Evaluation of Crash Effects of the Queensland Speed Camera Program

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Biography
Stuart Newstead is a Senior Research Fellow at the Monash University Accident Research Centre. He holds a Master of Science (Research) in the field of mathematical statistics and is accredited by the Australian Statistical Society. Having worked in the road safety field for a number of years, he has developed expertise in the areas of road safety program evaluation, vehicle safety research from mass data analysis and management and analysis of road crash databases. He has particular interest in the development and application of statistical methodology in road safety research.

Abstract
A speed camera program was introduced in Queensland from 1 May 1997 utilising overt deployment of cameras in marked white commercial vans at sites chosen on the basis of crash history. Sites at which cameras are operated have grown in number from 500 at program commencement to over 2,500 by June 2001. Operations are scheduled using a randomised approach. This study has investigated the crash effects of the Queensland speed camera program over the period from its introduction to the end of June 2001 in areas within 6km of speed camera sites that had been used up to the end of the study period.

When operating at maximum coverage, the Queensland speed camera program was estimated to have produced a reduction in fatal crashes of around 45% in areas within 2km of speed camera sites. Corresponding reductions of 31%, 39% 19% and 21% were estimated for hospitalisation, medically treated, other injury and non-injury crashes respectively. This translates to an annual crash saving in the order of 110 fatal, 1100 hospitalisation, 2200 medically treated, 500 other injury and 1600 non-injury crashes. In terms of total annual road trauma in Queensland, these savings represent a 32% reduction in fatal crashes, a 26% reduction in fatal to medically treated crashes combined and a 21% reduction in all reported casualty crashes. The benefit cost ratio estimated for the program over the period from its introduction to June 2001 was 47.

Comparison of the estimated crash reductions and program operational measures showed variations in estimated crash reduction over time were strongly related to the size of the overall program and the density of enforcement. Periods of program growth were also associated with larger crash reductions beyond that expected from the increasing size of the program alone. Higher levels of true randomness in selection of speed camera sites for operation was also associated with higher levels of crash reduction when comparing differential performance of the program across police regions in Queensland.

1. BACKGROUND AND AIMS

A speed camera program was introduced in Queensland from 1 May 1997. The program commenced with three operational camera units with five more introduced two weeks after the program start, building to a total of fifteen units by the end of June 1997. Operations are overt, with the cameras being used in vehicles marked as a speed camera unit on the side of the vehicle. Additionally a 700mm high sign advising of the camera presence is placed within 5 to 10 metres past the vehicle. Speed cameras in Queensland can only be operated in approved zones, defined as an area of land that is 1km in diameter in urban areas or 5km in diameter in rural areas and chosen based on a high incidence of speed related or non-intersection casualty crashes (Queensland Transport, 2000).

Within each approved speed camera zone, specific sites are defined where the camera may be placed for use. Each camera is scheduled to operate at one or more of 3 sites per day, not necessarily each in the same zone, operating for up to 6-hours. The 3 sites are chosen randomly using a scheduling procedure (Leggett, 1997) based on the Random Road Watch (RRW) technique with limited potential to vary sites. A program of public education was undertaken prior to the introduction of the Queensland speed camera program, commencing around Christmas 1996 and an amnesty period was declared before the start of the program, running for six weeks up to the 1st of May 1997. A full description of the program can be found in Walsh and Wessling (1999) with the background to its introduction documented in Queensland Parliament (1994).

The speed camera program has grown substantially since its commencement. Notable changes include the ability to operate at more specific sites within a zone and the expansion of the program to cover local government roads (Queensland Transport, 2000). The number of approved zones has grown from the initial 500 to approximately 1500 by April 2001 and the average number of specific sites within a zone has increased from 1.2 at program commencement to 1.5 by April 2001. Hours of camera operation have grown from an average of 1000 hours per month in the early stages of the program, to 4000 hours per month by April 2001.

The broad aim of this research was to establish the effect of the speed camera program on crash frequency in Queensland. The evaluation also aimed to investigate differential effects of the program by crash severity as well as over time. A secondary aim of the study was to establish the mechanisms of program effectiveness if established through relating the estimated crash changes to program operational measures.

2. EVALUATION DESIGN AND HYPOTHESES

Given the overt nature of speed camera operations in Queensland, along with the tightly defined allowable areas of operation, it was hypothesised that the largest crash effects would be concentrated around areas where the speed cameras are operating. This is consistent with the hypothesised effects that were tested in the evaluation of the RRW program (Newstead et al, 2001), a program that has a similarly visible mode of operation scheduled within set areas and uses the same system of randomised operations scheduling. Based on experience in evaluating the localised effects of the Victorian speed camera program (Rogerson et al, 1994), along with the definition of zones of camera operation in the Queensland program, a localised influence in areas within a radius of 6km of operational speed camera sites was hypothesised for the Queensland speed camera program. Examination of the crash data showed that sufficient data was available to examine the hypothesised 6km radius of speed camera influence in three separate annuli. These were defined as 0 to <2km, 2km to < 4km, 4km to <6km, allowing testing for diminishing crash effects with distance from the speed camera location. Where a crash occurred within the vicinity of multiple speed camera sites, the distance to the closest camera site was assigned to the crash. Over 85% of crashes in Queensland during the study period occurred within 6km of a speed camera site.

A quasi-experimental design was used comparing crash history within the annuli up to 6km from camera sites (treatment area) against crash history in areas further than 6km from a camera site (control area) before and after implementation of the camera program. This is similar to the analysis methods used for evaluation of the Queensland RRW program (Newstead et al, 2001) and allows for the control of other factors affecting crashes in parallel to the program of interest. The before treatment period in the evaluation design was defined as January 1992 to December 1996, the period before introduction of the mass media campaigns on the program. Complete reported crash data was available up to June 2001 giving a post-implementation period from January 1997 to June 2001.

The generic null hypothesis tested in this evaluation is that the introduction of the speed camera program in Queensland had no effect on crash frequency in areas within a 6km radius of speed camera sites that had been used up to June 2001. This has been assessed against the two-sided alternative hypothesis that the introduction of the speed camera program has led to a change in crash frequency in the defined areas of influence. As a result of the study design, the alternative hypothesis allows for differential crash effects of the speed camera program within each 2km annulus around the speed camera sites.

3. DATA

Queensland Transport (QT) staff provided data on all reported crashes in Queensland over the period January 1992 to June 2001. Data was defined as belonging to treatment or control groups using the distance of the crash from the nearest approved speed camera site. QT assigned the distance of each crash in the data from the nearest approved speed camera site using Geographical Information System (GIS) software that related the physical location of crash and speed camera sites.

The GIS speed camera location information was dynamic, covering all speed camera sites that had been used up to the time of data interrogation with no facility for linking the crash and speed camera site records with respect to time. Consequently, the labelling of crash data with respect to the distance to the nearest speed camera site, referred to any speed camera site that had been used up to the time of matching the data (June 2001). This was irrespective of whether the camera site had been used operationally or not at the time of the crash. In practice, this meant a site was considered treated throughout January 1997 to June 2001 if a camera was used at it any time during the period.

Around 30% of sites were active in the first two and a half years of the program to mid-1999 with the number becoming active rising sharply and consistently from then until late 2000. Before and after implementation periods were defined using the date of the crash. QT also provided information on the number of speed camera zones and sites that were operational in each month from January 1997 to June 2001 for each Queensland police region as well as the number of hours the cameras were worked.

4. METHODS

Net crash effects of the Queensland speed camera program under the quasi-experimental study design have been estimated using a Poisson log-linear statistical model. The analysis approach used here is similar to the approach used for evaluation of the Queensland Random Road Watch program (Newstead et al, 2001), as well as a number of other road safety program evaluation studies employing quasi-experimental designs. Conventional linear regression techniques were used to compare estimated crash effects with operational measures of the speed camera program. Where appropriate, stepwise model selection techniques have been used to arrive at the models best describing the outcome measure. Comparison between speed camera program operational measures and estimated crash effects has been carried out in two dimensions. Variations in program effectiveness, firstly with respect to time and secondly with respect to region of operation, have been examined.

5. RESULTS

5.1 State-wide Crash Effect Estimates

Table 1 presents estimates of crash reductions associated with the speed camera program in each calendar year after its hypothesised commencement of influence in January 1997. Results are presented separately for each of the five crash injury severity levels coded in the Queensland crash data as well as for fatal, hospitalisation and medically treated crashes combined and all severity levels combined. They are also stratified by each of the three annuli within the hypothesised 6km radius of speed camera influence. Negative estimated percentage crash reductions indicate an estimated crash increase. The statistical significance levels of the estimated percentage crash reductions are also indicated in Table 1.

Table 1: *Estimated percentage crash reductions attributable to the Queensland speed camera program by year after program implementation.*

		Year				
Crash Severity	**Distance From Nearest Camera Site**	**1997**	**1998**	**1999**	**2000**	**2001++**
Fatal	0-1.99 km	14.6	24.8	34.4	45.3**	42.6
	2-3.99 km	-13.0	30.5	8.2	-3.0	8.5
	4-5.99 km	-30.0	4.6	-37.7	37.4	-81.3
Hospital Admission	0-1.99 km	18.4**	28.4**	38.5**	30.5**	34.4**
	2-3.99 km	13.8	12.8	20.7*	6.7	14.3
	4-5.99 km	2.6	21.1*	24.8*	26.7*	29.8
Medically Treated	0-1.99 km	6.2	20.4**	36.4**	39.0**	33.9**
	2-3.99 km	1.8	16.1	24.0**	18.4	22.8
	4-5.99 km	8.5	5.9	26.7*	31.6**	27.0
Fatal to Medically Treated	0-1.99 km	12.4**	25.1**	38.0**	36.3**	34.6**
	2-3.99 km	7.2	16.6**	23.1**	13.4	19.4*
	4-5.99 km	4.7	13.7	24.0**	29.2**	25.2*
Other Injury	0-1.99 km	10.2	9.7	36.7**	19.3	8.2
	2-3.99 km	-11.8	-11.5	21.9	5.2	-21.0
	4-5.99 km	3.2	-22.2	-6.5	4.4	-33.5
No Injury	0-1.99 km	20.4**	18.1**	16.5**	21.4**	6.9
	2-3.99 km	14.5**	13.1*	14.5*	16.2*	-5.0
	4-5.99 km	18.4**	18.8**	21.9**	23.5**	9.1
All Severity Levels	0-1.99 km	15.6**	20.4**	29.6**	28.4**	21.7**
	2-3.99 km	8.4*	12.3**	19.9**	14.3**	7.3
	4-5.99 km	10.8*	12.7**	20.4**	24.6**	14.8

Notes: Negative crash reduction estimates indicate an estimated crash increase
++: First 6 months of 2001only
**: Statistically significant at the 10% level*
***: Statistically significant at the 5% level*

Table 1 shows that, generally, estimated crash reductions attributable to the speed camera program have increased with time since the introduction of the program. This is particularly evident when examining results for higher severity crashes within 2km of a speed camera site and reflect the growth in operational camera sites over time. Results in Table 1 also suggest a differential effect of the speed camera program on crashes by crash severity level, particularly evident in later years after the program introduction. In these later years, estimates of fatal to medically treated crash effects within 2km of speed camera sites are in the order of 35%, with fatal effects being the highest individually at around 45%. In contrast, estimates of effects on other injury and non-injury crashes within 2km of speed camera sites in 2000 and 2001 are around 20% or less. None of the estimated crash increases in Table 1 (indicated by negative reductions) were statistically significant and could have occurred through chance variation in the data.

Estimates of the absolute magnitude of crash savings attributable to the speed camera program during 2000 when the program was operating at maximum coverage are shown in Table 2 and have been derived by using the estimated percentage reductions in Table 1. It should be noted that the estimates of crash savings for 'fatal to medically treated crashes combined' and 'all crashes combined' categories were obtained independently of the individual severity level figures and will not necessarily be equal to the sum of the individual severity level results.

Table 2: *Estimated total crash savings attributable to the Queensland speed camera program during the year 2000*

	Distance From Nearest Camera Site		
Crash Severity	0-1.99 km	2-3.99 km	4-5.99 km
Fatal	113	-2	6
Hospital Admission	1097	35	70
Medically Treated	2201	136	88
Fatal to Medically Treated	3469	177	162
Other Injury	503	14	4
No Injury	1599	201	126
All Severity Levels	5579	407	294

Notes: Negative crash saving estimates indicate an estimated crash deficit

The annual crash saving over all severity levels for areas within 2km of a speed camera site was estimated at approximately 5,500 in the year 2000. The comparable figure for fatal, hospitalisation and medically treated crashes being around 3,500. Table 2 reflects the breakdown of crashes saved by distance from a speed camera site, with the majority of crash savings occurring within 2km of the speed camera site. Because of this, it is evident that final assessment of the measure of effectiveness of the speed camera program in Queensland should focus mainly on crash effects within 2km of the nearest camera site.

An indicative social benefit to cost ratio (BCR) of the speed camera program over the period from program introduction to June 2001 was estimated as 47. This was obtained using the estimates of annual crash savings presented in Table 2 along with crash costs estimated by the Bureau of Transport Economics (BTE, 2000) and actual costs of implementing and running the speed camera program supplied by Queensland Transport. Revenue from speed camera offence penalties was not included in the benefit to cost ratio as fine revenue is not typically considered either a social benefit or a negative program cost.

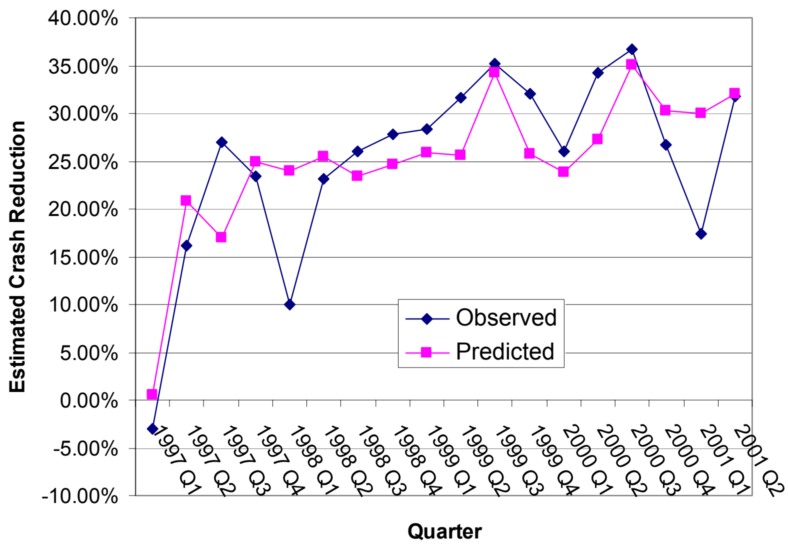
5.2 Time-Based Effects and Their Relationship to Operation Measures

The 'observed' line in Figure 1 shows the estimated reduction in all casualty crashes attributable to the speed camera program by quarter of the year. Broadly reflecting the results in Table 1, it shows an increase in effectiveness of the program consistent with the growth in the program over time.

Analysis of the relationship between speed camera operational measures and crash effects of the program over time was carried out on the quarterly estimates of program crash effects shown in Figure 1 using linear regression analysis. The estimated crash reduction was modelled as a function of key program measures using a stepwise regression approach to chose the subset of significant predictor variables. Operation measures included in the models were: the number of active camera zones in a quarter as the measure of program size, the average number of camera hours per zone as the measure of enforcement density, and the rate of increase in active sites per month as the measure of program growth rate.

Each of the three program operation measures was statistically significantly related to crash reduction estimates in the linear regression model. The size of the program showed the strongest association with crash reduction achieved, closely followed by the density of enforcement and then the rate of program growth. The regression model R-squared was around 0.6 indicating the model explained around 60% of the quarterly variation in the crash effect estimates. Figure 1 shows the level of fit of the regression model predicted values (predicted) to the original program crash reduction estimates (observed), confirming the high level of fit as indicated by the R-squared value.

Figure 1: *Estimated percentage crash reduction associated with the Queensland speed camera program by quarter after implementation and prediction using operational measures: All reported crashes within 2km of a speed camera site*

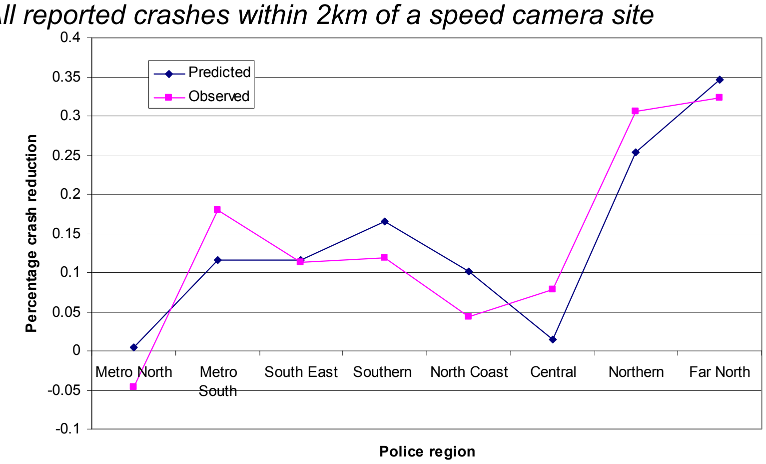


5.3 Police Region Based Crash Effects and Their Relationship to Operational Measures

Net crash reductions associated with the introduction of the speed camera program have been estimated for each Police region in Queensland. Because of the relatively small quantities of data available at this level of stratification, only the average crash effects within 2km of a speed camera site across the total post-implementation period have been estimated for all crash severity levels combined. Estimates are shown in Figure 2 as the 'observed' line and suggest significant variation in crash effects between police regions.
Analysis of the relationship between speed camera operational measures and estimated crash reduction outcomes across Police regions was carried out using the same approach as used to examine the relationship across time. Operation measures included in the models were: the number of active camera zones as the measure of program size, number of camera hours per zone as the measure of enforcement density, the size of the crash population in the region, the number of zones per crash as a measure of program coverage density and a measure of percentage compliance with the fully randomised enforcement schedule.

The measures of program coverage density and compliance with the randomised schedule were the only factors statistically significantly related to crash reduction estimates by Police region. The model explained around 80% of the regional variation in estimated crash effects with Figure 2 shows the level of fit of the regression model predicted values (predicted) to the original program crash reduction estimates (observed).

Figure 2: *Estimated percentage crash reduction associated with the Queensland speed camera program by Police region and prediction using operational measures: All reported crashes within 2km of a speed camera site*



6. DISCUSSION AND CONCLUSIONS

Analysis presented in this study shows clear association between the introduction of the speed camera program in Queensland and reductions in reported crashes in areas within 6km of camera sites, relative to areas outside these.

The estimates of program crash effects most indicative of the real potential of the program in reducing crashes are those from 2000, the last full year of data considered in the analysis when the program was operating at maximum coverage. Table 2 confirms that the results in the area up to 2km from the camera sites are the most relevant, covering 73% of the crash population and comprising the majority of crash savings. In these areas during 2000, the program was estimated to have produced a reduction in fatal crashes of around 45% in areas within 2km of speed camera sites.

Corresponding reductions of 31%, 39% 19% and 21% were estimated for hospitalisation, medically treated, other injury and non-injury crashes respectively. This translates to an annual crash saving in the order of 110 fatal, 1100 hospitalisation, 2200 medically treated, 500 other injury and 1600 non-injury crashes. In terms of total annual road trauma in Queensland, these savings represent a 32% reduction in fatal crashes, a 26% reduction in fatal to medically treated crashes combined and a 21% reduction in all reported casualty crashes. The social benefit to cost ratio of the Queensland speed camera program over the period from its introduction to June 2001 was estimated to be 47 clearly indicating the program is a highly cost effective means of road trauma reduction.

Estimates of the crash effects of the Queensland speed camera program are not considered likely to be confounded with the effects of the other wide coverage major road safety program operational in Queensland, Random Road Watch (RRW). There were only between 500 and 1500 operational speed camera zones in the study period in comparison to the RRW program that covered the whole of Queensland, with varying density, from before the time of introduction of the speed camera program. Hence there is likely to be essentially the same influence of the RRW program on crashes both within and outside of areas hypothesised to be influenced by the speed camera program.

Comparison with program operational measures has given insight into the mechanisms of effectiveness of the Queensland speed camera program. Not surprisingly, total crash reductions are strongly related to the size of the overall program as well as to the density of enforcement. Perhaps less expected is the increased effectiveness of the program during periods of growth. This is possibly the result of added general awareness of enforcement when drivers see speed cameras operated at new sites or perhaps a response to likely heightened publicity concerning the program during times of growth. Further research would be needed to confirm the real mechanism. Conversely, lower periods of growth appear to be associated with decreased crash reduction. It is noted that QT and the Queensland Police Service use an in-house performance monitoring process that provides feedback to operational police on rates of site growth and faithfulness to the scheduler. This process detected and effectively rectified periods of lack of site growth so that deteriorations in program effectiveness were short term.

Another important determinant of program effectiveness highlighted by difference in regional performance, is the level of true randomness in site selection achieved. This is supported by the established effectiveness of the Random Road Watch program also operated in Queensland that has been shown to produce significant crash savings through randomisation of relatively low levels of enforcement effort (Newstead et al 2001). Finally, the level of site coverage per crash also appears to be related to crash effects although this is not supported for higher severity crashes.

The relationships established between crash effects and speed camera operations indicate how the effectiveness of the Queensland program may be optimised. Increased coverage should be sought, whilst increasing the density of enforced areas per crash may also be beneficial (eg the RRW program has 12,000 sites, 4 times the current number of speed camera sites). Increased hours of operation per site should lead to increased effect on crashes although the research here is not able to identify the point of diminishing returns for enforcement input. Further research would be needed to determine this for the Queensland program. Police regions should also aim to maximise the randomness of enforcement scheduling within the options given to them under the standard site selection regime.

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Keywords

speed camera, speed enforcement, evaluation, road trauma, statistical analysis.