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.

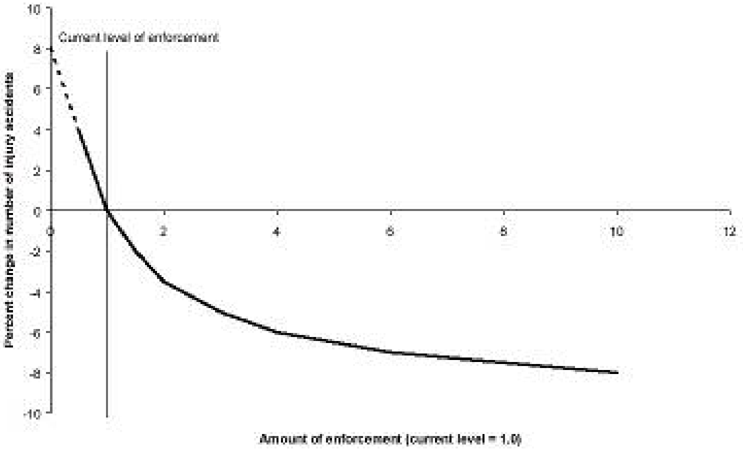

Figure 1: General relationship between traffic enforcement and crashes identified by Elvik (2001)

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.

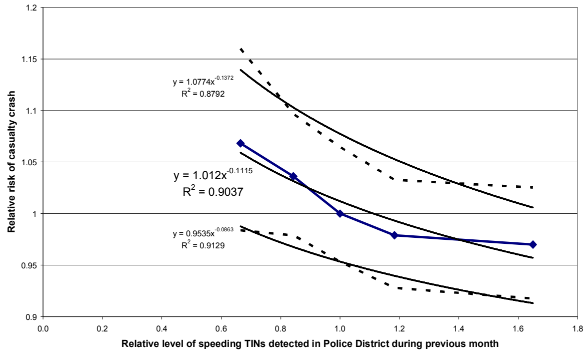

Figure 3: Relative relationship between casualty crash risk and level of speeding TINs detected by covert mobile speed cameras

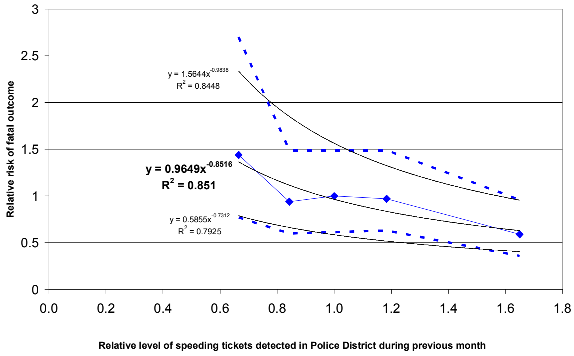

Figure 4: Relative relationship between the risk of fatal outcome in casualty crashes and the level of speeding TINs

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.

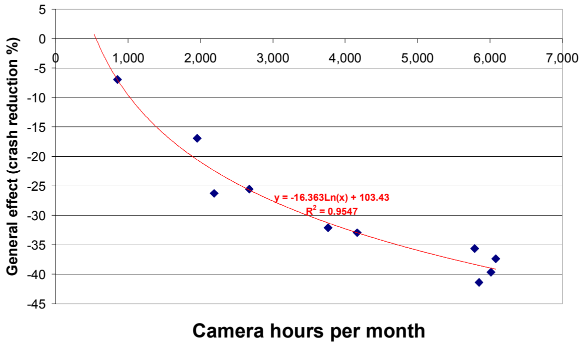

Figure 5: Relationship between casualty crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

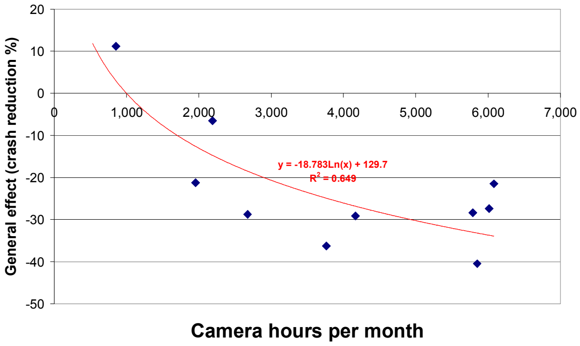

Figure 6: Relationship between fatal crash reductions and monthly hours of overt mobile speed cameras with randomised scheduling

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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