An investigation of the relationship between speed enforcement, vehicle speeds and injury crashes in New Zealand

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Biography
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Abstract
There exists in the literature material dealing with dose-response relationships between enforcement effort and vehicle speeds and also vehicle speeds and crash risk. This literature pertains to various road networks and jurisdictions around the world. New Zealand's mix of road network and enforcement has some unique features which merit further investigation.
This paper examines the relationship between enforcement activity, vehicle speeds and injury crashes in New Zealand. Enforcement activity taken into account includes speeding infringements (camera and non-camera), hidden and visible speed camera activity and the advent of marked State Highway Patrol cars.
Estimated reductions in open road mean speeds of 0.7% and 0.8% were found, associated with each increase of 10000 speed camera infringements and 10000 other speed infringements respectively. Higher reductions of 1.1% and 1.6% were found in the 85th percentile speeds. An estimated injury crash reduction of 12% was found to be associated with a 1km/h reduction in mean open road speed during low alcohol hours. The relationships between enforcement, speeds and crashes apply to the systems in place in New Zealand over the study period of 1996-2002 and should not be applied beyond the range of the enforcement practices studied.

1. INTRODUCTION

Speeding is one of the major causes of death and injury on New Zealand roads. At the time of the introduction of speed cameras in 1993, travelling too fast for conditions was a contributing factor to 38% of deaths and 19% of injuries on New Zealand roads. This paper examines the relationship between enforcement and open road car speeds, and between speeds and crashes.

Speed enforcement is designed to affect speeds via a deterrent effect on drivers. The effect of deterrence on the driver's speed choice depends on the perceived risk of being caught, fear of being caught and fear of the resulting punishment (Zaal, 1994). Specific deterrence refers to the effect of enforcement (in this case, receiving a ticket) on given individuals' behaviour. Speeding tickets have a well-attested effect on individual behaviour. In a recent study in Canada, Redelheimer et al (2003) found that the risk of a given driver being involved in a fatal crash was 35% lower during the month after receipt of a speeding ticket, than in a comparable month during which no speeding ticket was received. General deterrence targets the wider population by increasing the perception that offenders will be caught, by means both of police activity and publicity about this activity.

Speed cameras were introduced to New Zealand in 1993. Mara et al (1996) examined the effect on crashes of road safety countermeasures including the introduction of speed cameras. They found a 13% crash reduction in urban areas generally, associated with the

introduction of speed cameras, but were unable to detect such an effect in rural areas. At speed camera sites, Mara et al found a 10.9% reduction in crashes at rural speed camera sites and a 23% reduction in crashes at urban sites. Similar results were found in Victoria (Cameron et al, 1992), Norway (Elvik, 1997) and the UK (Corbett, 1995).

Newstead et al (1995) examined casualty crashes at speed camera sites in the Melbourne metropolitan area in high alcohol hours during 1990-1993, finding a casualty crash reduction of 8.9% during the first week after receipt of tickets from a speed camera operation. Reductions in crashes associated with speed cameras have also been found in Victoria (Cameron et al, 1992), Norway (Elvik, 1997) and the UK (Corbett, 1995).

In a case-control study of crashes on rural roads in Australia with speed limits of 80km/h and above, Kloeden et al (2001) found an increased risk of casualty crash involvement for vehicles travelling at speeds above the mean non-crash involved vehicle speed. Specifically, the risk of crash involvement was found to be twice as high for vehicles travelling 10km/h above the mean speed of non-crash involved vehicles and nearly six times as high when travelling 20km/h above the mean speed. Nilsson (1982) combined a number of evaluations of speed limit changes in Sweden to validate a theoretical model for estimating the relationship between mean speed and crashes. This model predicted a number of power relationships between crashes and proportional change in mean speed. The exponent ranged from 2 for injury crashes to 4 for fatal crashes.

Speed enforcement is carried out by the New Zealand Police, using radar and laser speed measurement devices. Speed cameras were introduced in the last quarter of 1993. Cameras must be visible and may only be used within designated ‘Speed camera sites’ up to five kilometres in length. On the open road most cameras are mobile cameras, operated from the rear of a (usually unmarked) Police vehicle. In urban areas, both mobile and pole-mounted fixed cameras are used.

Speeding infringements carry fines ranging from $30 for speeds up to 10km/h over the posted speed limit up to $630 for speeds from 45-50 km/h above the limit. Speeds higher than 50 km/h above the limit are classed as Traffic Offences rather than Infringements and require a Court appearance. These are relatively rare and are not included in this analysis. Demerit points are incurred by offenders caught by Police using radar or laser technology, but are not currently attached to speed camera infringements.

In recent years additional enforcement programmes have been introduced. The Supplementary Road Safety Package, a high intensity publicity and enforcement programme, was introduced late in 1995. This programme focusses on the key areas of drink-driving, speeding and safety belt use. Ongoing enforcement is supported by related television, radio and billboard advertising campaigns. A trial of hidden speed cameras was carried out from July 1997 to May 2000 in the then Midland Police Region, which was equivalent to the Waikato, Bay Of Plenty and part of the current Eastern Police Districts. A reduction of 11% in injury crashes and 19% in injuries on open roads across the region was found (Keall et al, 2002).

A dedicated State Highway Patrol was introduced to New Zealand State Highways throughout 2001 and early 2002. The State Highway Patrol operates from specially marked cars with the aim of providing a highly visible, dedicated police presence. The associated deterrent effect on speeding comes from both an increase in ticketing (and reduced tolerances) and from increased Police visibility.

2. DATA

Because of the effect of the Hidden Camera Trial on speeds in the former Midland Police Region, this analysis excluded data from this area.
Speed estimates were derived from LTSA winter speed surveys undertaken in July / August of each year. Surveys were conducted unobtrusively at randomly selected locations for two hours between 9 and 12 a.m. or 2 and 4 p.m., on normal working weekdays. Surveys were conducted at the same site, time and day of week each year. The speed and type (car, van, truck, and so on) of each passing vehicle was recorded. Only free speeds were measured as these were considered to best represent the drivers' choice of speed. A consistent series of these surveys is available for 1996 – 2002.
The numbers of tickets issued by speed cameras in each speed limit zone, and the number of other infringement notices issued by Police, were provided by the Police Infringement Bureau.
The analysis was based on reported injury crashes obtained from the LTSA's Traffic Crash Reporting database. (Throughout this paper the term "injury" or "injury crash" includes fatalities and fatal crashes). All reported injury crashes in the study region which occurred outside high alcohol hours, that is, between 4am and 9.59pm on Monday to Friday, or between 6am and 9.59pm on Saturday or Sunday, were included in the analysis. Crashes in high alcohol hours were excluded from the analysis as significant interventions relating to drink-driving have been implemented over the study period. Speed enforcement activity is concentrated outside high-alcohol hours.

3. METHOD

3.1 Speed and enforcement

The relationship between speed and the number of tickets issued was examined in areas where the open road speed limit of 100km/h applied. It was expected that speeds would decrease by a fixed proportion in response to a given increase in number of tickets issued. This was expressed as a model of the form

$$\log(Speed\_measure) = \alpha + \beta_1\, camera\_tickets + \beta_2\, non\_camera\_tickets + \epsilon_i \quad \text{(Equation 1)}$$

where *Speed_measure* was a) the mean open road free speed or b) the 85th percentile open road free speed, as described above, *camera_tickets* and *non_camera_tickets* were the number of speed camera and non-speed camera speeding infringement notices issued in the previous January to June period, α is an intercept term, β_1 and β_2 were constant coefficients and the errors ϵ_i were assumed to be independently and identically normally distributed.
In some years, there was a considerable increase in the number of tickets issued per month. To relate speeds more closely to the level of enforcement current at the time of the survey, enforcement data series were restricted to the period January to June of each year, the six months preceding the speed measurements.

Due to the operational differences described in section 1, it was expected that the deterrent effect of speed camera tickets might differ from that of non-camera tickets, and these were included separately in the model. The number of non-camera tickets was however moderately (negatively) correlated with the number of speed camera tickets, so an alternative model was investigated which used the total tickets issued as an explanatory variable instead of the two separate variables shown in equation 1.

Traffic volume was not included in the model as speed surveys measure only free (unimpeded) vehicle speeds. Any changes in traffic volume are unlikely to have affected free vehicle speeds on the open road over the period under study. Fuel prices and unemployment

were considered as potential explanatory variables but historical precedent gave no reason to consider that they might affect speeds over this period, given the range of values involved.

It was expected that any deterrent effect of the State Highway Patrol on speeds would be generated both by increased (non-camera) ticketing and by visibility. Any increase in the number of tickets issued is accounted for in the model described above. The visible presence of the State Highway Patrol was highly correlated with the number of non-camera tickets issued and for this reason was not included as a separate explanatory variable.

New Zealand has a long history of speed creep, and at present speeds are below the level they have reached in the past. In the absence of enforcement, speeds are likely to increase. To be conservative in terms of the effect of ticketing on speeds, we assumed that speeds would remain constant in the absence of enforcement and omitted a year term from the model.

The model described above (equation 1) was fitted to the annual mean speeds in New Zealand, excluding the Waikato, Bay of Plenty and Eastern Police Districts. SAS Proc Genmod (SAS Institute, 1996) was used to fit the model, using the maximum likelihood estimation method.

3.2 Speed – crash relationship

The relationship between mean speeds and crashes was modelled as

$$\log(Crashes) = \alpha + \beta_1 Mean\_speed + \beta_2 Year + \epsilon_i \qquad \text{(Equation 2)}$$

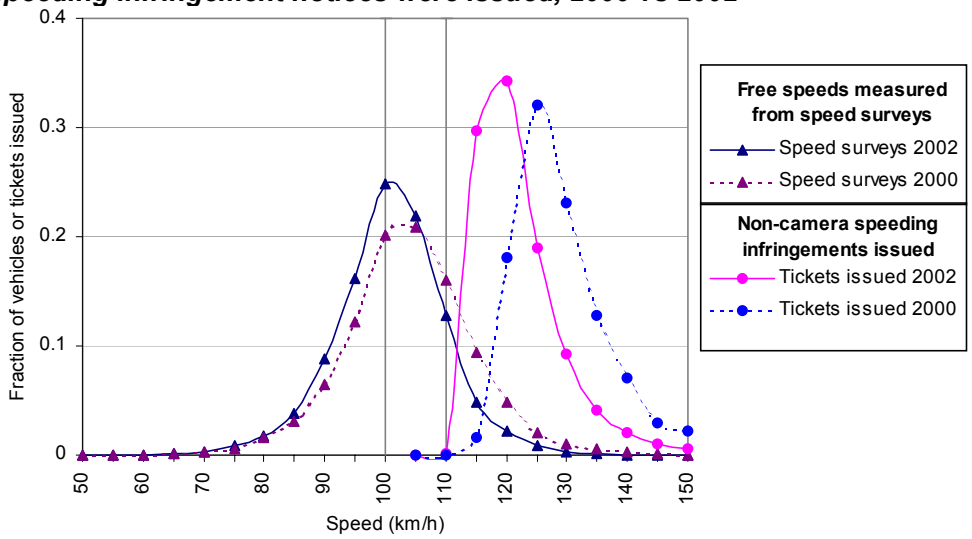
where *Crashes* was the number of injury crashes in the study region during low alcohol hours, *Mean_speed* was the winter open road mean car speed, *Year* was a trend term to capture gradual changes in such things as vehicle safety, road engineering, traffic volume and occupant protection, α was an intercept term, β_1 and β_2 were constant coefficients and the errors ϵ_i were assumed to be identically and independently Poisson distributed. The presence of the State Highway Patrol was highly correlated with speeds and was not included separately in the model.

The relationship between speed and injuries (including deaths) was modelled similarly. Because injuries are clustered within crashes, the errors were assumed to follow a negative binomial distribution thus allowing the variance to differ from the mean.

4. RESULTS

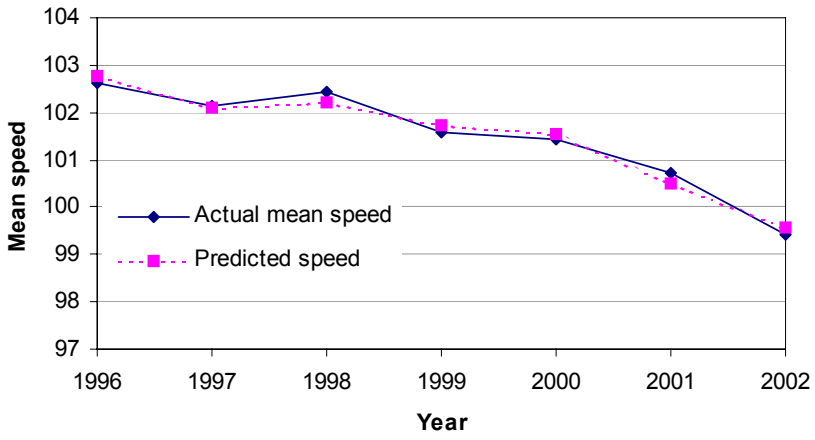
Figure 1 shows the distributions of open road free speeds and speeds at which non-camera speeding tickets were issued, on the same scale. The number of non-camera tickets issued to vehicles travelling between 111 and 120 km/h has increased substantially in recent years from just over 10000 in 2000 to more than 90000 in 2002. Changes are also evident in the speed distributions. Both the mean speed and the percentage of vehicles travelling at speeds greater than 110 km/h have decreased between 2000 and 2002.

Fig 1: Distributions of a) open road free speeds and b) speeds at which non-camera speeding infringement notices were issued, 2000 vs 2002



The model described in equation 1 was fitted to the series of mean open road speeds in New Zealand from 1996-2002. The model was found to describe the data well. Maximum likelihood methods do not generate an R^2 value, but standard diagnostics (including plots of residuals against the fitted values), indicated no problems with the fit of the model. Fig 2 shows a comparison of the actual and predicted mean speeds.

Fig 2: Comparison of actual and predicted mean speeds



The model described in equation 1 was also fitted to the series of 85th percentile open road speeds

Table 1: Estimated change in open road mean and 85th percentile speeds for every 10000 speed infringement notices issued, 1996-2002

	Per 10000 speed infringement notices issued	95% confidence interval	p-value
Mean speed (km/h)	-0.7	(-0.8, -0.6)	<0.01
85th percentile speed (km/h)	-1.5	(-1.8, -1.1)	<0.01

The model described in equation 2 was fitted to the series of open road injury crashes in low alcohol hours from 1996-2002. The model provided a good fit to the data. A 12% reduction in crashes for each 1 km/h reduction in mean speed was found. A significant trend of 6%

reduction in crashes per year was also found. The year term was highly correlated with mean speed and was included in the analysis to be conservative.

The same model was fitted to all reported open road injuries (including fatalities), and to the series of fatal and serious open road crashes and the numbers of fatal and serious injuries sustained in open road crashes. Results are summarised in Table 2. A significant decrease in injuries was found. Numbers of fatal and serious crashes and injuries were too small to enable detection of an effect due to change in the mean speed.

Table 2: Estimated change in open road injury crashes/ injuries during low alcohol hours

Estimated change in…	Per 1km/h change in mean speed	95% confidence interval	Per year (1996-2002)	95% confidence interval
Injury crashes	-12%**	(-20%, -3%)	- 6%*	(-11%, -1%)
All injuries	-13%**	(-20%, -5%)	- 7%**	(-11%, -2%)
Fatal & serious injury crashes	- 7%	(-17%, 3%)	- 3%	(- 8%, 3%)
Fatal & serious injuries	- 7%	(-18%, 6%)	- 3%	(- 9%, 4%)

* significant at 0.05 level; **significant at 0.01 level.

5. DISCUSSION

In recent years the amount and the visibility of speed enforcement has increased. The increase in both types of speed infringement notices reflects a decrease in enforcement tolerances and a policy of issuing tickets rather than warnings. The advent of a dedicated State Highway Patrol has resulted in a sharp increase in non-camera speeding infringement notices, particularly to vehicles travelling at speeds between 111 and 120 km/h. Enforcement activity has been supported by high-impact advertising and publicity campaigns to convey the harmful consequences of speeding.

The perceived risk of being caught is a major determinant of drivers' choice of speed (Zaal, 1994). Annual monitoring of public perceptions shows a recent upward shift in the perceived risk of being caught by a Police officer if speeding, and an earlier and similarly marked shift in the risk of being caught by a speed camera (LTSA 2002). The shift in perceptions coincides with a reduction in open road speeds, providing evidence to reinforce the link between enforcement and speed behaviour.

A multiplicative model was used to describe the relationship between speed and tickets as it was expected that a change in ticketing levels would result in a proportional rather than an absolute change in speed. Both mean and 85th percentile speeds have shown a significant decrease associated with the increase in enforcement activity. Over the period studied, mean speed decreased by 0.7% for every 10000 speed infringement notices issued. Vehicles travelling at higher speeds were the most affected, with a reduction in the 85th percentile speed of 1.5% for every 10000 speed infringement notices issued. This is consistent with the focus of enforcement activity on vehicles travelling at over 110 km/h, and with the effects of other speed camera enforcement such as that evaluated in Keall et al (2002).

Changes in speed were found to have a significant effect on open road injury crashes in low alcohol hours. A 1km/h reduction in mean speed was found to be associated with a reduction of 12% in injury crashes and 13% in injuries and deaths. (Note that this reduction is compounding; that is, a 5% reduction in the mean speed leads to a predicted 48% reduction in crashes, not a 60% reduction). No significant effect could be detected for fatal and serious injury crashes. The relationship between speed and fatal and serious injury crashes is well established. The inability to detect an effect here is likely to be due to insufficient data.

The reduction in injury crashes is higher than the reduction predicted by Nilsson (1982) from his analyses of changes in crashes following changes in speed limits in Sweden. There are several reasons for this. A change in speed limit is expected to have less effect on the shape of the speed distribution than enforcement where the higher speeds are particularly targeted, resulting in a slimmer speed distribution. Thus, the same change in mean speed may result in a different crash reduction due to other differences in the speed distributions. In addition, New Zealand open roads are typically 2-lane undivided highways of a lower safety standard than the motorways and high-standard, low-volume roads studied by Nilsson. It is possible that the effect of reducing speeds on lower standard roads would be greater than on higher standard roads.

The relationships between injury crashes, speed and enforcement described above apply to the systems currently in place in New Zealand. Using these models in a predictive sense outside the range of the speeds and ticketing rates evaluated, or with major changes to the enforcement environment may generate invalid conclusions. As one example, it is unlikely that this model would apply at very low or very high ticketing rates. At very low annual ticketing rates, speeds will be largely unaffected. One would expect that there would be a natural lower limit of speed behaviour if the speed countermeasures were highly effective. This limit would occur at the point where speeds became very close to the speed limit or the tolerance. This would result in ticketing levels consolidating at a level at which these speeds are sustained. There is no sign that NZ has reached this point, which would be outside the range of the existing data.

6. CONCLUSION

New Zealand's enforcement programme has been associated with significant reductions in open road speeds and injury crashes. Further analysis is planned to investigate changes in speeds and injury crashes on State Highways and in urban speed zones. Sub-national breakdowns of data may also be possible.

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Keywords

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