number of compromises in the second stage of this project and the development of advice on the optimum mix of speed enforcement technologies. Nevertheless, it is believed that sufficient information will be available to provide adequate guidance on these matters.

The lack of information available in relation to some aspects of speed enforcement programs and the associated impacts on the quality of existing evaluation research has been considered as part of a recent systematic review of studies related to the effectiveness of speed cameras (Pilkington and Kinra, 2005). This review considered in some depth the quality of research in this area. The authors identified 21 relevant studies related to speed camera enforcement of which 14 provided sufficient information to be included in the final review of quality. These studies were conducted between 1992 and 2003 and considered the impact of speed camera enforcement on collisions, deaths and injuries. The author's assessed the quality of the studies on the basis of the following characteristics:

- The representativeness of the study areas to the general population
- Control areas being representative of intervention areas
- Objective and valid outcome measure provided with estimates of uncertainty
- The main conclusions based on study hypothesis; and
- Important confounders measured and controlled for.

Based on these criteria, the authors classified no studies as being of good quality methodologically, seven as average, two as average-poor and five as poor. The authors recognise that the lack of evaluation research of the highest quality is influenced by the practical difficulties of implementing speed enforcement programs in a way that enables robust evaluation. For example, the implementation of randomised controlled trials in the speed enforcement domain may be problematic due to resource availability, political and ethical concerns. The authors suggest that the next best approach would be to introduce speed enforcement in a phased manner thereby enabling the collection of before and after casualty crash data and the estimation of the effects of increasing the intensity of enforcement. Studies of this nature have been conducted and are included in this review.

A recommendation for the implementation of new speed enforcement regimes in a manner which their effects on speeds and road trauma can be evaluated is a logical consequence of the above concerns about the quality of available speed enforcement research. As can be seen, the available research on the effects of this important behaviour change area leaves much to be desired as the basis of future strategic advice and, where possible, implementation should give consideration to allowing definitive scientific evaluation to be carried out.

5 OPTIONS FOR SPEED ENFORCEMENT IN WA

A speed enforcement strategy for WA needs to recognise the vast size of the State and also its relatively light traffic density compared with other Australian states. The area of WA is more than ten times that of Victoria and even 46% greater than Queensland. While the length of each state's road systems are of the same order of magnitude, the traffic density in Victoria is nearly 30 times higher and even in Queensland it is nearly 2.5 times the WA density. However the proportion of total travel in urban areas in WA (63%, mainly in Perth) falls between the proportions in Victoria (71%) and Queensland (37%).

For these reasons a range of speed enforcement options have been considered for WA which reflect their relative suitability for the different road environments, the evidence of their effectiveness, and the existing enforcement technology already held and operated by the WA Police Service. Ultimately each of these options will be subjected to cost-benefit analysis to determine the optimal level at which each speed enforcement method should be operated in WA and also the relative priority for each method in the overall program. The analysis will also consider the operating costs of the existing capacity to process speed offences recorded photographically or by on-the-spot fine notices as part of the economic assessment of each speed enforcement method.

5.1 EXISTING SPEED ENFORCEMENT METHODS IN WA

The Multanova 6f speed camera system is the principal method for the detection of speed offenders in WA, detecting over 616,600 offenders in 2004 compared with about 303,000 offenders detected by non-photographic methods (mobile radar units, which can also be operated in stationary mode, and hand-held laser speed detectors). A small number of hand-held radar units also exist, but apparently laser units are now favoured for hand-held operation. The WA Police Service provided details of the number of units, costs, operating staff and support vehicle requirements, vehicles assessed (in the case of the cameras) and offences detected per annum, offence processing staff numbers and costs, and offence processing equipment costs (see Appendix A). This resource cost information will be used in the cost-benefit analysis of each of the speed enforcement options for WA (see later chapter).

The Multanova speed camera operations have a number of characteristics which make them overt in nature and focused on "black spot" sites, as follows:

- Tripod-mounted system operated at the roadside with no attempt to hide the system, a method which is understood to be overt, at least during daylight
- Signage advising drivers that they have passed a camera in operation
- Public announcement of the date and route of camera operations (specifying only the suburb and road name, many of which are arterial roads traversing the suburb over many kilometres) through television and press news segments
- Sites selected on the basis of the following criteria:
    - locations subject to crashes, based on reported crash records
    - locations of "speed-related complaint" from the public
    - locations frequented by vulnerable pedestrians
    - locations where speeds need to be reduced by at least 5 km/h

- locations where other speed detection methods cannot be used safely.

The non-photographic methods of speed enforcement are used in similar ways to that used in other jurisdictions, as described in sections 2.3 and 2.4 of this report. Mobile (moving mode) radar units are most often used in rural areas of WA whereas the hand-held laser speed detectors can be used in both urban and rural traffic environments. Both of these non-photographic methods require interception of the offending driver, issuing of an appropriate penalty notice usually on-the-spot, and subsequent processing of the notice. There are also opportunities for the Police to detect other traffic or criminal offences during these interceptions, which may require other procedures to be undertaken.

5.2 OTHER SPEED ENFORCEMENT OPTIONS

The following options for speed enforcement operations are proposed for consideration in WA and will be further analysed in the next stage of this project. These options are proposed because of clear evidence of their effectiveness when operated in appropriate road environments, but final recommendations must await further analysis to determine their relative cost-effectiveness when operated at optimal and feasible levels. At this stage, many of the proposed enforcement options overlap in terms of the road environment covered, but it is envisaged that this will not be the case in the recommended speed enforcement package for WA.

5.2.1 Covert mobile speed cameras

There is clear evidence from Victoria that covertly-operated car-mounted mobile speed cameras have a general effect on casualty crashes and, separately, the risk of fatal outcome of those crashes. The evidence is strong for operations in urban areas but weaker for operations on rural highways. This is probably because the operations are most suitable for operation on roads where parked cars are not unusual and the presence of the camera-car does not betray its purpose. For this reason it is proposed that covert mobile speed cameras be considered particularly for urban arterial roads, which lie principally in Perth.

The proposed operations would have the following characteristics:

- Car-mounted system in unmarked car using a variety of popular makes/models
- "Flashless" operations when ambient light permits (or digital technology allows)
- No advance warning or departure signs
- No public announcements of camera locations or camera presence
- Sites identified by "black spot" criteria, similar to current site selection in WA. It is understood that there are about 6000 current sites in WA, with about 1500 in regular use. A broad coverage of the focus road system is important, but a focus on black spot sites is less critical in the case of covert speed camera operations.

During 2005, 13.98% of traffic on urban highways in Perth with 60 km/h speed limits exceeded the limit by at least 10 km/h (Radalj, 2006, personal communication). This is substantially higher than the proportion exceeding speed limits by 10 km/h in Perth generally (7.89%). The proportion on urban highways with 70 km/h limits was also relatively high (10.66%), further supporting the need for speed enforcement to be focused on urban arterial roads in Perth.

5.2.2 Overt mobile speed cameras with randomised scheduling

The overt operation of mobile speed cameras in Queensland, where the operations are randomly scheduled across time and space, has also been clearly shown to reduce casualty crashes and, to a much lesser extent, material-damage-only crashes. The effect on crashes appears to be principally a local effect within 2 km of each speed camera site, for a substantial time after each camera operation. This is apparently because the random scheduling increases drivers' perceived risk of detection with long duration. A general effect across the focus road environment is apparently achieved by choosing sites so that the collective areas within 2 km of each site cover a high proportion of crash locations (e.g. 83% coverage by Queensland speed camera sites in 2002). Apart from this, the sites are not necessarily speed-related "black spots" as, for example, currently defined in WA (where criteria in addition to high crash frequencies are used to select speed camera sites, but it is unclear what weight is given to these additional criteria).

It is proposed that overtly-operated mobile speed cameras be considered for operation in this way in WA, but separately analysed for Perth and rural WA to determine their suitability in each of these environments. Because of the need for operational sites to cover a high proportion of crashes within 2 km, it is proposed that the focus roads be Perth arterial roads (highways) and rural highways (but not local roads) outside Perth. Because these are relatively highly-trafficked roads in each environment, sites on them could be expected to be found covering a high proportion of crashes on or near the road within 2 km. However, a new set of speed camera sites may need to be defined for WA, based solely or principally on crash frequencies within 2 km of the selected sites.

The proposed operations would have the following characteristics:

- Conspicuous camera system, either mounted in a designated van or car, or tripod operations used more overtly than in WA at present
- Signage within 10 metres of an operating site advising of camera presence
- No public announcements of camera locations or camera presence
- Numerous sites chosen such that at least 80% of casualty crash locations during the previous three years are covered by areas within 2 km of camera sites
- Random allocation of camera shifts to sites and time blocks (four hours each, excluding late night/early morning), with very limited opportunities for actual operations to depart from the random assignment.

The relatively high proportion of traffic exceeding speed limits by at least 10 km/h on Perth arterial roads during 2005 has been described above in the context of the proposal for covert mobile speed camera operations on these roads (section 5.2.1). In rural WA, the proportion exceeding speed limits by 10 km/h on highways during 2005 was 6.45%, which is typical of such speeding behaviour on rural roads generally (not surprisingly, since highways carry out 70% of rural traffic, the remainder travelling on rural local roads).

5.2.3 Covert mobile speed cameras on publicly announced routes

Experience from New Zealand suggests that there are additional benefits from operating covertly previously overtly-operated cameras in road sections where speed cameras are known to operate (designated speed camera zones in New Zealand's case). The principally localised effect appeared to spread beyond the camera zones to have a general effect across the whole police region in which the hidden cameras operated.

In WA the public announcement of the substantially-long routes on which speed cameras will operate sometime during the next day effectively defines a "speed camera zone" (and has the advantage that these zones are not fixed in time and space). It is proposed that the covert operation of mobile speed cameras within these publicly announced routes be considered and analysed further in the next stage of the project. It is expected that a general effect on crashes would extend the likely localised effect of the WA speed camera program and add to any existing general effect.

The proposed operations would have the following characteristics:

- Car-mounted system in unmarked car using a variety of popular makes/models
- "Flashless" operations when ambient light permits (or digital technology allows)
- No advance warning or departure signs
- Public announcement of the date and route of camera operations (specifying only the suburb and arterial road name traversing the suburb) through television and press news segments
- Sites selected on the basis of speed-related "black spot" criteria.

This proposed speed camera option has the advantage of departing from current speed camera operations only by making fully covert the current "semi-covert" camera operations. The social acceptability of continuing to announce the date and route of camera operations, and continuing to focus on speed-related black spots (which many believe is intuitively appropriate), may offset any negative reaction to the camera operations becoming covert. The disadvantage is that the proposed option is unlikely to have a general effect as large as a covert mobile speed camera program with no public announcements of camera locations (option 1 above) based on the New Zealand experience.

It is envisaged that operations would focus on the same road environment as the current WA speed camera system, which is understood to be principally urban arterials in Perth and rural highways. The extent of traffic travelling at excessive speeds on these roads during 2005 has been previously described in sections 5.2.1 and 5.2.2 above.

5.2.4 Mobile radar units on rural highways and local roads

Moving mode (mobile) radar-based speed detection units are currently in operation in WA, principally in rural areas. Mobile radar units mounted in patrol cars have been shown to reduce casualty crashes on undivided rural roads in Victoria. Their use is generally constrained to lightly-trafficked undivided roads because of the need to intercept an offending driver, commonly involving a U-turn by the patrol car. The clearest effects on crashes arise from operations when the patrol car is operating covertly (unmarked car) and from a mixture of marked and unmarked cars on highways in the same region. The effect appears to generalise across all undivided highways in the area and to take effect 1-4 days after the enforcement operation (perhaps also on the day of operation).

It is proposed that mobile radar units be analysed for consideration of increased operations on undivided highways and local roads in rural WA. The ability of these operations to influence speeds and crashes across long sections of rural road potentially make these operations more suitable for local roads in WA than randomly-scheduled overt mobile speed cameras (option 2 above) because of the latter's need to be based on sites covering a high proportion of crashes within 2 km. The limited measured duration of the operations' effects to a maximum of four days will require the mobile radar units to be scheduled carefully so that they can maintain an ongoing influence across all undivided roads in the region.

The research on mobile radar operations in Victoria has shown a strong synergy with mass media publicity (principally television-based) with speed-related themes, particularly publicity with messages about the enforcement operation. It is beyond the scope of this project to consider the cost-effectiveness of the combination of various levels of mobile radar operations and the publicity support, but it should be noted that the effectiveness of the enforcement can be enhanced by carefully scheduled publicity if required.

The extent of traffic travelling at excessive speeds on rural highways during 2005 has been previously described in section 5.2.2. On rural local roads, the proportion of traffic exceeding speed limits by at least 10 km/h was 8.17%, which was substantially higher than the proportion on rural roads generally (6.70%). This supports the need for a method of speed enforcement in rural WA which is most suitable for the vast extent of the lightly-trafficked local road system on which speed cameras may not be able to operate cost-effectively.

5.2.5 Laser speed detectors on urban local roads

The research on overtly-operated hand-held laser speed detectors showed they were successful in reducing casualty crashes on arterial roads (and perhaps local streets) in Melbourne when conducted at low- to medium-intensity levels (sessions typically less than one hour, for up to 15 hours per site per year). The results suggest that this overt mode of speed enforcement has a general deterrent effect that is limited to the location at which enforcement activity is observed. To expand the general effect, an extensive geographical coverage is required. Low- to medium-intensity, overt laser speed enforcement (defined as up to 15 enforcement hours per site per year) at multiple sites will have a greater effect on crashes than high intensity enforcement at fewer locations.

While the strongest findings of the research related to arterial road operations, it is proposed to consider and analyse the cost-effectiveness of using laser speed detectors on urban local roads, principally in Perth. Three other, camera-based, speed enforcement options have already been proposed for consideration on urban arterial roads. These camera-based options are generally unsuitable for use in lightly-trafficked urban streets for various reasons described above. Because of the extent of the local street system in urban areas, the operations will need to be scheduled across very many sites, probably with low intensity per site, to provide a general effect on crashes in this road environment.

The proportion of traffic exceeding the speed limit by at least 10 km/h on Perth's local access roads during 2005 was 18.32% on 50 km/h speed limit roads and 8.60% on the 60 km/h limit roads (Radalj, 2006, personal communication). The relatively high extent of excessive speeding in this road environment compared with other urban areas provides support for a method of speed enforcement focused on these roads.

5.2.6 Fixed speed cameras on Perth freeways

Fixed speed cameras have not been shown clearly to have anything other than a local effect on crashes, nevertheless the measured effects are very substantial, especially the effects on fatal and serious injury crashes. For this reason they are most suitable for use on highly-trafficked high-speed roads such as urban freeways, where other forms of speed enforcement such as mobile camera units at the roadside present a danger to the operators and the traffic itself.

It is proposed that fixed speed cameras be considered for use on freeways in Perth, and the density of their placement be analysed in the next stage of this project. Experience from the U.K., where the use of overtly-operated fixed speed cameras is extensive and their effects on crashes have been analysed, is expected to be most relevant. The limited experience with fixed cameras on freeways in Victoria, and on rural highways in New South Wales, is also expected to contribute.

Unfortunately there is no recent information on the extent of excessive speeding on Perth's freeways as this road environment has not been included in the Main Roads Department's surveys of general speed behaviour on WA roads (Radalj 2006).

5.2.7 Point-to-point speed camera systems on highly-trafficked rural highways

While overt fixed speed cameras measuring "spot" speeds appear to be very effective in reducing speeds and road trauma at specific sites, in general they do not influence drivers other than at those sites (unless the density of cameras is high and above a critical threshold). If the intention is to reduce speeds along a substantial "black" route using overt fixed cameras, there may be a case for installing point-to-point camera systems to enforce speeds along the whole route.

Point-to-point camera technology uses a number of cameras mounted at staged intervals along a particular route. The cameras are able to measure the average speed between two points or the spot speed at an individual camera site. In order to measure the average speed between two points the cameras must be linked to one another and the time clocks on both machines must be synchronised. The average speed is then determined by dividing the distance travelled by the time taken to travel between the two points. The distance between two camera sites may vary from as low as 300 meters to up to tens of kilometres. An enforcement threshold may also be implemented to allow for acceptable variations in driver speed along the route. Potentially, a lower enforcement threshold could be considered for the average speed measured by this technology than the spot speeds measured by mobile and fixed speed cameras.

The limited number of published evaluations of such systems in the U.K. suggest that they are effective in reducing speeds and casualty crashes along the whole route on which they are installed. It is unclear what routes would be suitable for this form of speed enforcement in WA. The route would need to be relatively highly-trafficked, have a sufficient crash rate to make these relatively expensive systems cost-effective, and have limited access/egress opportunities along its length to make it operationally viable (though the presence of local traffic making small trips along the route is not an issue). The national highway across the Nullabor Plain has been suggested as a suitable route and the cost-effectiveness of the use of a point-to-point camera system will be investigated in the next stage of the project, if possible.

5.3 SIZE OF ROAD TRAUMA PROBLEM IN EACH ROAD ENVIRONMENT

A necessary first step in the economic analysis of each of the speed enforcement options outlined in section 5.2 above is to determine the size of the road trauma problem in each of the road environments proposed as the principal focus for each of the options (Table 3). There is evidence that each option reduces casualty crashes to a measured extent, and some enforcement methods have been found to reduce fatal crashes to a larger extent. The economic analysis will consider the reductions in crashes weighted by their social costs. Hence the proportion of fatal crashes, in particular, in each environment needs to be noted.

Table 3: Road environments proposed as the focus of each of the speed enforcement options for WA to be analysed in the next stage

Type of speed enforcement and road type proposed applicable to	Length of road (km)	Estimated traffic (million veh-km) 1991	No. of casualty crashes 2002-2004 (note *)	Percentage of casualty crashes with fatal outcome
URBAN ROADS (mainly in Perth)				
Covert mobile speed cameras on urban highways	1815	7910	4341	1.41%
Overt mobile speed cameras randomly scheduled on urban highways	1815	7910	4341	1.41%
Laser speed detectors on urban local roads	8200	2090	8859	1.25%
Fixed cameras on Perth freeways	62	230	697	1.43%
RURAL ROADS				
Overt mobile speed cameras randomly scheduled on rural highways	20,194	4170	1776	8.05%
Mobile radar units on undivided rural highways and local roads	123,800 (estimate)	5200	3211	7.04%
Point-to-point speed camera systems on highly-trafficked rural highways	NK	NK	NK	NK

* Includes only 2002-2004 crashes with known speed zone at the crash location (i.e. 73.0% of all reported casualty crashes and 87.6% of fatal crashes)

The length of each road environment in WA, and the amount of traffic on them, will determine the density of the level of enforcement applied to each type of road in comparison with the application rates in other jurisdictions from which the evidence of effect will be derived. Table 3 provides the length and estimated traffic volume (in 1991) on each of the focus types of road in WA. This data has been derived from information in the Mass Limits Review (NRTC 1996) providing data for each Australian State. The traffic volume estimates for 1991 probably under-estimate current volumes, but in practice only the relative volumes across states will be used in the next stage of the project and the analysis will not be sensitive to any disproportionate increases in volume between states.

6 ROAD TRAUMA REDUCTIONS RELATED TO OPERATIONAL LEVELS

After reviewing a large number of studies of the effects of varied levels of traffic enforcement on casualty crashes, Elvik (2001) concluded that the relationship is of the form shown in Figure 1. Even for the most effective forms of enforcement, the relationship with crash reductions is not linear. Diminishing returns apply as the level of enforcement increases. However, within the range of increases observed in the studies (up to 10-12 fold), it appears that at least some crash reductions occur for each increase in enforcement effort. Effects beyond that level are uncertain. While most of the studies from which this relationship was derived relate to stationary (intercept) speed enforcement, Elvik quotes evidence supporting its applicability to speed cameras as well.

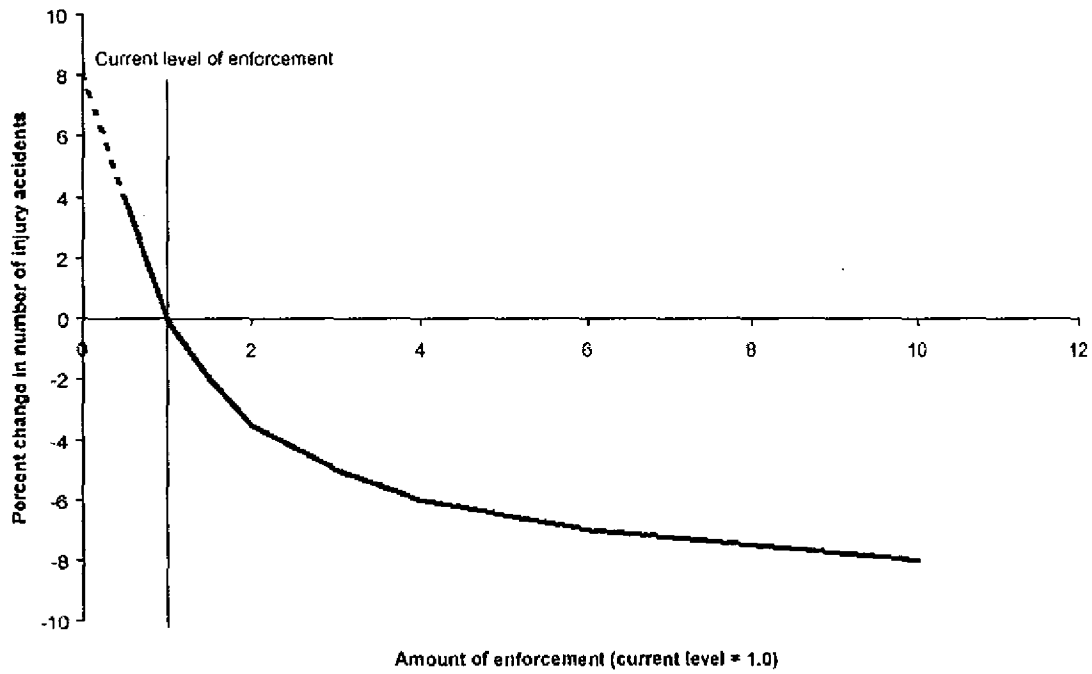

Figure 1: General relationship between traffic enforcement and crashes identified by Elvik (2001)

Elvik (2001) proposed a number of potential functional forms for the relationship shown in Figure 1. Perhaps the most suitable are:

the logarithmic function: $Y = A + B \cdot \log(X)$

the power (or geometric) function: $Y = A \cdot X^B$

or the exponential function: $Y = A \cdot \exp(B \cdot X)$

where Y is the number of casualty crashes, X is the level of enforcement, and A and B are parameters related to the shape and level of the relationship. Figure 1 indicates that B is negative, ie. that a given increase in enforcement from its current level leads to a lower level of crashes. The magnitude of B depends on the strength of the relationship between the specific type of enforcement and crashes.

6.1 VICTORIAN COVERT MOBILE SPEED CAMERA PROGRAM

The level of speed enforcement can be measured in a variety of ways, including the number of operational hours, the number of offences detected, and the number of traffic infringement notices (tickets) issued to detected offenders. In camera-based systems, not all detected offences result in tickets being issued, hence the specific deterrence following detection is eroded. Cameron, Newstead and Gantzer (1995) have found that the most appropriate measure of the level of the Victorian speed camera program is the number of speeding tickets issued from camera detections. In Victoria, with its vigorous follow-up processes and escalating sanctions, a very high proportion of the speeding fines are paid. The best indicator, in terms of deterrent value, of the level of covert mobile speed camera operations would appear to be the number of speeding tickets issued.

A number of Victorian studies have calibrated the relationship between the level of speeding tickets issued and road trauma reductions. The most definitive study has confirmed the key role of the number of speeding TINs detected having an influence on crashes in subsequent periods (Cameron et al., 2003a, b). During 1999, the Victoria Police varied the levels of speed camera activity substantially in four Melbourne police districts according to a systematic plan. Camera hours were increased or reduced by 50% or 100% in respective districts for a month at a time, during two separate months when speed-related publicity was present and during two months when it was absent. Monthly casualty crashes in the ten Melbourne police districts during 1996-2000 were analysed to test the effects of the enforcement, publicity and their interaction. Monthly levels of speeding offences detected by cameras varied substantially over time in all districts, but the most extreme variations occurred in the four districts as planned. Changes in crash frequency were found to be inversely associated with changes in the levels of speeding TINs issued following detection in the same district during the previous month (Figure 2).

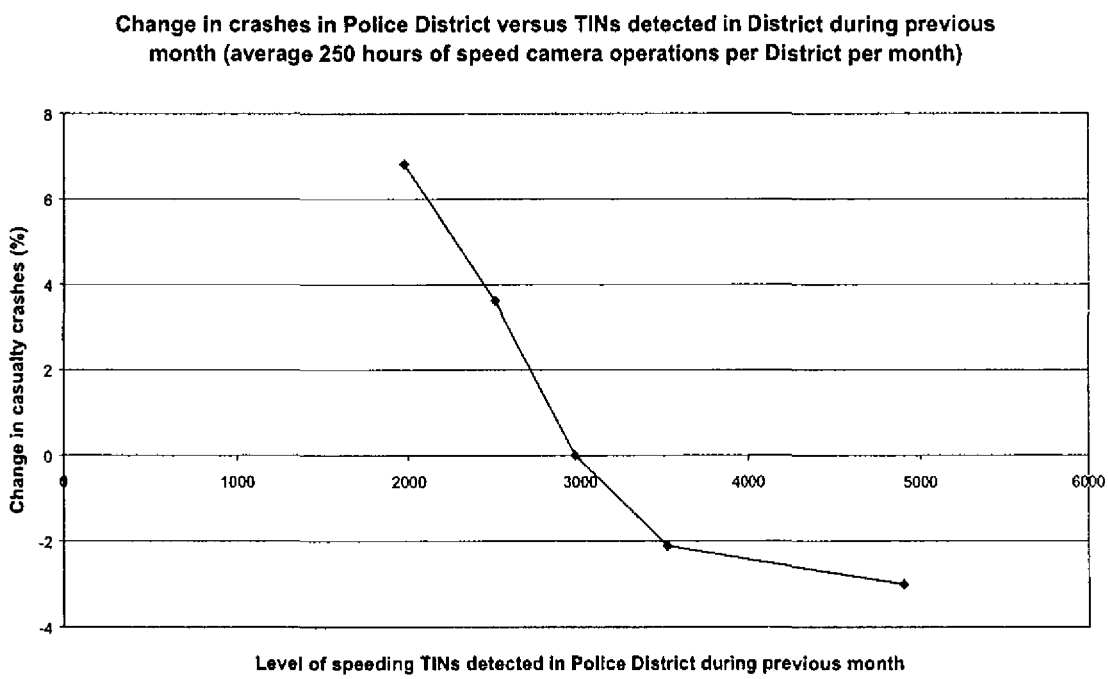

Figure 2: Relationship between casualty crashes and level of speeding Traffic Infringement Notices (TINs) issued following detection by Victorian covert mobile speed cameras

The risk of fatal outcome of the casualty crashes was also found to be inversely associated with changes in the levels of speeding TINs issued following detection in the same district during the previous month. It was reduced by more than 40% when the level of speeding TINs from offences detected during the previous month was at relatively high levels (65% greater than average).

Figure 3 shows the same relationship as Figure 2, expressed as a relative risk and relative to the average level of speeding TINs issued following detection during the previous month. Also shown is the 95% confidence limits on the risk estimates, which indicate the degree of uncertainty in them due to the chance variation in crash frequencies. It was found that the power function was the best of Elvik's proposed functional forms to represent this relationship. When this functional form was fitted to the relationship, the key parameter B was estimated to be -0.1115. The same function fitted to the 95% confidence limits indicated that B could range between -0.0863 and -0.1372. These values were considered to represent the range of uncertainty in B.

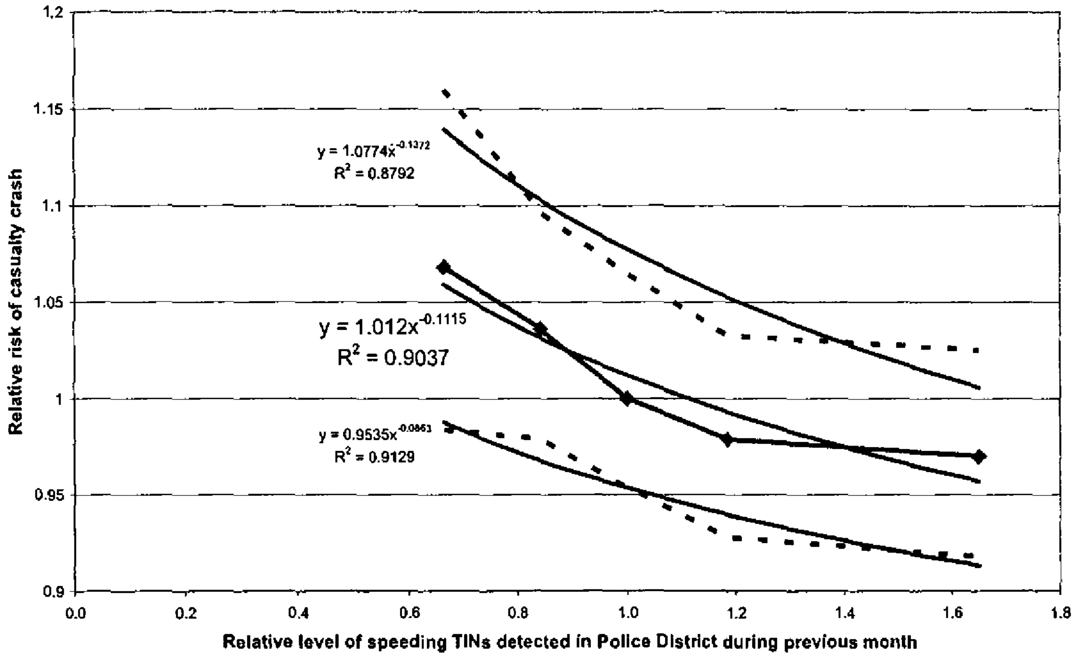

Figure 3: Relative relationship between casualty crash risk and level of speeding TINs (with 95% confidence limits on the risk, and power functions fitted to each relationship)

Figure 4 shows the relationship between the risk of fatal outcome of the casualty crashes and the level of speeding TINs issued, again expressed in relative terms and with 95% confidence limits. The power function also best represented this relationship, resulting in an estimate of B of -0.8516 in this case. The estimates of B when the same function was fitted to the 95% confidence limits were -0.7312 and -0.9838, indicating the range of uncertainty in B.

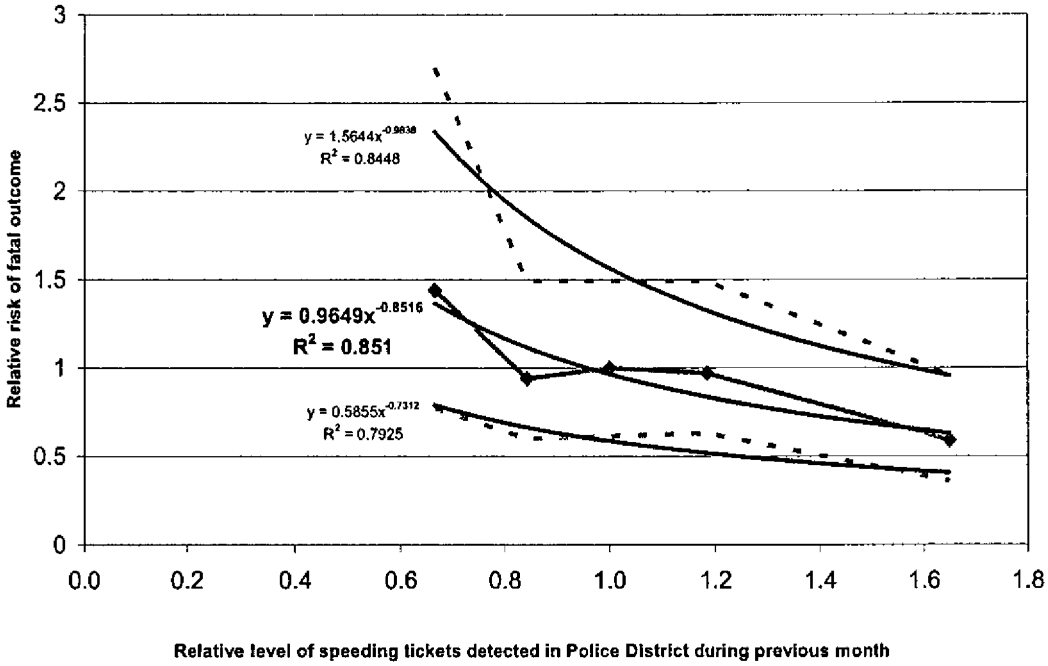

Figure 4: Relative relationship between the risk of fatal outcome in casualty crashes and the level of speeding TINs (with 95% confidence limits on the risk, and power functions fitted to each relationship)

The relationships shown in Figures 2-4 relate to the Victorian mobile speed camera program as it operated during 1996-2000, i.e. around 4000 operational hours per month and before the change to operate more covertly (using "flashless" cameras and less obvious cars) and the lower enforcement tolerance introduced in 2001/02.

From 2001/02 the relationship between operational hours, offences detected and TINs issued became more complex due to the changed detection threshold and subsequent research was based on monthly hours as the measure of the operational level of the program, together with qualitative factors representing the degree of covertness and the enforcement tolerance. During the period 1998-2003, Bobevski et al (2004) fitted power functions to monthly camera hours (which rose to around 6000 hours over the period) and other relevant factors. The analysis estimated B to be -0.092 in the case of casualty crash risk and -2.03 in the case of the risk of fatal outcome of the casualty crashes. These results suggest that in the more recent phase of the Victorian speed camera program, its marginal effect on casualty crash risk has weakened somewhat whereas the effect on the risk of fatal outcome has strengthened and more than doubled. To what extent this stronger effect of increased operational levels on the most severe crashes is due to the more covert operations and/or reduced enforcement tolerance is unclear.

6.2 QUEENSLAND OVERT MOBILE SPEED CAMERA PROGRAM

Studies have been conducted on the crash reduction effects of the Queensland program as it has grown from 852 hours per month in 1997 to about 6,000 hours per month during 2003 (Newstead and Cameron, 2002; Newstead 2004). The crash reductions have generally been limited to an area within two kilometres of the camera sites. The strongest effects have been on casualty crashes, with no differential effect on crashes of different severity (fatal, hospital admission, or medical treatment crashes). There were smaller reductions in material damage only crashes within two kilometres of camera sites. The estimated crash reduction during 2003 was limited to the first nine months of the year (Newstead 2004).

As the program grew, the two kilometre areas around camera sites covered a greater proportion of the total casualty crashes in Queensland, rising from about 50% to 83% over the evaluation period. Thus the localised crash reductions around camera sites can be interpreted as a general effect on crashes, assuming that the program had no effect beyond the two kilometre areas (this is likely to be a conservative assumption and the general effect could be larger). The relationship between the increased monthly hours and the general casualty crash reductions over 1997 to 2003 can be seen in Figure 5.

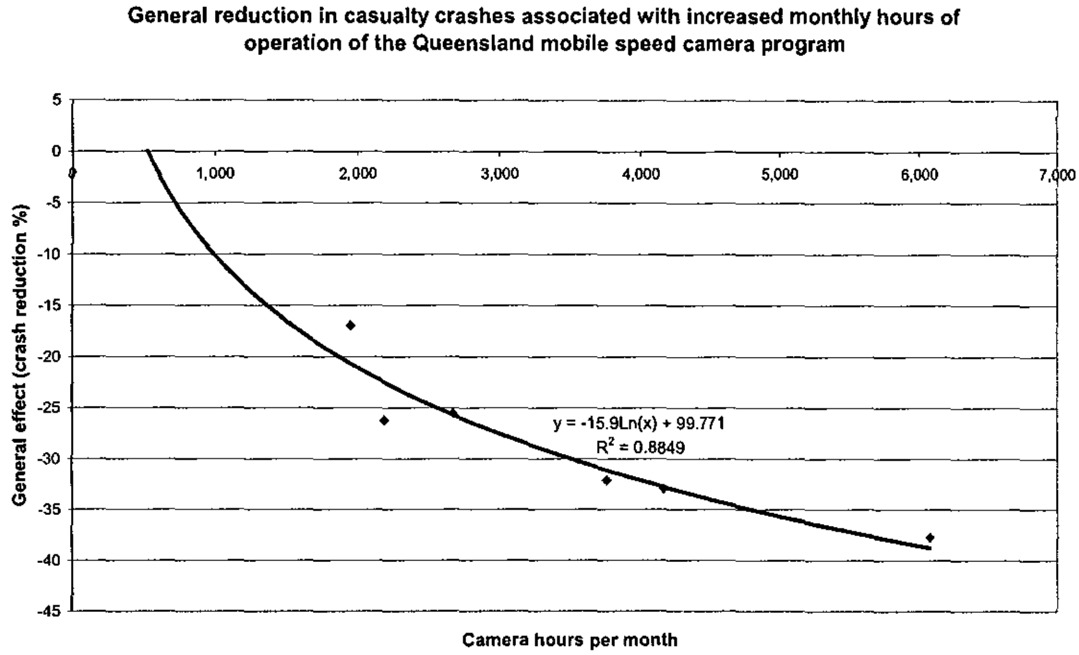

Figure 5: Relationship between casualty crashes in Queensland and monthly hours of the overt mobile speed camera program with randomised scheduling

The last point in Figure 5 was obtained from a separate study of the effect of increased activity in the Queensland Road Safety Initiatives Package during 2003, a component of which was a 50% increase in speed camera hours. Modelling of the relationships between monthly crashes and many program operational factors showed that monthly speed camera hours during 1998 to 2003 were statistically significantly related to serious casualty crashes (those resulting in death or hospital admission) (Newstead, Bobevski, Hosking, Delaney and Cameron, 2004). On the basis that previous research had shown no differential effect of the program by crash severity, the fitted relationship was used to estimate the casualty crash reduction from the monthly average camera hours during 2003. Figure 5 shows that the 2003 estimate of the general casualty crash reduction is consistent with the overall relationship between increasing monthly hours and the effect of the Queensland speed camera program, which on this occasion was found to be best represented by the logarithmic functional form.

The Queensland speed camera program achieved this effect on crashes by committing the hours to about 23,818 kilometres of urban and rural highways which carried an estimated

20,450 million vehicle-kilometres of travel during 1991. While the WA roads of the same type are not much shorter (22,009 kilometres), they carried substantially less traffic (12,080 million vehicle-kilometres) and hence a lower crash rate could be expected on those roads. For this reason, fewer hours of overt mobile speed camera operations need to be committed to the urban and rural highways in WA to achieve the same crash reductions achieved by the Queensland program shown in Figure 5.

The ratio of the estimated levels of traffic on highways in WA and Queensland during 1991 was used to adjust the fitted relationship shown in Figure 5 to estimate the corresponding relationship for WA:

$$\text{Casualty crash change (\%)} = -15.9 \log_e (\text{monthly camera hours in WA}) + 91.40$$

It should be emphasised that this relationships represents a fit to the estimated crash reductions over a limited range of estimated monthly hours and should be extrapolated with caution outside the range; especially low monthly hours may produce a misleading result.

The proportion of total speed camera hours in Queensland carried out in Brisbane was 27-29% during 1999-2003. This corresponds approximately with 33% of total travel on Queensland highways being in urban areas. In WA the proportion of total travel on highways being in urban areas (mainly Perth) was 65.5%, which is reflected in 11 of the 14 existing Multanova speed cameras and 86% of the speeding offences detected being associated with those areas. There was no evidence from the Queensland research that their speed camera program was more or less effective in metropolitan areas compared with rural areas (Newstead and Cameron 2002). The proposed economic analysis of overt mobile speed cameras with randomised scheduling planned to consider their operations in Perth and rural WA separately because different economic values could be found in these two environments given the crash patterns on highways in each area.

6.3 HIDDEN MOBILE SPEED CAMERAS IN NEW ZEALAND

In section 5.2.3, it was suggested that experience from New Zealand indicates that there are additional crash reduction benefits to be gained from hiding (operating covertly) previously overtly-operated speed cameras in road sections where speed cameras are known to operate. The effect appears to generalise beyond the camera zones to produce a general effect across a broader area, perhaps because drivers perceived the threat from hidden surveillance to be broader than camera zones (Keall, Povey and Frith 2001).

The research from New Zealand relates to a two year period when mobile speed cameras were hidden in camera zones on 100 km/h speed limit rural roads in one major Police Region. As well as the covertness of the camera surveillance, there was a 26% increase in camera hours on the 100 km/h roads during the first year, but this fell by 13% during the second year. The speeding detection rate increased five-fold, but because of constraints in the back-office to process the increased offence number, the ticketing rate (speeding infringement notices issued per photograph taken) fell by about one-third. The net result was a four-fold increase in the number of speeding tickets issued in the Police Region.

While the increased number of speeding tickets was considered to be an integral part of the move to hidden camera operations and together they represent the hidden camera program (Keall, Povey and Frith 2002), it is not clear to what extent the crash reduction benefits were also due to the additional hours of operation. For this project, the additional hours were considered to be a relatively minor contributor, though their increase is acknowledged in the economic analysis in section 7.3.

As outlined in section 2.5.1, there was an 11% reduction in casualty crashes on 100 km/h roads throughout the Police Region during the hidden camera program. The number of persons killed or injured in these same crashes was reduced by 19%, suggesting a reduction in injury severity as well as crash risk, but no direct evidence was presented of a reduction in the risk of fatal or serious injury outcome. There was also less reliable evidence that the reduction in casualty crashes was greater (22%) within the speed camera zones on 100 km/h roads. However, the major benefit of the hidden camera program was the general effect across all 100 km/h roads, of which the camera zones were a relatively small part.

The hidden camera program in New Zealand was a relatively short trial and since that time all mobile cameras have returned to overt operations (notwithstanding recommendations to the contrary to the New Zealand government). Hence there is no evidence of any further benefits which might have been achieved had the camera hours escalated over time as, for example, has been seen from research on the Victorian and Queensland speed camera programs. However, the research is definitive regarding the crash reduction benefits from a change from overt to covert operations within known speed camera zones (recognising the small increase in hours and the four-fold increase in speeding tickets in the New Zealand case). It is one of the few studies where the effect of an operational change is measured.

6.4 MOVING MODE (MOBILE) RADAR UNITS IN VICTORIA

Studies of the crash reduction effects of mobile radar in Victoria considered two periods in depth: 1995/96 when 48 units operated and 1996/97 when 73 units operated (Diamantopoulou et al, 1998 and 2002). Almost the same number of operational hours on undivided rural roads were achieved during each period, namely 47,140 hours p.a. However, the proportion of hours achieved by covert units (unmarked patrol cars) was greater in the second period, 27.8% compared with 19.5%, and a greater number of speeding offences were detected, 39,183 compared with 32,051.

The clearest crash reduction effects from the different forms of mobile radar operations during these periods came from roads were the patrol cars operated covertly or there was a mixture of covert and overt operations on highways in the same region on the same days. During 1995/96, there was 16.9% reduction in casualty crashes 1-4 days after either covert or mixed overt/covert operations (perhaps also on the day of operation). During 1996/97, the crash reduction of the same type was 20.3%. The greater effect from the same total hours of operation was thought to be due to the increased covertness and/or the greater number of total speeding apprehensions (including offences detected by overt operations). This is not to say that overt operations from marked mobile radar cars were not effective, only that the evidence was less clear in this case.

Assuming also zero crash reduction if there were no mobile radar hours and no speeding offenders apprehended, an exponential relationship between the crash reduction and the total number of speeding offences detected by moving mode radar per annum was found to best represent this association in Victoria. The reduction in casualty crashes was assumed to apply from the next day and up to four days after the mobile radar operations of any type. To achieve this effect across all mobile radar operations in WA, there appears to be a need for a high proportion of operations (say, at least 80%) to be conducted covertly, though there is a case for a reasonable proportion of overt (and mixed) operations to increase the visibility of the overall program. This requirement for a high proportion of the mobile radar cars to be unmarked may create a difficulty for general policing operations in rural WA, which traditionally have made use of the same traffic patrol cars.

The fitted relationship was:

Casualty crash reduction (%) = 100 (1 - exp [(8.89 – annual offences detected)/172822])

and is shown in Figure 6 for annual offences detected up to 250,000 (about six times the level achieved by the operations in Victoria).

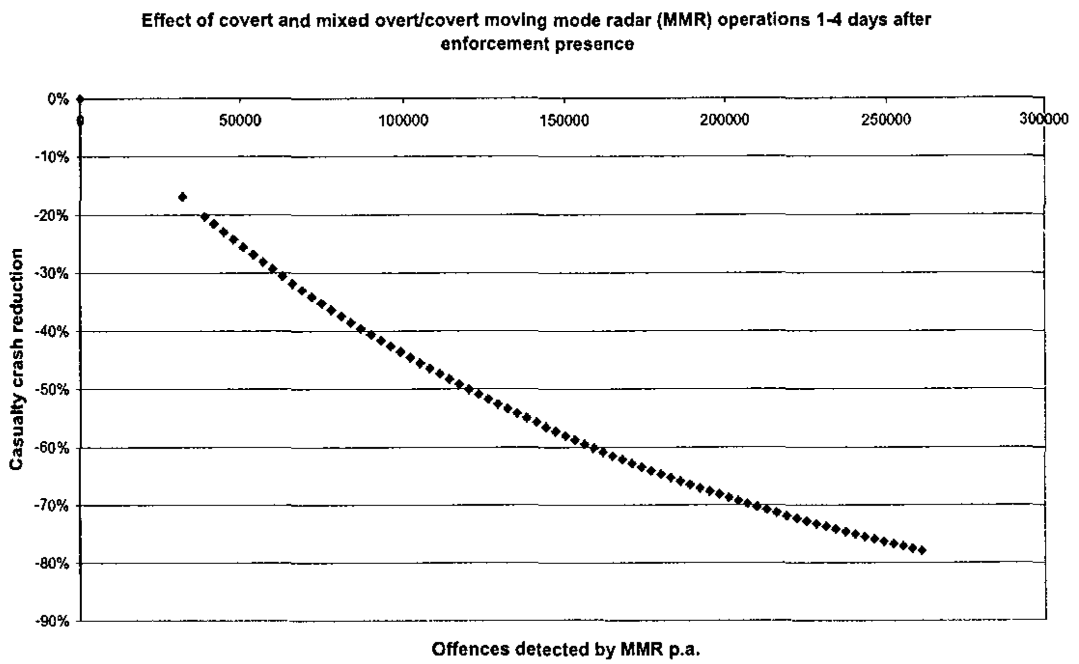

Figure 6: Relationship between casualty crash reduction and mobile radar operations in Victoria, extrapolated beyond 1995/96 and 1996/97 levels (first two data points)

The crash reduction effects achieved in Victoria were produced generally from two shifts of mobile radar operations per day on undivided roads in the same area, with about seven hours operated per shift. For the crash reductions effects shown in Figure 6 to apply to all casualty crashes throughout the year in an area, the operations would need to be carefully scheduled so that the four day effect is continuous. This is achieved, ideally if each mobile radar unit is operated for two shifts every fourth day, that is for 91.5 days per year, assuming that the rural areas are too far apart to make it feasible for an individual unit to be operated in more than one area. Operated for 14 hours on each of those days, an optimised mobile radar unit would achieve 1,281 hours per year, after which additional optimised units would be necessary to achieve additional hours while maintaining the crash reduction effects shown in Figure 6.

In practice, it was not expected that police could maintain the optimal scheduling of mobile radar units to achieve the full potential crash reduction that Figure 6 suggests. There is also the question of whether the effects measured for overt and mixed overt/covert operations can be confidently assumed to apply to all operations, notwithstanding the recommendation that high proportion of operations should be conducted covertly in WA.

Because of concern about both of these practical issues, the economic analysis in section 7.3 assumed only half the crash reduction effects shown in Figure 6 for each level of annual speed offences detected by mobile radar operations.

6.5 HAND-HELD LASER SPEED DETECTORS IN MELBOURNE

The study of laser speed detectors in Melbourne during 1997 provides some indication of the effects on crashes related to the intensity of the enforcement operations (Fitzharris et al 1999). The research considered the effects of the overtly-operated hand-held laser speed detectors on urban freeways, arterial roads and local streets, but only the effects in the local street environment will be examined here (see section 5.2.5).

During 1997, laser speed detectors were used with low intensity (less than 3 hours per site per year) at 70% of local street sites and with medium intensity (3 to 15 hours per site per year) at 25% of the sites. Sessions were typically of one hour duration at each site per occasion, during which on average 3.33 speeding offenders were detected. The sites had been chosen on the basis of high crash frequencies over their two kilometre length during 1993-1995 and averaged 4.8 casualty crashes per year.

The overall results suggested that the overt operations at low-to-medium intensity had a localised effect of substantial duration (apparently up to a year) which could be expanded to a general effect if there were multiple sites covering (within two kilometres) a high proportion of crashes. With limited enforcement resources available, the finding that low-to-medium intensity of enforcement per annum is adequate is an important factor in maximising the number of sites while retaining the effect on casualty crashes.

The detailed results from the study (Harrison et al 1999) showed that, when some questionable data from three Police Districts was ignored, there was 3.76% reduction in casualty crashes and 4.46% reduction in serious casualty crashes (those resulting in death or hospital admission) at the local street sites during 1997. The analysis took into account a range of alternative explanatory factors, so there is confidence that these road trauma reductions were due to the low-to-medium intensity of laser operations at the sites.

The crash reduction effects of laser speed detector operations at sites on arterial roads were apparently larger (7.6% to 9.6%), perhaps in part due to higher proportions of medium and high (greater than 15 hours per site per year) intensity operations at those sites. However, three alternative, camera-based methods of speed enforcement on urban arterial roads, with clear evidence of general effects extending beyond enforcement sites, are being considered for this road environment in this project.

6.6 FIXED SPEED CAMERAS

As outlined in Chapter 3, the most comprehensive experience with fixed speed cameras comes from the UK, where the program has also been carefully evaluated at each stage during its expansion. The initial evaluation study (Hooke et al 1996) noted that the social benefit from cameras in their first year was five times the investment, leading to the recommendation that at least part of the fine revenue from camera-detected offences should be used to recover the costs of the camera program and thus allow its expansion to provide wider social benefits. This led to the Cost Recovery Program, initially in eight pilot areas, then expanding to at least 38 areas based on partnerships of the responsible agencies. The evaluations of each stage are summarised in the following table.

Table: Fixed speed cameras. Measured effects on road trauma and speeds at camera sites and benefit-cost ratios of programs evaluated.

Report and fixed speed camera program evaluated	**Size of program evaluated**	**Road trauma reduction at camera sites**			**Speed reduction at camera sites**			**Benefit-cost ratio of program (incl. mobile cameras)**
		Casualty crashes	Serious casualties	Fatalities or fatal crashes	Mean speed reduction	Reduction in proportion speeding	Reduction in prop. speeding excessively	
Hooke at al (1996). Mostly fixed speed cameras	475 sites serviced by up to 102 cameras in 10 Police Regions in UK	28%	Not stated	Not stated	4.2 mph	Not stated	Not stated	**3.4**
PA Consulting (2001). Cost Recovery Program first year	250 sites in 8 pilot partnership areas in UK	35% (6% over whole area)	47% (18% over whole area)	Not stated	5.6 mph	71%	Not stated	Not stated
Gains et al (2003). Cost Recovery Program first two years	599 sites in 8 pilot partnership areas in UK	5%	65% (4% over whole area)	Not stated	4.5 mph	67%	96%	**2.75** (2 years)
Gains et al (2004). Cost Recovery Program first three years	2300 sites in 24 partnership areas in UK	42%	51%	45%	5.3 mph (new sites)	71% (new sites)	80% (new sites)	**4.1** (3rd year)
Gains et al (2005). Cost Recovery Program first four years	4000 sites in 38 partnership areas in UK	24%	50%	29%	5.3 mph (new sites)	70% (new sites)	91% (new sites)	**2.7** (4th year)
ARRB (2005). Fixed Speed Camera Program	First 28 sites in New South Wales	23%	Not analysed	90%	6.3 km/h (12 months) 5.8 km/h (24 months)	70% (12 months) 72% (24 months)	86% (12 months) 87% (24 months)	**3.5 to 3.6** (depending on program life assumed)

Following its introduction in 1992, the UK speed camera program has expanded to an estimated 6,000 sites (ICF 2003), most of which are overt fixed camera installations. Most of that expansion has been due to the Cost Recovery Program. Results at each stage of the expansion indicate that the fixed cameras have achieved 5% to 42% reductions in casualty crashes and 47% to 65% reductions in serious casualties (fatalities and serious injuries) at camera sites. Initial results suggesting that the cameras produced a general effect on crashes over the broader area in which the cameras were situated have not been reported in the later evaluations and may have been an aberrant finding from the initial studies.

However there is little doubt that the UK fixed cameras reduce mean speeds and especially excessive speeds at camera sites, and consequently reduce road trauma in the vicinity. Similar experience has been seen with the initial 28 overt fixed speed cameras in New South Wales, and where fatal crashes at camera sites were reduced by 90% (ARRB 2005).

There is little evidence of a synergy between multiple overt fixed speed cameras, whereby a general effect on speeds and road trauma across the whole road system is produced to add to the strong localised effect outlined above. Although the UK speed camera program had expanded to 4,000 sites by the time of the most recent evaluation study (Gains et al 2005), the benefit-cost ratio for the program (including the mobile speed camera effects) of 2.7 during its 4th year was typical or marginally lower than what had been achieved in earlier years (BCRs of 2.75 to 3.4). The benefit-cost ratio of the first 28 overt fixed speed cameras in New South Wales was also no more than 3.6.

These findings suggest that the overall effects of overt fixed speed cameras is essentially the sum of their individual localised effects, and that the program benefit-cost ratio is essentially the same as individual fixed camera installations. The threshold of fixed camera density to produce an additional general effect appears not to have been reached in the UK, notwithstanding that it was considered to represent best practice in European Union countries so far as the level of investment in camera-based speed enforcement is concerned (ICF 2003).

6.7 POINT-TO-POINT SPEED CAMERAS

Point-to-point speed camera systems measuring average speeds between two or more fixed cameras have the potential to produce a general effect well beyond the localised effect at overt fixed camera sites. They have been installed at a few sites as part of the UK Cost Recovery Program described in section 6.6, but apart from information which can be gleaned from the detailed information in that program's evaluation reports, there is little scientific evidence of their effects on road trauma. Gains et al (2003) indicated that the two 0.5 km apart point-to-point cameras in Nottingham produced 31% reduction in serious casualties (not statistically significant) which was not significantly different from the road trauma reduction from speed cameras of all types. Keenan (2002) found 36% reduction in casualty crashes at the Nottingham site.

The manufacturer of the UK point-to-point speed camera systems, Speed Check Services, have claimed that systems in Nottinghamshire (now 48 pairs of cameras), Northamptonshire (four pairs of cameras on a 4 km section) and South Yorkshire (eight pairs of cameras on an 11 km section of highway) have substantially reduced speeding and road trauma on the road sections they cover. In July 2005, the Scottish government launched a pilot scheme of 15 linked cameras on a 46 km section of highway in the Strathclyde area. In the first six months, road trauma on the route appears to have been substantially reduced but no formal evaluation has yet been carried out.

To date, the Speed Check Services point-to-point speed camera system is the only such system to receive Home Office Type Approval in the UK. In 2003, their website indicated that a pair of point-to-point cameras costs £70,000 ($170,000) and requires at least another £100,000 ($244,000) for the computer network to support it. There may be economies of scale with larger numbers of linked cameras because the Scottish government has reported that the 15 camera system in Strathclyde cost £775,000 ($1.891 million) in 2005.

In the absence of clear scientific evidence of point-to-point speed camera systems having a general effect on road trauma over a substantial length of highway, it was decided that it was not possible to conduct a valid economic analysis of the potential introduction of such a system on suitable routes in WA (see section 5.2.7 for a discussion of suitable routes). There were also difficulties in obtaining information on the cost of installing, maintaining and operating such a system in the Australian environment. However, this decision could be revisited when definitive scientific evidence emerges from the UK (especially from the system over a long route in the Strathclyde area) and operational cost information from the pilot program in Victoria becomes available.

7 ECONOMIC ANALYSIS OF SPEED ENFORCEMENT OPTIONS

The economic analysis of each speed enforcement option outlined in section 5.2 was carried out making use of the calibrated relationships established in chapter 6 linking road trauma reductions with the level of operation of each type of enforcement. The relationships established in other jurisdictions generally needed to be recalibrated for the WA environment to reflect the relative traffic level and/or total length of the type of road considered to be the focus of the enforcement, compared with the other jurisdiction.

The economic benefits from the road trauma reductions estimated to be produced by each level of enforcement (or increase in level) were initially calculated using the unit costs at each crash severity level published by BTE (2000), updated from 1996 values to 2005 using the Consumer Price Index, as follows:

- Fatal crashes $2,047,615
- Severe injury crashes resulting in hospitalisation $505,390
- Injury crashes resulting in other medical treatment $17,065

Where the calibrated relationship was in terms of a reduction in casualty crashes generally (all levels of severity), the average crash cost was calculated by weighting each of the above unit costs in proportion to the crash severity distribution on the focus roads during 2002-2004. In some analyses, the calibrated relationships indicated a greater effect on fatal crashes and/or severe injury crashes, so separate unit costs were used.

The operating costs per hour for each type of enforcement were estimated from information provided by the WA Police Service and are shown in Appendix A. The fixed costs of enforcement equipment were amortised over their useful life, at 7% p.a. interest rate, to provide a monthly cost. This cost was added to monthly vehicle leasing costs and operational manpower costs to provide the operating costs per hour under current structures. The cost per hour to operate a (Multanova) speed camera was estimated to be $67.47 in Perth and $49.48 in the rest of WA, whereas moving mode (mobile) radar units were estimated to cost $43.01 per hour to operate.

The offence processing costs, for each type of offence record (photographic evidence or on-the-spot notice), per offence detected were estimated in a similar way. The cost per 1000 speeding infringement notices issued was estimated to be $135.11 for offences detected photographically and $408.25 for offences recorded on on-the-spot notices. The fixed costs of the back office and equipment to process these offences was estimated to be $1,913,000 currently (excluding some unknown costs) which was amortised as $22,083 per month at 7% p.a. interest rate over an assumed ten year life. This amortised fixed cost was split in proportion to the number of offences of each type processed during 2004 to provide the monthly fixed cost for Multanova detected offence processing ($14,661) separate from on-the-spot offence processing ($7,422).

7.1 COVERT MOBILE SPEED CAMERAS ON URBAN HIGHWAYS

In section 5.2.1, it was proposed that the focus of covert mobile speed cameras for the economic analysis would be on urban arterial roads (highways), which lie principally in Perth. Table 3 indicates that 120.58 casualty crashes per month occurred on those roads in Perth during 2002-2004, of which 1.41% had fatal outcome. The average cost of a casualty crash on those roads was $152,015 in year 2005 prices.

To start the economic analysis, it was envisaged that the 14 existing Multanova speed cameras (11 in Perth, three in rest of WA) would be dedicated to the Perth arterial roads and would operate covertly as outlined in section 5.2.1. Since the effectiveness of the current Multanova operations is unknown, it is not known to what extent the change in operational method *per se* would result in a road trauma reduction without any increase in enforcement hours. However, the effect of increased hours of covert operations can be estimated from the relationships established in section 6.1 and, as will be seen, substantial increases in enforcement hours would be justified.

The 14 existing Multanova speed cameras achieved close to 36,000 hours of operation or 3,000 hours per month during 2004. Based on 623.43 vehicles per hour processed by Multanovas in Perth during 2004, the 14 Multanovas could be expected to measure the speeds of 1,870,290 vehicles per month. Based on experience in Victoria over many years prior to 2001/02, it would be expected that the offence detection rate would fall rapidly to about 2% associated with the covert operations (and the absence of public announcements about camera locations). Coupled with an estimated non-prosecutability rate of 20% (based on the current rate of 21%), it could be expected that 30,000 speeding infringement notices issued would result from the 3,000 hours of covert speed camera operations per month on Perth arterial roads. The 1:10 ratio of camera hours to speeding TINs issued was typical of the Victorian speed camera program during 1995-1998 (Gelb et al, 1999).

The economic benefits and costs of each extra 100 hours of covert speed camera operations per month were estimated based on the road trauma relationships (casualty crash risk and risk of fatal outcome) calibrated in section 6.1 and using the costs per hour of the additional enforcement. The costs of processing each additional 1,000 speeding infringement notices generated by the increased camera hours were also calculated, but this additional cost was much smaller than the cost of the additional hours. For this reason, it was not necessary to assume that the offence detection rate would fall as the level of enforcement increased (as would be expected if the transgression rate falls). This would have involved questionable assumptions about the extent of reductions in transgression and detection rates, which ultimately would have had little effect on the economic analysis.

Table 4 shows increases in covert mobile speed camera hours in Perth from a base level of 3,000 hours per month would be associated with decreasing marginal benefit-cost ratios (BCR), but the marginal BCR would always be greater than one up to 10,000 hours per month. The program BCR (for the additional enforcement above the base level) would increase initially then fall. As a basis of comparison with other enforcement options, if the hours per month were to triple to 9,000 hours, it is estimated that the program BCR would be 6.1. In addition, a program of that size is estimated to produce an 11.5% reduction in casualty crashes and, more importantly, over 65% reduction in fatal crashes on Perth's arterial roads.

A program of covert mobile speed cameras operating for 9,000 hours per month in Perth, and generating 90,000 speeding infringement notices, is estimated to cost $634,100 per month to operate. Against this cost should be compared the $9 million per month in expected fine revenue.

Table 4: Economic analysis of an increase in covert mobile speed camera operations on Perth's arterial roads (from a base level of 3,000 camera hours/month).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fatal crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
3000	**30000**	22.7	0.0	0.0%	0.0%	*3000*	221.1	2778.9
4000	**40000**	14.3	4.4	3.2%	24.2%	*4000*	289.9	3710.1
5000	**50000**	10.0	5.9	5.5%	38.9%	*5000*	358.8	4641.2
6000	**60000**	7.6	6.3	7.4%	48.7%	*6000*	427.6	5572.4
7000	**70000**	6.0	6.4	9.0%	55.8%	*7000*	496.4	6503.6
8000	**80000**	4.9	6.3	10.4%	61.1%	*8000*	565.2	7434.8
9000	**90000**	4.1	6.1	11.5%	65.3%	*9000*	634.1	8365.9
10000	**100000**	3.5	5.9	12.6%	68.6%	*10000*	702.9	9297.1

7.2 OVERT MOBILE SPEED CAMERAS WITH RANDOMISED SCHEDULING

In section 5.2.2, it was proposed that the focus for overt mobile speed cameras with randomised scheduling would be on relatively highly-trafficked roads, and Perth arterial roads (highways) and rural highways outside Perth would be considered separately. Table 3 indicates that 120.58 casualty crashes per month occurred on arterial roads in urban areas and 49.33 per month occurred on rural highways during 2002-2004. The average cost of a casualty crash on urban arterial roads was $152,015 in year 2005 prices. The average cost on rural highways was $403,552, the higher unit cost being due to a greater proportion of fatal crashes among the casualty crashes on rural roads compared with urban roads.

To provide a direct comparison with the speed enforcement option whereby all 14 existing Multanova speed cameras are operated covertly in Perth (section 7.1), the economic analysis initially envisaged the same 14 cameras operating overtly with randomised scheduling on Perth's arterial roads. Again, because the effectiveness of the current Multanova operations is unknown, it is not known to what extent the change in operational method would change crash frequencies on those roads. However, the effects of increases in operational hours can be estimated from the relationship established in section 6.2.

The existing Multanova cameras achieved 3,000 hours per month during 2004 and this was taken as the base level for the analysis. In Queensland, this many hours of speed camera operations detected 37,500 offences resulting in 30,000 speeding infringement notices being issued. Again, for comparison with the speed enforcement option using covert cameras, the base level number of infringement notices issued from the 3,000 hours in Perth was taken to be 30,000 per month. This level of offence notices is likely to result rapidly from the increased threat to speeding drivers from the randomised scheduling and absence of public announcements compared with current Multanova operations, resulting in the offence detection rate falling to about 2% compared with 2.9% recorded in 2004.

Table 5 shows increases in overt mobile speed camera hours with randomised scheduling in Perth from a base level of 3,000 hours per month would be associated with decreasing marginal BCRs, and the marginal BCR would always be greater than five up to 10,000 hours per month. The program BCR (for the additional enforcement above the base level) would not start to fall until the enforcement exceeds 9,000 hours per month. The program BCR at that level, representing a tripling of the base hours per month, would be 7.9. In addition, a program of that size is estimated to produce 27.3% reduction in casualty crashes on Perth's arterial roads.

Table 5: Economic analysis of an increase in overt mobile speed cameras with randomised scheduling on Perth's arterial roads (from a base level of 3,000 camera hours/month using all 14 existing camera units).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
3000	**30000**	21.7	0.0	0.0%	*3000*	221.1	2778.9
4000	**40000**	16.3	4.5	7.1%	*4000*	289.9	3710.1
5000	**50000**	13.1	6.5	12.7%	*5000*	358.8	4641.2
6000	**60000**	10.9	7.4	17.2%	*6000*	427.6	5572.4
7000	**70000**	9.4	7.8	21.0%	*7000*	496.4	6503.6
8000	**80000**	8.2	7.9	24.3%	*8000*	565.2	7434.8
9000	**90000**	7.3	7.9	27.3%	*9000*	634.1	8365.9
10000	**100000**	6.6	7.8	29.9%	*10000*	702.9	9297.1

Operating a program of overt mobile speed cameras for 9,000 hours per month in Perth, and generating 90,000 speeding infringement notices, is estimated to cost the same $634,100 per month to operate as the operations using covert cameras previously described. There would be adequate funds from the fine revenue to hypothecate to the program.

While there would appear to be greater economic benefits from operating mobile speed cameras overtly (with randomised scheduling) on Perth's arterial roads compared with covert operations, this relative benefit could be reversed if fatal crashes are valued more highly than the "human capital" unit costs published in BTE (2000). In other jurisdictions, the social cost of crashes is valued by methods based on society's "willingness to pay" to prevent serious crashes. BTCE (1997) derived "willingness to pay" values of fatal crashes during 1992, and the unit value of a fatal crash updated to 2005 would be $5,351,506. This is 2.6 times the cost of a fatal crash used in the economic analyses in this report. The implications of using a higher value for fatal crashes will be discussed later.

7.2.1 Urban arterial roads in Perth

In section 5.2.2, it had been proposed that overt mobile speed cameras with randomised scheduling would be analysed separately for urban arterial roads and rural highways. In this section the 11 existing Multanova cameras operating in Perth and achieving about 2,400 camera hours per month were taken as the base level. This leaves the existing three Multanovas operating in rural WA as the base level for the following section.

Table 6 confirms the previous finding that an increase in overt mobile speed camera hours with randomised scheduling in Perth from the base level of 2,400 hours (and assuming 24,000 speeding infringement notices per month would result from the change in operational format alone) would be associated with decreasing marginal BCRs, and they would always be greater than five. A program of 7,000 camera hours per month, representing an approximate tripling of camera hours, would provide the highest program BCR and is estimated to produce 25.2% reduction in casualty crashes on Perth's arterial roads.

Table 6: Economic analysis of an increase in overt mobile speed cameras with randomised scheduling on Perth's arterial roads (from a base level of 2,400 camera hours/month using 11 existing camera units).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
2400	**24000**	25.6	0.0	0.0%	2400	177.8	2222.2
3000	**30000**	20.5	4.4	5.2%	3000	219.1	2780.9
4000	**40000**	15.5	7.6	12.0%	4000	287.9	3712.1
5000	**50000**	12.4	8.9	17.3%	5000	356.7	4643.3
6000	**60000**	10.3	9.3	21.5%	6000	425.5	5574.5
7000	**70000**	8.9	9.3	25.2%	7000	494.4	6505.6
8000	**80000**	7.8	9.2	28.3%	8000	563.2	7436.8
9000	**90000**	6.9	9.0	31.1%	9000	632.0	8368.0
10000	**100000**	6.2	8.8	33.5%	10000	700.8	9299.2

7.2.2 Rural highways outside Perth

For the purpose of comparison of overt mobile speed cameras randomly scheduled on rural roads with other rural enforcement options, an analysis was carried using a base level of 600 hours per month achieved by the existing Multanova cameras in rural WA. For this analysis the focus was on rural highways, not local roads, because of the need for the randomly scheduled overt operations to cover a high proportion of crashes in a 2 kilometre radius, suggesting that only operations on the relatively highly-trafficked highways could achieve this necessary constraint.

Table 7 shows increases in overt mobile speed camera hours with randomised scheduling on rural highways from a base level of 600 hours per month would be associated with decreasing marginal BCRs, and the marginal BCR would always be greater than ten up to 6,000 hours per month. The program BCR would start to fall when the enforcement exceeds 1,800 hours per month. The program BCR at that level, representing a tripling of the base hours per month, would be greater than 40. In addition, a program of that size is estimated to produce 19.5% reduction in casualty crashes on rural highways.

While the economic benefits of this modest increase in speed camera hours on rural highways are substantial, principally due to the higher unit costs of casualty crashes on rural roads compared with urban areas, the crash reduction effects are smaller than that achieved by a tripling of camera hours on urban arterial roads. A five-fold increase in overt camera hours on rural highways, with randomised scheduling, is estimated to produce 28.5% reduction in casualty crashes and still be associated with very high economic benefits. These benefits can also be compared with other rural speed enforcement options.

Table 7: Economic analysis of an increase in overt mobile speed cameras with randomised scheduling on rural highways outside Perth (from a base level of 600 camera hours/month using 3 existing camera units).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
600	**6000**	107.0	0.00	0.0%	*600*	32.5	567.5
1200	**12000**	55.6	38.8	12.3%	*1200*	63.0	1137.0
1800	**18000**	37.5	41.4	19.5%	*1800*	93.5	1706.5
3000	**30000**	22.8	36.8	28.5%	*3000*	154.5	2845.5
4000	**40000**	17.1	32.6	33.6%	*4000*	205.4	3794.6
5000	**50000**	13.7	29.2	37.6%	*5000*	256.2	4743.8
6000	**60000**	11.5	26.5	40.8%	*6000*	307.0	5693.0

7.3 COVERT MOBILE SPEED CAMERAS ON PUBLICLY ANNOUNCED ROUTES

In section 5.2.3, it was proposed that the evidence from the New Zealand hidden speed camera program (previously overtly-operated cameras operated covertly within known speed camera zones) could suggest the crash reduction benefits if WA's speed cameras were operated covertly within the publicly announced routes given high profile in the media the day before. The New Zealand experience suggests that the localised effect on crashes along these routes on the day of operation may extend in space and time to provide a general effect on crashes throughout the area in which drivers perceive a threat of detection. The general effect is likely to be very broad provided drivers perceive a threat.

The New Zealand experience was limited to a two-year trial on 100 km/h rural roads in one major Police Region. Hence the results are only definitive for the change from overt to covert operations on rural roads. However the mechanism through which the change in operations appears to have its effect, namely a broader and increased perceived risk of detection, suggests that the covert operations of WA speed cameras on publicly announced routes should have the same effect in urban areas as on rural roads.

7.3.1 Rural highways outside Perth

An economic analysis was carried out on the additional benefits to be expected if WA's Multanova speed cameras operated on publicly announced routes outside Perth were to be operated covertly, as outlined in section 5.2.3. It was assumed that the existing three rural-operated cameras are principally focused on rural highways, where they achieve about 600 hours of operation per month. Offences detected by these cameras appear to result in about 5,525 speeding tickets per month being issued. For the purpose of comparison with the base level assumed for the randomly-scheduled overt cameras on rural highways in section 7.2.2, it was assumed that 6,000 speeding tickets per month are issued from the existing rural camera operations.

As outlined in section 7.2, there were 49.33 casualty crashes per month on rural highways during 2002-2004, with a relatively high average cost of $403,552 in year 2005 prices. Thus there is potential for substantial savings in the economic costs of crashes on rural highways if the change to covert operations within the publicly announced routes makes WA's Multanova cameras more effective and increases their coverage in the same way as was achieved in New Zealand.

Table 8 shows the estimated economic benefits from the change to covert operations within the publicly announced routes. It is assumed that there would be an 11% reduction in casualty crashes on rural highways due to this change. Since the New Zealand hidden camera trial involved approximately 25% increase in camera hours and resulted in a four-fold increase in speeding tickets, these increased resource investments and costs have been included as part of the changed operations in WA (they are also considered to be relevant factors in achieving the crash reductions). Table 8 has been presented in a similar format to Tables 4-7 to allow direct comparison. However, the marginal BCR relates to the full increase in hours and tickets shown, not the next 100 hours as in the earlier tables. As discussed in section 4.3, the crash reduction effect of the existing Multanova operations on rural roads is not known and for this reason is indicated as "NK" in Table 8.

Table 8: Economic analysis of a change from overt to covert mobile speed camera operations within publicly announced routes on rural highways outside Perth (from a base level of 600 camera hours/month).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for increase in hours and tickets	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
600 (base)	**6000**	NA	0.0	NK	*600*	32.5	567.5
750	**24000**	222.2	51.6	11.0%	*2400*	42.4	2357.6

Table 8 indicates that the change to covert operations on rural highways would be highly cost-beneficial, notwithstanding the additional offence processing costs involved. However there is a question whether the existing three Multanova cameras operating for 600 hours per month across all WA rural highways (estimated 20,194 kilometres in length) could create a general effect on drivers which would result in 11% reduction in casualty crashes on this road system in the long term. Unlike the other forms of rural speed enforcement considered in this project (e.g. randomly-scheduled overt mobile speed cameras and moving mode radar units on undivided roads), the relationship between increased hours of covert mobile of speed cameras within designated camera zones and crash reductions is unknown. In particular, it is not known what minimum density of camera zones enforced in this way is necessary for the operations to achieve a general effect across the roads on which they lie.

7.3.2 Urban arterial roads in Perth

Assuming that the New Zealand experience with covert operations of speed cameras within designated speed zones is just as relevant on urban arterial roads as rural highways, an economic analysis was carried out for this change in camera operations in Perth. Based on the hypothesised mechanism by which the change in operations has its effect, there is more confidence that the general effect on crashes will result from the existing 11 Multanova cameras in Perth if operated in this way because their density is much greater than the rural-operated cameras (6 cameras per 1000 km compared with 0.15 per 1000 km).

It was assumed that the 11 existing Multanova cameras are principally focused on arterial roads in Perth, achieving about 2,400 hours of operation per month. Currently these 2,400 hours result in about 34,000 speeding tickets being issued per month. During 2002-2004, there were 120.58 casualty crashes per month on these roads, with average cost of $152,015 in 2005 prices. Table 9 shows the estimated economic benefits of a change to covert operations within the publicly announced routes, coupled with 25% increase in camera hours and four-fold increase in speeding tickets issued.

Table 9: Economic analysis of a change from overt to covert mobile speed camera operations within publicly announced routes on Perth's arterial roads (from a base level of 2400 camera hours/month).

Speed camera hours per month	Speeding tickets issued per month	Marginal BCR for increase in hours and tickets	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
2400 (base)	**34000**	NA	0.0	NK	*3400*	179.1	3220.9
3000	**136000**	37.2	8.6	11.0%	*13600*	233.4	13366.6

As with the change to covert operations on rural highways, Table 9 indicates that the change within the publicly announced routes in Perth would be highly cost-beneficial. Moreover, there is greater confidence that the effect will generalise across all arterial roads in Perth because many drivers will have an increased perceived risk of being detected speeding anywhere at any time, unless they are particularly attentive to the public announcements and in this case a localised effect along the whole of the announced route is the minimum effect that could be expected.

7.4 MOBILE RADAR UNITS ON RURAL HIGHWAYS AND LOCAL ROADS

In section 5.2.4, it was proposed that the focus for moving mode (mobile) radar speed enforcement would be on undivided highways and local roads in rural WA (the latter road type being considered to be all undivided). Table 3 indicates that 89.2 casualty crashes per month occurred on these roads in WA during 2002-2004, over 7% of which had fatal outcome. The average cost of these casualty crashes was $380,343 in year 2005 prices.

The total length of rural undivided highways and local roads in WA was estimated to be 123,820 kilometres compared with 134,040 kilometres in Victoria from where the evidence of the effectiveness of mobile radar operations had been obtained. While the estimated traffic on these roads in Victoria was greater than in WA during 1991 (9,259 versus 5,202 million vehicle-kilometres), the enforcement effort required to achieve the same effect in WA as achieved in Victoria was considered to be principally related to the length of road needed to be covered. Because the road lengths are similar, the relationship established in section 6.3 linking crash reductions with the number of speeding offences detected by mobile radar was considered to be applicable in WA as well as Victoria. However, the lower traffic volumes on the WA rural roads suggested that only about 0.75 offences per mobile radar hour could be detected compared with 0.83 per hour in Victoria.

The WA Police Service were not able to provide an indication of the total operational hours achieved by the existing 176 mobile radar units during 2004 (it is understood that the number of these units has recently been increased). However an estimated 179,000 on-the-spot speeding infringement notices were issued in 2004. If about 50% of these were the result of mobile radar detections, this suggests that about 7,500 notices per month come from this source. This in turn suggests that mobile radar units are currently operated for about 10,000 hours per month, principally in rural WA.

Assuming 10,000 hours per month to be the base level of current mobile radar operations on rural undivided highways and local roads, Table 10 shows the economic analysis of increases from that level. The marginal BCR would always be greater than ten for increases in hours up to 33,333 per month, but the program BCR would start to fall above 30,000 hours per month. A program of this size, representing a tripling of the estimated current hours, was estimated to produce 24.1% reduction in casualty crashes on the undivided rural roads.

Table 10: Economic analysis of an increase in mobile radar units on rural undivided highways and local roads in WA (from a base level of 10,000 operational hours per month).

MMR hours per month	Speeding offences detected per month	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)	Nett cash flow per month ($'000)
10000	**7500**	46.2	0.0	0.0%	*750*	440.6	309.4
13333	**10000**	38.8	3.4	5.9%	*1000*	585.0	415.0
16667	**12500**	32.7	5.1	10.9%	*1250*	729.4	520.6
20000	**15000**	27.4	5.9	15.1%	*1500*	873.7	626.3
23333	**17500**	23.1	6.2	18.7%	*1750*	1018.1	731.9
26667	**20000**	19.4	6.3	21.6%	*2000*	1162.5	837.5
30000	**22500**	16.3	6.3	24.1%	*2250*	1306.9	943.1
33333	**25000**	13.7	6.1	26.2%	*2500*	1451.3	1048.7

The cost of operating mobile radar units for 30,000 hours per month, and generating the 22,500 speeding infringement notices expected to result, is estimated to be $1,306,900 per month. However, the expected fine revenue from these operations is estimated to be $2.25 million per month, thus exceeding the operating costs.

7.5 LASER SPEED DETECTORS ON URBAN LOCAL ROADS

In section 5.2.5, it was proposed that the focus of hand-held laser speed detectors for the economic analysis would be on urban local roads, which lie principally in Perth. Table 3 indicates that 2,953 casualty crashes per annum occurred on those roads during 2002-2004. The average cost of a casualty crash on the urban local roads was $178,603 in year 2005 prices.

The total length of the urban local road system in WA was estimated to be 8,200 kilometres with an average traffic volume of 698 vehicles per day on those roads. To achieve a general effect on a substantial proportion of crashes on those roads, the laser operations need to take place at multiple sites of approximately two kilometres in length (see section 6.5), but fortunately the intensity of operations per site per year does not need to be high. Hence the sites need to be chosen as those having a high frequency of casualty crashes ("accident black spot" sites) relative to sites in general.

It has been found that accident black spots generally follow the Pareto principle, i.e. a high proportion of crashes (say, 80%) generally occur on a low proportion of the road system (say, 20%). On the basis that this principle has been followed empirically on urban local roads in WA, it was assumed that 80% of the casualty crashes (i.e. 2,362 per annum) occurred on 20% of the urban local roads (i.e. 1,640 kilometres of road). Thus these crashes could be covered by 820 sites of two kilometres in length. On this basis, the average crash rate at each site was 2.88 casualty crashes per annum. This is consistent with the crash rate of 4.8 casualty crashes per annum at the sites where laser speed detectors operated in Melbourne (see section 6.5), bearing in mind that the average daily traffic on urban local roads in Perth is about 60% of that in Melbourne (1,152 vehicles per day).

In Melbourne during 1997, the average maximum intensity of low-to-medium laser enforcement was 6.12 hours per site per annum (in sessions averaging one hour per occasion). In order that the crash reduction effects of laser speed detectors have similar effects at sites on Perth local roads, it is necessary that enforcement of at least a similar intensity be carried out. Over the 820 sites, this would require up to 5,020 hours of laser enforcement per annum. On the basis of 3.33 speeding offenders detected per hour, this will result in 16,720 speeding infringement notices which need to be processed per annum.

On the basis of the Melbourne experience with laser enforcement at that level on local roads, it is expected that the 2,362 casualty crashes per annum at the accident black spot sites would be reduced by 3.76%. The same experience suggests that the serious casualty crashes (688 of the total casualty crashes) would be reduced by 4.46% (see section 6.5). A stronger influence of effective speeding-related countermeasures on the more serious injury crashes is a not unexpected finding (see, for example, sections 6.1 and 6.6). Serious casualty crashes on Perth's local roads have higher average cost ($571,742) than casualty crashes in general, so the stronger effect of laser enforcement on this crash type has important economic benefits.

Table 11 shows the economic benefits of low-to-medium laser speed enforcement operated as outlined above. If this intensity of laser enforcement achieves the expected crash reduction effects, the program BCR is estimated to be greater than 60. The fine revenue would more than off-set the cost of $306,800 per annum to operate the program.

Table 11: Economic analysis of hand-held laser speed detectors operated at accident black spot sites on urban local roads in Perth (covering 80% of crashes)

Intensity of enforcement	Laser hours per year	Laser speeding offences detected per year	Program BCR	Casualty crash reduction	Serious casualty crash reduction	Fine revenue per year ($'000)	Program cost per year ($'000)	Nett cash flow per year ($'000)
Low to medium	**5020**	**16720**	60.42	3.76%	4.46%	*1672*	306.8	1365.2
Medium	**12300**	**40960**	29.78	3.76%	4.46%	*4096*	622.5	3473.5

The economic benefits of the laser enforcement program in local streets are so substantial that consideration could be given to operating the program at a higher, medium level of intensity (up to 15 hours per site per year) in order to ensure that the crash reduction effects would be achieved to the same extent in Perth as they were in Melbourne. If each of the 820 black spot sites on local roads were to receive 15 hours of laser enforcement per annum, this would require 12,300 hours of enforcement input and result in 40,960 speeding infringement notices to be processed per annum. Table 11 shows that the economic benefits of such a program of speed enforcement would still be very substantial, with a program BCR of nearly 30.

The research evidence does not allow an economic analysis of a larger program of laser enforcement of Perth's local roads. The Melbourne research did not suggest any additional benefits of enforcing each black spot site at higher than a medium level of intensity. There may be a case for laser enforcement on those parts of the local road system which do not have relatively high crash frequencies, but even if effective there would be much fewer crashes to provide the basis of an economic return.

7.6 FIXED SPEED CAMERAS ON PERTH FREEWAYS

In section 5.2.6, it was proposed that overt fixed speed cameras be considered for use on freeways in Perth and that an economic analysis be conducted. Table 3 indicates that 232.3 casualty crashes per annum occurred during 2002-2004 on these roads. Of these, 54.3 crashes per annum were serious casualty crashes resulting in death or serious injury. Fixed speed cameras are known to reduce serious casualty crashes to a greater extent than non-serious casualty crashes and this effect was taken into account in the economic analysis. On Perth freeways, the average cost of a serious casualty crash was $600,005 in 2005 prices, whereas the average cost of a non-serious casualty crash was only $17,065.

Based on European research, ICF (2003) estimated that overt speed cameras inhibit speeding for 4 to 6 km downstream from the camera site. The total length of Perth freeways (in fact, those roads classified as National Highways in urban WA by NRTC 1996) was estimated to be 62 km. Thus it was estimated that 24 fixed speed cameras could control speeding on this road system; twelve cameras in each direction about 5 km apart on average. The cost of each fixed camera installation in NSW was estimated to be $100,000 by ARRB (2005) and that each would have a useful life of 6 years. Thus the capital cost of each camera is $20,980 per year amortised at 7%, p.a. and the total annual capital cost of 24 fixed cameras would be $503,510.

In NSW it was found that the proportion of vehicles exceeding 100 km/h speed limits by at least 10 km/h (a typical threshold level for speeding offences detected by speed cameras) fell substantially following installation of the fixed speed cameras and reached about 1.2% some 24 months later. This parallels experience with the UK fixed camera program where the proportion of vehicles exceeding limits by 15 mph fell to 0.8% and 0.3% in the third and fourth years, respectively, of the Cost Recovery Program (Gains et al 2004, 2005). If an offence detection rate of 1.2% was achieved at the 24 fixed speed camera sites on Perth freeways, it was estimated that 534,200 speeding offences would be detected per annum. Assuming a prosecutability rate of 80%, it was further estimated that 427,355 speeding infringement notices per annum would be issued for these offences. It was assumed that these photographically detected offence notices would cost the same per unit as those from offences detected by the existing mobile speed cameras.

For the economic analysis, it was initially assumed that the measured effects on casualty crashes and serious casualty crashes documented in section 6.6 would apply across the whole freeway road system on which the 24 fixed speed cameras would be installed. From section 6.6, the average reduction in casualty crashes at fixed camera sites across all studies was 26.2%, whereas the average reduction in serious casualty crashes was 53.3%, about twice the magnitude. In the UK studies, the crash reductions had been measured over one kilometre road lengths centred on the fixed camera site. It may be ambitious to expect that the fixed speed cameras on Perth freeways will reduce speeds and road trauma to such an extent up to five kilometres from each overt fixed camera site.

The evaluation of fixed speed cameras in NSW also considered road sections adjacent to and upstream and downstream from the camera site section (each about 1-2 kilometres), so that effect on crashes on the total section of about five kilometres could be assessed. Over the combined lengths there was only 7.76% reduction in casualty crashes, apparently due to weaker crash reductions downstream beyond the camera sections and no evidence of an effect of the cameras upstream (ARRB 2005). This was the minimum casualty crash reduction which could be expected to occur as the result of installing the 24 fixed cameras on Perth freeways. Because of the known greater effect of fixed cameras on more serious injury crashes, it was assumed in the alternative economic analysis that serious casualty crashes would be reduced by twice this amount, i.e. 15.52%.

Table 12 shows the economic analysis of fixed speed cameras on Perth freeways under each of the assumptions outlined above regarding their effects on road trauma: liberal (26.2% reduction in casualty crashes and 53.3% reduction in serious casualty crashes) and conservative (7.76% reduction in casualty crashes and twice the reduction in serious casualty crashes). At either extreme the program appears to be very cost-beneficial.

Table 12: Economic analysis of 24 overt fixed speed cameras on freeways in Perth

Assumed crash reduction effect along full length of Perth freeways	Speeding offences detected per year	Program BCR	Casualty crash reduction	Serious casualty crash reduction	Fine revenue per year ($'000)	Program cost per year ($'000)	Nett cash flow per year ($'000)
Liberal	**427,355**	25.13	26.2%	53.3%	*42735*	712.6	42022.9
Conservative	**427,355**	7.33	7.76%	15.52%	*42735*	712.6	42022.9

The estimated benefit-cost ratio appears to be at least twice as great as those estimated for the fixed speed camera programs in the UK and NSW (see section 6.6). However, it should be noted that in the UK analyses the calculations did not take into account the finding that the speed cameras reduced serious casualties to a greater extent than they reduced casualty crashes in general (Gains et al 2005). In addition, the UK results were for a program of overt fixed and overt mobile speed cameras, and the same studies had generally found that the mobile speed cameras were less effective than the fixed (Gains et al 2003, 2004, 2005). The NSW analysis assessed the benefits in a similar way to that described here, but included some additional costs, namely the cost of initial camera installation, recurrent cost of camera operation (apart from offence processing), and triennial re-sheeting of the road where the camera sensors were embedded (ARRB 2005). It is not known if these extra costs are substantial, but their inclusion would have reduced the NSW benefit-cost ratio.

8 RECOMMENDED SPEED ENFORCEMENT PACKAGE

The recommended speed enforcement package for WA was developed based on the evidence of effects on road trauma at each level of operation, the economic value of each enforcement program, and the overall contribution to reducing road trauma in WA while avoiding overlap of enforcement operations on each part of the road system. The aim was to identify a package which, when fully implemented, would produce at least 25% reduction in fatal crashes, somewhat smaller reductions in less-serious casualty crashes, and have maximum cost-benefits in terms of the return on social cost savings for the investment.

The recommended enforcement programs, together with the level of input (usually operational hours per month) and the expected speeding ticket processing requirements (at least short-term), is shown in Table 13. This table needs to be read in conjunction with Table 14 where the actual crash savings per month are estimated, valued in terms of social costs using the unit crash costs (in 2005 prices) in chapter 7, then aggregated across the package components to provide the overall impacts for the full WA road system. The aggregated benefit-cost ratio for the total social cost savings from the package, relative to the total package cost per month, is also calculated in this way.

Table 13: Recommended speed enforcement programs (by level of input), benefit-cost ratios, and expected crash reductions at the individual program level and for the strategic enforcement package overall

Speed Enforcement Program	Speed Enforce-ment Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9000	90000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1025	3413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**8.01**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3000	30000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15000	11250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads			**9.98**	**9.0%**	**12.3%**	**26.0%**

Table 14: Economic benefits and costs of the recommended speed enforcement programs and for the strategic enforcement package overall

Speed Enforcement Program	Crash savings per month			Social Cost Saving per month ($'000)	Program Cost per month ($'000)	Fine Revenue per month ($'000)
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3974.64	634.1	9000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1551.51	51.9	341.3
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.27	59.4	3561.3
Total for urban roads	**17.0**	**6.1**	**1.3**	**5967.42**	**745.4**	12903
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5673.94	154.5	3000
Mobile radar units on rural local roads	6.2	4.9	0.62	3864.00	653.5	1125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9537.93**	**808.0**	4125
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15505.4**	**1553.3**	17027.6

The use of covert mobile speed cameras on urban highways (arterial roads) in Perth was recommended because of clear evidence of the strong effects of these enforcement operations on fatal crashes, and evidence that an increase in hours committed to this type of speed camera enforcement would further reduce road trauma. A level of 9,000 hours of camera operations per month, representing approximately tripling of the level currently achieved by the existing Multanova cameras in WA, is estimated to produce 65% reduction in fatal crashes on Perth's arterial roads, as well as about 12% reduction in injury crashes. Total social costs of crashes would be reduced by 22%, when crash costs are valued by the "human capital" method (BTE 2000).

An alternative to covert mobile cameras on Perth's arterial roads was overt mobile cameras randomly scheduled on the same roads. The evidence of effect of these enforcement operations could not identify a greater effect on fatal crashes, but their effect on casualty crashes overall was substantial and was estimated to be 27% reduction if 9,000 hours of camera operations per month were committed to Perth's arterial roads. A benefit-cost ratio of 7.9 was estimated for randomly-scheduled overt cameras on these roads, compared with

6.1 for covert cameras, when the social cost of crashes was valued by the "human capital" method. The effect on the total speed enforcement package of replacing the covert camera recommendation with randomly-scheduled overt cameras on urban highways in Perth is shown in Table 15. It can be seen that while the total speed enforcement package would apparently be more cost-beneficial (benefit-cost ratio of 10.64 compared with 9.98), the package would not achieve the target 25% reduction in fatal crashes. For this reason the recommended speed enforcement option for Perth's arterial roads was covert mobile speed cameras. The substantially greater effect of these operations on fatal crashes would also result in this option being more cost-beneficial than the alternative if the social cost of fatal crashes was valued by the "willingness to pay" method (BTCE 1997).

Table 15: Alternative to recommended speed enforcement programs (by level of input), benefit-cost ratios, and expected crash reductions at the individual program level and for the strategic enforcement package overall

Speed Enforcement Program	Speed Enforcement Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Overt mobile speed cameras randomly scheduled on urban highways	9000	90000	7.9	27.3%	27.3%	27.3%
Laser speed detectors at black spot sites on urban local roads	1025	3413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**9.39**	**11.2%**	**10.4%**	**12.2%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3000	30000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15000	11250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads			**10.64**	**13.4%**	**15.2%**	**20.4%**

Car-mounted covert mobile speed cameras are more suitable for relatively highly-trafficked urban arterial roads than lightly-trafficked local streets where the presence of a parked car may betray its purpose and erode the general effect. For this reason, overtly-operated hand-held laser speed detectors have been recommended for speed enforcement at accident black spot sites on Perth's local roads and streets (Tables 13 and 14). They should be operated at sites identified with relatively high frequencies of casualty crashes, the aim being to enforce speeds at a large number of such sites (estimated about 820 in Perth) with low-to-medium intensity of return to the same site each year, rather than enforce fewer sites with higher intensity. Because of the high estimated benefit-cost ratio of this type of speed enforcement, it is recommended that each site be enforced for 15 hours per year (with sessions typically one hour in length), this being the maximum intensity at which the road trauma reductions shown in Table 13 have been demonstrated. The benefit-cost ratio of this level of enforcement intensity is estimated to be close to 30, but an intensity beyond that level may be counterproductive.

Overt fixed speed cameras are recommended for speed enforcement on freeways in Perth, notwithstanding that they have not been clearly demonstrated to have other than a localised effect on casualty crashes. Twenty four camera installations located about 5 km apart, each continuously covering the freeway traffic in one direction, are recommended and are expected to produce at least 7.8% reduction in medically-treated injury crashes and twice that reduction in fatal and hospital admission crashes along the total freeway length (substantially higher crash reductions are expected at the fixed camera sites and these effects may extend to produce higher reductions overall). At minimum, a benefit-cost ratio greater that seven could be expected, but the total crash and social cost saving would be relatively small because freeways are a relatively small component of the Perth road system (Table 14).

Randomly-scheduled overt mobile speed cameras are recommended for speed enforcement on rural highways in WA. Car-mounted covert speed cameras would be unsuitable for this road environment because the presence of the parked car would betray its purpose and erode the general effect. However, the general effect of the randomly-scheduled overt cameras appears to be principally achieved by the aggregation of localised effects at camera sites. Hence, it is important that the camera sites cover a high proportion of crashes on the focused roads. For this reason, the randomly-scheduled overt cameras are recommended for operation (at appropriate sites) on relatively highly-trafficked rural highways, but not on rural local roads (except perhaps at sites with high crash frequencies on those roads, if they occur). As discussed above, there is no evidence that randomly-scheduled overt cameras have greater effect on fatal crashes than casualty crashes in general. To contribute to the target 25% reduction in fatal crashes, Table 7 indicates that this type of speed enforcement should be operated for about 3,000 hours per month on rural highways, which represents about five-fold increase in rural speed camera hours.

Moving mode (mobile) radar units are recommended for speed enforcement on rural local roads, which were assumed to all be undivided roads in WA. A high proportion of the operations should be conducted using unmarked cars (say, 80%) or from mixed unmarked and marked cars in the same area, to ensure casualty crash reductions for up to four days after the enforcement presence. The economic analysis of this enforcement option was conducted for its application to undivided rural highways in WA as well as local roads. It was estimated that 30,000 hours per month of mobile radar operations across these two road environments would produce 24% reduction in casualty crashes and the program would have a benefit-cost ratio greater than six. While rural local roads in WA are estimated to be substantially longer than undivided rural highways, they sustain close to 50% of the total social cost of crashes on undivided rural roads. For this reason, it is recommended that 15,000 hours of mobile radar operations per month be committed to rural local roads, notwithstanding that this enforcement would need to cover a greater length of road per mobile radar unit than the same number of hours on rural highways. With careful scheduling of the enforcement operations on those roads, it is expected that 24% reduction in casualty crashes could still be achieved. It should be recalled that the expected effects based on Victorian experience had already been halved for the economic analysis to allow for any sub-optimal implementation of the enforcement method in WA (section 6.4).

The covert operation of mobile speed cameras within the publicly announced routes (as currently announced each day in WA) outlined in section 5.2.6 is not recommended as a contributor to the target 25% reduction in fatal crashes on either rural highways or arterial roads in Perth. While the economic analysis showed this enforcement option to be cost-beneficial in either environment, the experience from New Zealand suggested that this change in speed camera operations compared with current practice would result in only 11% reduction in casualty crashes (and perhaps a further, unspecified reduction in the injury severity of these crashes). In addition, there is no evidence that a substantial increase in enforcement hours above current levels, in conjunction with the change in method, would have increased crash effects above the 11% reduction. This lack of evidence contrasts with that available for covert mobile speed cameras and randomly-scheduled overt speed cameras based on experience in Victoria and Queensland, respectively.

Table 13 shows that the recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes and a saving of $186 million in social costs per annum (from the monthly savings in Table 14). The total cost of the enforcement package to produce these savings is estimated to be $18.6 million per annum. The benefit-cost ratio of the package is estimated to be at least 10 and would be higher if the road trauma savings were valued by the "willingness to pay" method to establish unit crash costs.

9 IMPLEMENTATION OF THE PACKAGE

9.1 PRIORITIES FOR IMPLEMENTATION

Five speed enforcement programs have been recommended for implementation in WA, which together are expected to achieve 26% reduction in fatal crashes, substantial reductions in injury crashes, and have social cost savings at least ten times the program costs. However the investment in the speed enforcement package is also substantial, being about $18.6 million per annum, and having considerable demands on trained police officers to service most of the recommended enforcement operations and/or offence processing.

Theoretically, when faced with the choice among a number of programs for implementation, the maximum benefit-cost ratio at each stage of implementation is achieved if the programs are chosen in order of their individual benefit-cost ratios. However, this implementation strategy needs to be tempered in the WA context by the desire of the WA government to have the maximum impact on serious road trauma in the short term.

Tables 13 and 14 show that a program of overt mobile speed cameras randomly scheduled on rural highways is estimated to have the highest benefit-cost ratio, the largest social cost savings, and would prevent 1.13 fatal crashes per month (about 14 per year). Programs of covert mobile speed cameras on urban highways (mainly Perth arterial roads) and mobile radar units on rural local roads have similar estimated benefit-cost ratios and social cost savings, but the former program would prevent 1.11 fatal crashes per month (about 13 per year) compared with 0.62 per month (about 7 per year) prevented by the rural program. The order of the remaining two programs is clearly defined by their relative benefit-cost ratios and estimated social cost savings, though in each case these are relatively small compared with the other three programs.

On this basis, the recommended order of implementation of the programs included in the speed enforcement package defined in chapter 8 is:

1. Overt mobile speed cameras randomly scheduled on rural highways
2. Covert mobile speed cameras on urban highways (mainly Perth arterial roads)
3. Mobile radar units on rural local roads
4. Laser speed detectors at black spot sites on urban local roads (mainly Perth local streets)
5. Overt fixed speed cameras on Perth freeways.

9.2 ADDITIONAL ENFORCEMENT EQUIPMENT

Implementation of the recommended speed enforcement package will require significant additional resources of various types. The first of these is additional enforcement equipment, in particular additional speed cameras mounted in unmarked cars (covert operations) or in specially-designated marked vans or perhaps cars (overt operations). It is not known whether the existing Multanova speed cameras, normally operated from a tripod at the roadside, could be mounted inside a car or van or whether new speed cameras must be obtained.

The required number of enforcement units of each type has been estimated based on the current number and the number of operating hours estimated to have been achieved during 2004. The operating hours for the Multanova cameras are based on specific information provided by the WA Police summarised in Appendix A. The current hours of operation of the 176 mobile radar units existing in 2004 were estimated in section 7.4 assuming that 50% of the 179,000 on-the-spot speeding infringement notices were derived from offences detected by this source. The remaining 50% were assumed to derive from laser speed detection operations and these were assumed to detect 3.33 speeding offences per hour based on experience with this type of enforcement in Melbourne (section 6.5). Only the required number of fixed speed cameras for use on Perth freeways was not estimated in this way; the recommended number had been estimated from the total freeway length and the required density of overt fixed cameras to provide a general effect on crashes (section 7.6).

Table 16: Estimated number of speed enforcement units for the recommended speed enforcement package, based on current output rates from existing units

Speed Enforcement Program	Current no. of enforcement units in WA	Operating hours achieved in 2004	Monthly hours per unit	Rec'd operating hours per month	Required no. of enforcement units
URBAN ROADS (Perth)					
Covert mobile speed cameras on urban highways	11 Multanova cameras	28472	216	9000	42
Laser speed detectors at black spot sites on urban local roads	286	26877 (estimate)	8	1025	131
Overt fixed speed cameras on Perth freeways	Nil			Continuous operation	24
RURAL ROADS (Rest of WA)					
Overt mobile speed cameras randomly scheduled on rural highways	3 Multanova cameras	7332	204	3000	15
Mobile radar units on rural local roads	176	120000 (estimate)	57	15000	264

Table 16 indicates that 43 additional vehicle-mounted speed cameras will be required, assuming that the existing 14 Multanova speed cameras can be used in this way. There are no fixed speed cameras installed in WA at present, so 24 fixed camera installations will be required. An additional 88[3] mobile radar units will be required for use on rural local roads, but the existing number of laser speed detectors is more than twice the number required for

[3] Additional to the 176 mobile radar units existing in 2004, some of which have recently been purchased.

operations in Perth's local streets. The costs of this equipment, the support (or mounting) vehicle in each case, and the manpower to operate it have been included in the economic analyses in chapter 7.

9.3 ADDITIONAL OFFENCE PROCESSING CAPACITY

The recommended speed enforcement package will also require additional speeding infringement notices to be issued, at least in the short term until drivers respond to the increased threat of detection, reduce their speed limit transgression rate and consequently reduce the speed offence detection rate from vehicles assessed by the different forms of enforcement. (The reduction in transgression rate, especially from excessive speeding, is considered to be the principal mechanism through which the expected road trauma reductions will result. Other mechanisms include general improvements in driver behaviour as a result of seeing overt enforcement operations, but these are expected to be relatively minor contributors.)

Thus the second additional resource needed to implement the recommended speed enforcement package is a back-office with the capacity to process the expected increased number of speeding infringement notices. Table 13 indicates that 170,276 speeding tickets per month, or 2.043 million per year, will need to be issued in the short term. This is 3.1 times the number of speeding tickets estimated to have been issued by WA police during 2004 (Appendix A). The cost of the manpower to process the higher number of tickets has been included in the economic analyses in chapter 7. However the capital cost of the back-office and offence-processing equipment has been held fixed and has not been escalated to reflect a requirement for additional equipment to replicate its capacity. Since the capital cost of the back-office has been estimated to be about $1.9 million currently, up to an additional $4 million capital investment may be required to expand the back-office capacity in order to provide the infrastructure for the additional offence processing staff.

It is important that adequate resource be provided to process all the speeding offences detected by the recommended speed enforcement package and that speeding tickets be issued to a high proportion of offenders (excepting, of course, those offences which are not legally prosecutable for various operational reasons). While all of the enforcement options aim to reduce speeding behaviour by inflating drivers' *perceived* risk of detection, it is important that the credibility of the system be maintained by the actual receipt of a speeding ticket close to the time of the offence and with high certainty that this will always occur.

9.4 RISK MANAGEMENT

In this vain, it is also important during a time when speed enforcement levels are being escalated to a much higher level than previously that the Police and Government give careful attention to risk management. Delaney, Ward and Cameron (2005) have identified four areas of dilemma which can cause social controversy when major new speed enforcement programs are implemented in a jurisdiction. The two most relevant are legitimacy dilemmas (social concerns about the fairness of the enforcement operations) and implementation dilemmas (acceptance of the enforcement is hampered because difficulties and problems which arose during implementation have not been adequately compensated for in the view of society).

The absence of controversies relating to implementation dilemmas or legitimacy dilemmas during the substantial increase in the Victorian speed camera program during the early 1990's may be related to the attention given by the Victoria Police and the justice department to risk management while the new program was being established. Smith (2000), who had a key role in the justice department at the time, outlines the key issues which were addressed in implementing a program to detect and process a high volume of traffic offences (much higher than previously handled in Victoria). The risk management strategies included:

- independent technical testing and quality assurance (less than ten appeals against the initial five million speeding tickets issued for offences detected by the mobile speed cameras were successful)
- operational procedures that genuinely identified road safety as the primary objective
- winning public support for the program even though the level of fines was substantial
- subjecting the program to independent evaluation research to establish its road safety benefits, or modifications to the program if necessary.

Further details of the risk management principles necessary for successful establishment of a substantial speed camera program are given by Smith, Cameron and Bodinnar (2002).

It is also important to manage public opinion to avoid controversies associated with the credibility dilemma (Delaney et al 2005). This dilemma may arise if there are doubts about the Government's real purpose in escalating speed enforcement, e.g. whether the principal purpose is to raise revenue for the Government through a substantial increase in speeding infringement fine income. The importance of managing public opinion about the credibility of escalated speed enforcement is illustrated by the experience in British Columbia, Canada (Chen 2005). When their mobile speed camera program was introduced in 1996, two-thirds of the population supported the new initiative. The political opposition, reflecting emerging grassroots opinion, portrayed the program as a "cash cow" for the provincial government rather than a safety issue. The program subsequently became an election issue, the opposition party were elected, and the program was terminated in June 2001, notwithstanding that a scientific evaluation published in 2000 had demonstrated the safety benefits of the program (Chen et al 2000).

9.5 FUNDING OF THE PACKAGE

As outlined in chapter 8, the recommended speed enforcement package was estimated to cost $18.6 million per annum to operate (to this should be added the potential increased capital cost of $4 million, amortised on a per annum basis, of providing a back-office infrastructure for the manpower to process the expected speeding tickets needed to be issued, at least in the short term).

Table 14 indicates that the fine revenue from the escalated number of speeding tickets, at least initially, would be about $17 million per month or $204 million per annum. Thus the operational costs of the recommended speed enforcement package would be of the order of 9-10% of the fine revenue, this percentage probably increasing over time as transgression rates and detected speeding offences fall in response to the escalated enforcement. It is not expected that the operational costs would exceed 20% of the fine revenue for many years.

Associated with the rapid expansion in speed cameras in the UK since 2000 has been a Cost Recovery mechanism whereby the road safety partnership agencies in each area operating cameras have been able to recover their operational costs from the central government fund receiving the fine revenue. Over the first four years of the Cost Recovery Program, £217.5 million in fines has been received and £175.2 million in costs have been recovered, representing about 80% of the fine revenue (Gains et al 2005). The Cost Recovery Program is tightly controlled by Her Majesty's Treasury and the camera partnerships only recover their costs after submitting audited accounts. Apparently, this transparent system has not led to any public controversy about the use of (most of) the fine revenue in this way. The surplus fine revenue is transferred to the Government's consolidated fund.

It is recommended that the Western Australian Government give consideration to funding the operational costs of the speed enforcement package recommended here in a similar way. A transparent system whereby it is recognised that the costs of providing an effective system to reduce road trauma and social costs are met from the fines paid by speeding motorists should have broad public acceptance. From the Government's point of view, the impact on the fine revenue should be no more than 20%. The surplus revenue may also be the basis of Government investment in other effective road safety programs addressing problems other than speeding.

10 CONCLUSION

A package of speed enforcement programs has been defined for the WA road environment which recognises its relatively unique characteristics of vast size and light traffic density, except in Perth. The evidence of the effects on speeds and road trauma in other jurisdictions due to speed camera systems and manual speed enforcement methods has been reviewed and synthesised to provide strategic understanding of their mechanisms. In the case of some key speed enforcement operations, it has been possible to calibrate the road trauma reductions against the operational levels.

From this research base, it has been possible to define a suitable speed enforcement method for each part of the WA road system and calculate the road trauma reductions and economic benefits if operated at each level. The recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes per annum.

The package is estimated to provide a saving of at least $186 million in social costs per annum. The total cost to produce these savings is estimated to be $18.6 million per annum. Thus the benefit-cost ratio of the package is estimated to be at least 10. The expected fine revenue from speeding motorists detected by the recommended speed enforcement operations, at least in the short term, is estimated to be $204 million per annum. Thus the estimated cost to operate the recommended package would initially be less than 10% of the fine income. In the longer term, the operational cost is not expected to exceed 20% of the expected diminishing fine income as speeding behaviour improves and detected offenders reduce in response to the escalated speed enforcement activity recommended here.

11 REFERENCES

Andersson, G. and Nilsson, G. (1997). Speed management in Sweden. Swedish National Road and Transport Institute VTI, Linkoping.

Andersson, G. (1990). Speeds as a function of tolerance limit, penalties and surveillance intensity. Swedish Road and Traffic Research Institute, Report 337.

Arberg, L., Engdahl, S. and Nilsson, E., (1989). Increased speeding fines. Effects on drivers' knowledge about amounts of fines and effects on speeds, Transportforskningsberedningen, Report No. 10, Stockholm.

ARRB (2005) Evaluation of the fixed digital speed camera program in NSW. RC2416

Bjørnskau, T. and Elvik, R. (1990). Can road traffic law enforcement permanently reduce the number of accidents? In: Proceedings of road safety and traffic environment in Europe in Gothenburg, Sweden, September 26-28, 1990, VTI report 365A p.122-145.

Bobevski, I., Hosking, S., Oxley, P., and Cameron, M.H. (2004). Evaluation of speed enforcement initiatives in Victoria, 2000-2002. Draft final report, Monash University Accident Research Centre.

Cameron, M.H. (1999). Methodology for evaluation of the Enhanced Traffic Enforcement Program in Western Australia. Report to Office of Road Safety, Western Australia.

Cameron, M.H. and Sanderson J.T. (1982) Review of Police operations for traffic law enforcement. RACV Traffic and Safety Department.

Cameron, M.H., Cavallo, A. and Gilbert, A. (1992). Crash-based evaluation of the speed camera program in Victoria 1990-1991. Phase 1: General effects. Phase 2: Effects of program mechanisms (Report No. 42). Melbourne: Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003a). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria. Report No. 201, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003b). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria, Australia. Paper accepted for presentation at 47th Annual Scientific Conference, Association for the Advancement of Automotive Medicine, Lisbon, Portugal, September 2003.

Cameron, M.H., Newstead, S.V., Gantzer, S., (1995). Effects of enforcement and supporting publicity programs in Victoria, Australia. In: Proceedings of Conference, Road Safety in Europe and Strategic Highway Research Program, Prague, The Czech Republic, VTI, Sweden.

Chen, G. (2005). Safety and economic impacts of photo radar program. Traffic Injury Prevention, Vol. 6, pp. 299-307.

Chen, G., Wilson, J., Meckle, W., and Cooper, P. (2000). Evaluation of photo radar in British Columbia. Accident Analysis and Prevention, Vol. 32, pp. 517-26.

Diamantopoulou, K., Cameron, M.H., and Shtifelman, M. (1998). Evaluation of Moving Mode Radar for Speed Enforcement in Victoria, 1995-1997 (Report 141). Melbourne: Monash University Accident Research Centre.

Diamantopoulou, K and Corben, B. (2001) The Impact of Speed Camera Technology on Speed Limit Compliance in Multi-Lane Tunnels. Report to LMT.

Diamantopoulou, K and Cameron, M. (2002). An evaluation of the effectiveness of overt and covert speed enforcement achieved through mobile radar operations (Report 187). Monash University Accident Research Centre.

Elvik, R. (1997) Effects of accidents of automatic speed enforcement in Norway, Transportation Research Record 1997: 1571:1-19

Elvik, R (2001). Cost-benefit analysis of Police enforcement. Working paper 1, ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement) Project, European Union.

Fitzharris, M, Gelb, KR, Harrison, WA, Newstead SV, Diamantopoulou, K, Cameron, MH. (1999) Evaluation of the Effect of the Deployment of Hand-held Laser Speed-detection Devices in the Melbourne Metropolitan Area. Road Safety: Research, Policing & Education Conference: Handbook and proceedings (pp.709-720).

Gains, A, Humble, R, Heydecker, B, and Robertson, S (2003). A cost recovery system for speed and red-light cameras – two year pilot evaluation. Research paper, 11 February 2003, prepared for Department for Transport, Road Safety Division, U.K. PA Consulting Group and University College London.

Gains, A., Heydecker, B., Shrewsbury, J. and Robertson, S. (2004). The national safety camera programme: Three-year evaluation report. Report prepared for Department for Transport, Road Safety Division, U.K. PA Consulting Group and University College London.

Gains, A., Nordstrom, M., Heydecker, B. and Shrewsbury, J. (2005). The national safety camera programme: four year evaluation report. London: PA Consulting Group and University College London.

Gelb, K, Narayan, S, Diamantopoulou, K and Cameron, MH. (2000). An Economic Assessment of the Speed Camera Program. Report to the Transport Accident Commission.

Goldenbeld, C and van Schagen, I. (2005) The effects of speed enforcement with mobile radar on speed and accidents: an evaluation study on rural roads in the Dutch province Friesland. Accident Analysis and Prevention, Vol. 27, pp. 1135-1144.

Gunarta, S. and Kerr, G. (2005). Speed impact of mobile speed cameras in Christchurch. Road and Transport Research, Vol. 14, No. 2.

Harrison, WA, Fitzharris, M, Newstead SV, Gelb, KR, Diamantopoulou, K, Cameron, MH. (1999) Evaluation of the Effect of the Deployment of Hand-held Laser Speed-detection Devices in the Melbourne Metropolitan Area. Report to Transport Accident Commission, Victoria.

Hooke, A., Knox, J. and Portas, D. (1996). Cost benefit analysis of traffic light and speed cameras. Police Research Series, Paper 20. Home Office, London.

ICF Consulting (2003). Costs-benefit analysis of road safety improvements: Final report. ICF Consulting, London.

Keall, M.D., Povey, L.J. and Frith, W.J. (2001). The relative effectiveness of a hidden versus a visible speed camera programme. Accident Analysis and Prevention 33, 277-284.

Keall, M.D., Povey, L.J. and Frith, W.J. (2002). Further results from a trial comparing a hidden speed camera programme with visible camera operation. Accident Analysis and Prevention, Vol. 34, 773-777.

Keenan, D. (2002) Speed cameras - the true effect on behaviour. Traffic Engineering & Control, 43, 154-160.

Kloeden, C.N., McLean, A.J., Moore, V.M. and Ponte, G. (1997) Travelling speed and the risk of crash involvement (CR172). Canberra: Federal Office of Road Safety.

Mara, M.K. Davies, R.B. and Frith, W.J. (1996). Evaluation of the effect of compulsory breath testing and speed cameras in New Zealand. Proceedings Combined 18th ARRB Transport Research Conference and Transit NZ Land Transport Symposium, Christchurch, New Zealand.

National Highway Traffic Safety Administration. Traffic safety facts, 2003: speeding. Report no. DOT HS-809-771, 2004. Washington, DC. Available: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2003/809771.pdf. Accessed: 23 December 2004.

Newstead, S. (2004) Evaluation of the crash effects of the Queensland speed camera program to September 2003. Draft Report prepared for Queensland Transport.

Newstead, S., Bobevski, I., Hosking, S. and Cameron, M. H. (2004). Evaluation of the Queensland road safety initiatives package. Unpublished report, Monash University Accident Research Centre.

Newstead, SV, Cameron MH and Leggett, M. (1999). Evaluation of the Queensland Random Road Watch Program. Report No. 149, Monash University Accident Research Centre.

Newstead, S. and Cameron, M. (2003) Evaluation of the crash effects of the Queensland Speed Camera Program, Report No. 204, Monash University Accident Research Centre, Melbourne, Australia.

Newstead, SV, Mullan, N and Cameron, MH. (1995). Evaluation of the Speed Camera Program in Victoria 1990-1993. Phase 5: Further investigation of localised effects on casualty crash frequency. Report No. 78, Monash University Accident Research Centre.

Nilsson, G (1984). Speeds, accident rates and personal injury consequences for different road types. Rapport 277, Swedish National Road and transport Research Institute (VTI), Sweden.

National Road Transport Commission (1996) Mass Limits Review Appendices to Technical Supplement No. 2: Road and bridge statistical data tables.
PA Consulting (2001). Cost Recovery System for traffic safety cameras – First year report: Executive Summary. Report prepared for DTLR Road Safety Division, U.K.

Palamara, P. and Bosch, B. (2005). Western Australia Speed Review: Data sources and countermeasures. Injury Research Centre, University of Western Australia.

Pilkington, P and Kinra, S (2005). Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. BMJ 2005;330:331-334.

Radalj, T. (2006). Driver speed behaviours on Western Australia road network 2000, 2003, 2004 and 2005. Main Roads Western Australia.

Road and Traffic Authority (2006) Fixed Speed Cameras. Available: (http://www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/fixeddigitalspeedcameras/index.html Accessed: 11 May 2006.

Rogerson, P, Newstead, SV and Cameron, MH. (1994). Evaluation of the speed program in Victoria 1990-91. Phase 3: Localised effects on casualty crashes and crash severity. Phase 4: General effects on speeds. Report No. 54, Monash University Accident Research Centre.

Ross, H.L. (1981). Deterrence of the drinking driver: an international survey. U.S. Department of Transportation, Report No DOT-HS-805-820.

Ross, H.L. (1990). Reducing drink driving by individuals through enforcement. In: Enforcement and rewarding: strategies and effects. Proceedings of the International Road Safety Symposium in Copenhage, Denmark. pp.25-28.

Smith, R.R. (2000). Speed, Traffic Cameras and Justice: Lessons Learned in Victoria, Australia. Proceedings of Conference, *Road Safety on Three Continents,* Pretoria, South Africa. Swedish National Road and Transport Research Institute, Sweden.

Smith, R.R., Cameron, M.H., and Bodinnar, J.G. (2002). The use of speed cameras in Ireland: Executive Summary. National Roads Authority, Republic of Ireland.

Zaal, D. (1994). Traffic Law Enforcement: a review of the literature. Report No. 53. Monash University Accident Research Centre.

Speed enforcement and offence processing estimates based on information provided by WA Police, May 2006

	Perth	Rest of WA	TOTAL Western Australia					
	Multanova speed cameras	Multanova speed cameras	Multanova speed cameras	Mobile radar units	Hand-held laser units	Total mobile radar and hand-held laser units	Hand-held radar units	TOTAL (Photographic Evidence TINs plus OTS TINs/Offences)
Manufacturer's designation	6F	6F	6F	Decatur	LTI 20-20		Kustom Flacon	
No. of units	11	3	14 operational (20 total)	176	286		32	
ENFORCEMENT OPERATING COSTS								
Capital cost of speed detector equipment ($ per unit)	$ 109,233	$ 109,233	$ 109,233	$ 4,541	$ 4,890			
Year purchased	2003/4	2004	2004	2003	2003			
Maintenance cost ($ p.a. per unit)								
Useful life (years)	10	10	10	7	7			
Amortised cost per month ($ per unit) @ 7% p.a.	$1,260.93	$1,260.93	$1,260.93	$68.14	$73.38			
Support vehicles (no. per unit)	1	1	1	1	1			
Capital cost ($ per vehicle) **PER MONTH**	620	620	620	620	620			
Maintenance cost ($ p.a. per vehicle) **PER MONTH**	593	593	593	593	593			
Useful life (years) **3 year lease**	3	3	3	3	3			
Vehicle cost per month ($ per vehicle)	$ 1,213.00	$ 1,213.00	$ 1,213.00	$ 1,213.00	$ 1,213.00			
No. of shifts per day	2	2	2	2	3			
Shift duration (hours)	8	8	8	8	8			
Operating duration target (hours/shift)	4.0	6.0 est.	5.0	7.0	7.0			
Operators per unit per shift	1	1	1	1	1			
Operator cost per hour ($ gross)	$ 28.00	$ 28.00	$ 28.00	$ 35.00	$ 35.00			
Operator cost per shift	$ 224.00	$ 224.00	$ 224.00	$ 280.00	$ 280.00			
Operator cost per enforcement operating hour	$ 56.00	$ 37.33	$ 44.80	$ 40.00	$ 40.00			
Equipment cost per month ($ per unit plus vehicle)	$ 2,473.93	$ 2,473.93	$ 2,473.93	$ 1,281.14	$ 1,286.38			
Enforcement operating hours per unit/vehicle per day	7.09	6.70	7.01	14.00	21.00			
Enforcement operating hours per unit/vehicle per month	215.70	203.67	213.13	425.83	638.75			
Equipment cost per enforcement operating hour	$ 11.47	$ 12.15	$ 11.61	$ 3.01	$ 2.01			
Total operation cost per enforcement hour	**$ 67.47**	**$ 49.48**	**$ 56.41**	**$ 43.01**	**$ 42.01**			
Locations visited (of 5 - 6,000 speed camera sites) [2004]			12,313					
Operating hours achieved [2004]								
~ per year	28,472	7,332	35,805	N/a	N/a			
~ per day	78.0	20.1	98.1	N/a	N/a			
~ per shift per unit	3.5	3.3	3.5	N/a	N/a			

	Perth	Rest of WA	TOTAL Western Australia					
OFFENCE PROCESSING COSTS	Multanova speed cameras	Multanova speed cameras	Multanova speed cameras	Mobile radar units	Hand-held laser units	Total mobile radar and hand-held laser units	Hand-held radar units	**TOTAL (Photographic Evidence TINs plus OTS TINs/Offences)**
MARGINAL COSTS PER OFFENCE DETECTED								
Vehicles processed [2004]	17,750,253	3,218,382	20,968,635	N/a	N/a			
Vehicles per operating hour	623.43	438.95	585.63					
Over speed limit (%)	16.80%	17.80%	17.04%					
Offence detection rate (%) [Over enforcement limit]	2.90%	2.60%	2.94%					
Speed camera offences detected [2004] *est. by area*	*514,757*	*83,678*	616,617					616,617
Other photographic evidence offences [red light?] (av.)								65,933
Photographic evidence offences detected/processed (av.)								682,550
OTS offences detected/processed (average)						302,950		302,950
No. offence processing staff - **TOTAL** (exc. sworn mgt.)								77.5
Photographic offences processed per day **Avg**								1870
OTS offences processed per day **Avg**								830
Offence processor days required to process offences	275.3	44.7	329.7			365		
Offence processor cost per day								
~ sworn members ($ gross p.a.) **26 Total**								$189.67
~ unsworn ($ gross p.a.) **77.5 Total**								$136.99
Total cost to process 2004 offences (inc. mgt component)	$55,112.27	$8,958.94	$66,017.83			$73,076.92		
Output from offence processors								
~ photographic evidence offence TINs	407,912	66,309	488,629					488,629
~ OTS offence TINs						179,000		179,000
Non-prosecutability rate (%) est. by area	*20.8%*	*20.8%*	20.8%			40.9%		
Processor cost per 1000 TINs output	**$135.11**	**$135.11**	**$135.11**			**$408.25**		
Fine revenue per offence TIN issued								
~ photographic evidence offences ($ per unit) AVG								$100
~ OTS offences ($ per unit)(**Avg Offence amount**)								$100
FIXED COSTS ***(assumed constant with increased offences)***								
Back Office accommodation cost ($ p.a.)								Not known
No. offence processing workstations (Pol. staff only)								80
Capital cost per workstation								700
Total cost of workstations								$56,000.00
Capital investment in Back Office ($)								$300,000.00
~ Digitisation/image management equipment ($)								Fotovix for wet film - $NK
~ Computers and software ($)								$312,000.00
~ Other substantial capital costs ($)								
Print and Postage								$180,000.00
Barcodes for film								$5,000.00
Photo packs for customer								$30,000.00
Consumables								$30,000.00
Total radar spare parts/training units and NATA laboratory equipment ($)								$1,000,000.00
Total known capital investment								**$1,913,000**
Amortised capital cost per month over 10 years @ 7% p.a.								$22,082.74
Split of capital cost:								
- Perth Multanova detections								$12,610.87
- RoWA Multanova detections								$2,050.00
- Mobile radar/hand-held laser detections								$7,421.87

Sub 21
Part 3

MONASH University
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DEVELOPMENT OF STRATEGIES FOR BEST PRACTICE IN SPEED ENFORCEMENT IN WESTERN AUSTRALIA

SUPPLEMENTARY REPORT

by

Max Cameron

May, 2008

MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE
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277	May 2008	0 7326 2347 2	xi + 50

Title and sub-title: Development of strategies for best practice in speed enforcement in Western Australia: Supplementary report

Author(s): Max Cameron

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Abstract:
This report is a supplement to the final report of a 2006 study with the same title. The objective of the 2006 research was for the results and recommendations to be utilised to enhance speed enforcement strategies in WA, by assisting the WA Police in developing formal business cases for the deployment of enforcement technology (what, where and how) and the purchasing of enforcement technology (number, mix and type). The supplementary research aimed to include newly reviewed and emerging technologies available such as point-to-point speed cameras; update the recommended mix of speed enforcement practices, the circumstances in which each should be applied, and the objective seeking to be achieved; and review available infringement management models worldwide in terms of their ability to facilitate a reduction in speeding effectively and efficiently through deterrence and detection.

In the 2006 study, a package of speed enforcement programs was defined for the WA road environment which recognises its relatively unique characteristics of vast size and light traffic density, except in Perth. Evidence of the effects on speeds and road trauma in other jurisdictions due to speed camera systems and manual speed enforcement was reviewed and synthesised to provide strategic understanding of their mechanisms. A suitable speed enforcement method for each part of the WA road system was defined and the road trauma reductions and economic benefits were estimated. The recommended speed enforcement package, when fully implemented, was estimated to produce 26% reduction in fatal crashes, 12% reduction in crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. The package was subsequently proposed for implementation by the Monash University Accident Research Centre (MUARC) in their recent recommendations for a new road safety strategy for Western Australia spanning the period 2008-2020.

The extension project reviewed new evidence and information about point-to-point speed cameras; updated previous evaluations of the randomly-scheduled overt mobile speed cameras in Queensland; and reviewed offence processing and likely deterrence effects of the camera programs in Victoria, Queensland, Sweden, France and the United Kingdom. The effects of reducing speeding offence detection thresholds in Victoria were also reviewed.

Key Words:

Traffic enforcement	Speeding

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EXECUTIVE SUMMARY

Tasks and objectives

During 2006, the WA Office of Road Safety commissioned MUARC to develop strategies for best practice in speed enforcement in the state (Cameron and Delaney 2006). The principal tasks of the 2006 project were to:

- Conduct an analysis of current Australian and international activity, research and literature in relation to best practice in speed enforcement strategies and technology;
- Develop recommendations on the implementation of best practice in speed enforcement specifically for the WA setting; and
- Develop a detailed implementation plan in order to move from the current situation to what has been recommended.

Since being proposed for implementation by MUARC in their recent recommendations for a new road safety strategy for Western Australia spanning the period 2008-2020, to ensure the most up-to-date best practice methods are adopted, an extension of the 2006 project was commissioned in December 2007 with the following objectives:

1. Review of the 2006 report to include newly reviewed and emerging technologies available such as point-to-point speed cameras;
2. Update the recommended mix of technological and non-technological speed enforcement practices, the circumstances in which each should be applied and the objective seeking to be achieved, given the inclusion of these new and emerging technologies and practices (e.g., point-to-point);
3. Identify and review available infringement management models worldwide including processing and camera management in terms of their ability to facilitate a reduction in speeding effectively and efficiently through deterrence and detection.

This supplementary report should be read in conjunction with the final report of the 2006 study (Cameron and Delaney 2006).

Previously recommended speed enforcement package

The previously recommended package of speed enforcement programs, together with the recommended level of program input (usually operational hours per month), is shown in the tables below. The second table shows the crash savings per month, by severity of crash, which derive from the percentage crash reductions if the program is implemented in that part of the WA road system. The social cost savings have been calculated from the crash savings using the Federal government's road trauma cost figures (BTE 2000), indexed to 2005 prices.

Point-to-point speed camera systems on highly-trafficked rural highways were also an option reviewed, however the evidence of their effects from the UK was too limited at the time of the 2006 study to allow further consideration.

The previously recommended speed enforcement package, when fully implemented, was estimated to produce 26% reduction in fatal crashes, 12% reduction in crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes.

Speed Enforcement Program	**Speed Enforce-ment Hours per month**	**Speeding Tickets Issued per month**	**Program BCR**	**Program Crash Reduction**		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9,000	90,000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35,613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**8.01**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	30,000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads			**9.98**	**9.0%**	**12.3%**	**26.0%**

Speed Enforcement Program	**Crash savings per month**			**Social Cost Saving per month ($'000)**	**Program Cost per month ($'000)**	**Fine Revenue per month ($'000)**
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3,974.64	634.1	9,000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1,551.51	51.9	341.3
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.27	59.4	3,561.3
Total for urban roads	**17.0**	**6.1**	**1.3**	**5,967.42**	**745.4**	12,903
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5,673.94	154.5	3,000
Mobile radar units on rural local roads	6.2	4.9	0.62	3,864.00	653.5	1,125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9,537.93**	**808.0**	4,125
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15,505.4**	**1,553.3**	17,027.6

Extension project

The extension project reviewed new evidence and information about point-to-point speed cameras; updated previous evaluations of the randomly-scheduled overt mobile speed cameras in Queensland; and reviewed offence processing and likely deterrence effects of the camera programs in Victoria, Queensland, Sweden, France and the United Kingdom. The effects of reducing speeding offence detection thresholds in Victoria were also reviewed. The following conclusions were reached:

1. Point-to-point speed cameras are likely to be effective speed enforcement systems covering substantial lengths of freeways and highways in WA with limited access/egress opportunities. Economic analysis has identified 40 road links where the application of point-to-point systems would have benefit-cost ratios of 10 or greater.

2. The Victorian covert mobile speed camera program is reliant principally on the prosecution of speeding drivers to achieve specific deterrence. Thus it is heavily dependent on processing all of the offenders detected (within limits of legal integrity) in order to achieve its effects. The efficiency of processing speeding offences detected by mobile cameras in Victoria, as well as offences detected by fixed cameras, is improved by the existence of "owner-onus" legislation making the vehicle owner initially liable for the offence.

3. The Queensland overt mobile speed camera program achieves substantial general deterrence around camera sites, producing local effects which amalgamate to produce a broad general effect due to the random scheduling in space and time and the comprehensive coverage of crash sites by camera sites. Prosecuting a substantial number of speeders detected by the cameras appears necessary to give real fear of detection/punishment behind the thinly spread enforcement operations.

4. The Swedish overt fixed speed camera program focuses on general deterrence of speeding on the camera routes exclusively, and places relatively little emphasis on specific deterrence. The density of cameras on the specific routes, no matter whether each is operational or not, produces a strong general deterrence effect. The high perceived risk of detection is supported by the prosecution of only a relatively small number of offenders. The effect of the program is limited to the camera routes and there is the question of whether general deterrence can be maintained long-term.

5. The French speed camera program is focused on specific deterrence of speeding through a high rate of surveillance of each driver and the capacity to prosecute all of the offences detected. Some general deterrence of speeding at camera sites is also achieved, especially at fixed camera sites. The efficiency of the French system is assisted by owner-onus legislation and the requirement that the owner is immediately liable to pay the fine.

6. The UK speed camera program is focused on general deterrence through the very conspicuous operation of large numbers of fixed and mobile cameras. However, the operations do not produce a broad effect which extends the strong local effects.

Specific deterrence appears to be a secondary effect of the program and is focused on excessive speeders because of the relatively high enforcement threshold.

7. A reduction in the speed enforcement threshold will produce a short-term increase in the offence detection rate, but in the medium to long term the offence rate will return to its previous level. In addition, the proportion of drivers exceeding the old enforcement threshold will reduce substantially because of more effective deterrence of speeding above that level.

8. Based on the review of speed offence processing models in other jurisdictions, it was concluded that the number of offences estimated to be processed, in the originally recommended package, was over-stated and could be reduced. The reduction in the offence processing load reduces the cost of the package and increases the benefit-cost ratio, as shown in the tables below. The benefit-cost ratio of the alternative to the originally recommended package is also increased. A second alternative package, involving the use of both covert and overt mobile speed cameras on urban highways in Perth, may combine the best features of these two forms of operation and produce crash reductions and a benefit-cost ratio between those of the originally recommended package and the alternative.

Speed enforcement package	Reduction in fatal crashes	Reduction in hospital admission crashes	Reduction in medical treatment crashes	Package Benefit-Cost Ratio
1. Originally recommended package (covert mobile speed cameras in Perth)	26.0%	12.3%	9.0%	9.98
2. Originally recommended package (covert mobile speed cameras in Perth) – REVISED (reduced offence processing)	26.0%	12.3%	9.0%	10.08
3. Alternative to recommended package (overt mobile speed cameras in Perth) – REVISED (reduced offence processing)	20.4%	15.2%	13.4%	10.81
4. Second alternative to recommended package (covert and overt mobile speed cameras in Perth)	23.2%	13.8%	11.2%	10.44

Speed enforcement package	Program Cost per month ($'000)	Program Cost per year ($m)	Speeding Tickets issued per year (short-term)	Fine revenue ($m) at $100 per ticket (short-term)	Fines Enforcement Registry additional cost per year ($m)
1. Originally recommended package (covert mobile speed cameras in Perth)	1,553.3	18.64	2,043,315	204.3	1.530
2. Originally recommended package (covert mobile speed cameras in Perth) – REVISED (reduced offence processing)	1,538.5	18.46	1,495,960	149.6	0.831
3. Alternative to recommended package (overt mobile speed cameras in Perth) – REVISED (reduced offence processing)	1,530.3	18.36	755,960	75.6	0.075
4. Second alternative to recommended package (covert and overt mobile speed cameras in Perth)	1,534.4	18.41	1,135,960	113.6	0.514

9. Pending decisions on the application of point-to-point speed cameras, the originally recommended speed enforcement package remains the most effective set of options for WA. It is nearly the most cost-beneficial set of options and would be certainly so if fatal crash reductions were valued more highly, because of the strong effect of covert mobile speed cameras on fatal outcomes in crashes. Randomly-scheduled overt mobile speed cameras have no greater effect on reducing fatal crashes than on non-fatal crashes.

10. Point-to-point speed camera systems have the potential to replace the originally recommended speed enforcement program on Perth freeways, and the recommended programs on parts of the urban and rural highway system. Links of freeway and highway have been identified where point-to-point systems are economically warranted, as summarised in the table below. Decisions about the specific links suitable for application of the point-to-point technology must await consideration of all of the characteristics of the nominated roads.

Region	Roads warranted for Point-to-Point camera systems	Total Length of Links (km)	Reduction in fatal and hospital admission crashes	Reduction in medical treatment crashes	Point-to-Point system capital cost ($)	Speeding Tickets issued per year (short term)	BCR
Perth metro-politan	Freeways	74	33.3%	12.6%	4,900,000	496,758	10.35
	Other links in top 40	248	33.3%	12.6%	4,450,000	218,210	16.54
Rural	Links in top 40	2,990	33.3%	12.6%	11,800,000	133,591	15.76

1 INTRODUCTION

1.1 PROJECT TASKS AND OBJECTIVES

During 2006, the WA Office of Road Safety commissioned MUARC to develop strategies for best practice in speed enforcement in the state (Cameron and Delaney 2006). The principal tasks of the 2006 project were to:

- Conduct an analysis of current Australian and international activity, research and literature in relation to best practice in speed enforcement strategies and technology;
- Develop recommendations on the implementation of best practice in speed enforcement specifically for the WA setting; and
- Develop a detailed implementation plan in order to move from the current situation to what has been recommended.

The main objective was for the results and recommendations from the research to be utilised to enhance enforcement strategies in WA. Specifically, to assist the WA Police in developing formal business cases for:

- The deployment of enforcement technology (what, where and how);
- The purchasing of enforcement technology (number, mix and type); and
- Funding options and service delivery models for the purchase and support of the future enforcement technologies and activities.

Since being proposed for implementation by MUARC in their recent recommendations for a new road safety strategy for Western Australia spanning the period 2008-2020, to ensure the most up-to-date best practice methods are adopted, an extension of the 2006 project was commissioned in December 2007 with the following objectives:

1. Review of the 2006 report to include newly reviewed and emerging technologies available such as point-to-point speed cameras;
2. Update the recommended mix of technological and non-technological speed enforcement practices, the circumstances in which each should be applied and the objective seeking to be achieved, given the inclusion of these new and emerging technologies and practices (e.g., point-to-point);
3. Identify and review available infringement management models worldwide including processing and camera management in terms of their ability to facilitate a reduction in speeding effectively and efficiently through deterrence and detection.

This supplementary report should be read in conjunction with the final report of the 2006 study (Cameron and Delaney 2006). Only the most relevant material from that report is repeated here.

1.2 CONTEXT

A speed enforcement strategy for WA needs to recognise the vast size of the State and also its relatively light traffic density compared with other Australian states. The area of WA is more than ten times that of Victoria and even 46% greater than Queensland. While the length of each state's road systems are of the same order of magnitude, the traffic density in Victoria is nearly 30 times higher and even in Queensland it is nearly 2.5 times the WA density. However the proportion of total travel in urban areas in WA (63%, mainly in Perth) falls between the proportions in Victoria (71%) and Queensland (37%).

The Multanova 6f speed camera system is the principal method for the detection of speed offenders in WA, detecting over 616,600 offenders in 2004 compared with about 303,000 offenders detected by non-photographic methods (mobile radar units, which can also be operated in stationary mode, and hand-held laser speed detectors). A small number of hand-held radar units also exist, but apparently laser units are now favoured for hand-held operation. The WA Police Service had provided details of the number of units, costs, operating staff and support vehicle requirements, vehicles assessed (in the case of the cameras) and offences detected per annum, offence processing staff numbers and costs, and offence processing equipment costs (see Cameron and Delaney, 2006, Appendix A).

2 POINT-TO-POINT SPEED CAMERAS

Point-to-point speed cameras, or average speed cameras, are the most relevant new technology for speed enforcement which was not fully covered in the report on the 2006 study. The technology was described, but insufficient information was available at that time about its effectiveness, cost and operational aspects for this to be considered as an option for speed enforcement in WA in appropriate circumstances. This situation has now changed.

2.1 OPERATION OF POINT-TO-POINT SPEED CAMERAS

Point-to-point camera technology uses a number of cameras mounted at staged intervals along a particular route. The cameras are able to measure the average speed between two points or the spot speed at an individual camera site. In order to measure the average speed between two points the cameras must be linked to one another and the time clocks on both machines must be synchronised. The average speed is then determined by dividing the distance travelled by the time taken to travel between the two points. The distance between two camera sites may vary from as low as 300 meters to up to tens of kilometres. An enforcement threshold may also be implemented to allow for acceptable variations in driver speed along the route. Potentially, a lower enforcement threshold could be considered for the average speed measured by this technology than the spot speeds measured by mobile and fixed speed cameras.

In the U.K., point-to-point camera technology, using digital imaging, was first installed on Nottingham's main link road from the M1 Motorway in July 2000, as part of a trial program of additional speed cameras in eight Police areas. Two cameras were mounted along the enforced 40 mph road length approximately 0.5 kilometres apart. In a comparison with traditional wet-film spot-speed fixed cameras, Keenan (2002) found that reported casualty crashes at the Nottingham digital camera site fell from 33 during the year before installation to 21 during the year after, a reduction of 36%. In addition, both mean and 85th percentile speeds were below the 40 mph speed limit along the 0.5km road length enforced by the two cameras. In contrast, crashes at the spot-speed camera sites studied appeared to increase, but not statistically significantly so.

Commenting on the relative merits of the new technology, Keenan (2002) noted that the spot-speed fixed cameras have a site-specific effect whereas the point-to-point camera system has a link-long influence on drivers and their speeds despite enforcement being visible only at the start and end of the enforced road length. Further, Keenan (2002) noted from his study that "around the [spot-speed camera] sites a significant proportion of the drivers observed manipulated their behaviour in close vicinity to the installations, suddenly applying their brakes 50 metres before the camera and then promptly accelerating away from it. Most alarming was the fact that the accident statistics at some of the [spot-speed camera] sites had worsened since the camera installation". While the crash data were probably too few for Keenan to claim that the situation had worsened, it is possible that any speed and crash reduction benefits at the overt fixed spot-speed camera sites were eroded by some drivers behaving in the way Keenan suggests. However, given the policy in the U.K. of making fixed camera sites conspicuous and the placing of advance camera warning signs a requirement of the scheme, there should be less likelihood of drivers being taken by surprise. This effect may be even less likely to be a significant consequence of the point-to-point camera systems.

2.2 EVALUATIONS OF U.K. SYSTEMS

Point-to-point speed camera systems measuring average speeds between two or more fixed cameras have the potential to produce a general effect well beyond the localised effect at overt fixed camera sites. They have been installed at a few sites as part of the comprehensively-evaluated UK Cost Recovery Program, but apart from information which can be gleaned from the detailed information in that program's evaluation reports, there is little scientific evidence of their effects on road trauma. Gains et al (2003) indicated that the two 0.5 km apart point-to-point cameras in Nottingham produced 31% reduction in serious casualties (not statistically significant) which was not significantly different from the road trauma reduction from speed cameras of all types. Keenan (2002) found 36% reduction in casualty crashes at the Nottingham site.

The manufacturer of the UK point-to-point speed camera systems, Speed Check Services, have claimed that systems in Nottinghamshire (now 48 pairs of cameras), Northamptonshire (four pairs of cameras on a 4 km section) and South Yorkshire (eight pairs of cameras on an 11 km section of highway) have substantially reduced speeding and road trauma on the road sections they cover. It is understood that each pair of cameras needs to be hard-wired together in some way, and that this requirement constrains the distance over which the average speed can be measured.

In July 2005, the Scottish government launched a pilot scheme of 15 Speed Check Services SPECS cameras on a 46 km section of the A77 highway in the Strathclyde area. It is described as a complex route including single and dual carriageways with varying speed limits. The southern section is a winding and challenging coastal road in South West Scotland. The route had experienced 20 road deaths and 95 serious injuries over the five-year period 2000-2004. Published descriptions of the system are unclear: apparently there are 14 camera sections, averaging 0.5 mile in length, between which the pairs of cameras are switched on periodically. The cameras are supported by around 50 safety camera warning signs with the message "average speed – speed cameras" and a camera symbol. The intention is to deter speeding along the full length of the route. However, the system does not appear to measure average speeds along contiguous sections of the route nor over the whole route. This may relate to the varying speed limit zones along the highway covered.

A preliminary evaluation of the Strathclyde A77 system by Transport Scotland has found that there was a statistically significant 20% reduction in reported injury crashes (including fatal) during the first two years of operation on the route, compared with crash experience during the previous three years (A77 Safety Group, 2007). Fatal and serious injury crashes each fell by one-third and road deaths were more than halved; however none of these reductions were statistically significant, perhaps due to the small frequencies in each case. A full assessment of the effects of the system on crashes and casualties on the A77 route is planned when three years' experience has been accumulated in July 2008.

To date, the Speed Check Services SPECS point-to-point speed camera system is the only such system to receive Home Office Type Approval in the UK. In 2003, their website indicated that a pair of point-to-point cameras costs £70,000 and requires at least another £100,000 for the computer network to support it. In 2005, Speed Check Services suggested around £290,000 for a fully installed SPECS system, compared to around £45,000 for a single spot-speed camera. There may be economies of scale with larger numbers of cameras because the Scottish government has reported that the 15 camera system in Strathclyde cost £775,000 in 2005.

2.3 EVALUATIONS IN AUSTRIA AND THE NETHERLANDS

A careful evaluation has been conducted of the point-to-point camera system covering speeds through a 2.3 km long urban tunnel in Austria (Stefan 2006). While there are limits on the generalisability to other non-tunnel road environments, the results indicate strong effects consistent with those seen in the preliminary evaluation of the Strathclyde A77 system.

The Austrian tunnel has separate tubes with 3-4 lanes in each direction and carries a total of 91,900 vehicles per day. There is one camera above each of three lanes at the beginning and end of the tunnel, and a separate laser scanner to differentiate between passenger cars and heavy goods vehicles because of the different speed limits applicable to each vehicle type (80 km/h for cars and 60 km/h for HGVs). The system is designed to operate with speeds up to 250 km/h and a maximum traffic flow rate of two vehicles per second and lane. Vehicle detection is independent of the position of a vehicle in or between lanes.

During the first year of operation, average speeds fell by 10-15 km/h and then levelled at average speeds about 5 km/h below the applicable speed limit for each vehicle type. During the same period, 29.4 million vehicles passed through the tunnel and 40,900 drivers were charged with speeding, suggesting a detection rate of 0.139%.

The evaluation found that injury crashes (including fatal) were reduced by one-third, fatal and serious injuries by 49% and slight injuries by 32%. These figures are consistent with those found elsewhere (see section 2.2) and with the expectation that a greater effect is expected on more serious injury crashes than those resulting in minor injury.

The capital cost of the Austrian system was €1.2 million (in 2002) and annual costs of operation and maintenance are about €60,000. When the capital costs were amortised over 10 years at 4% p.a. discount rate, Stefan (2006) estimated that the annual cost of the system is €207,950. Using relatively modest costs for the economic value of crashes prevented, at each level of severity (e.g. €949,900 for a fatality), Stefan's analysis indicated a benefit-cost ratio of 4.9 (or 5.3 if the social benefits of reduced traffic emissions were included).

In the Netherlands, a point-to-point system was installed on the motorway between Rotterdam and Delft in support of a new 80 km/h speed limit. No comprehensive evaluation of the system has been published, apart from information that the proportion of offenders declined to less than 1% (RWS 2003). This result, and the low detection rate observed in the Austrian tunnel, suggests that point-to-point camera systems have the capacity to reduce speeding transgression rates to a lower level than that achieved by overt fixed speed cameras enforcing spot-speeds (1.2% exceeding speed limits by at least 10 km/h in the case of the NSW fixed cameras).

2.4 VICTORIAN EXPERIENCE

Victoria launched a point-to-point speed camera system on the initial section of the Hume Freeway north of Melbourne on 5 April 2007. Four contiguous sections of lengths 8, 14, 7 and 25 km are covered by five double-camera banks, one at the beginning and end of each section in each direction. Three traffic lanes are covered by each bank of cameras; one camera per lane (but not the emergency stopping lane, which is sometimes used by vehicles trying to avoid surveillance). Vehicle detectors in the road pavement trigger each camera imaging. Some camera banks have cameras facing rearward, some facing forward, and some with cameras facing in both directions. The forward facing cameras are aimed at capturing truck prime-mover number plates, and rearward facing to capture motorcycle number plates. Over the four contiguous sections, the number plates of all types of vehicle are captured more than once, but not necessarily at the beginning and end of each section.

Every vehicle passing a camera is digitally photographed, the image stored, the number plate is optically character recognised (OCR'd) on-site and the characters transmitted to a central computer in Melbourne where they are then matched (where possible) with the registration number captured in the same way by a downstream camera. Following a successful match, if the calculated average speed exceeds the enforcement threshold (same as that used with spot-speed cameras), the two matched images are transmitted from the on-site camera systems and are referred to the infringement processing agency for manual verification. An infringement notice is issued in the same way as other camera-detected speeding offences. Because of this form of operation, apparently there has been no constraint on the length of the section over which average speed is measured, unlike the SPECS systems in the UK.

The system used is the Redflex HDX system which comprises the cameras, OCR computers, transmission equipment and the central computer. Redflex hosts and maintains the central computer, but has no access to the registration numbers, images and other information protected for legal integrity reasons. Redflex also maintains the field cameras and supporting equipment. A type approval system is not used in Victoria, but the Redflex system has been subjected to an equivalent test and acceptance plan. The central computer has the capacity to handle more camera banks and it is understood that the Department of Justice has plans to extend the lengths of highway covered. The camera banks are capable of measuring spot speeds and this extension of their use is being considered; a current Victorian requirement for secondary verification of fixed digital speed camera detected offences inhibits this. The system could also measure average speed over any combination of the four contiguous sections; currently up to four separate assessments could be made, in which case the highest detected illegal speed is prosecuted if more than one offence is detected.

The criteria for installing the system on the Hume Freeway were a relatively high number of fatalities and serious injuries, and a high proportion of heavy vehicle traffic with the attendant potential for severe injury outcomes in crashes. Other criteria were relatively few opportunities (or incentives) to enter or leave the highway between a pair of cameras, so that a substantial proportion of traffic has its average speed assessed. In Victoria, another current operational requirement is that the speed limit be fixed for the entire length of the section between pairs of cameras. It is understood that this requirement relates to the current absence of an "average speed offence" in the relevant legislation, which could be used to prosecute such an offence over multiple speed limit zones. Currently, the Victorian system is turned off during periods of lowered speed limits due to road works.

About 1,000 offences per day are detected when the system is operational, suggesting an offence detection rate of 1-2% from an estimated 50,000 to 100,000 vehicles per day on the highway. This detection rate is similar to that detected by the covert mobile speed cameras in Victoria. The shorter sections have somewhat higher detection rates, perhaps because there are fewer benefits to speeders who try to avoid detection by stopping or leaving the highway.

The Victorian point-to-point speed camera system appears to differ fundamentally from the Strathclyde A77 system in that it appears to be aimed at deterring speeding over long sections of highway (minimum 7 km) rather than relatively short sections (average 0.5 mile in Strathclyde). While the Strathclyde system also appears to be aimed at covering the full route, less than half of the route (even if allowing for a "halo" effect) is actually apparently enforced by their conspicuous high-mounted cameras. In a sense, the Strathclyde system may be viewed as a variation of the much more common, overt fixed speed cameras operating in the UK. While the "spot" at which the average speed is measured is in fact about 0.5 mile in length, on average, the Strathclyde system apparently does not aim to average the speed over long sections of highway, unlike the Victorian system. The only constraint on the length of the Victorian sections appears to be the current legislative restriction to lengths with a fixed speed limit throughout.

A press release by Redflex in June 2003 suggested that the contract to provide the ten camera-bank system was valued at $2 million. However, it is understood that the final specification for the system was changed substantially over the next four years.

2.5 COSTS OF POINT-TO-POINT SYSTEMS IN WA CONTEXT

Redflex provided indicative costs of point-to-point systems if they were to be installed in WA. The cost per camera bank depends on the number of traffic lanes to be covered (hence the number of cameras, potentially doubling if forward and rearward imaging is required) and the traffic volume past the camera site (since this affects the computer processing power required for OCR and the image storage requirements). If two camera banks are installed at the same location for surveillance of two directions of travel (as at the five double-camera banks on the Hume Freeway), there are savings in some site infrastructure costs (power supply, OCR computer capacity, etc.). Because of the variations in lane coverage, traffic volumes and imaging requirements, the cost per camera bank can range from $75,000 to $200,000-$300,000. The cost of the central computer to match the previously OCR'd number plate characters (at each camera site) is a relatively small cost compared with each camera bank, at least two of which are required.

Redflex emphasised that the above estimates are only indicative costs, suitable for the cost-benefit analysis envisaged in this report, and would be pleased to provide firmer cost estimates when the number and location of point-to-point camera banks in WA is determined.

2.6 MOBILE POINT-TO-POINT CAMERA SYSTEMS

Redflex also provided information about a mobile version of the point-to-point camera technology which they have developed. Each camera is vehicle-mounted and is triggered by slant radar across one or two traffic lanes. The system also measures spot-speed of each passing vehicle (reflecting Redflex's history in providing spot-speed camera systems). The camera vehicle has a computer to capture the image of each passing vehicle, OCR the registration number plate, and transmit the number plate characters to a central computer for matching with registration numbers obtained in the same way by a second camera vehicle. It is essentially a mobile version of the fixed camera banks.

The two vehicles need to be carefully stationed at designated locations for which the road distance between them has been accurately surveyed. There appears to be no limit to the number of pairs of stations, and distances between them, which could be used for this purpose apart from the need to be able to park the camera vehicles safely. Parallex errors associated with the use of slant radar to trigger each camera are minimised if the two vehicles are stationed many kilometres apart.

For two-lane undivided highways (one lane in each direction), each camera vehicle can captured the images and times of same-direction vehicles and opposite-direction vehicles. A decision can be made to rearward photograph same-direction vehicles and front photograph opposite-direction vehicles, or vice versa. A second camera vehicle operating in the same way at the other end of the route under surveillance then provides the information to match registration numbers and calculate average speeds for vehicles travelling in either direction, and for a focus on front or rear number plates as required.

As noted above, the mobile point-to-point camera vehicles can also measure the spot-speeds of passing vehicles and provide the images to prosecute speeding offences in the usual way. Thus these camera vehicles could represent, in addition to average speed enforcement, a resource to function as overt mobile speed cameras randomly scheduled [at locations defined by their proximity to crash locations] on rural highways, as recommended in the 2006 study. This potential dual role of the camera vehicles could improve the cost-effectiveness of an investment in mobile point-to-point camera technology.

2.7 USE ON FREEWAYS AND HIGHWAYS IN WA

While overt fixed speed cameras measuring "spot" speeds appear to be very effective in reducing speeds and road trauma at specific sites, in general they do not influence drivers other than at those sites (unless the density of cameras is high and above a critical threshold). If the intention is to reduce speeds along a substantial "black" route using a number of overt fixed cameras, there may be a case for using point-to-point camera systems to enforce speeds along the whole route.

The published evaluations of such systems in the U.K. and Austria suggest that they are effective in reducing speeds and casualty crashes along the whole route on which they are installed. It is unclear what routes would be suitable for this form of speed enforcement in WA. The route would need to have a sufficient crash rate to make these relatively expensive systems cost-effective, and have limited access/egress opportunities along its length to make it operationally viable (though the presence of local traffic making small trips along the route is not an issue for the integrity of the system).

In theory, any road would be suitable for point-to-point technology, but the most suitable would be those routes meeting the criteria outlined below. An additional criterion would be those roads with lower-standard safety infrastructure warranting priority attention during the next WA road safety strategy program, but for which substantial reduction and control of speeds is warranted in the short term until the road infrastructure is improved. Information was sought from Main Roads WA about routes which they considered suitable for point-to-point speed camera enforcement, including the length, traffic volume, and crash rate by injury severity level.

2.7.1 Potential criteria for application of Point-to-Point systems in WA

It is proposed that the following criteria be considered for choosing suitable routes in WA for application of point-to-point technology:

- High crash rate per kilometre, particularly fatal and serious injury crashes (this criterion being aimed at potentially justifying the economic benefit to be obtained from this relatively expensive technology)

- Roads currently with lower-standard safety infrastructure warranting priority attention for upgrading, following which the point-to-point technology should be moved to other suitable roads with sub-standard infrastructure

- Speed distribution and speed profile along the road suggesting need to control speed along the full route rather than at individual locations

- Limited opportunities and incentives for traffic to enter or leave significant-length sections on which pairs of point-to-point cameras would be installed at the beginning and end of each section (which could be contiguous with adjacent sections)

- Sections with a fixed speed limit throughout its length, at least in the short term until WA enacts legislation to prohibit an "average speed offence" which could be used to prosecute speeding along a section with multiple speed limit zones.

2.8 SIZE OF ROAD TRAUMA PROBLEM ON SUITABLE ROUTES

In the 2006 study, each of the viable speed enforcement options for application to different parts of the WA road system (in many cases there was more than one option) was analysed to estimate its economic benefits relative to the cost of enforcement (Cameron and Delaney 2006).

A necessary first step in the economic analysis of the speed enforcement options was to determine the size of the road trauma problem in the road environment proposed as the principal focus for the option (Table 1). There was evidence that each option reduces casualty crashes to a measured extent, and some enforcement methods have been found to reduce fatal crashes to a larger extent. The economic analysis considered the reductions in crashes weighted by their social costs. Hence the proportion of fatal crashes, in particular, in each environment needed to be noted by Cameron and Delaney (2006).

Because the specific routes, lengths, traffic volumes and crash rates relevant to point-to-point speed cameras have not yet been determined, it is not yet possible to complete Table 1 in this supplementary study. In addition, if a large proportion of a road environment (e.g., Perth freeways or rural highways) currently recommended for application of another technology (see 2006 study report) is considered suitable for point-to-point enforcement, then the economic analysis of the alternative technologies may need to be revisited following the necessary modifications to Table 1.

Table 1: Road environments proposed as the focus of each speed enforcement option (from Cameron and Delaney 2006)

Type of speed enforcement and road type proposed applicable to	Length of road (km)	Estimated traffic (million veh-km) 1991	No. of casualty crashes 2002-2004 (note *)	Percentage of casualty crashes with fatal outcome
URBAN ROADS (mainly in Perth)				
Covert mobile speed cameras on urban highways	1815	7910	4341	1.41%
Overt mobile speed cameras randomly scheduled on urban highways	1815	7910	4341	1.41%
Laser speed detectors on urban local roads	8200	2090	8859	1.25%
Fixed cameras on Perth freeways	62	230	697	1.43%
RURAL ROADS				
Overt mobile speed cameras randomly scheduled on rural highways	20,194	4170	1776	8.05%
Mobile radar units on undivided rural highways and local roads	123,800 (estimate)	5200	3211	7.04%
Point-to-point speed camera systems on highly-trafficked rural highways	**NK**	**NK**	**NK**	**NK**

* Includes only 2002-2004 crashes with known speed zone at the crash location (i.e. 73.0% of all reported casualty crashes and 87.6% of fatal crashes)

2.9 ECONOMIC ANALYSIS OF POINT-TO-POINT ENFORCEMENT

In the 2006 study it was decided, in the absence of clear scientific evidence of point-to-point speed camera systems having a general effect on road trauma over a substantial length of highway, that it was not possible to conduct a valid economic analysis of the potential introduction of such a system on suitable routes in WA. There were also difficulties in obtaining information on the cost of installing, maintaining and operating such a system in the Australian environment. It was proposed that this decision be revisited when definitive scientific evidence emerges from the UK (especially from the system over a long route in the Strathclyde area) and operational cost information from the pilot program in Victoria becomes available. An economic analysis is now viable.

2.9.1 Unit costs of crashes, enforcement equipment and offence processing

The economic benefits from the road trauma reductions estimated to be produced by each form of enforcement considered in the 2006 study were calculated using the unit costs at each crash severity level published by BTE (2000), updated from 1996 values to 2005 using the Consumer Price Index, as follows:

- Fatal crashes $2,047,615
- Severe injury crashes resulting in hospitalisation $505,390
- Injury crashes resulting in other medical treatment $17,065

Based on the information from Redflex about point-to-point system requirements and costs, it was estimated that each camera bank covering two lanes of traffic (with either forward or rearward imaging, but not both) in each direction would cost $200,000, potentially rising to $300,000 if coverage of more than two lanes is required. Divided highway sections were assumed to require two camera banks in each direction. For two-lane undivided highways, it was assumed that one camera costing $75,000 could be placed at each end of each section and could cover vehicles travelling in both directions. Where sections are contiguous, it was assumed that the camera bank at the end of section could be the entry camera bank for the next section. Both types of system were assumed to require a central computer system, costing $25,000, to receive the OCR'd number plate characters from each passing vehicle, match them, and initiate processes to download the images from the on-site cameras. The fixed costs of the enforcement equipment were amortised over their assumed useful life of 6 years, at 7% p.a. interest rate, to provide an annual cost.

Only fixed-location point-to-point camera systems have been analysed. Although a mobile vehicle-mounted camera could cost about the same as a single fixed camera (one of a pair) covering traffic in both directions, in practice there would be the substantial additional cost of the operator's time. The opportunity to combine this form of operation with randomly-scheduled overt mobile speed camera operations, requiring an operator to be present, needs to be further considered and an economic analysis conducted.

Offence processing costs, for each type of offence record (photographic evidence or on-the-spot notice), per offence detected had been estimated from information provided by the WA Police Service (Cameron and Delaney, 2006, Appendix A). The cost per 1000 speeding infringement notices issued was estimated to be $135.11 for offences detected photographically (as would be the case for notices issued for point-to-point camera detections). The fixed costs of the WA Police back office and equipment to process 667,629 infringement notices in 2004 was estimated to be $1,913,000 (excluding some unknown costs) which was amortised as $254,550 per year at 7% p.a. interest rate over an assumed ten year life.

It is expected that there would be no additional cost to process a speeding offence detected photographically by point-to-point technology than other spot-speeding offences detected by Multanova speed cameras and fixed digital speed cameras in WA. In Victoria, once an average speed offence has been detected by the point-to-point system (cameras plus back-office central computer analysing the time between two images successfully matched), the information and images are transferred to the same infringement processing system as the spot-speed offences detected by speed cameras are.

It should be noted that the estimated costs to process the speeding offences are limited to those borne by the WA Police Service, at this stage, and do not include the additional costs to further process any unpaid offence notices referred to other WA agencies by the Police. It is acknowledged that any increase in the number of speed detection devices, especially a significant increase as proposed by Cameron and Delaney (2006), would result in a growth in infringement activity (especially in the short term) and would impact considerably on the business processes and resources of other agencies, such as the Department for Planning and Infrastructure. It is therefore essential that this 'upstream' consequence be appropriately measured and costed to ensure that other agencies are adequately resourced to meet the increased demand in services. The additional cost of fines enforcement by the Fines Enforcement Registry for the additional speeding infringements is estimated in section 4.5 of this report.

2.9.2 Data provided by Main Roads WA

MRWA provided information on 194 State Highway and Main Road links, each with reasonably homogeneous character along their length with respect to traffic level, road type and use. As well as the 2003-2007 crash history, traffic volumes, road cross-sections and link lengths, the data included an indication of whether the link may be problematic for point-to-point camera enforcement because of closely-spaced intersections and/or numerous other points of access (such as driveways).

The provided data was initially analysed to calculate the total social cost of the crashes (weighting crashes at each severity level by unit costs based on BTE 2000) and the social cost per kilometre of road and per 100 million vehicle kilometres of travel. It was noted that a number of road links which had been previously nominated as potentially suitable for point-to-point enforcement were considered problematic (as defined above) or had relatively low crash social costs per vehicle kilometre, potentially giving them lower priority because of their high safety standard. However, the analysis also suggested many other candidate road links because of their relatively high crash social cost rate, possibly due to their lower standard safety infrastructure.

Final recommendations on road links considered most appropriate for point-to-point camera enforcement were made on the basis of the following economic analysis which also took into account the potential saving in social costs, the appropriate camera configuration for the link, and the cost of processing the likely level of speeding infringements in the short term. These considerations allowed the benefit-cost ratio to be estimated.

2.9.3 Economic analysis and results

The crash reduction benefits of point-to-point enforcement applied to each link were estimated from the crash history during 2003-2007. The crash reductions experienced during the first two years of the Strathclyde A77 system were considered most relevant, in contrast with the larger reductions observed in the Austrian tunnel system, because nearly all the WA links are open road links not involving tunnels (however, the effect in any WA tunnel environment is likely to be greater). Following the Scottish experience, it was assumed that casualty crashes would be reduced by 20% and, of these, serious casualty crashes (including fatal) would be reduced by one-third; non-serious casualty crashes would be reduced to a lesser extent. The crash reductions were then valued by the unit costs based on BTE (2000) to estimate the saving in social costs of crashes per annum.

The annual total number of vehicles which would be monitored by the point-to-point system on each link (assumed to operate continuously) was estimated from the two-way annual daily traffic estimates provided by MRWA. A relatively low short-term offence detection rate of 0.5% was assumed based on experience in the Netherlands (less than 1%) and in the Austrian tunnel environment (0.139%). A substantial short-term effect on transgression rates is expected on the WA links because the threat of detection for speeding along each link will rapidly become known (especially if publicised and intensely sign-posted) and is likely to reduce further in the medium to long term. Assuming a non-prosecutability rate of 20%, the assumed detection rate was used to estimate the annual number of speeding tickets which would result on each link in the short term. The cost of processing these tickets was based on the unit cost of issuing photographically-detected speeding infringement notices, plus a proportionate share of the back-office capital equipment costs (amortised) which would also be necessary to provide capacity to process the offences (see section 2.9.1).

Based on the length of each link, the number of sections over which average speeds would be measured, and hence the number of camera banks, was calculated assuming that no section could be longer than 30 km (based on the 25 km longest section in Victoria). It was also assumed that the sections within a link would be contiguous, so that the interim banks performed the role of both entry and exit cameras for abutting sections. Divided roads with two lanes in each direction were assumed to require two opposite-direction camera banks with two cameras in each bank, at the beginning and end of each section, and three cameras per bank in the case of three-lane divided highways. These considerations allowed the total capital cost of investment in the point-to-point camera system necessary for each link to be estimated, which was then amortised to provide an annual cost to add to the annual costs of speeding ticket processing and supporting back-office capacity.

The benefit-cost ratio (BCR) of the application of the appropriate point-to-point camera system to each road link was estimated by dividing the annual saving in social costs of crashes by the annual costs of capital equipment (amortised) plus offence processing. Forty road links considered suitable (i.e. not problematic) for this speed enforcement approach were estimated to have BCRs close to 10 or greater, the overall BCR for the speed enforcement package recommended by Cameron and Delaney (2006).

Table 2 summarises the economic analysis for the top 40 links, in groups of 10 ranked by BCR, and Table 3 provides the analysis for each individual road link. There were an additional 21 road links, principally in the Perth metropolitan region, that were estimated to have BCRs greater than 10 if point-to-point speed cameras were applied, but the application was considered to be problematic because of numerous access and egress opportunities along each link. The problematic, but otherwise economically justifiable, metropolitan links for application of point-to-point systems included Albany Highway (link 134), Wanneroo Road (links 159 and 160) and Perth-Bunbury Highway (links 136 and 137), all of which had relatively high crash social cost rates per 100 million vehicle-kilometres of travel during 2003-2007.

Table 2: Summary of economic benefits and costs of Point-to-Point (P2P) speed camera systems applied to top 40 road links with high BCRs

Rank of Links	Total Length of Links (km)	Saving in Social Cost of Crashes p.a. ($000s)	Speeding Tickets p.a. (short term)	P2P system capital cost ($)	Total cost of capital equipment (amortised) plus ticket processing p.a. ($)	BCR
Top 10	512	16,197	77,650	2,575,000	$580,313	27.91
2nd 10	633	22,508	261,734	5,225,000	$1,231,310	18.28
3rd 10	1,313	13,344	40,225	4,750,000	$1,017,297	13.12
4th 10	817	15,020	294,910	6,150,000	$1,442,499	10.41

Table 3: Estimated economic benefits and costs of P2P applied to each road link

Region	Link No	Road No	Road Name	Length (km)	Social Cost Saving p.a. ($000s)	Speeding Tickets p.a. (short term)	No. of sec-tions	P2P system capital cost ($)	Total cost of capital equip. (amortised) + processing p.a. ($)	BCR
Metro-politan	45	H009	South Western Highway	58.05	2934.9	14,076	2	250,000	$59,716	49.15
South West	46	H009	South Western Highway	78.88	2341.4	9,102	3	325,000	$72,883	32.13
South West	47	H009	South Western Highway	16.27	1088.9	10,019	1	175,000	$41,887	26.00
Metro-politan	174	H033	Toodyay Road	22.13	1024.5	7,353	1	175,000	$40,510	25.29
Wheat-belt North	190	H005	Great Eastern Highway	42.39	1390.9	6,416	2	250,000	$55,762	24.94
South West	61	H043	Bussell Highway	80.87	1768.4	5,386	3	325,000	$70,964	24.92
Kimb-erley	31	H042	Broome Highway	41.52	1289.7	2,553	2	250,000	$53,767	23.99
South West	60	H043	Bussell Highway	34.86	1371.9	9,308	2	250,000	$57,254	23.96
South West	123	M043	Caves	111.00	2034.0	3,285	4	400,000	$85,614	23.76
Pilbara	35	H046	Dampier Road	25.84	952.6	10,154	1	175,000	$41,956	22.70
Top 10				**511.81**	**16197.2**	**77,650**	**21**	**2,575,000**	**$580,313**	**27.91**
South West	55	H009	South Western Highway	57.07	1209.6	4,618	2	250,000	$54,833	22.06
Gold-fields-Esp.	16	H049	Goldfields Highway	56.26	1145.9	2,997	2	250,000	$53,996	21.22
Metro-politan	153	H021	Reid Highway	21.23	4000.6	40,417	1	825,000	$193,948	20.63
Metro-politan	116	M034	Lancelin	75.14	1417.3	3,428	3	325,000	$69,953	20.26
Metro-politan	150	H016	Mitchell Freeway	25.35	6314.5	155,345	1	1,225,000	$337,201	18.73
Wheat-belt North	48	H004	Brand Highway	174.90	2097.4	3,486	6	550,000	$117,187	17.90
South West	54	H009	South Western Highway	32.61	965.5	7,211	2	250,000	$56,172	17.19
Midwest	25	H007	North West Coastal Highway	100.66	1440.2	3,920	4	400,000	$85,942	16.76
Metro-politan	152	H017	Tonkin Highway	28.21	2932.9	39,650	1	825,000	$193,552	15.15
Kimb-erley	22	H006	Great Northern Highway	61.24	983.9	663	3	325,000	$68,526	14.36
2nd 10				**632.67**	**22507.7**	**261,734**	**25**	**5,225,000**	**$1,231,310**	**18.28**

Region	Link No	Road No	Road Name	Length (km)	Social Cost Saving p.a. ($000s)	Speeding Tickets p.a. (short term)	No. of sec-tions	P2P system capital cost ($)	Total cost of capital equip. (amortised) + processing p.a. ($)	BCR
Pilbara	36	H051	Port Hedland Road	10.38	609.3	13,640	1	175,000	$43,756	13.92
Wheat-belt North	6	H006	Great Northern Highway	216.80	1998.7	1,497	8	700,000	$147,630	13.54
Wheat-belt South	40	H001	Albany Highway	161.04	1563.9	2,476	6	550,000	$116,666	13.41
South West	107	M053	Pinjarra-Williams	66.96	910.4	1,375	3	325,000	$68,894	13.22
South West	62	H045	Coalfields Highway	36.25	724.0	4,615	2	250,000	$54,832	13.20
Great South--ern	41	H001	Albany Highway	84.44	924.8	4,596	3	325,000	$70,556	13.11
South West	56	H009	South Western Highway	36.82	712.4	3,703	2	250,000	$54,360	13.10
Midwest	50	H004	Brand Highway	70.76	920.7	4,138	3	325,000	$70,320	13.09
Wheat-belt South	113	M031	Northam-Cranbrook	352.23	2714.2	1,073	12	1,000,000	$210,350	12.90
Wheat-belt North	2	H005	Great Eastern Highway	276.94	2265.0	3,113	10	850,000	$179,933	12.59
3rd 10				**1312.62**	**13343.5**	**40,225**	**50**	**4,750,000**	**$1,017,297**	**13.12**
Great South-ern	58	H009	South Western Highway	49.90	682.6	3,836	2	250,000	$54,429	12.54
Kimb-erley	14	H011	Victoria Highway	87.51	849.5	962	3	325,000	$68,680	12.37
Wheat-belt North	95	M010	Chidlow-York	46.02	648.6	2,412	2	250,000	$53,694	12.08
Wheat-belt North	87	M002	Bindoon-Moora	86.26	740.8	838	3	325,000	$68,616	10.80
Wheat-belt South	39	H001	Albany Highway	125.04	1087.6	3,647	5	475,000	$101,536	10.71
Metro-politan	155	H018	Roe Highway	30.56	2901.2	45,602	2	1,225,000	$280,543	10.34
South West	57	H009	South Western Highway	184.57	1353.1	1,128	7	625,000	$131,705	10.27
Gold-fields-Esp.	53	H008	South Coast Highway	183.85	1324.1	1,426	7	625,000	$131,859	10.04
Metro-politan	181	H017	Tonkin Highway	12.40	2088.8	67,686	1	825,000	$208,026	10.04
Metro-politan	151	H015	Kwinana Freeway	10.50	3343.3	167,374	1	1,225,000	$343,411	9.74
4th 10				**816.61**	**15019.6**	**294,910**	**33**	**6,150,000**	**$1,442,499**	**10.41**

Two links of metropolitan freeways were estimated to have high BCRs if point-to-point camera systems were applied to them (Mitchell Freeway, link 150, and Kwinana Freeway, link 151). While these two freeway links had relatively low crash social cost rates per 100 million vehicle-kilometres, the number of crashes on them (and their severity) results in a point-to-point system being economically justifiable, notwithstanding that these roads are apparently already very safe roads.

If all metropolitan freeway links are considered (i.e. also Kwinana Freeway, link 147, and the Graham Farmer Freeway, link 156), totalling 74 kilometres, it was estimated that point-to-point camera systems covering five sections would have a BCR of 10.4 (Table 4). This is greater than the BCR of 7.3 estimated by Cameron and Delaney (2006) if 24 overt fixed speed cameras were to be installed on Perth freeways. The capital cost of investment in the point-to-point systems would be greater ($4.9 million compared with $2.4 million for the fixed spot-speed cameras), as would the number of speeding tickets needed to be processed annually in the short term (estimated 497,000 p.a. compared with 427,000 p.a.).

Table 4: Freeway and other types of links in the metropolitan and non-metropolitan regions with high BCRs for P2P application

Region	Road Type	Total Length of Links (km)	Social Cost Saving p.a. ($000s)	Speeding Tickets p.a. (short term)	No. of sections	P2P system capital cost ($)	Total cost of capital equip. (amortised) + processing p.a. ($)	BCR
Metro-politan	Freeways	74	13,290	496,758	5	4,900,000	1,284,463	10.35
	Other links in top 40	248	17,300	218,210	11	4,450,000	1,046,248	16.54
Non-metro-politan	Links in top 40	2,990	40,110	133,591	116	11,800,000	2,544,560	15.76

The other seven metropolitan links included in the top 40 ranked by BCR cover 248 kilometres of highway and would require 218,200 speeding tickets per annum needing to be processed in the short-term. The capital cost of point-to-point systems to cover these links in 11 sections would be $4.45 million and the program would have a BCR of 16.5. This is greater than the BCR of 6.1 estimated by Cameron and Delaney (2006) if covert mobile speed cameras were to operate at 9,000 hours per month on Perth arterial roads and highways, estimated to represent a total of 1,815 kilometres in length. Thus, point-to-point speed cameras have greater economic justification than covert mobile cameras on this sub-set of Perth highways, about 14.8% of the total length.

The non-metropolitan links in the top 40 cover 2,990 kilometres of highway and would require a capital cost investment of 11.8 million to install the point-to-point systems covering an estimated 116 sections (all on undivided roads assumed to require one camera covering both directions at the terminals of each section). About 133,600 speeding tickets per annum would need to be processed in the short term and the overall BCR of the non-metropolitan point-to-point systems is estimated to be 15.8. This BCR is substantially less than the BCR of 36.8 estimated by Cameron and Delaney (2006) if randomly-scheduled overt mobile speed cameras were to operate for 3,000 hours per month on rural highways. In addition, the non-metropolitan links in the top 40 cover less than 15% of the total 20,194 kilometres of rural highway (excluding local roads) considered as the focus for the mobile speed cameras. Nevertheless, some of the non-metropolitan links in the top 10 especially may be considered to warrant the closer enforcement of speeding that point-to-point camera systems provide with perhaps greater certainty than the overt mobile speed cameras can be expected to achieve.

3 PROCESSING OF DETECTED SPEEDING OFFENCES

3.1 IMPLICATIONS OF ORIGINALLY RECOMMENDED PACKAGE

The originally recommended speed enforcement package required additional speeding infringement notices to be issued, at least in the short term until drivers respond to the increased threat of detection, reduce their speed limit transgression rate and consequently reduce the speed offence detection rate from vehicles assessed by the different forms of enforcement. (The reduction in transgression rate, especially from excessive speeding, is considered to be the principal mechanism through which the expected road trauma reductions will result. Other mechanisms include general improvements in driver behaviour as a result of seeing overt enforcement operations, but these are expected to be relatively minor contributors.)

Thus a key resource needed to implement the recommended speed enforcement package is a back-office with the capacity to process the expected increased number of speeding infringement notices. Cameron and Delaney (2006) indicated that 170,276 speeding tickets per month, or 2.043 million per year, would need to be issued in the short term. This is 3.1 times the number of speeding tickets estimated to have been issued by WA Police during 2004. The cost of the manpower to process the higher number of tickets has been included in the economic analyses. However the capital cost of the back-office and offence-processing equipment had been held fixed and had not been escalated to reflect a requirement for additional equipment to replicate its capacity. Since the capital cost of the back-office had been estimated to be about $1.9 million currently, up to an additional $4 million short-term capital investment may be required to expand the back-office capacity in order to provide the infrastructure for the additional offence processing staff.

Thus the total cost to process the estimated 2.043 million speeding tickets per year which would need to be issued in the short term, at least during the first year, would be approximately $18.6 million plus $4 million capital cost, a total of about $22.6 million. However, it is expected that this offence processing load would drop substantially in the medium term as WA motorists react to the increased risk of detection and prosecution when speeding, leading to a reduction in transgression rates and, unless detection thresholds are reduced, a similar reduction in detection rates. While it is difficult to predict that rate at which WA motorists will improve their behaviour in response to this threat, it could be expected that detection rates would be halved in the medium term and be further reduced in the long term.

In the 2006 study report, it was considered important that adequate resource be provided to process all the speeding offences detected by the recommended speed enforcement package and that speeding tickets be issued to a high proportion of offenders (excepting, of course, those offences which are not legally prosecutable for various operational reasons). While all of the enforcement options aim to reduce speeding behaviour by inflating drivers' *perceived* risk of detection, it was considered important that the credibility of the system be maintained by the actual receipt of a speeding ticket close to the time of the offence and with high certainty that this will always occur.

3.2 SPEED OFFENCE PROCESSING IN OTHER JURISDICTIONS

Since the 2006 report, the Office of Road Safety requested a review of infringement management models worldwide in terms of their ability to facilitate a reduction in speeding effectively and efficiently through deterrence and detection of speeding behaviour. This review has been limited to processes in Victoria, Queensland, Sweden, France and the United Kingdom in the time available for this extension project.

3.2.1 Victoria

During the year ended September 2007, the Victoria Police issued 1,148,474 speeding infringement notices for offences detected by mobile speed cameras, fixed digital speed cameras, speed/red-light cameras, and the point-to-point speed camera system on the Hume Freeway (from April 2007 in the latter case). There were also 473,120 on-the-spot infringement notices issued for offences detected by manual Police operations, such as laser speed detectors and moving mode (mobile) radar patrols. The Traffic Camera Office also issued 146,425 infringement notices for red-light running offences detected by red light cameras, and 495,258 notices for toll road offences.

Of the speeding infringement notices, 633,418 were for offences detected by covert mobile speed cameras operating for a total of 71,380 hours during the year or 5,950 hours per month on average. This represents about 8.9 speeding infringement notices per hour of mobile speed camera operation. The other 515,056 speeding infringements detected by non-manual operations during the year were all from fixed camera installations of various types, generally operating for 24 hours per day.

An important feature of the Victorian safety camera system, which bears on the efficiency and cost of processing all of the above photographically-detected infringements, is the existence of "owner-onus" legislation making the owner of the detected vehicle liable for the offence unless he or she makes a statutory declaration nominating the name, address and licence number of the driver at the time. If a driver is so nominated, the infringement notice is then transferred to the driver for fine payment, receipt of demerit points, and perhaps licence loss in some circumstances. Owners who are licensed drivers bear the same penalties. In the case of corporate owners, in cases where a driver is not nominated, the vehicle registration is suspended for three months and a substantial fine administered. The owner-onus legislation makes it unnecessary to identify the driver photographically, allows rearward photographing of vehicles as well as forward, and increases the efficiency of offence processing in Victoria. It is recommended that legislation of this type be pursued in WA to support the efficient processing of camera-detected speeding offences.

MUARC research has suggested that the principal mechanism through which the covert mobile speed camera program in Victoria achieves its effects on road trauma is specific deterrence, i.e. encouraging apprehended speeding offenders to avoid re-offending via the actual experience of detection and punishment (Cameron et al 1995). Some general deterrence (i.e. raising the perceived risk of detection and punishment) is achieved through word-of-mouth communication between offenders and potential offenders, and by mass-media publicity. There is little evidence of a local effect around the sites of covert mobile camera operations and what little there is generally takes place in the weeks after speeding infringement notices are received through the mail specifying the location at which the offence was detected.

3.2.2 Queensland

After rising to just over 6,000 hours per month during 2003, the Queensland mobile speed camera program stabilised around that level throughout 2003-2006. An annual average of 300,250 speeding offences was detected by the program and 249,500 infringement notices per year were issued. From an average of 5,934 hours of camera operation per month, 4.2 offences per hour were detected and 3.5 notices per hour were issued during 2003-2006. Notwithstanding possible differences in traffic volumes at camera sites, this relatively low rate of infringement notices per mobile camera hour in Queensland compared with Victoria is to be expected from the overt, conspicuous Queensland form of operation. It is also substantially lower than that experienced with Multanova mobile speed cameras in WA, from which 17.2 offences per hour were detected and 13.6 notices per hour issued during 2004 when operating at about 3,000 hours per month throughout the state.

The offence detection rate was substantially higher during the early years of the Queensland program, starting at 11.6 detected offences per hour during 1998, then fell rapidly to 6.4 per hour in 2002 as the operational hours were increased each year. Following the 50% increase in monthly hours during 2003, the offence detection rate initially fell again during the next two years, but has since stabilised at the 2003-2006 average level. The prosecutability rate of detected offences has also risen during the life of the program and remained constant at around 83% throughout 2003-2006.

The key mechanism of effect of the Queensland overt mobile speed camera program appears to be general deterrence in a 2 km radius area around camera sites, producing local effects, and a broad general effect achieved by random scheduling in space and time and by comprehensive coverage of crash sites in Queensland by the camera sites. Some specific deterrence of speeding is no doubt achieved by the detection and punishment of speeders, but this appears to be a secondary mechanism.

3.2.3 Sweden

The Swedish speed camera program is based almost entirely on fixed speed cameras placed generally on undivided roads, with a few on divided roads in tunnels. The roads are not the most heavily trafficked, averaging about 6,000 vehicles per day (ranging from 3,000 to 10,000 per day), so presumably the camera installations are warranted by high crash rates and/or known speeding problems. About 870 fixed cameras cover about 120 routes with a total length of around 2,500 kilometres, so on average there are about 7.25 cameras per route with a spacing of about 2.9 kilometres between each pair of cameras. However, the pairs do not operate in point-to-point mode, only assessing spot speeds of passing vehicles. It is understood that an additional 100 fixed cameras will be installed during 2008 (Tingvall, personal communication, January 2008). The camera routes are clearly marked, so the fixed camera program can be considered overt.

When operational, the fixed cameras have an enforcement threshold to detect speeds at least 6 km/h above the applicable speed limit. Just over 1% of vehicles exceed the threshold in 90 km/h speed limit zones, 4% in 70 km/h zones, and 5% in 50 km/h zones, with an overall average of 2-3%. The back-office has the capacity to process about 200,000 offence photographs per year, and this will be increased to 230,000 during 2008. The prosecutability rate is about 50%, in part due to the need to be able to identify the driver in the image, but also due to the vehicle being a motorcycle or having a foreign registration. Because of the constraint on offence processing capacity, any one camera may be operational only 3-4% of the time (Tingvall, personal communication). [A calculation based on the above data suggests that, on average, each camera is operational less than 0.5% of the time.]

Deterrence of speeding on each route is apparently achieved because "the cameras are normally put in a row of 7-15 cameras" and "as the driver does not know which camera is on, he will act as [if] they are all operating" (Tingvall, personal communication). It seems that the overt visibility of apparently frequent surveillance of driver speeds, no matter whether it is real, persuades Swedish drivers that there is a non-zero chance of being caught speeding somewhere on the camera route. There is the question of whether the deterrence effect can be maintained long-term as more and more, perhaps occasionally speeding, drivers become aware that individual cameras are not active some of the time.

Andersson and Larsson (2005) reported that the initial installation of 225 fixed speed cameras on 30 routes totalling about 500 kilometres reduced average speeds by about 8 km/h at camera sites and by nearly 5 km/h between them on the higher-speed routes (average speed before enforcement was 95 km/h). There were statistically significant reductions in personal injury crashes and injured persons. Fatal crashes and fatalities were reduced by 50% and the number of severely injured persons was reduced by 25%; however these reductions could have been due to random variation (not statistically significant). Tingvall (personal communication) confirmed that the speed reductions have been maintained and that the possible short-term deterrence effects have continued long-term. However, there is no evidence that the program has had an effect on roads other than the routes on which the fixed cameras are installed.

The mechanism of effect of the Swedish fixed speed camera program appears to be general deterrence at each camera site and, because the cameras on each route are so dense (and there is the possibility that each one is operational), the local effects amalgamate to provide a general effect throughout the camera route. However, there is no evidence that the route-specific effects extend beyond the camera routes to other roads or more generally. The limited number speeding drivers apprehended and punished makes specific deterrence a likely secondary mechanism only, and probably deters re-offending only on camera routes.

3.2.4 France

Since July 2002, when President Jacques Chirac made road safety a priority for France, the French speed camera program has grown to 1,700 devices in 2007 and there is an aim to have 4,000 by 2012. Two-thirds of the devices are overtly-operated fixed speed cameras and the remainder are mobile cameras operated from an unmarked vehicle without advance warning signage. The roads on which the cameras are operated are generally heavily-trafficked with 24 hour flows apparently averaging about 16,000 vehicles per day, though 56% of the cameras are located on roads with less than 10,000 vehicles per day (Carnis, personal communication).

During 2005, the camera systems checked vehicle speeds on 270 million occasions, an average of six checks per month per driver (Carnis 2007). Each camera recorded about 1000-1500 speeding infringements per month, resulting in a total of about 7.5 million infringements detected during 2006.

Limited information is available about speeding transgression rates on French roads. During 2006, the proportion of passenger cars travelling more than 10 km/h above the speed limit (the enforcement threshold for the speed cameras) was 14% on 110 km/h limit roads, 9% on 90 km/h roads, and 17-23% on 50 km/h roads in villages or towns (Carnis, personal communication). No information is available on detection rates achieved by the cameras, but the information provided in the previous paragraph suggests that it could have been as high as 2.8% of passing vehicles during 2006.

An image of each offending vehicle is transmitted by WiFi to a central office where the owner of the vehicle is identified and an infringement notice sent to that person. The central office has the capacity to handle the outputs from up to 3,000 speed cameras or 15 million speeding infringement notices (Carnis, personal communication). Apparently the prosecutability rate of each offending vehicle is high (over 90%). The French legal requirement that the vehicle owner is immediately liable for the fine and must pay it at the same time as nominating the driver, where applicable, apparently leads to high payment rates. The owner is refunded the fine and the liability transferred to the driver in such cases.

The impact of the French speed camera program on speeds and road trauma has not been thoroughly researched to separate it from other initiatives following President Chirac's statement. Average speeds and the proportion exceeding speed limits by 10 km/h have fallen substantially (but were falling prior to the program commencing in 2003). Road fatalities have fallen from around 7,200 in 2002 to around 4,700 in 2006, a decrease of 35%. The French authorities have estimated that about 75% of this gain has been due to the speed camera program (Carnis 2007).

The mechanism of effect of the French speed camera program appears to be principally based on specific deterrence through a high rate of surveillance of each driver and, at this stage, no constraint on the back-office to prosecute nearly all the offences detected. Some general deterrence of speeding at camera sites is probably also achieved, especially at fixed camera sites. The efficiency of the French system is apparently assisted by a type of owner-onus legislation and the requirement that the owner is immediately liable for the fine.

3.2.5 United Kingdom

While the Cost Recovery Program which led to the rapid expansion of speed cameras in the UK during 2000/01 to 2003/04 has been comprehensively evaluated (Gains et al 2003, 2004, 2005), very little has been published about the processing of offences detected by the cameras. During 2003/04 there were 4,172 cameras funded under the Program, but ICF (2003) had estimated that there were a total of 6,000 cameras. The Cost Recovery Program cameras were predominantly operated in urban areas (speed limit up to 40 mph) with 59% being overt fixed cameras. In rural areas, mobile speed cameras (also operated overtly) represented 59% of the total speed cameras (Gains et al 2005).

No information is available about traffic flows past speed camera sites. In urban areas during 2006, 19% of passenger cars exceeded 30 mph speed limits by 5 mph and 10% exceeded 40 mph limits by the same amount. In rural areas, 17% of passenger cars on motorways and 12% on dual carriageways exceeded the speed limit of 70 mph by 10 mph, but only 2% exceeded the 60 mph limit on single carriageway roads by the same amount (Department for Transport 2007). In contrast, during 2003/04 only 0.3% of vehicles detected at fixed camera sites and 1.8% detected by mobile speed cameras were found to exceed the speed limit by 15 mph (Gains et al 2005). It is understood that the typical speed camera enforcement threshold in Great Britain is 110% of the speed limit plus 5 mph (Heydecker, personal communication), representing 8 mph in excess in 30 mph zones and 12 mph in excess in 70 mph zones.

This relatively high enforcement threshold led to 1.978 million fixed penalty notices being issued for offences detected by the Cost Recovery Program speed cameras during 2003/04. This output from the 4,172 Program cameras operated during the same year can be compared with the 7.5 million speeding infringements detected by the 1,400 speed cameras operating in France during 2006. The difference is apparently due to the relatively low enforcement threshold of 10 km/h in excess of the limit in France. Another explanation may be that the UK speed cameras are required to operate very conspicuously, including the mobile cameras.

The effects of the UK speed camera program have been summarised by Cameron and Delaney (2006). There is little doubt that speeds and road trauma are reduced substantially in the vicinity of fixed cameras and at mobile camera sites (at least when operating). However, there is little or no evidence of general effects which extend beyond the camera sites to broader parts of the UK road system.

The principal mechanism of effect of the UK speed camera program appears to be general deterrence through the very conspicuous operation of both fixed and mobile cameras in large numbers. However, the number of cameras and/or the mode of operation of the mobile units (compare with Queensland) are not sufficient to produce a broad, general effect to extend the strong local effects. Specific deterrence of excessive speeders is probably achieved because even they are detected by the relatively high enforcement threshold, but this mechanism appears to be secondary to the effects of the program.

3.2.6 Conclusions from review of infringement management models

The five jurisdictions reviewed covered speeding infringement detection and processing models ranging from high numbers of offenders detected covertly and prosecuted in Victoria, to low numbers of offenders prosecuted in Sweden because cameras are aimed at general deterrence and only photograph offenders infrequently in order to prevent overloading of the back-office capacity.

The Victorian mobile speed camera program is reliant principally on the prosecution of speeding drivers to achieve (specific) deterrence. The covert operations are generally invisible to all but the most astute drivers, and general deterrence is achieved only through formal and informal publicity (the latter by word-of-mouth from other drivers caught). Thus the Victorian mobile program is heavily dependent on processing all of the offenders detected (within limits of legal integrity) in order to achieve its effects. While this has implications for back-office processing capacity, a very key benefit of the Victorian program is the reduction in the risk of fatal outcome in crashes to a greater extent than other speed enforcement methods. The Queensland overt mobile speed camera program does not appear to have an effect on fatal crashes to any greater extent than non-fatal crashes. The efficiency of processing speeding offences detected by mobile cameras in Victoria, as well as offences detected by fixed cameras, is improved by the existence of "owner-onus" legislation making the vehicle owner initially liable for the offence.

The Queensland program achieves substantial reductions in casualty crashes through overt mobile operations whose effects extend well beyond (in time and space) the localised effects which are to be expected from visible enforcement. The random allocation appears to be responsible for this, as does focusing the camera site zones on crash sites and not other criteria. A capacity to prosecute a substantial number of speeders still passing the overt camera operations appears necessary to give real fear of detection/punishment behind the thinly spread operations aimed at raising the perceived risk above zero. However, the detection rate has fallen substantially over the years of the program operation, perhaps due to greater recognition of camera operations as well as real improvement in transgression rates. The rate of issue of infringement notices during recent years is about one-third of the

10 notices per camera hour assumed in the 2006 study economic analysis, based on the limited information from 2001 then available about the Queensland program.

The Swedish fixed speed camera program is focused on general deterrence of speeding on the camera routes exclusively, and appears to place relatively little emphasis on specific deterrence. The limited numbers of speeders who are prosecuted are likely to be chronic speeders for whom the general deterrent operations have little effect, and/or occasional speeders who are caught by chance through inattention. The density of the cameras on the specified routes, no matter whether each is operational or not, apparently produces a strong general deterrence effect. Prosecution of some offenders appears to be necessary to ensure that the perceived risk of apprehension is in fact real and is communicated via word-of-mouth. However the effect of the program is limited to the camera routes, each with the necessary high density of cameras. There is also the question of whether the general deterrence effect can be maintained long-term when chronic and occasional speeders passing camera sites come to realise that they are seldom prosecuted.

The French speed camera program is focused on specific deterrence of speeding through a high rate of surveillance of each driver and the capacity to prosecute all of the offences detected. Some general deterrence of speeding at camera sites is also achieved, especially at fixed camera sites. The efficiency of the French system is assisted by owner-onus legislation and the requirement that the owner is immediately liable to pay the fine.

The UK speed camera program is focused on general deterrence through the very conspicuous operation of large numbers fixed and mobile cameras. However, the operations do not produce a broad effect which extends the strong local effects. Specific deterrence appears to be a secondary effect of the program and is focused on excessive speeders because of the relatively high enforcement threshold.

3.3 FUNDING OF THE PACKAGE FROM FINE REVENUE

The originally recommended speed enforcement package was estimated to cost $18.6 million per annum to operate (to this should be added the potential increased capital cost of $4 million, amortised on a per annum basis, of providing a back-office infrastructure for the manpower to process the expected speeding tickets needed to be issued, at least in the short term).

Cameron and Delaney (2006) indicated that the fine revenue from the escalated number of speeding tickets, at least initially, would be about $17 million per month or $204 million per annum. Thus the operational costs of the recommended speed enforcement package (estimated $18.6 million per annum short-term) would be of the order of 9-10% of the fine revenue, this percentage probably increasing over time as transgression rates and detected speeding offences fall in response to the escalated enforcement.

Associated with the rapid expansion in speed cameras in the UK since 2000 has been a Cost Recovery mechanism whereby the road safety partnership agencies in each area operating cameras have been able to recover their operational costs from the central government fund receiving the fine revenue. Over the first four years of the Cost Recovery Program, £217.5 million in fines has been received and £175.2 million in costs have been recovered, representing about 80% of the fine revenue (Gains et al 2005). The Cost Recovery Program is tightly controlled by Her Majesty's Treasury and the camera partnerships only recover their costs after submitting audited accounts. Apparently, this transparent system has not led to any public controversy about the use of (most of) the fine revenue in this way. The surplus fine revenue is transferred to the Government's consolidated fund.

In the 2006 study it was recommended that the Western Australian Government give consideration to funding the operational costs of the speed enforcement package in a similar way. A transparent system whereby it is recognised that the costs of providing an effective system to reduce road trauma and social costs are met from the fines paid by speeding motorists should have broad public acceptance. The surplus revenue could also be the basis of Government investment in other effective road safety programs addressing problems other than speeding.

3.4 RISK MANAGEMENT

It is important during a time when speed enforcement levels are planned to escalate to a higher level than previously that the Police and Government give careful attention to risk management. Delaney, Ward and Cameron (2005) have identified four areas of dilemma which can cause social controversy when major new speed enforcement programs are implemented in a jurisdiction. The two most relevant are legitimacy dilemmas (social concerns about the fairness of the enforcement operations) and implementation dilemmas (acceptance of the enforcement is hampered because difficulties and problems which arose during implementation have not been adequately compensated for in the view of society).

The absence of controversies relating to implementation dilemmas or legitimacy dilemmas during the substantial increase in the Victorian speed camera program during the early 1990's may be related to the attention given by the Victoria Police and the justice department to risk management while the new program was being established. Smith (2000), who had a key role in the justice department at the time, outlines the key issues which were addressed in implementing a program to detect and process a high volume of traffic offences (much higher than previously handled in Victoria). The risk management strategies included:

- independent technical testing and quality assurance (less than ten appeals against the initial five million speeding tickets issued for offences detected by the mobile speed cameras were successful)
- operational procedures that genuinely identified road safety as the primary objective
- winning public support for the program even though the level of fines was substantial
- subjecting the program to independent evaluation research to establish its road safety benefits, or modifications to the program if necessary.

Further details of the risk management principles necessary for successful establishment of a substantial speed camera program are given by Smith, Cameron and Bodinnar (2002).

It is also important to manage public opinion to avoid controversies associated with the credibility dilemma (Delaney et al 2005). This dilemma may arise if there are doubts about the Government's real purpose in escalating speed enforcement, e.g. whether the principal purpose is to raise revenue for the Government through a substantial increase in speeding infringement fine income. The importance of managing public opinion about the credibility of escalated speed enforcement is illustrated by the experience in British Columbia, Canada (Chen 2005). When their mobile speed camera program was introduced in 1996, two-thirds of the population supported the new initiative. The political opposition, reflecting emerging grassroots opinion, portrayed the program as a "cash cow" for the provincial government rather than a safety issue. The program subsequently became an election issue, the opposition party were elected, and the program was terminated in June 2001, notwithstanding that a scientific evaluation published in 2000 had demonstrated the safety benefits of the program (Chen et al 2000).

The experience in a number of jurisdictions indicates that it is important that the strategic principles and aims behind a program of escalated speed enforcement be openly communicated to politicians and the community, making it clear that reduction in road trauma is the objective. There should be transparency in management and operation of the program throughout its life, so that the objective remains clear to all concerned and there is no doubt that no hidden objectives exist.

4 SPEED ENFORCEMENT PACKAGE

The originally recommended speed enforcement package for WA was developed based on the evidence of effects on road trauma at each level of operation, the economic value of each enforcement program, and the overall contribution to reducing road trauma in WA while avoiding overlap of enforcement operations on each part of the road system. The aim was to identify a package which, when fully implemented, would produce at least 25% reduction in fatal crashes, somewhat smaller reductions in less-serious casualty crashes, and have maximum cost-benefits in terms of the return on social cost savings for the investment.

The addition of point-to-point speed camera technology to this recommended package awaits specific decisions on suitable links for its application on WA roads. It may replace other forms of speed enforcement on parts of some road types.

4.1 ORIGINALLY RECOMMENDED ENFORCEMENT PROGRAMS

The originally recommended enforcement programs, together with the level of input (usually operational hours per month) and the expected speeding ticket processing requirements (at least short-term), are shown in Table 5. This table needs to be read in conjunction with Table 6 where the actual crash savings per month are estimated, valued in terms of social costs using the unit crash costs (in 2005 prices), then aggregated across the package components to provide the overall impacts for the full WA road system. The aggregated benefit-cost ratio for the total social cost savings from the package, relative to the total package cost per month, was also calculated in this way.

Table 5 shows that the recommended speed enforcement package, when fully implemented, was estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes and a saving of $186 million in social costs per annum (from the monthly savings in Table 6). The total cost of the enforcement package to produce these savings is estimated to be $18.6 million per annum. The benefit-cost ratio of the package is estimated to be at least 10 and would be higher if the road trauma savings were valued by the "willingness to pay" method to establish unit crash costs.

Table 5: Recommended speed enforcement programs (by level of input), benefit-cost ratios, and expected crash reductions at the individual program level and for the strategic enforcement package overall

Speed Enforcement Program	Speed Enforce-ment Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9,000	90,000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35,613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**8.01**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	30,000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**170,276**	**9.98**	**9.0%**	**12.3%**	**26.0%**
- per year (short-term)		**2,043,315**				

Table 6: Economic benefits and costs of the recommended speed enforcement programs and for the strategic enforcement package overall

Speed Enforcement Program	Crash savings per month			Social Cost Saving per month ($'000)	Program Cost per month ($'000)	Fine Revenue per month ($'000)
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3974.64	634.1	9000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1551.51	51.9	341.3
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.27	59.4	3561.3
Total for urban roads	**17.0**	**6.1**	**1.3**	**5967.42**	**745.4**	12903
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5673.94	154.5	3000
Mobile radar units on rural local roads	6.2	4.9	0.62	3864.00	653.5	1125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9537.93**	**808.0**	4125
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15505.4**	**1553.3**	17027.6

The use of covert mobile speed cameras on urban highways (arterial roads) in Perth was recommended because of clear evidence of the strong effects of these enforcement operations on fatal crashes, and evidence that an increase in hours committed to this type of speed camera enforcement would further reduce road trauma. A level of 9,000 hours of camera operations per month, representing approximately tripling of the level currently achieved by the existing Multanova cameras in WA, is estimated to produce 65% reduction in fatal crashes on Perth's arterial roads, as well as about 12% reduction in injury crashes. Total social costs of crashes would be reduced by 22%, when crash costs are valued by the "human capital" method (BTE 2000).

4.2 ALTERNATIVE TO COVERT MOBILE SPEED CAMERAS

An alternative to covert mobile cameras on Perth's arterial roads was overt mobile cameras randomly scheduled on the same roads. The evidence of effect of these enforcement operations could not identify a greater effect on fatal crashes, but their effect on casualty crashes overall was substantial and was estimated to be 27% reduction if 9,000 hours of camera operations per month were committed to Perth's arterial roads. A benefit-cost ratio of 7.9 was estimated for randomly-scheduled overt cameras on these roads, compared with

6.1 for covert cameras, when the social cost of crashes was valued by the "human capital" method. The effect on the total speed enforcement package of replacing the covert camera recommendation with randomly-scheduled overt cameras on urban highways in Perth is shown in Table 7. It can be seen that while the total speed enforcement package would apparently be more cost-beneficial (benefit-cost ratio of 10.64 compared with 9.98), the package would not achieve the target 25% reduction in fatal crashes. It was for this reason that the recommended speed enforcement option for Perth's arterial roads was covert mobile speed cameras. The substantially greater effect of these operations on fatal crashes would also result in this option being more cost-beneficial than the alternative if the social cost of fatal crashes was valued by the "willingness to pay" method (BTCE 1997).

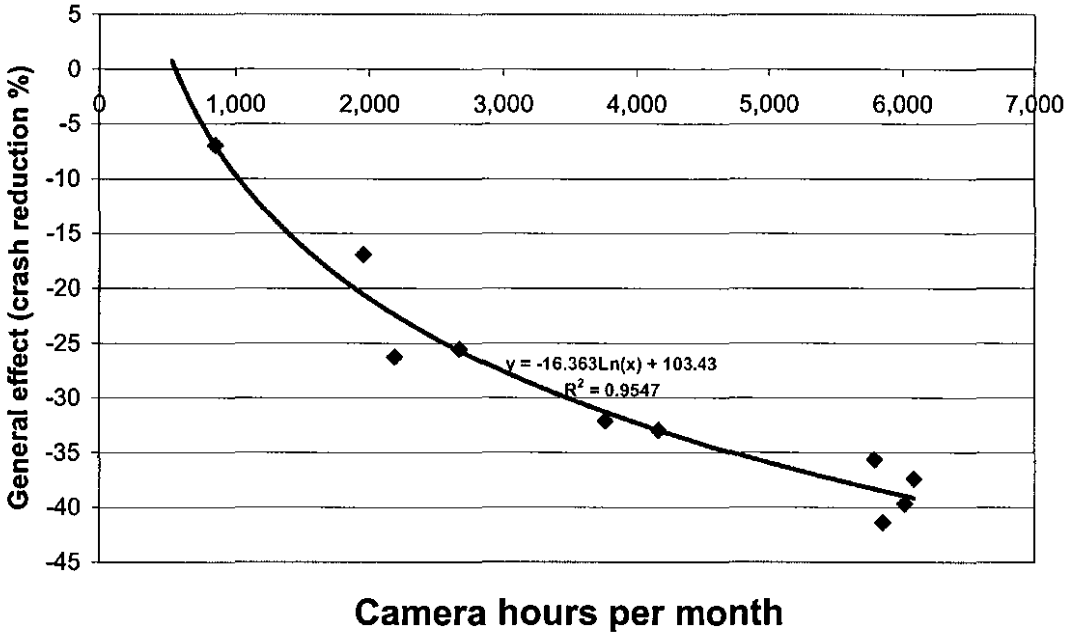
Table 7: Alternative to recommended speed enforcement programs originally considered

Speed Enforcement Program	Speed Enforce-ment Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Overt mobile speed cameras randomly scheduled on urban highways	9,000	90,000	7.9	27.3%	27.3%	27.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Continuous at 24 sites	35,613	7.33	7.76%	15.52%	15.52%
Total for urban roads			**9.39**	**11.2%**	**10.4%**	**12.2%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	30,000	36.8	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.81**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**170,276**	**10.64**	**13.4%**	**15.2%**	**20.4%**
- per year (short-term)		**2,043,315**				

4.3 UPDATE OF QUEENSLAND RELATIONSHIPS

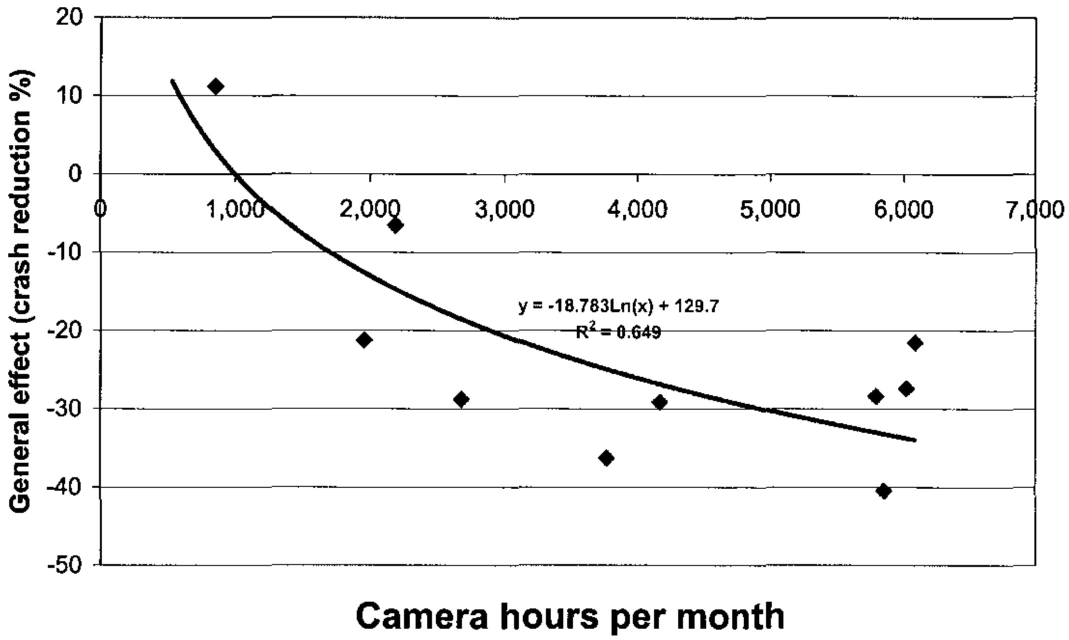
The option of overt mobile speed cameras randomly scheduled on urban and rural highways was analysed based on relationships established from evaluations of the Queensland mobile speed camera program up to 2003. Since those studies, there have been a series of evaluations of the program up to 2006 (Newstead 2004, 2005, 2006). While the Queensland program continued to operate at about 6,000 hours per month throughout 2003-2006, the additional estimates of effect had the potential to improve the reliability of the relationship between camera hours and crash reductions. However, Figure 1 shows that the updated relationship is almost identical to that found in the 2006 study, suggesting only a marginally stronger relationship and hence marginally greater economic benefits.

Figure 1: Relationship between casualty crashes in Queensland and monthly hours of the overt mobile speed camera program with randomised scheduling, 1997-2006 (update of Figure 5 in Cameron and Delaney, 2006, MUARC report 270)



The availability of additional evaluations of the Queensland program also allowed reconsideration of whether the program had greater effect on fatal crashes than non-fatal crashes, a characteristic to be expected for effective anti-speeding countermeasures such as this. Figure 2 shows the estimated reductions in fatal crashes associated with the level of monthly hours operated each year from 1997 to 2006. It should be noted that the individual annual estimated reductions are not as reliable as the reductions in all casualty crashes shown in Figure 1 and that no individual reduction is statistically significant. Nevertheless, the estimates do suggest a relationship between fatal crash reductions and camera hours of the same type as that in Figure 1 for casualty crash reductions. However, there is no evidence that the magnitude of the reduction achieved by the Queensland program on fatal crashes is any greater than that achieved on casualty crashes in general (of which fatal crashes are a part).

Figure 2: Relationship between fatal crashes in Queensland and monthly hours of the overt mobile speed camera program with randomised scheduling, 1997-2006



It was concluded that, notwithstanding the additional information now available, the relationship established in the 2006 study does not need to be updated to reflect a greater effect of randomly-scheduled overt mobile speed cameras on fatal crashes than that previously used in the analysis.

4.4 REVISIONS AND OTHER OPTIONS FOR THE SPEED ENFORCEMENT PACKAGE

Following the review of speed offence processing models in other jurisdictions, it was decided that the number of offences estimated as required to be processed, according to the 2006 study, were over-stated and could be reduced. Specifically:

- Based on Queensland experience where the detection rate of speed offences per hour of overt mobile speed camera operation dropped by nearly two-thirds, it was estimated that the number of speeding tickets issued per month from overt mobile speed cameras operating at the originally recommended hours would be about one-third of that originally estimated in the short term.

- Based on experience in Sweden with the operation of their overt fixed speed cameras intermittently on designated routes, it was proposed that the 24 fixed cameras recommended for Perth freeways could also be operated intermittently without any reduction in effectiveness on road crashes. It was further proposed that the active times of these cameras be scheduled so that they detect offences resulting in about 10,000 speeding tickets issued per month in the short term (compared with 35,600 per month originally estimated from continuous operation of the cameras).

A further alternative to the operation of covert mobile speed cameras on urban highways was also proposed. This was to operate the covert and overt mobile cameras on a 50:50 basis in this road environment. The rationale for this proposal is given in section 4.4.2.

The option to replace the proposed fixed speed cameras on Perth freeways with point-to-point camera systems covering five sections was not considered as an alternative for this road environment because of the absence of evidence from the limited experience to date that such systems operated intermittently would be equally effective. However, if it is decided that the Perth freeway cameras should be operated continuously, then the alternative of point-to-point operation should be revisited because of its superior BCR (see section 2.9, Table 4).

The application of point-to-point speed cameras on the other Perth highway links for which they are suitable and economically warranted (about 15% of the total length of metropolitan highways and arterial roads; Table 4) is an alternative to covert/overt mobile speed cameras on that sub-set of roads. However, further consideration of that option needs to await decisions about the specific highway links to be covered by point-to-point systems, hence the Perth highways not covered, and the traffic densities and offence processing requirements if mobile speed cameras operated on the remaining highways.

In a similar way, the application of point-to-point speed cameras as an alternative to randomly-scheduled overt mobile speed cameras on rural highways needs to await specific decisions about suitable links. While the relative BCR of point-to-point cameras is not favourable, some rural highway links may warrant the closer enforcement of speeding that they can provide with perhaps greater certainty than the overt mobile speed cameras.

4.4.1 Revisions to speed offence ticketing requirements

Table 8 shows the implications for the originally recommended speed enforcement package if the speed offence processing loads are reduced following the Queensland and Swedish experience. The estimated number of speeding tickets required to be issued drops to just under 1.5 million per year in the short term and the estimated benefit-cost ratio of the package rises to above 10. It is expected that this package of enforcement programs and offence processing load would be equally effective as the originally recommended package.

Table 8: Recommended speed enforcement programs – REVISED (shown in bold)

Speed Enforcement Program	Speed Enforce-ment Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9,000	90,000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways (Swedish-style)	**Intermittent** at 24 sites	**10,000**	**9.33**	7.76%	15.52%	15.52%
Total for urban roads			**8.14**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	**10,000**	**37.4**	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.84**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**124,663**	**10.08**	**9.0%**	**12.3%**	**26.0%**
- per year (short-term)		**1,495,960**				

The 2006 study considered an alternative to the operation of covert mobile speed on Perth's arterial roads, namely the operation of overt mobile speed cameras randomly scheduled on these roads (see section 4.2 above). This alternative would substantially reduce the speeding offence ticketing load, based on experience with overt mobile speed cameras in Queensland. Table 9 shows that the estimated number of speeding tickets would be about 756,000 per year in the short term and the benefit-cost ratio would increase marginally compared with the same enforcement package analysed in Table 7. It is expected that this alternative package would be no less effective as analysed previously.

Table 9: Alternative to recommended speed enforcement programs – REVISED

Speed Enforcement Program	Speed Enforcement Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Overt mobile speed cameras randomly scheduled on urban highways	9,000	**30,000**	**8.0**	27.3%	27.3%	27.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways (Swedish style)	**Intermittent** at 24 sites	**10,000**	**9.33**	7.76%	15.52%	15.52%
Total for urban roads			**9.65**	**11.2%**	**10.4%**	**12.2%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	**10,000**	**37.4**	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.84**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**64,663**	**10.81**	**13.4%**	**15.2%**	**20.4%**
- per year (short-term)		**755,960**				

4.4.2 Covert and overt mobile speed cameras on urban highways

A new option for speed enforcement on urban highways (arterial roads) in Perth considered in this extension project was the operation of covert and overt mobile speed cameras on a 50:50 basis. This balance of the two forms of operation was chosen for illustrative purposes only. Such operations are unprecedented and hence the likely effect of the combined operations on crashes and their injury outcomes is unknown. However, research on experience in Victoria regarding moving mode radar operations using marked and unmarked cars, separate operations and combined, suggests that the combined operations had greater effect on crashes than either of the separate operations.

In the case of the urban operation of covert mobile speed cameras, combined with randomly scheduled overt mobile speed cameras, it could be expected that the net effect would benefit from:

(a) the strong effect of the covert mobile cameras on fatal crashes, estimated to result in about 65% reduction in these crashes when the cameras are operated at 9000 hours per month, and

(b) the substantial effect of the randomly scheduled overt mobile cameras on casualty crashes in general, estimated to result in about 27% reduction in non-fatal crashes at each level of severity when the cameras are operated at 9000 hours per month.

To be conservative, the analysis of the combined operations on urban highways in Perth assumed that the effect of this speed enforcement program, at each level of crash injury severity, would be the average of the estimated effects of each individual program operated at 9000 hours per month. This assumes that the intensity of the combined operations at 9000 hours per month would go some way to achieving the separate benefits of each form of operation, but that there would not be full synergy which would produce the maximum effects of each operation.

The estimated effects of the combined program on crashes at each level of severity are shown in Table 10, together with the other revised programs given in Tables 8 and 9. It was assumed that 15,000 speeding tickets would emanate from the 4,500 hours of overt mobile camera operations per month, whereas 45,000 tickets would emanate from 4,500 hours of covert mobile cameras operations per month, making a total of 60,000 tickets per month. These ticketing rates per camera hour of each type are the same as used in Table 8.

Table 10: Second alternative to recommended speed enforcement programs

Speed Enforcement Program	Speed Enforcement Hours per month	Speeding Tickets Issued per month	Program BCR	Program Crash Reduction		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert & overt mobile speed cameras randomly scheduled on urban highways (50:50)	9,000	**60,000**	**7.1**	**19.4%**	**19.4%**	**46.3%**
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.78	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways (Swedish style)	**Intermittent at 24 sites**	**10,000**	**9.33**	7.76%	15.52%	15.52%
Total for urban roads			**8.89**	**8.6%**	**8.3%**	**18.5%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	**10,000**	**37.4**	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads			**11.84**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**94,663**	**10.44**	**11.2%**	**13.8%**	**23.2%**
- per year (short-term)		**1,135,960**				

Another way of considering the expected crash reduction effects of the combined covert and overt mobile speed cameras on Perth's arterial roads is to examine the expected effects if the current 3,000 hours of speed camera activity per month is split, each half committed to covert or overt operation (1,500 hours each), and then each increased by 3,000 hours per month, making a total of 9,000 hours. The increase of 3,000 hours of covert mobile speed camera activity, based on Cameron and Delaney's (2006) Table 4, is estimated to result in 48.7% reduction in fatal crashes and 7.4% reduction in non-fatal casualty crashes, additional to the effects of current camera operations. The increase of 3,000 hours of randomly scheduled overt mobile camera activity, based on their Table 8, is estimated to produce 17.2% reduction in casualty crashes across all levels of severity, again additional. Both types of estimate are general effects and, in the overt camera case, rely on the camera sites covering a substantial proportion of crash sites within two kilometres. However, although these estimates are of the same magnitudes as those estimated previously (see Table 10), they assume that there is no synergy between the two types of operation. Both sets of estimated effects of the combined operations could be conservative.

The second alternative speed enforcement package, shown in Table 10, would require an estimated 1.136 million speeding tickets to be issued per year in the short-term. The benefit-cost ratio would be greater than the originally recommended package, including in revised form (Table 8). It is estimated that this package would produce 23% reduction in fatal crashes (compared with 26% originally predicted), 14% reduction in hospital admission crashes, and 11% reduction in medically treated injury crashes. The social costs of crashes, when crashes are valued by the "human capital" method (BTE 2000), would be reduced by 16%.

4.4.3 Operations of covert and overt mobile speed cameras

In the 2006 study, the current operation of Multanova speed cameras in WA was reviewed and contrasted with the operations of the covert and overt mobile cameras in Victoria and Queensland, respectively (Cameron and Delaney 2006). The Multanova operations were found to have a number of characteristics, as follows:

- Tripod-mounted system operated at the roadside with no attempt to hide the system, a method which is understood to be overt, at least during daylight
- Signage advising drivers that they have passed a camera in operation
- Public announcement of the date and route of camera operations (specifying only the suburb and road name, many of which are arterial roads traversing the suburb over many kilometres) through television and press news segments
- Sites selected on the basis of the following criteria:
  - locations subject to crashes, based on reported crash records
  - locations of "speed-related complaint" from the public
  - locations frequented by vulnerable pedestrians
  - locations where speeds need to be reduced by at least 5 km/h
  - locations where other speed detection methods cannot be used safely.

The operations of covert mobile speed cameras in WA were proposed with the following characteristics, following the Victorian approach:

- Car-mounted system in unmarked car using a variety of popular makes/models
- "Flashless" operations when ambient light permits (or digital technology allows)
- No advance warning or departure signs
- No public announcements of camera locations or camera presence
- Sites identified by "black spot" criteria, similar to current site selection in WA. It is understood that there are about 6000 current sites in WA, with about 1500 in regular use. A broad coverage of the focus road system is important, but a focus on black spot sites is less critical in the case of covert speed camera operations.

In Queensland, the sites for mobile speed camera operation are chosen on the basis of a high number of crash locations in the near vicinity (within a few kilometres). They are not necessarily speed-related "black spots" as, for example, currently defined in WA.

The operations of overt mobile speed cameras in WA were proposed with the following characteristics:

- Conspicuous camera system, either mounted in a designated van or car, or tripod operations used more overtly than in WA at present
- Signage within 10 metres of an operating site advising of camera presence
- No public announcements of camera locations or camera presence
- Numerous sites chosen such that at least 80% of casualty crash locations during the previous three years are covered by areas within 2 km of camera sites (a new set of speed camera sites may need to be defined for Perth based principally on this criterion)
- Random allocation of camera shifts to sites and time blocks (four hours each, excluding late night/early morning), with very limited opportunities for actual operations to depart from the random assignment.

The combined operations (covert and mobile speed cameras operating on the same urban arterial road system) should be focused on sites chosen primarily on their proximity to crash locations within the last three years, supplemented by a sites aiming to give a broad coverage of the arterial road system in Perth. This site selection aims to maximise the general deterrent effect of the overt operations on speeding and crashes for up to two kilometres around camera sites, thus achieve a broad general effect, and to specifically deter speeding behaviour at these sites and elsewhere in Perth by detecting and prosecuting a substantial number of speeders using covert operations.

In addition, there should be no public announcements of camera operations, no matter whether overt or covert, in order to maximise the deterrent effects (as outlined above) anywhere on the Perth arterial road system at any time. The overt operations can be made as conspicuous as possible, using designated vehicles and signage, but the covert operations should be as inconspicuous as possible by, for example, mounting the cameras in unmarked standard cars which are not obvious to drivers travelling in either direction.

4.5 FINES ENFORCEMENT AND FINE REVENUE

The revised and alternative speed enforcement packages considered in this chapter have different implications for the number of speed offences detected and speeding tickets issued, and hence for the costs of processing the offences, fines enforcement, and the fine revenue collected. In general, each of the packages requires essentially the same number of operational police hours and supporting equipment (mobile or fixed location) to detect offences, so that cost is effectively the same with all options considered.

Table 11 shows the estimated fine revenue to be expected from the speeding tickets estimated to result from each speed enforcement package in the short term. The average fine associated with each ticket was taken to be $100, based on information supplied by the WA Police regarding the situation in 2004. It is understood that the average fine per speeding ticket is now greater. The program costs do not include the cost of any additional capital investment in infrastructure to increase the capacity of the back-office to process offences. It is not known to what extent this would be necessary given that the increased offence processing load could possibly be handled by Police over-time in the short term.

Table 11: Costs of original, revised and alternative speed enforcement packages compared with annual speeding tickets and fine revenue in the short term

Speed enforcement package	Program Cost per month ($'000)	Program Cost per year ($m)	Speeding Tickets issued per year (short-term)	Fine revenue ($m) at $100 per ticket (short-term)	Fines Enforce-ment Registry additional cost ($m)
1. Originally recommended package (covert mobile speed cameras in Perth)	1,553.3	18.64	2,043,315	204.3	1.530
2. Originally recommended package (covert mobile speed cameras in Perth) – REVISED (reduced offence processing)	1,538.5	18.46	1,495,960	149.6	0.831
3. Alternative to recommended package (overt mobile speed cameras in Perth) – REVISED (reduced offence processing)	1,530.3	18.36	755,960	75.6	0.075
4. Second alternative to recommended package (covert and overt mobile speed cameras in Perth)	1,534.4	18.41	1,135,960	113.6	0.514

Also shown in Table 11 is an estimate of the additional costs which would be incurred by the Fines Enforcement Registry to process the expected increase in unpaid speeding infringement notices referred to the Registry by the WA Police for follow-up. Currently about 15% of traffic infringement notices are referred and it was assumed that this proportion of the additional speeding tickets would require follow-up in each speed enforcement package, at least in the short-term. The additional short-term cost to the Fines Enforcement Registry was estimated from information on the staffing requirements and costs of additional infringements, provided by the Registry (Table 12). The program costs in Table 11 are those estimated to be incurred by the WA Police to conduct the speed enforcement operations and process the speeding infringement notices, but not the costs of pursuing unpaid notices.

Table 12: Impact of additional speeding infringement notices referred to the Fines Enforcement Registry on staffing requirements and cost per infringement processed

Additional referrals to Fines Enforcement Registry (per year)	Additional Full Time Equivalent (FTE) staff required	Fixed Cost Component of additional staff $	Marginal Cost per additional lodgement $
8,250 - 16,500	0.5	27,536	2.92
16,500 - 24,750	1	53,071	2.92
24,750 - 33,000	1.5	80,607	2.92
33,000 - 41, 250	2	106,143	2.92
41,250 - 49,500	2.5	133,679	2.92
49,500 - 57,750	3	181,714	2.92
57,750 - 66,000	3.5	213,000	2.92
66,000 - 74,250	5*	309,059	2.92
74,250 - 82,500	5.5*	340,345	2.92
82,500 - 90,750	6*	369,631	2.92
90,750 - 99,000	6.5*	400,917	2.92

* Includes an additional Level 3 Supervisor for each additional 4 FTE staff added to the registry.

The short-term fine revenue ranges from 4 to 8 times the estimated annual operating cost of any of the newly-considered packages. It is expected that speeding transgression rates would be halved in the medium term, as would detection rates (unless enforcement thresholds are reduced), and would reduce even further in the longer term. The costs of operating the package would reduce very little under these scenarios because the offence processing costs are a relatively minor component of the program costs, as can be seen by implication in Table 11. (An estimate of $135.11 per 1000 speeding infringement notices issued for offences detected photographically was derived from information provided by WA Police and used in this and the original analysis.) Thus, in the medium term, the expected fine revenue would be 2 to 4 times the cost of any of the newly-considered packages and the transgression rate would need to fall by three-quarters before the fine revenue would not meet the costs of the first alternative package (package 3 in Table 11).

5 REDUCED ENFORCEMENT THRESHOLD: DE FACTO LIMIT REDUCTIONS

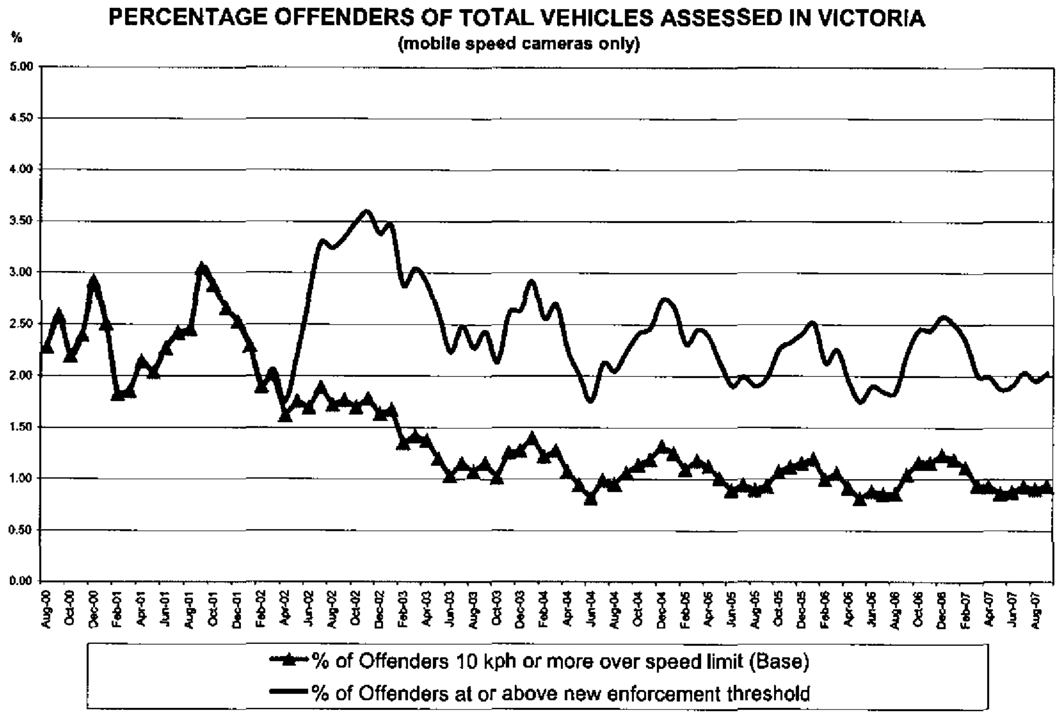
In their recent recommendations for a new road safety strategy for Western Australia, MUARC proposed that speed limits in WA be reduced by 10 km/h in various stages. An additional way of achieving speed reductions, which complements the speed enforcement package, would be through reduction in the speed enforcement threshold. This in turn reduces the *de facto* speed limit, i.e. the speed limit to which motorists drive above the posted speed limit in the belief that they are safe from detection and prosecution even though they are driving illegally.

During 2002, Victoria reduced its speed enforcement threshold in three steps, from the previously well-known threshold of 10 km/h in excess of the posted limit, to an unpublicised level. The threshold reductions were part of a package of speed enforcement intitiatives (50% increase in mobile speed camera hours; "flashless" operation of mobile cameras; and other changes to make them more covert), high-profile speed-related advertising, and a speeding penalty restructure.

An analysis attempted to link each of the elements of the speed-related package with monthly variations in casualty crashes and the injury severity of their outcome (Bobevski et al 2007). The analysis suggested that the second step of the threshold reduction was associated with casualty crash decreases, but it was concluded that the threshold reductions were probably not adequately tested because of uncertainty about the timing of their effects on speeds and crashes. A subsequent analysis evaluated the overall effect of the speed-related package and found that it was associated with 10% reduction in casualty crashes and about 19% reduction in the risk of fatal outcome during the period to December 2004 (D'Elia et al 2007).

A better indication of the longer-term effects of the threshold reduction is indicated in Figure 3 which shows the offence detection rate for offenders at or above the old threshold of 10 km/h, as well as those at or above the new threshold. The percentage of offenders approximately doubled in the first six months, then both the percentage exceeding the old threshold fell as well as the percentage between the new and the old thresholds.

Figure 3: Speed offence detection rates relative to old and new thresholds



After an initial two year period, the offence rates have stabilised but have seasonal variation which was not previously apparent. The percentage at or above the old threshold of 10 km/h has fallen from 2-2.5% to around 1%. This appears to indicate a real improvement in speeding, if the covert operation of the mobile speed cameras can be considered to measure typical on-road behaviour. The percentage of drivers detected at or above the new threshold has stabilised around 2-2.5%, about the same percentage of offenders detected when the old threshold was applicable.

Thus it appears that the threshold reduction has led to a real reduction in speeding, 10 km/h or more above the speed limit, and as noted earlier there was a substantial reduction in road trauma in the period up to December 2004 (D'Elia et al 2007). Unfortunately, there has been no research to indicate whether this reduction in road trauma associated with changes in speed enforcement in Victoria has continued, though it is likely to be the case.

Apart from a short term increase in the detection rate and the number of offenders needing to be processed, after two years the number of offenders to be processed was about the same number per year as that with the old threshold. Thus the threshold reduction in Victoria did not lead to an increased infringement processing load in the medium to long term. The Victorian infringement processing system was originally designed with the capacity to process up to 100,000 speeding offenders detected by mobile cameras per month. That level was exceeded in November 2002.

6 CONCLUSIONS

1. Point-to-point speed cameras are likely to be effective speed enforcement systems covering substantial lengths of freeways and highways in WA with limited access/egress opportunities. Economic analysis has identified 40 road links where the application of point-to-point systems would have benefit-cost ratios of 10 or greater.

2. The Victorian covert mobile speed camera program is reliant principally on the prosecution of speeding drivers to achieve specific deterrence. Thus it is heavily dependent on processing all of the offenders detected (within limits of legal integrity) in order to achieve its effects. The efficiency of processing speeding offences detected by mobile cameras in Victoria, as well as offences detected by fixed cameras, is improved by the existence of "owner-onus" legislation making the vehicle owner initially liable for the offence.

3. The Queensland overt mobile speed camera program achieves substantial general deterrence around camera sites, producing local effects which amalgamate to produce a broad general effect due to the random scheduling in space and time and the comprehensive coverage of crash sites by camera sites. Prosecuting a substantial number of speeders detected by the cameras appears necessary to give real fear of detection/punishment behind the thinly spread enforcement operations.

4. The Swedish overt fixed speed camera program focuses on general deterrence of speeding on the camera routes exclusively, and places relatively little emphasis on specific deterrence. The density of cameras on the specific routes, no matter whether each is operational or not, produces a strong general deterrence effect. The high perceived risk of detection is supported by the prosecution of only a relatively small number of offenders. The effect of the program is limited to the camera routes and there is the question of whether general deterrence can be maintained long-term.

5. The French speed camera program is focused on specific deterrence of speeding through a high rate of surveillance of each driver and the capacity to prosecute all of the offences detected. Some general deterrence of speeding at camera sites is also achieved, especially at fixed camera sites. The efficiency of the French system is assisted by owner-onus legislation and the requirement that the owner is immediately liable to pay the fine.

6. The UK speed camera program is focused on general deterrence through the very conspicuous operation of large numbers fixed and mobile cameras. However, the operations do not produce a broad effect which extends the strong local effects. Specific deterrence appears to be a secondary effect of the program and is focused on excessive speeders because of the relatively high enforcement threshold.

7. A reduction in the speed enforcement threshold will produce a short-term increase in the offence detection rate, but in the medium to long term the offence rate will return to its previous level. In addition, the proportion of drivers exceeding the old enforcement threshold will reduce substantially because of more effective deterrence of speeding above that level.

8. Based on the review of speed offence processing models in other jurisdictions, it was concluded that the number of offences estimated to be processed, in the originally recommended package, was over-stated and could be reduced. The reduction in the

offence processing load reduces the cost of the package and increases the benefit-cost ratio, as shown in Table 12. The benefit-cost ratio of the alternative to the originally recommended package is also increased. A second alternative package, involving the use of both covert and overt mobile speed cameras on urban highways in Perth, may combine the best features of these two forms of operation and produce crash reductions and a benefit-cost ratio between those of the originally recommended package and the alternative (see Table 12).

Table 12: Estimated effects of the original, revised and alternative speed enforcement packages on crashes, and estimated benefit-cost ratio of each package

Speed enforcement package	Reduction in fatal crashes	Reduction in hospital admission crashes	Reduction in medical treatment crashes	Package Benefit-Cost Ratio
Originally recommended package (covert mobile speed cameras in Perth)	26.0%	12.3%	9.0%	9.98
Originally recommended package (covert mobile speed cameras in Perth) – REVISED (reduced offence processing)	26.0%	12.3%	9.0%	10.08
Alternative to recommended package (overt mobile speed cameras in Perth) – REVISED (reduced offence processing)	20.4%	15.2%	13.4%	10.81
Second alternative to recommended package (covert and overt mobile speed cameras in Perth)	23.2%	13.8%	11.2%	10.44

9. Pending decisions on the application of point-to-point speed cameras, the originally recommended speed enforcement package remains the most effective set of options for WA. It is nearly the most cost-beneficial set of options and would be certainly so if fatal crash reductions were valued more highly, because of the strong effect of covert mobile speed cameras on fatal outcomes in crashes. Randomly-scheduled overt mobile speed cameras have no greater effect on reducing fatal crashes than on non-fatal crashes.

10. Point-to-point speed camera systems have the potential to replace the originally recommended speed enforcement program on Perth freeways, and the recommended programs on parts of the urban and rural highway system. Links of freeway and highway have been identified where point-to-point systems are economically warranted, as summarised in Table 13. Decisions about the specific links suitable for application of the point-to-point technology must await consideration of all of the characteristics of the nominated roads.

Table 13: Freeways and highway links warranted for Point-to-Point speed cameras

Region	Roads warranted for Point-to-Point camera systems	Total Length of Links (km)	Reduction in fatal and hospital admission crashes	Reduction in medical treatment crashes	Point-to-Point system capital cost ($)	Speeding Tickets issued per year (short term)	BCR
Perth metro-politan	Freeways	74	33.3%	12.6%	4,900,000	496,758	10.35
	Other links in top 40	248	33.3%	12.6%	4,450,000	218,210	16.54
Non-metro-politan	Links in top 40	2,990	33.3%	12.6%	11,800,000	133,591	15.76

7 BIBLIOGRAPHY AND REFERENCES

A77 Safety Group (2007). Casualties halved on A77 – SPECS: End of 2nd year casualty statistics. News Release, 26 October 2007. Strathclyde, Scotland.

Andersson, G. and Larsson, J. (2005). Automatic speed cameras in Sweden 2002-2003. VTI Notat 10A-2004. Swedish National Road and Transport Institute VTI, Linkoping.

Andersson, G. and Nilsson, G. (1997). Speed management in Sweden. Swedish National Road and Transport Institute VTI, Linkoping.

Andersson, G. (1990). Speeds as a function of tolerance limit, penalties and surveillance intensity. Swedish Road and Traffic Research Institute, Report 337.

Arberg, L., Engdahl, S. and Nilsson, E., (1989). Increased speeding fines. Effects on drivers' knowledge about amounts of fines and effects on speeds, Transportforskningsberedningen, Report No. 10, Stockholm.

ARRB (2005) Evaluation of the fixed digital speed camera program in NSW. RC2416

Bjørnskau, T. and Elvik, R. (1990). Can road traffic law enforcement permanently reduce the number of accidents? In: Proceedings of road safety and traffic environment in Europe in Gothenburg, Sweden, September 26-28, 1990, VTI report 365A p.122-145.

Bobevski, I., Hosking, S., Oxley, P., and Cameron, M.H. (2007). Generalised linear modelling of crashes and injury severity in the context of the speed-related initiatives in Victoria during 2000-2002. Report No. 268, Monash University Accident Research Centre.

Cameron, M.H. (1999). Methodology for evaluation of the Enhanced Traffic Enforcement Program in Western Australia. Report to Office of Road Safety, Western Australia.

Cameron, M.H. and Delaney, A. (2006). Development of strategies for best practice in speed enforcement in Western Australia: Final Report. Report to Department of Premier and Cabinet, Office of Road Safety, Western Australia, September 2006. Report No. 270, Monash University Accident Research Centre.

Cameron, M.H. and Sanderson J.T. (1982) Review of Police operations for traffic law enforcement. RACV Traffic and Safety Department.

Cameron, M.H., Cavallo, A. and Gilbert, A. (1992). Crash-based evaluation of the speed camera program in Victoria 1990-1991. Phase 1: General effects. Phase 2: Effects of program mechanisms. Report No. 42, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003a). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria. Report No. 201, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003b). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria, Australia. Proceedings, 47th Annual Scientific Conference, Association for the Advancement of Automotive Medicine, Lisbon, Portugal, September 2003.

Cameron, M.H., Newstead, S.V., Gantzer, S., (1995). Effects of enforcement and supporting publicity programs in Victoria, Australia. In: Proceedings of Conference, Road Safety in Europe and Strategic Highway Research Program, Prague, The Czech Republic, VTI, Sweden.

Carnis, L. (2007). The automated speed enforcement programme in France. Paper presented at Road Safety Research, Policing, Education Conference, Melbourne.

Carnis, L. (2008). Personal communication via emails with M. H. Cameron. Senior researcher, French National Institute for Transport and Safety Research, Paris.

Chen, G. (2005). Safety and economic impacts of photo radar program. Traffic Injury Prevention, Vol. 6, pp. 299-307.

Chen, G., Wilson, J., Meckle, W., and Cooper, P. (2000). Evaluation of photo radar in British Columbia. Accident Analysis and Prevention, Vol. 32, pp. 517-26.

Corben, B., Logan, D., and Johnston, I. (2007). Development of a new road safety strategy for Western Australia. Draft report to Department of Premier and Cabinet, Office of Road Safety, Western Australia, August 2007.

Department for Transport (2007). Transport Statistics Bulletin – Road Statistics 2006: Traffic, Speeds and Congestion. DfT, London.

Diamantopoulou, K., Cameron, M.H., and Shtifelman, M. (1998). Evaluation of Moving Mode Radar for Speed Enforcement in Victoria, 1995-1997 (Report 141). Melbourne: Monash University Accident Research Centre.

Diamantopoulou, K and Corben, B. (2001) The Impact of Speed Camera Technology on Speed Limit Compliance in Multi-Lane Tunnels. Report to LMT.

Diamantopoulou, K and Cameron, M. (2002). An evaluation of the effectiveness of overt and covert speed enforcement achieved through mobile radar operations. Report No. 187, Monash University Accident Research Centre.

D'Elia, A., Newstead, S., and Cameron, M. (2007). Overall impact during 2001-2004 of Victorian speed-related package. Report No. 267, Monash University Accident Research Centre.

Elvik, R. (1997) Effects of accidents of automatic speed enforcement in Norway, Transportation Research Record 1997: 1571:1-19

Elvik, R (2001). Cost-benefit analysis of Police enforcement. Working paper 1, ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement) Project, European Union.

Elvik, R., Christensen, P., and Amundsen, A. (2004). Speed and road accidents. An evaluation of the Power Model. Report 740/2004, Institute of Transport Economics, Oslo, Norway.

Fitzharris, M, Gelb, KR, Harrison, WA, Newstead SV, Diamantopoulou, K, Cameron, MH. (1999) Evaluation of the Effect of the Deployment of Hand-held Laser Speed-detection Devices in the Melbourne Metropolitan Area. Road Safety: Research, Policing & Education Conference: Handbook and proceedings (pp.709-720).

Gains, A, Humble, R, Heydecker, B, and Robertson, S (2003). A cost recovery system for speed and red-light cameras – two year pilot evaluation. Research paper, 11 February 2003, prepared for Department for Transport, Road Safety Division, U.K. PA Consulting Group and University College London.

Gains, A., Heydecker, B., Shrewsbury, J. and Robertson, S. (2004). The national safety camera programme: Three-year evaluation report. Report prepared for Department for Transport, Road Safety Division, U.K. PA Consulting Group and University College London.

Gains, A., Nordstrom, M., Heydecker, B. and Shrewsbury, J. (2005). The national safety camera programme: four year evaluation report. London: PA Consulting Group and University College London.

Gelb, K, Narayan, S, Diamantopoulou, K and Cameron, MH. (2000). An Economic Assessment of the Speed Camera Program. Report to the Transport Accident Commission.

Goldenbeld, C and van Schagen, I. (2005) The effects of speed enforcement with mobile radar on speed and accidents: an evaluation study on rural roads in the Dutch province Friesland. Accident Analysis and Prevention, Vol. 27, pp. 1135-1144.

Gunarta, S. and Kerr, G. (2005). Speed impact of mobile speed cameras in Christchurch. Road and Transport Research, Vol. 14, No. 2.

Harrison, WA, Fitzharris, M, Newstead SV, Gelb, KR, Diamantopoulou, K, Cameron, MH. (1999) Evaluation of the Effect of the Deployment of Hand-held Laser Speed-detection Devices in the Melbourne Metropolitan Area. Report to Transport Accident Commission, Victoria.

Heydecker, B. (2008). Personal communication via email with M. H. Cameron. Professor of Transport Studies, University College London, England.

Hooke, A., Knox, J. and Portas, D. (1996). Cost benefit analysis of traffic light and speed cameras. Police Research Series, Paper 20. Home Office, London.

ICF Consulting (2003). Costs-benefit analysis of road safety improvements: Final report. ICF Consulting, London.

Keall, M.D., Povey, L.J. and Frith, W.J. (2001). The relative effectiveness of a hidden versus a visible speed camera programme. Accident Analysis and Prevention 33, 277-284.

Keall, M.D., Povey, L.J. and Frith, W.J. (2002). Further results from a trial comparing a hidden speed camera programme with visible camera operation. Accident Analysis and Prevention, Vol. 34, 773-777.

Keenan, D. (2002) Speed cameras - the true effect on behaviour. Traffic Engineering & Control, 43, 154-160.

Kloeden, C.N., McLean, A.J., Moore, V.M. and Ponte, G. (1997) Travelling speed and the risk of crash involvement (CR172). Canberra: Federal Office of Road Safety.

Mara, M.K. Davies, R.B. and Frith, W.J. (1996). Evaluation of the effect of compulsory breath testing and speed cameras in New Zealand. Proceedings Combined 18th ARRB Transport Research Conference and Transit NZ Land Transport Symposium, Christchurch, New Zealand.

National Highway Traffic Safety Administration. Traffic safety facts, 2003: speeding. Report no. DOT HS-809-771, 2004. Washington, DC. Available: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2003/809771.pdf. Accessed: 23 December 2004.

Newstead, S. (2004). Evaluation of the crash effects of the Queensland speed camera program in the years 2001-2003. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2005). Evaluation of the crash effects of the Queensland speed camera program in the years 2003-2004. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2006). Evaluation of the crash effects of the Queensland speed camera program in the year 2005. Consultancy Report prepared for Queensland Transport.

Newstead, S., Bobevski, I., Hosking, S. and Cameron, M. H. (2004). Evaluation of the Queensland road safety initiatives package. Report No. 272, Monash University Accident Research Centre.

Newstead, SV, Cameron MH and Leggett, M. (1999). Evaluation of the Queensland Random Road Watch Program. Report No. 149, Monash University Accident Research Centre.

Newstead, S. and Cameron, M. (2003). Evaluation of the crash effects of the Queensland Speed Camera Program, Report No. 204, Monash University Accident Research Centre.

Newstead, SV, Mullan, N and Cameron, MH. (1995). Evaluation of the Speed Camera Program in Victoria 1990-1993. Phase 5: Further investigation of localised effects on casualty crash frequency. Report No. 78, Monash University Accident Research Centre.

Nilsson, G. (1981). The effects of speed limits on traffic accidents in Sweden. Proceedings, International Symposium, Dublin. OECD.

Nilsson, G. (1984). Speeds, accident rates and personal injury consequences for different road types. Rapport 277, Swedish National Road and transport Research Institute (VTI).

Nilsson, G. (2004). Traffic safety dimensions and the Power Model to describe the effect of speed on safety. Bulletin 221, Lund Institute of Technology, Department of Technology and Society, Traffic Engineering, Lund, Sweden.

National Road Transport Commission (1996) Mass Limits Review Appendices to Technical Supplement No. 2: Road and bridge statistical data tables.

PA Consulting (2001). Cost Recovery System for traffic safety cameras – First year report: Executive Summary. Report prepared for DTLR Road Safety Division, U.K.

Palamara, P. and Bosch, B. (2005). Western Australia Speed Review: Data sources and countermeasures. Injury Research Centre, University of Western Australia.

Pilkington, P and Kinra, S (2005). Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. BMJ 2005;330:331-334.

Radalj, T. (2006). Driver speed behaviours on Western Australia road network 2000, 2003, 2004 and 2005. Main Roads Western Australia.

Road and Traffic Authority (2006) Fixed Speed Cameras. Available: (http://www.rta.nsw.gov.au/roadsafety/speedandspeedcameras/fixeddigitalspeedcameras/index.html Accessed: 11 May 2006.

Rogerson, P, Newstead, SV and Cameron, MH. (1994). Evaluation of the speed program in Victoria 1990-91. Phase 3: Localised effects on casualty crashes and crash severity. Phase 4: General effects on speeds. Report No. 54, Monash University Accident Research Centre.

Ross, H.L. (1981). Deterrence of the drinking driver: an international survey. U.S. Department of Transportation, Report No DOT-HS-805-820.

Ross, H.L. (1990). Reducing drink driving by individuals through enforcement. In: Enforcement and rewarding: strategies and effects. Proceedings of the International Road Safety Symposium in Copenhage, Denmark. pp.25-28.

RWS (2003). Evaluatie 80 km/uur-maatregel A13 Overschie: doorstroming en verkeersveiligheid. Rijkswaterstaat Directie Zuid-Holland, Rotterdam, The Netherlands.

Smith, R.R. (2000). Speed, Traffic Cameras and Justice: Lessons Learned in Victoria, Australia. Proceedings of Conference, *Road Safety on Three Continents,* Pretoria, South Africa. Swedish National Road and Transport Research Institute, Sweden.

Smith, R.R., Cameron, M.H., and Bodinnar, J.G. (2002). The use of speed cameras in Ireland: Executive Summary. National Roads Authority, Republic of Ireland.

Stefan, C. (2006). Section control – Automatic speed enforcement in the Kaisermühlen Tunnel (Vienna, A22 Motorway). Austrian Road Safety Board, Vienna, Austria.

Tingvall, C. (2008). Personal communication via emails with M. H. Cameron. Director of Traffic Safety, National Road Administration, Sweden.

Zaal, D. (1994). Traffic Law Enforcement: a review of the literature. Report No. 53. Monash University Accident Research Centre.

Speed enforcement – Effects, mechanisms, intensity and economic benefits of each mode of operation

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Abstract
Significant programs of speed enforcement have been in operation in a number of State and international jurisdictions for some time and many have been the subject of rigorous evaluation. Such programs aim to reduce crash frequency and/or injury severity through reductions in mean speed and/or changes to the speed distribution. In broad terms, the speed enforcement programs evaluated have been demonstrated to be beneficial in reducing road trauma. However, it is only in examining the individual characteristics of such programs that the mechanisms of effect become evident and information useful for the development of new speed enforcement programs can be obtained. This paper describes the speed enforcement program evaluations and the information concerning the relationship between enforcement intensity and program outcomes that they contain. Such analysis was conducted for all major speed enforcement modes, including mobile and fixed speed cameras operated overtly or covertly (including point-to-point average speed cameras), moving mode radar and hand-held laser speed detectors. An economic analysis of program outcomes was also conducted for each of these modes. This analysis was used to inform the development of a new speed enforcement strategy for Western Australia (WA) that can be expected to reduce road fatalities by 25 percent in a cost efficient way.

Keywords: traffic enforcement, speeding, effectiveness, economic analysis

Introduction

The research described in this paper was carried out to develop a speed enforcement strategy for WA reflecting best practice nationally and internationally, with the mix of enforcement options, number and intensity tailored to the WA road environment and their strategic targets. However the range of options considered and the analysis methods have universal applicability and can be used to define speed enforcement strategies in other jurisdictions. The paper is structured as follows. First, an explanation of characteristics likely to influence the outcome of an enforcement program is provided. A description of the WA road environment and the speed enforcement options available for use in that State follows. The relationships between enforcement intensity and expected program outcome for each of these enforcement options are then derived from existing evaluations and an economic assessment of these options conducted. Finally, a package of speed enforcement options is recommended for use in WA on the basis of the economic analysis.

Program characteristics

There are a number of variables that likely influence the outcome of speed enforcement operations. In particular, an enforcement program may operate overtly or covertly, use fixed or mobile technology and may be directed at treating black-spot locations or addressing problem behaviour across the entire road network. A brief explanation of the principles surrounding these modes of operations follows. In addition, the key mechanisms through which enforcement operations are thought to operate are identified.

- Enforcement programs are generally classified as either overt or covert in nature. It is the intention of overt operations to be highly visible to road users and in doing so increase the perceived risk of detection, thus altering the behaviour of road users immediately in time and space. Conversely, covert operations are not intended to be seen by road users and road users should be unaware of the location and timing of such enforcement operations. Effective covert operations will create a perception that detection may occur at any location and at any time (Keall, Povey & Frith, 2002).
- In general, speed enforcement technology can be either fixed or mobile. Fixed devices are located permanently at one site. In contrast mobile technologies are portable and tend to operate at one site for only a short period of time.
- In some circumstances, the location of safety cameras, whether fixed or mobile, may be chosen to affect a known problem of high crash risk or the risk of particularly severe crashes in a defined area. Such treatments are referred to as black spot treatments. Where the increased risk relates to a particular route or area, the treatment can be spread across this black route or area. In general, black spot or black route programs are intended to have the greatest effect at the black spot site or along the black route and are rarely aimed at treating speed across the road network.

The choice between overt or covert, mobile or fixed, and black spot or network wide operations may be dependent on a number of factors and this is reflected in the variety of enforcement programs operating in different jurisdictions. Some common factors that likely influence the nature and extent of speed enforcement operations are the level of resources available (e.g. equipment, staff, back office processing facilities), the road type to be enforced, the prevalence of speeding behaviour prior to enforcement, and public attitudes towards the use of automated or semi-automated enforcement technologies. These factors, insofar as they impact upon the mode of enforcement, will also determine the mechanisms through which the enforcement achieves its effect.

The two primary mechanisms through which speed enforcement may effect positive behaviour change are general deterrence and specific deterrence. The key reasoning behind these processes relies on utility theory as described by Ross (1981). In general, this assumes that road users will decide whether on not to commit a traffic offence based on a rational analysis of the benefits and risks associated with committing the offence. It is noted, that it is the *perceived* risks and benefits of committing the offence that determines the utility of the action. The perceptions of the certainty, swiftness and severity of punishment (in that order of importance) are generally accepted as the key elements of deterrence theory applied to traffic law enforcement and adjudication (Nichols & Ross, 1990).

General deterrence is a process of influencing a potential traffic law offender, through his fear of detection and the consequences, to avoid offending (Cameron & Sanderson, 1982). Therefore, operations employing general deterrence mechanisms necessarily target all road users irrespective of whether they have previously offended. It follows that general deterrence programs have the potential to influence the behaviour of all road users. Homel (1988) has established this as the key mechanism in the deterrence of drink-driving using random breath testing. In contrast, *specific deterrence* is a process of encouraging an apprehended offender, through his actual experience of detection and the consequences, to avoid re-offending (Cameron & Sanderson, 1982). Therefore, the potential impact of a specific deterrence program may be more limited than that of a program relying on the general deterrence mechanism. Enforcement programs relying solely on the mechanism of specific deterrence have the potential to immediately influence only those offenders who have previously been detected and punished for committing offences. (Other, potential offenders may be influenced by word-of-mouth communication with apprehended offenders.) It follows that the magnitude of the penalty, especially that applying if subsequent offences are committed, is of greater importance to specific deterrence programs than those relying on the general deterrence mechanism.

Speed enforcement options for Western Australia

The State of WA has a population of approximately two million people with around 1.45 million concentrated in the Perth area. The State measures approximately 2.5 million square kilometers constituting around one third of the area of Australia. Table 1 below details the nature and extent of the road environments that are likely targets for speed enforcement in WA. It should be noted that despite the extensive rural road network, around 63 percent of all travel in WA is undertaken on urban roads. While the available traffic data was for the year 1991, only the relative proportions on each road type were relevant to the following analysis.

Table 1. Road environments targeted for speed enforcement in Western Australia

Urban road type	Road length (km)	Estimated traffic (million vehicle km) 1991	Rural road type	Road length (km)	Estimated traffic (million vehicle km) 1991
Arterial roads	1,815	7,910	*Highways*	20,194	4,170
Local roads	8,200	8,200	*Undivided highways and local roads*	123,800 (estimate)	5,200
Freeways	62	230			

Currently, the principal method for the detection of speed offender in WA is the Multanova 6f speed camera system. This mode of enforcement detected over 616,000 offenders in 2004 compared with about 303,000 offenders detected by non-photographic methods (mobile radar units, which can also be operated in stationary mode, and hand-held laser speed detectors). The Multanova cameras are operated using a tripod-mounted system at the roadside with no attempt to hide the system. Further, signage advising drivers that they have passed a camera in operation is used. Public announcement of the date and route of camera operations is made through television and press news segments. Sites are selected on the basis of criteria relating primarily to the existence of a speed related problem, such as a crash history, speed related complaints from the public, and relatively high pedestrian activity or speeding levels. However, given the diversity of the road environment in WA there is the potential for, and perhaps the requirement that, a range of enforcement modes be used to maximize the road safety benefits achieved. Following is a description of the enforcement modes identified as having potential for use in WA.

Considering arterial roads, there are two potential enforcement modes each of which might be expected to generate network wide crash reductions when optimally implemented. First, as in Victoria, mobile speed cameras could operate covertly using a car-mounted system in unmarked cars using a variety of popular vehicle makes/models. These operations should be 'flashless' when ambient light or digital technology permits. No advance warning or departure signs should be used and public announcements of camera locations or presence should not be made. Second, as in Queensland, mobile speed cameras could operate overtly with signs advising of camera presence but with operations scheduled randomly in time and space to promote uncertainty among drivers as to the time and location of enforcement activities, in order to increase drivers' perceived risk of detection. That is, camera shifts would be randomly allocated to sites and time blocks (four hours each, excluding late night/early morning) with very limited opportunities for actual operations to depart from the random assignments. Public announcements of camera locations or camera presence would not be made. Further, operational sites should be selected so as to cover a high proportion (at least 80%) of crash locations with 2 km of camera sites. Each of the mobile camera enforcement modes described has the potential to reduce casualty crashes, however, the magnitude of effect is likely to vary by crash severity and across the enforcement modes. This will be the focus of later discussion.

Considering local streets in the urban environment, hand-held laser speed detectors provide another speed enforcement option. The two enforcement modes discussed above are unlikely to be suitable for use in lightly trafficked urban streets and are not considered further for this environment. The proportion of traffic exceeding the speed limit by at least 10 km/h on Perth's local access roads during 2005 was 18.3% on 50 km/h speed limit roads and 8.6% on the 60 km/h limit roads (Radalj, 2006). The relatively high extent of excessive speeding in this road environment compared with other urban areas provides support for a method of speed enforcement focused on these roads.

Speed enforcement options for rural highways and rural local roads include the use of moving mode (mobile) radar units. The use of this technology is generally constrained to lightly trafficked undivided roads because of the need to intercept an offending driver, commonly involving a U-turn by the patrol car. Given the evidence concerning the effectiveness of this technology, operations should be conducted using vehicles operating covertly (unmarked car) or from a mixture of marked and unmarked cars on highways in the same region (Diamantopoulou & Cameron, 2002). During 2005 on local rural roads, the proportion of traffic exceeding speed limits by at least 10 km/h was 8.2%. This was substantially higher than the proportion on rural roads generally (6.7%). This supports the need for a method of speed enforcement in rural WA which is most suitable for the vast extent of the lightly trafficked local road system on which speed cameras may not be able to operate cost-effectively.

Finally, considering urban freeways and highly trafficked rural highways, there is the potential for use of individual fixed speed cameras or point-to-point speed camera systems. Fixed speed cameras have not been shown clearly to have anything other than a local effect on crashes, nevertheless the measured effects are very substantial, especially the effects on fatal and serious injury crashes (Gains, Nordstrom, Heydecker & Shrewsbury, 2005). For this reason they are most suitable for use on highly-trafficked high-speed roads such as urban freeways, where other forms of speed enforcement such as mobile camera units at the roadside present a danger to the operators and the traffic itself. However, if the intention is to reduce speeds along a substantial "black" route using overt fixed cameras, there may be a case for installing point-to-point camera systems to enforce speeds along the whole route. This technology uses a number of fixed cameras mounted at staged intervals along a particular route. The cameras are able to measure the average speed between two points or the spot speed at individual camera sites. The distance between two camera sites may vary from as low as 300 meters to up to tens of kilometres.

Relationships between enforcement intensity and crash outcome

On the basis of a review of a large number of studies, Elvik (2001) derived a general relationship between enforcement intensity and casualty crash reductions (Figure 1). It was concluded that, even for the most effective forms of enforcement, the relationship with crash reductions is not linear. Rather, diminishing returns apply as the level of enforcement increases. However, within the range of increases observed in the studies (up to 10-12 fold), it appears that at least some crash reductions occur for each increase in enforcement effort. Effects beyond that level are uncertain. While most of the studies from which this relationship was derived relate to stationary (intercept) speed enforcement, Elvik quotes evidence supporting its applicability to speed cameras as well.

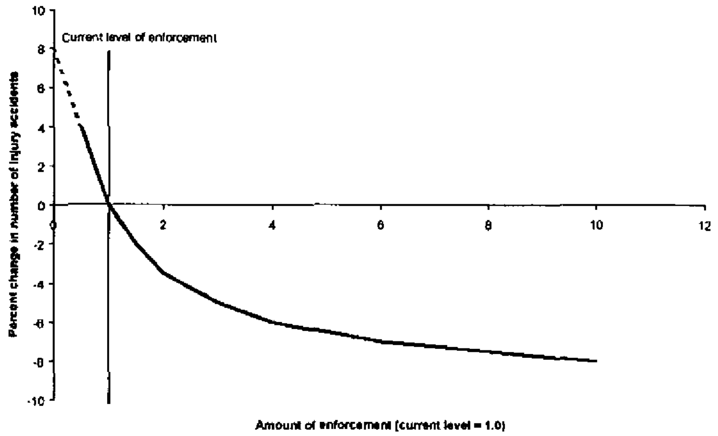

Figure 1: General relationship between traffic enforcement and crashes identified by Elvik (2001)

For the purposes of this study similar relationships have been derived for each of the key enforcement modes considered. This enables the additional benefits associated with each increase in speed enforcement intensity to be estimated and used as inputs into an economic analysis. Following is a description of the relationships derived.

Covert mobile speed cameras

Evaluations of the covert mobile speed camera program operating in Victoria provide the data from which the relationship between enforcement levels using this technology and crash outcomes is derived (Cameron, Newstead, Diamantopoulou &Oxley, 2003a,b). During 1999, Victoria Police varied the levels of speed camera activity substantially in four Melbourne Police districts according to a systematic plan. Analysis of the associated changes in casualty crash frequency revealed that crash frequency was inversely associated with changes in the levels of speeding TINs (Traffic Infringement Notices) issued following detection in the same district during the previous month. A similar relationship was found for the risk of fatal outcome in a casualty crash. The relationships are displayed in the following two figures together with 95% confidence limits on the estimates.

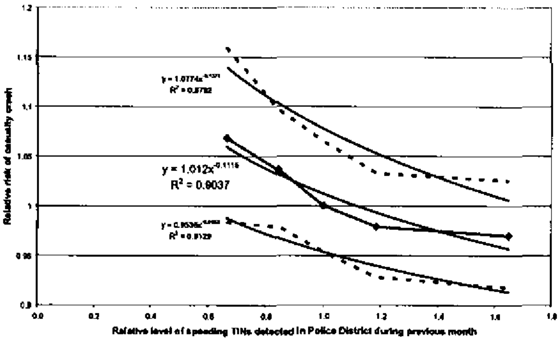

Figure 3: Relative relationship between casualty crash risk and level of speeding TINs detected by covert mobile speed cameras

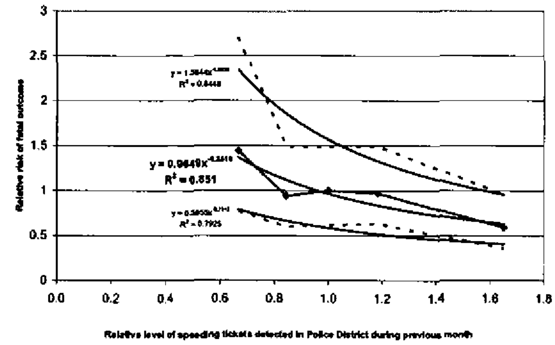

Figure 4: Relative relationship between the risk of fatal outcome in casualty crashes and the level of speeding TINs

Figure 3 shows the relative relationship between casualty crash risk and the level of speeding TINs issued in the prior month, relative to the average level of TINs issued, which was about 3,000 TINs per month from speeding offences detected in each Police District during 1999. It was found that the power function was the best of Elvik's proposed functional forms to represent this relationship. When this functional form was fitted to the relationship, the key parameter B ("elasticity") was estimated to be -0.1115. Figure 4 shows the relationship between the risk of fatal outcome of a casualty crashes and the level of speeding TINs issued, again expressed in relative terms. The power function also best represented this relationship, resulting in an estimate of B of -0.8516 in this case.

Overt mobile speed cameras with randomised scheduling

Studies have been conducted on the crash reduction effects of the Queensland program as it has grown from 852 hours per month in 1997 to about 6,000 hours per month during 2003-2006 (Newstead and Cameron, 2003; Newstead, 2004, 2005, 2006). The crash reductions have generally been limited to an area within two kilometres of the camera sites. The strongest effects have been on casualty crashes, with no differential effect on crashes of different severity (fatal, hospital admission, or medical treatment crashes). As the program grew, the two kilometre areas around camera sites covered a greater proportion of the total casualty crashes in Queensland, rising from about 50% to 83% over the evaluation period. Thus the localised crash reductions around camera sites can be interpreted as a general effect on crashes, assuming that the program had no effect beyond the two kilometre areas (a conservative assumption). The relationship between the increased monthly hours and the general casualty crash reductions can be seen in Figure 5.

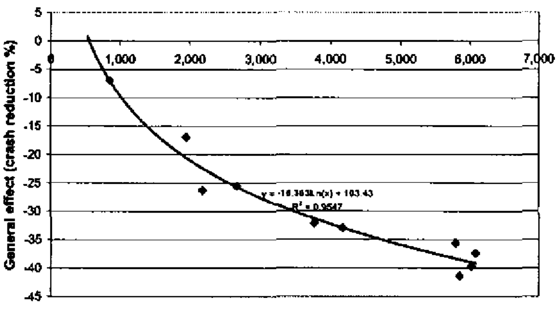

Figure 5: Relationship between casualty crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

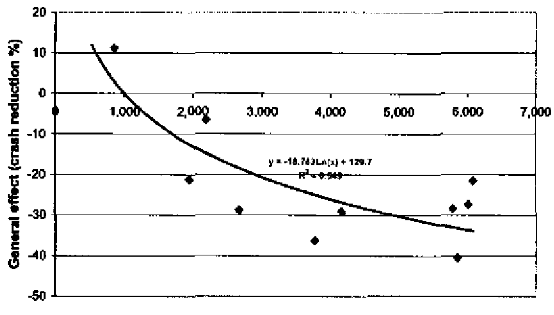

Figure 6: Relationship between fatal crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

It could be expected that an effective anti-speeding countermeasure such as this would have greater effect on fatal crashes than non-fatal crashes. Figure 6 shows the estimated reductions in fatal crashes associated with the level of monthly hours operated each year. It should be noted that the individual annual estimated reductions are not as reliable as the reductions in all casualty crashes shown in Figure 5 and that no individual reduction is statistically significant. Nevertheless, the estimates do suggest a relationship between fatal crash reductions and camera hours of the same type as that in Figure 5. However, there is no evidence that the magnitude of the reduction achieved by the Queensland program on fatal crashes is any greater than that achieved on casualty crashes in general (of which fatal crashes are a part).

Economic analysis of key enforcement options

Economic analysis was conducted of the benefits (savings in social costs of crashes) and costs (equipment, operating, and detected offence processing costs) of each of the speed enforcement options outlined above, if applied to the appropriate road environment in WA (Cameron and Delaney, 2006; Cameron, 2008). The options analysed were:

- Covert mobile speed cameras on urban highways (arterial roads)
- Randomly-scheduled overt mobile speed cameras on urban and rural highways
- Covert mobile speed cameras on publicly announced routes
- Moving mode (mobile) radar units on rural highways (undivided) and rural local roads
- Hand-held laser speed detectors operated overtly on urban local roads
- Fixed speed cameras on Perth freeways
- Point-to-point speed camera systems on Perth freeways and urban and rural highways with limited opportunities or incentives to leave or enter the enforced sections

The economic analysis of different levels of operation of covert mobile speed cameras is shown in Table 2. The base level of 3000 hours per month reflects that achieved by the existing Multanova speed cameras during 2004. The crash reduction effects of increased hours, using covert mobile cameras, are relative to the effect of the Multanova camera program (which was of unknown magnitude, given the absence of any crash-based evaluation to date). Reductions in casualty crashes were estimated from the fitted relationship in Figure 3. Reductions in fatal crashes were estimated by applying the reduction in risk of fatal outcome, estimated from the fitted relationship in Figure 4, to the estimated casualty crashes.

Table 2: Economic analysis of increase in covert mobile speed camera operations on Perth's arterial roads

Speed camera hours per month	Speeding tickets issued per month (short-term)	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fatal crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)
3000	30,000	22.7	0.0	0.0%	0.0%	3000	221.1
4000	40,000	14.3	4.4	3.2%	24.2%	4000	289.9
5000	50,000	10.0	5.9	5.5%	38.9%	5000	358.8
6000	60,000	7.6	6.3	7.4%	48.7%	6000	427.6
7000	70,000	6.0	6.4	9.0%	55.8%	7000	496.4
8000	80,000	4.9	6.3	10.4%	61.1%	8000	565.2
9000	90,000	4.1	6.1	11.5%	65.3%	9000	634.1
10000	100,000	3.5	5.9	12.6%	68.6%	10000	702.9

The economic analysis of different levels of operating hours of randomly-scheduled overt mobile speed cameras on Perth arterial roads is shown in Table 3. Reductions in casualty crashes were estimated from the fitted relationship in Figure 5 after recalibration of the hours needed to achieve the same crash reductions in WA compared with more heavily-trafficked Queensland. The detection rate of speeding offences per camera hour has fallen logarithmically as camera hours increased in Queensland, resulting in the estimated speeding tickets issued from overt mobile cameras growing substantially less than those from covert cameras. In both cases, the estimated number of tickets is short term until speeding transgression rates reduce in response to the more threatening speed enforcement.

Table 3: Economic analysis of increase in overt mobile speed cameras with randomised scheduling on Perth's arterial roads

Speed camera hours per month	Speeding tickets issued per month (short-term)	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)
3000	30,000	21.9	0.0	0.0%	3000	221.1
4000	33,020	16.6	4.5	7.1%	3302	289.0
5000	34,500	13.3	6.5	12.7%	3450	356.7
6000	34,760	11.1	7.4	17.2%	3476	424.2
7000	34,010	9.6	7.8	21.0%	3401	491.5
8000	32,390	8.4	8.0	24.3%	3238	558.8
9000	30,000	7.5	8.0	27.3%	3000	625.9
10000	26,940	6.8	7.9	29.9%	2694	693.0

Covert mobile speed cameras were preferred as the recommended option for speed enforcement on arterial roads in Perth because of clear evidence of the strong effects of these enforcement operations on fatal crashes, and evidence that an increase in hours committed to this type of speed camera enforcement would reduce road trauma generally. While there were apparently greater economic benefits from operating mobile speed cameras overtly (with randomised scheduling) compared with covert operations (Tables 2 and 3), this relative benefit was reversed when fatal crashes were valued more highly than the "human capital" unit costs (BTE, 2000) used to value the crash savings. For example, when the fatal crashes were valued using the "willingness to pay" method (BTCE, 1997), resulting in a unit value of $5.360 million per fatal crash prevented compared with the unit cost of $2.048 million based on the human capital method (both indexed to year 2005 using the CPI), the program BCR for 9,000 hours per month of covert mobile speed camera operations was 11.9 compared with 10.4 for the same intensity of overt mobile camera operations with randomised scheduling.

Recommended speed enforcement package

Following analysis of the type illustrated in Table 2 and 3 for each of the enforcement options at various levels of operation (number of devices and/or hours operated), a package was developed based on the economic value of each enforcement program and the overall contribution to reducing road trauma in WA while avoiding overlap of enforcement operations on each part of the road system (Cameron and Delaney, 2006). The aim was to identify a package which, when fully implemented, would produce at least 25% reduction in fatal crashes, somewhat smaller reductions in less-serious casualty crashes, and have maximum cost-benefits in terms of the return on social cost savings for the investment.

The recommended enforcement programs, together with the level of input and the expected speeding ticket processing requirements (at least short-term), are shown in Table 4. Table 5 shows the estimated crash savings per month, valued in terms of social costs (in 2005 prices), and then aggregated across the package components to provide the overall impacts for the full WA road system. The aggregated benefit-cost ratio for the total social cost savings from the package, relative to the total package cost per month, is also calculated in this way.

The level of input recommended for each of the programs with variable intensity (mobile cameras and moving-mode radar units) was generally chosen on the basis of maximum program BCR and the potential contribution to achieving the targeted reductions in road trauma. The other enforcement options were generally constrained by the size of the road environment and/or the locational density of the crashes the enforcement was aimed at. The recommendation to operate the 24 fixed speed cameras on Perth freeways overtly, and intermittently aiming to detect about 10,000 speeding tickets per month (short-term), was based on experience from Sweden. The Swedish fixed camera program covers 120 highway routes totalling 2,500 kilometres with spacing of about 2.9 kilometres between cameras. Any one camera may be operational only 3-4% of the time, but because there may be 7-15 cameras in a row, drivers are deterred from speeding along the full route (Cameron, 2008). If operated continuously, the 24 fixed cameras on Perth freeways were estimated to detect about 35,600 speeding tickets per month based on the traffic flows past them (Cameron and Delaney, 2006). The Swedish experience suggested that this level of ticketing could be unnecessary.

Table 4: Recommended speed enforcement programs

Speed Enforcement Program	**Speed Enforcement Hours per month**	**Speeding Tickets Issued per month (short-term)**	**Program BCR**	**Program Crash Reduction**		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9,000	90,000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.8	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Intermittent at 24 sites	10,000	9.3	7.76%	15.52%	15.52%
Total for urban roads		**103,413**	**8.1**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	10,000	37.4	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads		**21,250**	**11.8**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**124,663**	**10.1**	**9.0%**	**12.3%**	**26.0%**

Table 5: Economic benefits and costs of the recommended speed enforcement programs

Speed Enforcement Program	Crash savings per month			Social Cost Saving per month ($'000)	Program Cost per month ($'000)	Fine Revenue per month ($'000)
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3,974.6	634.1	9,000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1,551.5	51.9	341
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.3	47.3	1,000
Total for urban roads	**17.0**	**6.1**	**1.3**	**5,967.4**	**733.3**	**10,341**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5,673.9	151.8	1,000
Mobile radar units on rural local roads	6.2	4.9	0.62	3,864.0	653.5	1,125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9,537.9**	**805.3**	**2,125**
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15,505.3**	**1,538.5**	**12,466**

The economic analysis of point-to-point speed cameras was based on effects measured during the first two years of a major system in Strathclyde (A77 Safety Group, 2007) and even greater effects of a system installed in a long urban tunnel in Austria (Stefan, 2006). The analysis indicated that they would be cost-beneficial on Perth freeways and on links on the urban and rural highway system suitable for their application. The analysis for the top 40 road links ranked by BCR is shown in Table 6. Specific recommendations to replace the recommended enforcement programs (Tables 4 and 5) in whole or in part with point-to-point speed cameras, while potentially being more effective and having greater economic justification, were not made because of the need for further investigation of the nominated links, for example, examining the speed profile along the link (Cameron, 2008).

Table 6: Freeways and highway links economically warranted for Point-to-Point speed cameras

Region	Roads warranted for Point-to-Point camera systems	Total Length of Links (km)	Reduction in fatal and hospital admission crashes	Reduction in medical treatment crashes	Point-to-Point system capital cost ($)	Speeding Tickets issued per year (short term)	BCR
Perth metro-politan	Freeways	74	33.3%	12.6%	4,900,000	496,758	10.4
	Other links in top 40	248	33.3%	12.6%	4,450,000	218,210	16.5
Non-metro-politan	Links in top 40 ranked by BCR	2,990	33.3%	12.6%	11,800,000	133,591	15.8

Conclusions

A package of speed enforcement programs was defined for the WA road environment which recognised its relatively unique characteristics of vast size and light traffic density, except in Perth. The evidence of the effects on speeds and road trauma in other jurisdictions due to speed camera systems and manual speed enforcement methods was reviewed and synthesised to provide strategic understanding of their mechanisms. For some speed enforcement options, it was possible to calibrate the road trauma reductions against the operational levels.

From this research base, it was possible to define a suitable speed enforcement method for each part of the WA road system and calculate the road trauma reductions and economic benefits if operated at each level. The recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes per annum.

The package is estimated to provide a saving of at least $186 million in social costs per annum. The total cost to produce these savings is estimated to be $18.5 million per annum. Thus the benefit-cost ratio of the package is estimated to be at least 10 to 1. The inclusion of point-to-point speed cameras in the package, replacing the fixed cameras on Perth freeways and other recommended enforcement options on parts of urban and rural highways, where economically warranted, could make the package more cost-beneficial and effective.

Notwithstanding WA's uniqueness, the methods developed in this research have universal applicability and can be used to define speed enforcement strategies in other jurisdictions. The specific results, however, should not be directly translated to other jurisdictions because they relate to the mix of road types, traffic density, and crash rates in WA. In addition, the results are no more definitive than the evaluations of the different enforcement modes as applied in a broad range of interstate and international jurisdictions. Each of the effect estimates has a statistical range of error in which the true effect could lie. Time has not permitted consideration of the range of package outcomes which could result from these estimation errors. Furthermore, alternative relationships relating crash outcomes to the intensity of the mobile speed enforcement modes have not been considered. Finally, the results are dependent on the method of valuation of the road trauma savings, especially fatal crash savings, which are estimated to result from escalated speed enforcement. While the estimated economic benefits of the speed enforcement package were calculated based on the "human capital" method for valuing road trauma, the selection of covert mobile speed cameras to be operated on arterial roads in Perth was in fact based on a "willingness to pay" valuation of the fatal crashes predicted to be saved by this method of speed enforcement. All of these issues need to be given careful consideration before application of the methods in this paper elsewhere.

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References

A77 Safety Group (2007). Casualties halved on A77 – SPECS: End of 2nd year casualty statistics. News Release, 26 October 2007. Strathclyde, Scotland.

BTCE – Bureau of Transport and Communications Economics (1997). The costs of road accidents in Victoria – 1988. Unpublished monograph, BTCE, Canberra.

BTE – Bureau of Transport Economics (2000). Road crash costs in Australia. Report 102, BTE, Canberra.

Cameron, M.H. (2008). Development of strategies for best practice in speed enforcement in Western Australia: Supplementary Report. Report to Department of the Premier and Cabinet, Office of Road Safety, Western Australia, May 2008. Report No. 277, Monash University Accident Research Centre.

Cameron, M.H. and Delaney, A. (2006). Development of strategies for best practice in speed enforcement in Western Australia: Final Report. Report to Department of the Premier and Cabinet, Office of Road Safety, Western Australia, September 2006. Report No. 270, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003a). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria. Report No. 201, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003b). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria, Australia. *Proceedings, 47th Annual Scientific Conference, Association for the Advancement of Automotive Medicine*, Lisbon, Portugal, September 2003.

Cameron, M.H. and Sanderson J.T. (1982). Review of Police operations for traffic law enforcement. Report No. TS 82/5, RACV Traffic and Safety Department, October 1982.

Diamantopoulou, K. and Cameron, M. (2002). An evaluation of the effectiveness of overt and covert speed enforcement achieved through mobile radar operations. Report No. 187, Monash University Accident Research Centre.

Elvik, R (2001). Cost-benefit analysis of Police enforcement. Working paper 1, ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement) Project, European Union.

Gains, A., Nordstrom, M., Heydecker, B. and Shrewsbury, J. (2005). The national safety camera programme: four year evaluation report. London: PA Consulting Group and University College London.

Homel, R. (1988). Policing and punishing the drinking driver: A study of general and specific deterrence. (Research in Criminology). New York, Springer-Verlag.

Keall, M.D., Povey, L.J. and Frith, W.J. (2002). Further results from a trial comparing a hidden speed camera programme with visible camera operation. *Accident Analysis and Prevention*, Vol. 34, 773-777.

Newstead, S. (2004). Evaluation of the crash effects of the Queensland speed camera program in the years 2001-2003. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2005). Evaluation of the crash effects of the Queensland speed camera program in the years 2003-2004. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2006). Evaluation of the crash effects of the Queensland speed camera program in the year 2005. Consultancy Report prepared for Queensland Transport.

Newstead, S. and Cameron, M. (2003). Evaluation of the crash effects of the Queensland Speed Camera Program, Report No. 204, Monash University Accident Research Centre.

Nichols J.L. and Ross H.L. (1990). The Effectiveness of Legal Sanctions in Dealing with Drinking Drivers. *Alcohol, Drugs and Driving,* Vol. 6, No. 2, 33-60.

Radalj, T. (2006). Driver speed behaviours on Western Australia road network 2000, 2003, 2004 and 2005. Main Roads Western Australia.

Ross, H.L. (1981). Deterrence of the drinking driver: an international survey. U.S. Department of Transportation, Report No DOT-HS-805-820.

Stefan, C. (2006). Section control – Automatic speed enforcement in the Kaisermühlen Tunnel (Vienna, A22 Motorway). Austrian Road Safety Board, Vienna, Austria.

Speed enforcement – Effects, mechanisms, intensity and economic benefits of each mode of operation

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Abstract
Significant programs of speed enforcement have been in operation in a number of State and international jurisdictions for some time and many have been the subject of rigorous evaluation. Such programs aim to reduce crash frequency and/or injury severity through reductions in mean speed and/or changes to the speed distribution. In broad terms, the speed enforcement programs evaluated have been demonstrated to be beneficial in reducing road trauma. However, it is only in examining the individual characteristics of such programs that the mechanisms of effect become evident and information useful for the development of new speed enforcement programs can be obtained. This paper describes the speed enforcement program evaluations and the information concerning the relationship between enforcement intensity and program outcomes that they contain. Such analysis was conducted for all major speed enforcement modes, including mobile and fixed speed cameras operated overtly or covertly (including point-to-point average speed cameras), moving mode radar and hand-held laser speed detectors. An economic analysis of program outcomes was also conducted for each of these modes. This analysis was used to inform the development of a new speed enforcement strategy for Western Australia (WA) that can be expected to reduce road fatalities by 25 percent in a cost efficient way.

Keywords: traffic enforcement, speeding, effectiveness, economic analysis

Introduction

The research described in this paper was carried out to develop a speed enforcement strategy for WA reflecting best practice nationally and internationally, with the mix of enforcement options, number and intensity tailored to the WA road environment and their strategic targets. However the range of options considered and the analysis methods have universal applicability and can be used to define speed enforcement strategies in other jurisdictions. The paper is structured as follows. First, an explanation of characteristics likely to influence the outcome of an enforcement program is provided. A description of the WA road environment and the speed enforcement options available for use in that State follows. The relationships between enforcement intensity and expected program outcome for each of these enforcement options are then derived from existing evaluations and an economic assessment of these options conducted. Finally, a package of speed enforcement options is recommended for use in WA on the basis of the economic analysis.

Program characteristics

There are a number of variables that likely influence the outcome of speed enforcement operations. In particular, an enforcement program may operate overtly or covertly, use fixed or mobile technology and may be directed at treating black-spot locations or addressing problem behaviour across the entire road network. A brief explanation of the principles surrounding these modes of operations follows. In addition, the key mechanisms through which enforcement operations are thought to operate are identified.

- Enforcement programs are generally classified as either overt or covert in nature. It is the intention of overt operations to be highly visible to road users and in doing so increase the perceived risk of detection, thus altering the behaviour of road users immediately in time and space. Conversely, covert operations are not intended to be seen by road users and road users should be unaware of the location and timing of such enforcement operations. Effective covert operations will create a perception that detection may occur at any location and at any time (Keall, Povey & Frith, 2002).
- In general, speed enforcement technology can be either fixed or mobile. Fixed devices are located permanently at one site. In contrast mobile technologies are portable and tend to operate at one site for only a short period of time.
- In some circumstances, the location of safety cameras, whether fixed or mobile, may be chosen to affect a known problem of high crash risk or the risk of particularly severe crashes in a defined area. Such treatments are referred to as black spot treatments. Where the increased risk relates to a particular route or area, the treatment can be spread across this black route or area. In general, black spot or black route programs are intended to have the greatest effect at the black spot site or along the black route and are rarely aimed at treating speed across the road network.

The choice between overt or covert, mobile or fixed, and black spot or network wide operations may be dependent on a number of factors and this is reflected in the variety of enforcement programs operating in different jurisdictions. Some common factors that likely influence the nature and extent of speed enforcement operations are the level of resources available (e.g. equipment, staff, back office processing facilities), the road type to be enforced, the prevalence of speeding behaviour prior to enforcement, and public attitudes towards the use of automated or semi-automated enforcement technologies. These factors, insofar as they impact upon the mode of enforcement, will also determine the mechanisms through which the enforcement achieves its effect.

The two primary mechanisms through which speed enforcement may effect positive behaviour change are general deterrence and specific deterrence. The key reasoning behind these processes relies on utility theory as described by Ross (1981). In general, this assumes that road users will decide whether on not to commit a traffic offence based on a rational analysis of the benefits and risks associated with committing the offence. It is noted, that it is the *perceived* risks and benefits of committing the offence that determines the utility of the action. The perceptions of the certainty, swiftness and severity of punishment (in that order of importance) are generally accepted as the key elements of deterrence theory applied to traffic law enforcement and adjudication (Nichols & Ross, 1990).

General deterrence is a process of influencing a potential traffic law offender, through his fear of detection and the consequences, to avoid offending (Cameron & Sanderson, 1982). Therefore, operations employing general deterrence mechanisms necessarily target all road users irrespective of whether they have previously offended. It follows that general deterrence programs have the potential to influence the behaviour of all road users. Homel (1988) has established this as the key mechanism in the deterrence of drink-driving using random breath testing. In contrast, s*pecific deterrence* is a process of encouraging an apprehended offender, through his actual experience of detection and the consequences, to avoid re-offending (Cameron & Sanderson, 1982). Therefore, the potential impact of a specific deterrence program may be more limited than that of a program relying on the general deterrence mechanism. Enforcement programs relying solely on the mechanism of specific deterrence have the potential to immediately influence only those offenders who have previously been detected and punished for committing offences. (Other, potential offenders may be influenced by word-of-mouth communication with apprehended offenders.) It follows that the magnitude of the penalty, especially that applying if subsequent offences are committed, is of greater importance to specific deterrence programs than those relying on the general deterrence mechanism.

Speed enforcement options for Western Australia

The State of WA has a population of approximately two million people with around 1.45 million concentrated in the Perth area. The State measures approximately 2.5 million square kilometers constituting around one third of the area of Australia. Table 1 below details the nature and extent of the road environments that are likely targets for speed enforcement in WA. It should be noted that despite the extensive rural road network, around 63 percent of all travel in WA is undertaken on urban roads. While the available traffic data was for the year 1991, only the relative proportions on each road type were relevant to the following analysis.

Table 1. Road environments targeted for speed enforcement in Western Australia

Urban road type	Road length (km)	Estimated traffic (million vehicle km) 1991	Rural road type	Road length (km)	Estimated traffic (million vehicle km) 1991
Arterial roads	1,815	7,910	*Highways*	20,194	4,170
Local roads	8,200	8,200	*Undivided highways and local roads*	123,800 (estimate)	5,200
Freeways	62	230			

Currently, the principal method for the detection of speed offender in WA is the Multanova 6f speed camera system. This mode of enforcement detected over 616,000 offenders in 2004 compared with about 303,000 offenders detected by non-photographic methods (mobile radar units, which can also be operated in stationary mode, and hand-held laser speed detectors). The Multanova cameras are operated using a tripod-mounted system at the roadside with no attempt to hide the system. Further, signage advising drivers that they have passed a camera in operation is used. Public announcement of the date and route of camera operations is made through television and press news segments. Sites are selected on the basis of criteria relating primarily to the existence of a speed related problem, such as a crash history, speed related complaints from the public, and relatively high pedestrian activity or speeding levels. However, given the diversity of the road environment in WA there is the potential for, and perhaps the requirement that, a range of enforcement modes be used to maximize the road safety benefits achieved. Following is a description of the enforcement modes identified as having potential for use in WA.

Considering arterial roads, there are two potential enforcement modes each of which might be expected to generate network wide crash reductions when optimally implemented. First, as in Victoria, mobile speed cameras could operate covertly using a car-mounted system in unmarked cars using a variety of popular vehicle makes/models. These operations should be 'flashless' when ambient light or digital technology permits. No advance warning or departure signs should be used and public announcements of camera locations or presence should not be made. Second, as in Queensland, mobile speed cameras could operate overtly with signs advising of camera presence but with operations scheduled randomly in time and space to promote uncertainty among drivers as to the time and location of enforcement activities, in order to increase drivers' perceived risk of detection. That is, camera shifts would be randomly allocated to sites and time blocks (four hours each, excluding late night/early morning) with very limited opportunities for actual operations to depart from the random assignments. Public announcements of camera locations or camera presence would not be made. Further, operational sites should be selected so as to cover a high proportion (at least 80%) of crash locations with 2 km of camera sites. Each of the mobile camera enforcement modes described has the potential to reduce casualty crashes, however, the magnitude of effect is likely to vary by crash severity and across the enforcement modes. This will be the focus of later discussion.

Considering local streets in the urban environment, hand-held laser speed detectors provide another speed enforcement option. The two enforcement modes discussed above are unlikely to be suitable for use in lightly trafficked urban streets and are not considered further for this environment. The proportion of traffic exceeding the speed limit by at least 10 km/h on Perth's local access roads during 2005 was 18.3% on 50 km/h speed limit roads and 8.6% on the 60 km/h limit roads (Radalj, 2006). The relatively high extent of excessive speeding in this road environment compared with other urban areas provides support for a method of speed enforcement focused on these roads.

Speed enforcement options for rural highways and rural local roads include the use of moving mode (mobile) radar units. The use of this technology is generally constrained to lightly trafficked undivided roads because of the need to intercept an offending driver, commonly involving a U-turn by the patrol car. Given the evidence concerning the effectiveness of this technology, operations should be conducted using vehicles operating covertly (unmarked car) or from a mixture of marked and unmarked cars on highways in the same region (Diamantopoulou & Cameron, 2002). During 2005 on local rural roads, the proportion of traffic exceeding speed limits by at least 10 km/h was 8.2%. This was substantially higher than the proportion on rural roads generally (6.7%). This supports the need for a method of speed enforcement in rural WA which is most suitable for the vast extent of the lightly trafficked local road system on which speed cameras may not be able to operate cost-effectively.

Finally, considering urban freeways and highly trafficked rural highways, there is the potential for use of individual fixed speed cameras or point-to-point speed camera systems. Fixed speed cameras have not been shown clearly to have anything other than a local effect on crashes, nevertheless the measured effects are very substantial, especially the effects on fatal and serious injury crashes (Gains, Nordstrom, Heydecker & Shrewsbury, 2005). For this reason they are most suitable for use on highly-trafficked high-speed roads such as urban freeways, where other forms of speed enforcement such as mobile camera units at the roadside present a danger to the operators and the traffic itself. However, if the intention is to reduce speeds along a substantial "black" route using overt fixed cameras, there may be a case for installing point-to-point camera systems to enforce speeds along the whole route. This technology uses a number of fixed cameras mounted at staged intervals along a particular route. The cameras are able to measure the average speed between two points or the spot speed at individual camera sites. The distance between two camera sites may vary from as low as 300 meters to up to tens of kilometres.

Relationships between enforcement intensity and crash outcome

On the basis of a review of a large number of studies, Elvik (2001) derived a general relationship between enforcement intensity and casualty crash reductions (Figure 1). It was concluded that, even for the most effective forms of enforcement, the relationship with crash reductions is not linear. Rather, diminishing returns apply as the level of enforcement increases. However, within the range of increases observed in the studies (up to 10-12 fold), it appears that at least some crash reductions occur for each increase in enforcement effort. Effects beyond that level are uncertain. While most of the studies from which this relationship was derived relate to stationary (intercept) speed enforcement, Elvik quotes evidence supporting its applicability to speed cameras as well.

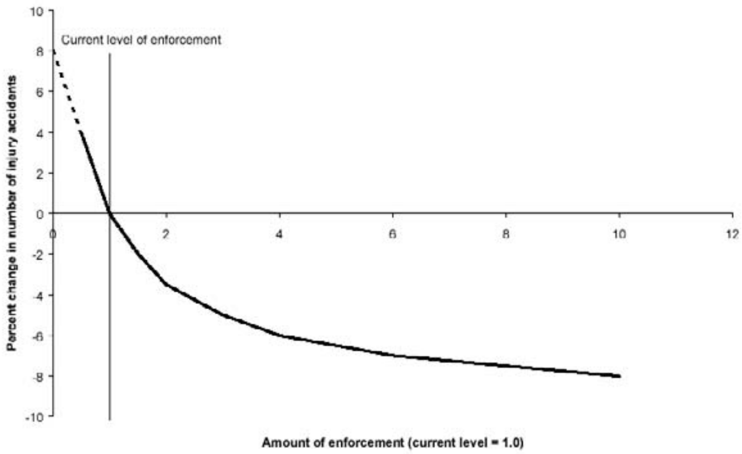

Figure 1: General relationship between traffic enforcement and crashes identified by Elvik (2001)

For the purposes of this study similar relationships have been derived for each of the key enforcement modes considered. This enables the additional benefits associated with each increase in speed enforcement intensity to be estimated and used as inputs into an economic analysis. Following is a description of the relationships derived.

Covert mobile speed cameras

Evaluations of the covert mobile speed camera program operating in Victoria provide the data from which the relationship between enforcement levels using this technology and crash outcomes is derived (Cameron, Newstead, Diamantopoulou &Oxley, 2003a,b). During 1999, Victoria Police varied the levels of speed camera activity substantially in four Melbourne Police districts according to a systematic plan. Analysis of the associated changes in casualty crash frequency revealed that crash frequency was inversely associated with changes in the levels of speeding TINs (Traffic Infringement Notices) issued following detection in the same district during the previous month. A similar relationship was found for the risk of fatal outcome in a casualty crash. The relationships are displayed in the following two figures together with 95% confidence limits on the estimates.

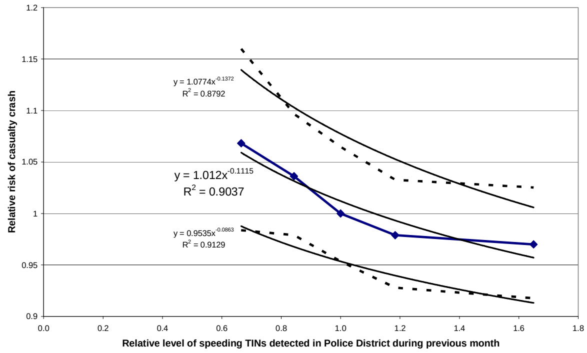

Figure 3: Relative relationship between casualty crash risk and level of speeding TINs detected by covert mobile speed cameras

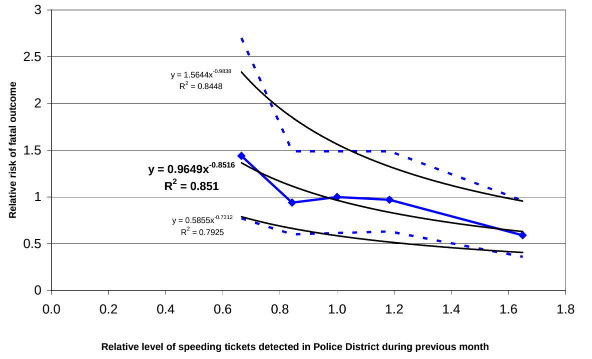

Figure 4: Relative relationship between the risk of fatal outcome in casualty crashes and the level of speeding TINs

Figure 3 shows the relative relationship between casualty crash risk and the level of speeding TINs issued in the prior month, relative to the average level of TINs issued, which was about 3,000 TINs per month from speeding offences detected in each Police District during 1999. It was found that the power function was the best of Elvik's proposed functional forms to represent this relationship. When this functional form was fitted to the relationship, the key parameter B ("elasticity") was estimated to be -0.1115. Figure 4 shows the relationship between the risk of fatal outcome of a casualty crashes and the level of speeding TINs issued, again expressed in relative terms. The power function also best represented this relationship, resulting in an estimate of B of -0.8516 in this case.

Overt mobile speed cameras with randomised scheduling

Studies have been conducted on the crash reduction effects of the Queensland program as it has grown from 852 hours per month in 1997 to about 6,000 hours per month during 2003-2006 (Newstead and Cameron, 2003; Newstead, 2004, 2005, 2006). The crash reductions have generally been limited to an area within two kilometres of the camera sites. The strongest effects have been on casualty crashes, with no differential effect on crashes of different severity (fatal, hospital admission, or medical treatment crashes). As the program grew, the two kilometre areas around camera sites covered a greater proportion of the total casualty crashes in Queensland, rising from about 50% to 83% over the evaluation period. Thus the localised crash reductions around camera sites can be interpreted as a general effect on crashes, assuming that the program had no effect beyond the two kilometre areas (a conservative assumption). The relationship between the increased monthly hours and the general casualty crash reductions can be seen in Figure 5.

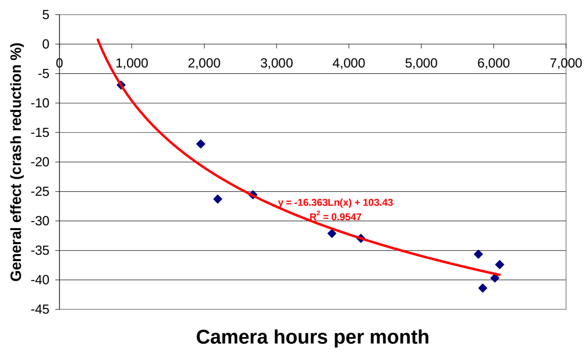

Figure 5: Relationship between casualty crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

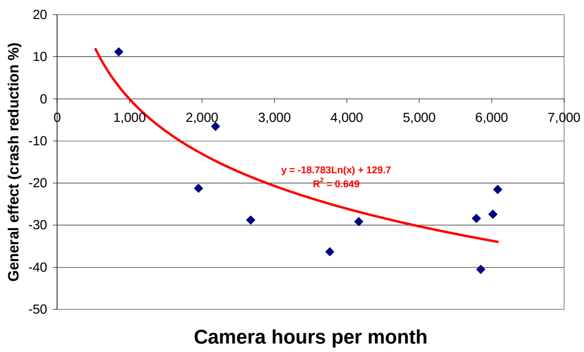

Figure 6: Relationship between fatal crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

It could be expected that an effective anti-speeding countermeasure such as this would have greater effect on fatal crashes than non-fatal crashes. Figure 6 shows the estimated reductions in fatal crashes associated with the level of monthly hours operated each year. It should be noted that the individual annual estimated reductions are not as reliable as the reductions in all casualty crashes shown in Figure 5 and that no individual reduction is statistically significant. Nevertheless, the estimates do suggest a relationship between fatal crash reductions and camera hours of the same type as that in Figure 5. However, there is no evidence that the magnitude of the reduction achieved by the Queensland program on fatal crashes is any greater than that achieved on casualty crashes in general (of which fatal crashes are a part).

Economic analysis of key enforcement options

Economic analysis was conducted of the benefits (savings in social costs of crashes) and costs (equipment, operating, and detected offence processing costs) of each of the speed enforcement options outlined above, if applied to the appropriate road environment in WA (Cameron and Delaney, 2006; Cameron, 2008). The options analysed were:

- Covert mobile speed cameras on urban highways (arterial roads)
- Randomly-scheduled overt mobile speed cameras on urban and rural highways
- Covert mobile speed cameras on publicly announced routes
- Moving mode (mobile) radar units on rural highways (undivided) and rural local roads
- Hand-held laser speed detectors operated overtly on urban local roads
- Fixed speed cameras on Perth freeways
- Point-to-point speed camera systems on Perth freeways and urban and rural highways with limited opportunities or incentives to leave or enter the enforced sections

The economic analysis of different levels of operation of covert mobile speed cameras is shown in Table 2. The base level of 3000 hours per month reflects that achieved by the existing Multanova speed cameras during 2004. The crash reduction effects of increased hours, using covert mobile cameras, are relative to the effect of the Multanova camera program (which was of unknown magnitude, given the absence of any crash-based evaluation to date). Reductions in casualty crashes were estimated from the fitted relationship in Figure 3. Reductions in fatal crashes were estimated by applying the reduction in risk of fatal outcome, estimated from the fitted relationship in Figure 4, to the estimated casualty crashes.

Table 2: Economic analysis of increase in covert mobile speed camera operations on Perth's arterial roads

Speed camera hours per month	Speeding tickets issued per month (short-term)	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fatal crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)
3000	30,000	22.7	0.0	0.0%	0.0%	3000	221.1
4000	40,000	14.3	4.4	3.2%	24.2%	4000	289.9
5000	50,000	10.0	5.9	5.5%	38.9%	5000	358.8
6000	60,000	7.6	6.3	7.4%	48.7%	6000	427.6
7000	70,000	6.0	6.4	9.0%	55.8%	7000	496.4
8000	80,000	4.9	6.3	10.4%	61.1%	8000	565.2
9000	90,000	4.1	6.1	11.5%	65.3%	9000	634.1
10000	100,000	3.5	5.9	12.6%	68.6%	10000	702.9

The economic analysis of different levels of operating hours of randomly-scheduled overt mobile speed cameras on Perth arterial roads is shown in Table 3. Reductions in casualty crashes were estimated from the fitted relationship in Figure 5 after recalibration of the hours needed to achieve the same crash reductions in WA compared with more heavily-trafficked Queensland. The detection rate of speeding offences per camera hour has fallen logarithmically as camera hours increased in Queensland, resulting in the estimated speeding tickets issued from overt mobile cameras growing substantially less than those from covert cameras. In both cases, the estimated number of tickets is short term until speeding transgression rates reduce in response to the more threatening speed enforcement.

Table 3: Economic analysis of increase in overt mobile speed cameras with randomised scheduling on Perth's arterial roads

Speed camera hours per month	Speeding tickets issued per month (short-term)	Marginal BCR for next increase in hours	Program BCR (above base level)	Casualty crash reduction	Fine revenue per month ($'000)	Program cost per month ($'000)
3000	30,000	21.9	0.0	0.0%	3000	221.1
4000	33,020	16.6	4.5	7.1%	3302	289.0
5000	34,500	13.3	6.5	12.7%	3450	356.7
6000	34,760	11.1	7.4	17.2%	3476	424.2
7000	34,010	9.6	7.8	21.0%	3401	491.5
8000	32,390	8.4	8.0	24.3%	3238	558.8
9000	30,000	7.5	8.0	27.3%	3000	625.9
10000	26,940	6.8	7.9	29.9%	2694	693.0

Covert mobile speed cameras were preferred as the recommended option for speed enforcement on arterial roads in Perth because of clear evidence of the strong effects of these enforcement operations on fatal crashes, and evidence that an increase in hours committed to this type of speed camera enforcement would reduce road trauma generally. While there were apparently greater economic benefits from operating mobile speed cameras overtly (with randomised scheduling) compared with covert operations (Tables 2 and 3), this relative benefit was reversed when fatal crashes were valued more highly than the "human capital" unit costs (BTE, 2000) used to value the crash savings. For example, when the fatal crashes were valued using the "willingness to pay" method (BTCE, 1997), resulting in a unit value of $5.360 million per fatal crash prevented compared with the unit cost of $2.048 million based on the human capital method (both indexed to year 2005 using the CPI), the program BCR for 9,000 hours per month of covert mobile speed camera operations was 11.9 compared with 10.4 for the same intensity of overt mobile camera operations with randomised scheduling.

Recommended speed enforcement package

Following analysis of the type illustrated in Table 2 and 3 for each of the enforcement options at various levels of operation (number of devices and/or hours operated), a package was developed based on the economic value of each enforcement program and the overall contribution to reducing road trauma in WA while avoiding overlap of enforcement operations on each part of the road system (Cameron and Delaney, 2006). The aim was to identify a package which, when fully implemented, would produce at least 25% reduction in fatal crashes, somewhat smaller reductions in less-serious casualty crashes, and have maximum cost-benefits in terms of the return on social cost savings for the investment.

The recommended enforcement programs, together with the level of input and the expected speeding ticket processing requirements (at least short-term), are shown in Table 4. Table 5 shows the estimated crash savings per month, valued in terms of social costs (in 2005 prices), and then aggregated across the package components to provide the overall impacts for the full WA road system. The aggregated benefit-cost ratio for the total social cost savings from the package, relative to the total package cost per month, is also calculated in this way.

The level of input recommended for each of the programs with variable intensity (mobile cameras and moving-mode radar units) was generally chosen on the basis of maximum program BCR and the potential contribution to achieving the targeted reductions in road trauma. The other enforcement options were generally constrained by the size of the road environment and/or the locational density of the crashes the enforcement was aimed at. The recommendation to operate the 24 fixed speed cameras on Perth freeways overtly, and intermittently aiming to detect about 10,000 speeding tickets per month (short-term), was based on experience from Sweden. The Swedish fixed camera program covers 120 highway routes totalling 2,500 kilometres with spacing of about 2.9 kilometres between cameras. Any one camera may be operational only 3-4% of the time, but because there may be 7-15 cameras in a row, drivers are deterred from speeding along the full route (Cameron, 2008). If operated continuously, the 24 fixed cameras on Perth freeways were estimated to detect about 35,600 speeding tickets per month based on the traffic flows past them (Cameron and Delaney, 2006). The Swedish experience suggested that this level of ticketing could be unnecessary.

Table 4: Recommended speed enforcement programs

Speed Enforcement Program	**Speed Enforcement Hours per month**	**Speeding Tickets Issued per month (short-term)**	**Program BCR**	**Program Crash Reduction**		
				Medical treatment crashes	Hospital admission crashes	Fatal crashes
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	9,000	90,000	6.1	11.5%	11.5%	65.3%
Laser speed detectors at black spot sites on urban local roads	1,025	3,413	29.8	3.76%	4.46%	4.46%
Overt fixed speed cameras on Perth freeways	Intermittent at 24 sites	10,000	9.3	7.76%	15.52%	15.52%
Total for urban roads		**103,413**	**8.1**	**6.0%**	**6.2%**	**24.9%**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	3,000	10,000	37.4	28.5%	28.5%	28.5%
Mobile radar units on rural local roads	15,000	11,250	6.3	24.1%	24.1%	24.1%
Total for rural roads		**21,250**	**11.8**	**26.2%**	**26.4%**	**26.8%**
Total package for WA roads		**124,663**	**10.1**	**9.0%**	**12.3%**	**26.0%**

Table 5: Economic benefits and costs of the recommended speed enforcement programs

Speed Enforcement Program	**Crash savings per month**			**Social Cost Saving per month ($'000)**	**Program Cost per month ($'000)**	**Fine Revenue per month ($'000)**
	Medical treatment crashes	Hospital admission crashes	Fatal crashes			
URBAN ROADS (Perth)						
Covert mobile speed cameras on urban highways	10.7	3.0	1.11	3,974.6	634.1	9,000
Laser speed detectors at black spot sites on urban local roads	5.2	2.4	0.11	1,551.5	51.9	341
Overt fixed speed cameras on Perth freeways	1.2	0.7	0.04	441.3	47.3	1,000
Total for urban roads	**17.0**	**6.1**	**1.3**	**5,967.4**	**733.3**	**10,341**
RURAL ROADS (Rest of WA)						
Overt mobile speed cameras randomly scheduled on rural highways	6.5	6.4	1.13	5,673.9	151.8	1,000
Mobile radar units on rural local roads	6.2	4.9	0.62	3,864.0	653.5	1,125
Total for rural roads	**12.7**	**11.4**	**1.7**	**9,537.9**	**805.3**	**2,125**
Total package for WA roads	**29.8**	**17.5**	**3.0**	**15,505.3**	**1,538.5**	**12,466**

The economic analysis of point-to-point speed cameras was based on effects measured during the first two years of a major system in Strathclyde (A77 Safety Group, 2007) and even greater effects of a system installed in a long urban tunnel in Austria (Stefan, 2006). The analysis indicated that they would be cost-beneficial on Perth freeways and on links on the urban and rural highway system suitable for their application. The analysis for the top 40 road links ranked by BCR is shown in Table 6. Specific recommendations to replace the recommended enforcement programs (Tables 4 and 5) in whole or in part with point-to-point speed cameras, while potentially being more effective and having greater economic justification, were not made because of the need for further investigation of the nominated links, for example, examining the speed profile along the link (Cameron, 2008).

Table 6: Freeways and highway links economically warranted for Point-to-Point speed cameras

Region	**Roads warranted for Point-to-Point camera systems**	**Total Length of Links (km)**	**Reduction in fatal and hospital admission crashes**	**Reduction in medical treatment crashes**	**Point-to-Point system capital cost ($)**	**Speeding Tickets issued per year (short term)**	**BCR**
Perth metro-politan	Freeways	74	33.3%	12.6%	4,900,000	496,758	10.4
	Other links in top 40	248	33.3%	12.6%	4,450,000	218,210	16.5
Non-metro-politan	Links in top 40 ranked by BCR	2,990	33.3%	12.6%	11,800,000	133,591	15.8

Conclusions

A package of speed enforcement programs was defined for the WA road environment which recognised its relatively unique characteristics of vast size and light traffic density, except in Perth. The evidence of the effects on speeds and road trauma in other jurisdictions due to speed camera systems and manual speed enforcement methods was reviewed and synthesised to provide strategic understanding of their mechanisms. For some speed enforcement options, it was possible to calibrate the road trauma reductions against the operational levels.

From this research base, it was possible to define a suitable speed enforcement method for each part of the WA road system and calculate the road trauma reductions and economic benefits if operated at each level. The recommended speed enforcement package, when fully implemented, is estimated to produce 26% reduction in fatal crashes, 12% reduction crashes resulting in hospital admission, and 9% reduction in medically-treated injury crashes. These effects correspond to a reduction of 36 fatal, 210 hospital admission and 357 medically-treated injury crashes per annum.

The package is estimated to provide a saving of at least $186 million in social costs per annum. The total cost to produce these savings is estimated to be $18.5 million per annum. Thus the benefit-cost ratio of the package is estimated to be at least 10 to 1. The inclusion of point-to-point speed cameras in the package, replacing the fixed cameras on Perth freeways and other recommended enforcement options on parts of urban and rural highways, where economically warranted, could make the package more cost-beneficial and effective.

Notwithstanding WA's uniqueness, the methods developed in this research have universal applicability and can be used to define speed enforcement strategies in other jurisdictions. The specific results, however, should not be directly translated to other jurisdictions because they relate to the mix of road types, traffic density, and crash rates in WA. In addition, the results are no more definitive than the evaluations of the different enforcement modes as applied in a broad range of interstate and international jurisdictions. Each of the effect estimates has a statistical range of error in which the true effect could lie. Time has not permitted consideration of the range of package outcomes which could result from these estimation errors. Furthermore, alternative relationships relating crash outcomes to the intensity of the mobile speed enforcement modes have not been considered. Finally, the results are dependent on the method of valuation of the road trauma savings, especially fatal crash savings, which are estimated to result from escalated speed enforcement. While the estimated economic benefits of the speed enforcement package were calculated based on the "human capital" method for valuing road trauma, the selection of covert mobile speed cameras to be operated on arterial roads in Perth was in fact based on a "willingness to pay" valuation of the fatal crashes predicted to be saved by this method of speed enforcement. All of these issues need to be given careful consideration before application of the methods in this paper elsewhere.

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References

A77 Safety Group (2007). Casualties halved on A77 – SPECS: End of 2nd year casualty statistics. News Release, 26 October 2007. Strathclyde, Scotland.

BTCE – Bureau of Transport and Communications Economics (1997). The costs of road accidents in Victoria – 1988. Unpublished monograph, BTCE, Canberra.

BTE – Bureau of Transport Economics (2000). Road crash costs in Australia. Report 102, BTE, Canberra.

Cameron, M.H. (2008). Development of strategies for best practice in speed enforcement in Western Australia: Supplementary Report. Report to Department of the Premier and Cabinet, Office of Road Safety, Western Australia, May 2008. Report No. 277, Monash University Accident Research Centre.

Cameron, M.H. and Delaney, A. (2006). Development of strategies for best practice in speed enforcement in Western Australia: Final Report. Report to Department of the Premier and Cabinet, Office of Road Safety, Western Australia, September 2006. Report No. 270, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003a). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria. Report No. 201, Monash University Accident Research Centre.

Cameron, M.H., Newstead, S.V., Diamantopoulou, K., and Oxley, P. (2003b). The interaction between speed camera enforcement and speed-related mass media publicity in Victoria, Australia. *Proceedings, 47th Annual Scientific Conference, Association for the Advancement of Automotive Medicine*, Lisbon, Portugal, September 2003.

Cameron, M.H. and Sanderson J.T. (1982). Review of Police operations for traffic law enforcement. Report No. TS 82/5, RACV Traffic and Safety Department, October 1982.

Diamantopoulou, K. and Cameron, M. (2002). An evaluation of the effectiveness of overt and covert speed enforcement achieved through mobile radar operations. Report No. 187, Monash University Accident Research Centre.

Elvik, R (2001). Cost-benefit analysis of Police enforcement. Working paper 1, ESCAPE (Enhanced Safety Coming from Appropriate Police Enforcement) Project, European Union.

Gains, A., Nordstrom, M., Heydecker, B. and Shrewsbury, J. (2005). The national safety camera programme: four year evaluation report. London: PA Consulting Group and University College London.

Homel, R. (1988). Policing and punishing the drinking driver: A study of general and specific deterrence. (Research in Criminology). New York, Springer-Verlag.

Keall, M.D., Povey, L.J. and Frith, W.J. (2002). Further results from a trial comparing a hidden speed camera programme with visible camera operation. *Accident Analysis and Prevention*, Vol. 34, 773-777.

Newstead, S. (2004). Evaluation of the crash effects of the Queensland speed camera program in the years 2001-2003. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2005). Evaluation of the crash effects of the Queensland speed camera program in the years 2003-2004. Consultancy Report prepared for Queensland Transport.

Newstead, S. (2006). Evaluation of the crash effects of the Queensland speed camera program in the year 2005. Consultancy Report prepared for Queensland Transport.

Newstead, S. and Cameron, M. (2003). Evaluation of the crash effects of the Queensland Speed Camera Program, Report No. 204, Monash University Accident Research Centre.

Nichols J.L. and Ross H.L. (1990). The Effectiveness of Legal Sanctions in Dealing with Drinking Drivers. *Alcohol, Drugs and Driving*, Vol. 6, No. 2, 33-60.

Radalj, T. (2006). Driver speed behaviours on Western Australia road network 2000, 2003, 2004 and 2005. Main Roads Western Australia.

Ross, H.L. (1981). Deterrence of the drinking driver: an international survey. U.S. Department of Transportation, Report No DOT-HS-805-820.

Stefan, C. (2006). Section control – Automatic speed enforcement in the Kaisermühlen Tunnel (Vienna, A22 Motorway). Austrian Road Safety Board, Vienna, Austria.