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

L. J. Povey, W.J. Frith and M. D. Keall

Land Transport Safety Authority

June 2003

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

L. J. Povey, W.J. Frith and M.D. Keall, Land Transport Safety Authority, June 2002.

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 that 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), visible speed camera activity and the introduction 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 10 000 speed camera infringements and 10 000 other speed infringements respectively. Higher reductions, of 1.1% and 1.6%, were found in the 85th percentile speeds.

The relationship between vehicle speeds and crashes was also examined. 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 assumed to apply 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 in New Zealand in 1993. The effect of speed cameras on speeds and crashes in New Zealand was examined by Mara et al (1996). 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, a 10.9%

reduction in crashes was estimated at rural speed camera sites and a 23% reduction in crashes at urban sites. 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 control (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 control speeds 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.

1.1 Speed enforcement in New Zealand

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. Non-camera infringement notices are delivered to the driver immediately. Speed camera photos are centrally processed. In 2000-2001, 99% of speed camera infringement notices reached the driver within 14 days of the photograph being taken.

In recent years various additional enforcement programmes have been introduced. Three major programmes that are designed to affect speed are described below.

Supplementary Road Safety Package: This package of high intensity publicity and enforcement programmes was introduced late in 1995 and is still continuing. 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. The amount of road safety advertising has not changed over the period examined here.

Hidden camera trial: A trial of hidden speed cameras was carried out from July 1997 to May 2000 in the then Midland Police Region, which consisted of the Waikato, Bay Of Plenty and part of the current Eastern Police Districts. A net reduction of 11% in injury crashes and 19% in injuries on open roads across the region was found (Keall et al, 2002), associated with the hidden cameras, over and above the effects of the existing speed camera programme.

State Highway Patrol: 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 (associated with reduced tolerances) and from increased Police visibility.

2 Data

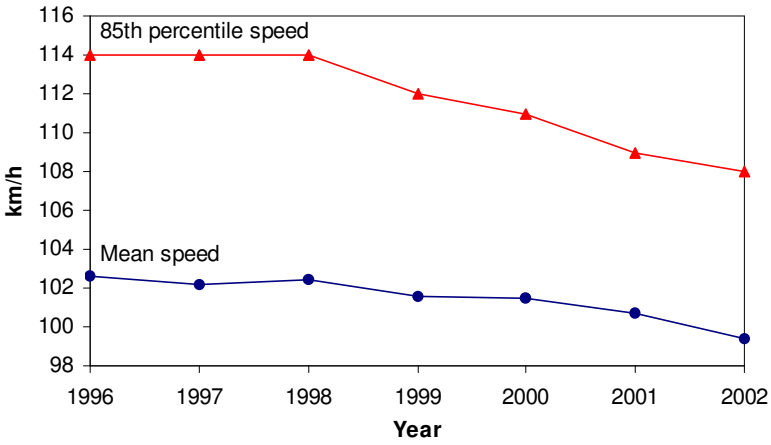
2.1 Study region

Because of the additional effect of the Hidden Camera Trial on speeds and crashes in the Midland Region, this analysis was restricted to areas outside the former Midland Police Region. The study region was all New Zealand open roads excluding the Waikato, Bay of Plenty and Eastern Police Districts.

2.2 Speeds

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 am or 2 and 4 pm, 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 were 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 (see Fig 1), and shows decreasing speeds, particularly from 1998 to 2002.

Figure 1: Open road free speeds (cars), NZ excluding Waikato, Bay of Plenty and Eastern Police Districts.



2.3 Speeding Infringements

2.3.1 Speed camera infringements

Data including the number of tickets issued by speed cameras were provided by the Police Infringement Bureau. The speed limit zone and the number of vehicles passing the camera in each 5km/h speed band were also recorded.

2.3.2 Other infringements

The number of infringement notices issued by Police, other than speed camera infringements, was provided by the Police Infringement Bureau. The data included the speed limit and number of kilometres above the speed limit (in 5km/h bands).

2.4 Crashes

The analysis was based on reported injury crashes, obtained from the LTSA's Traffic Crash Reporting database. Only crashes occurring 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 model. All reported injury crashes in the study region between these hours were included. 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. Throughout this paper the term "injury" or "injury crash" includes fatalities and fatal crashes.

2.5 State Highway Patrol

The deterrent effect of the State Highway Patrol on speeds is generated both by increased (non-camera) ticketing and by visibility. Any increase in the number of tickets issued will be accounted for in the model. A variable called SHP was included in the speed model to take into account any additional effect on speeds associated with the State Highway Patrol. The variable SHP took the value 0 prior to 2001, 1 during 2001 (the transitional phase) and 2 thereafter.

2.6 Perception of risk of being caught

A survey of New Zealanders' attitudes to road safety and enforcement is carried out annually by the LTSA (LTSA, 2002). Each year, 1645 people aged 15 and over are surveyed face to face in their own homes throughout New Zealand. The survey includes questions which enable tracking of changes in the perceived risk of being caught speeding.

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

$$\log(MeanSpeed) = \alpha + \beta_1\, camera\_tickets + \beta_2\, non\_camera\_tickets + \beta_3 state\_highway\_patrol + \beta_4\, fuel\ prices + \varepsilon_i \qquad \text{(Equation 1)}$$

where *MeanSpeed* is the winter open road mean speed as described above, *camera_tickets* and *non_camera_tickets* are the number of speed camera and non-speed camera speeding infringements issued in the previous January to June period, *state_highway_patrol* has the value 0 prior to 2001, 1 in 2001 (transition year) and 2 in 2002, *fuel prices* is the September quarter index from the Statistics New Zealand quarterly petrol price index series, α is an intercept term, β_1 to β_4 are constant coefficients and the errors ε_i are assumed to be normally distributed.

In some years there was a considerable increase in the number of tickets issued per month. Enforcement data series were restricted to the period January to June of each year, to relate speeds more closely to the level of enforcement current at the time of the survey. Traffic volume was not included in the model. 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.

New Zealand has a long history of speed creep, and speeds are currently below levels 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.

New Zealand Police apply an enforcement tolerance which in recent years has been 10km/h over the speed limit. This tolerance is well publicised and speeds of between 101km/h and 110 km/h are rarely penalised. For this reason, the speed measures examined here included the percentage of cars with measured speeds of 111km/h and above.

3.2 Speed – crash relationship

The relationship between mean speeds and crashes was modelled as

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

where *Crashes* is the number of crashes in the study region during low alcohol hours, *Mean_speed* is the winter open road mean car speed, *Year* is a trend term to capture gradual changes in such things as vehicle safety, road engineering and occupant protection, α is an intercept term, β_1 to β_4 are constant coefficients and the errors ε_i are assumed to be Poisson distributed. As the presence of the State Highway Patrol was found to be highly correlated with speeds, SHP was not included separately in the model.

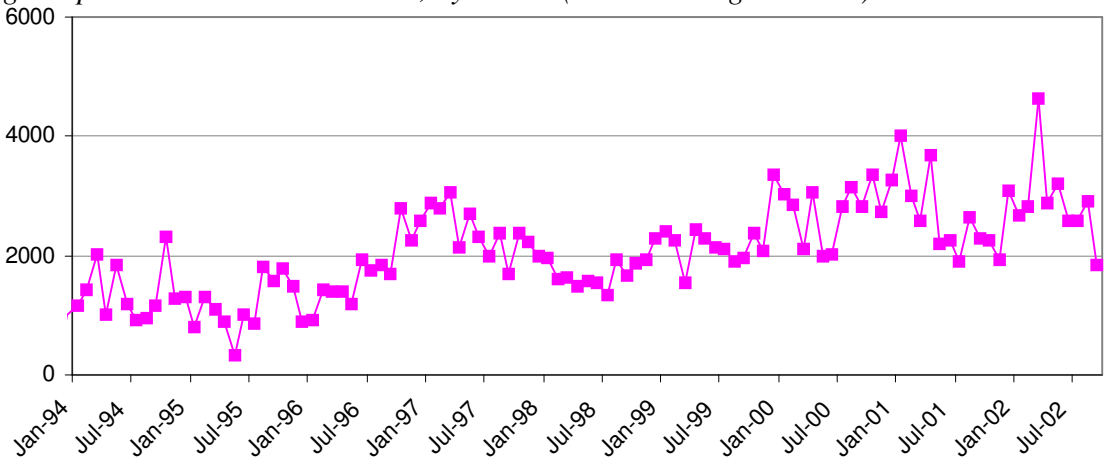
The relationship between speed and injuries (including deaths) was modelled similarly. Because injuries are clustered within crashes, the errors were assumed to follow a negative binomial distribution, thus allowing the variance to differ from the mean.

4 Results

4.1 Speed camera enforcement

Figure 2 shows the number of speed camera tickets issued, by month. There is no evidence of an annual cycle in camera activity.

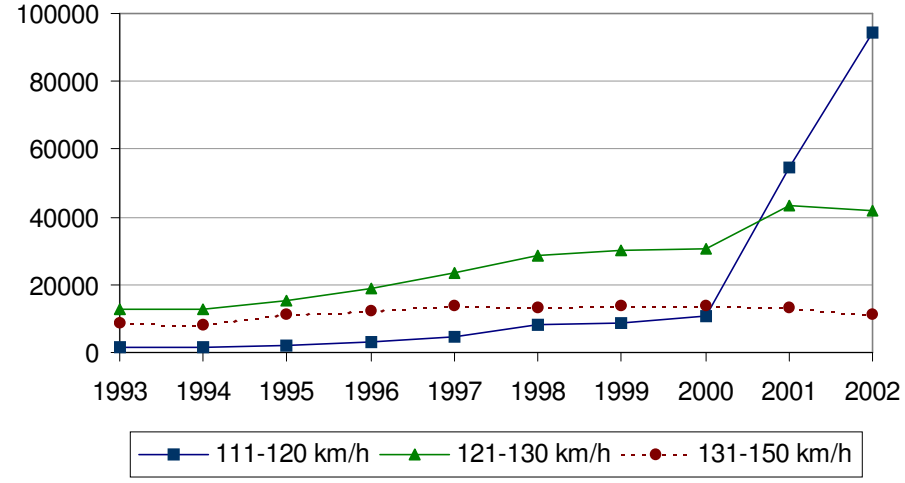
Fig 2: Speed camera tickets issued, by month (NZ excluding Midland)



4.2 Non-camera tickets issued

Figure 3 shows a recent large increase in the number of tickets issued to vehicles travelling between 111 and 120 km/h, from just over 10 000 in 2000 to more than 90 000 in 2002. The number of tickets issued to vehicles travelling at 110km/h or less is too small to show on this graph. This has increased in the last two years, from fewer than 20 in 2000 and earlier years to 160 in 2001 and 304 in 2002.

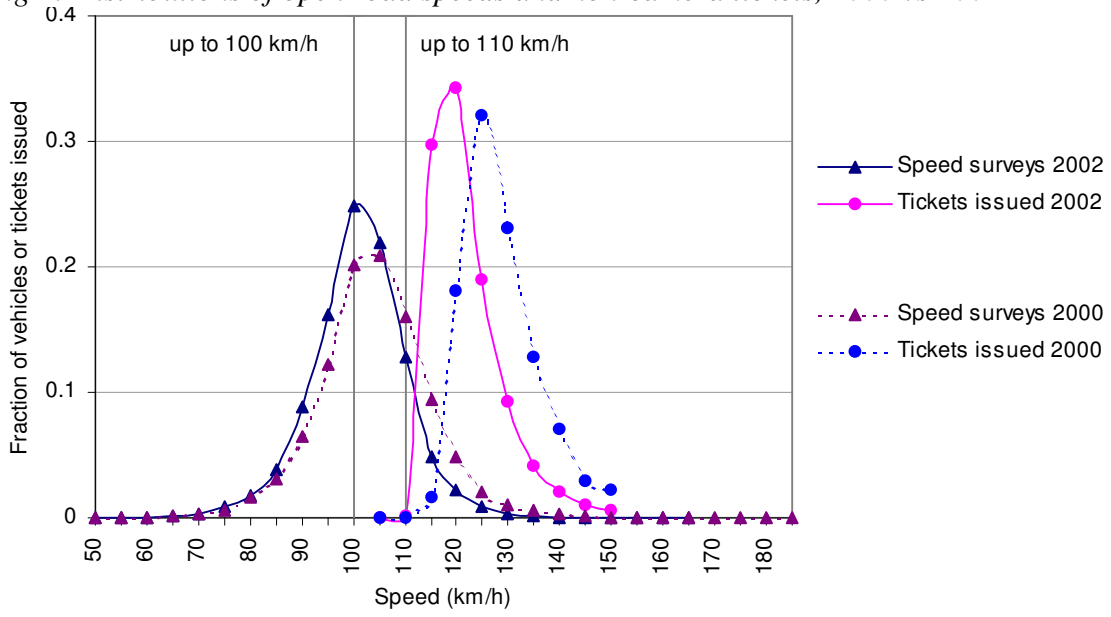
Fig 3: Non-camera speeding tickets issued in 100km/h zones, by vehicle speed (annual, whole of New Zealand)



4.3 Changes in the speed distribution

Figure 4 shows the (non-camera) ticketing and speed distributions on the same scale. As seen in figure 3 above, the distribution of tickets issued has changed markedly between 2000 and 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.

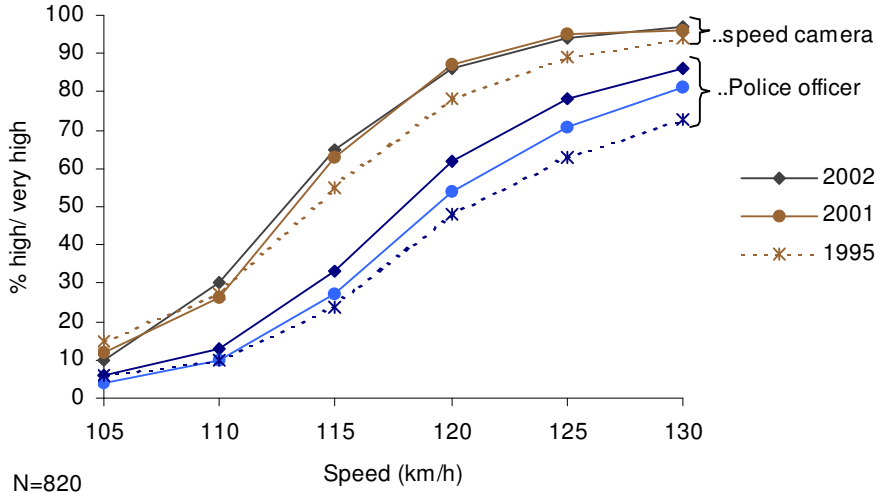
Fig 4: Distributions of open road speeds and non-camera tickets, 2000 vs 2002



4.4 Changes in perceived risk of being caught

Figure 5 shows responses to a series of questions designed to measure respondents' perceptions of the risk of being caught while speeding. Respondents were asked to estimate their chances of getting a speeding ticket if they drove past *either* a speed camera or a Police officer without a camera, while driving at each of six given speeds.

Fig 5: Perceived risk of being caught if passing a speed camera or Police officer at various speeds

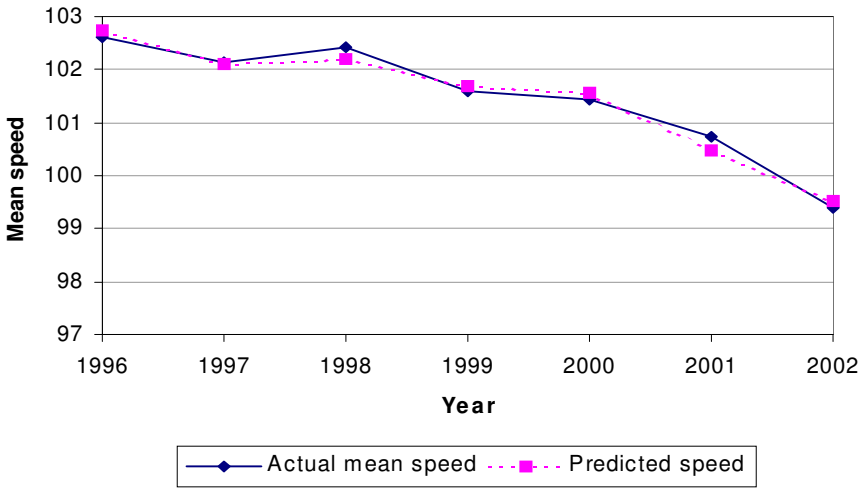


4.5 Modelling the relationship between speed and enforcement

The model described in section 3.1 was fitted to the 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 indicated no problems with the fit of the model. Figure 6 shows a comparison of the actual and predicted mean speeds.

Fig 6: Comparison of actual and predicted mean speeds



The advent of the State Highway Patrol is highly correlated with the increase in non-camera tickets issued. A variable to indicate the presence of the State Highway Patrol, which was

initially included in the model to test whether there was an additional non-ticket effect due to Police visibility, was not found to add significant information.

It was hypothesised that speeds might be affected by changes in fuel prices. The Statistics NZ fuel price index for the September quarter of each year was included in the initial model. No evidence of an effect on the open road mean speed was found.

Table 1:Estimated change in open road mean speed for every 10 000 tickets issued 1996-2002

	Estimated change in open road mean speed	95% confidence interval
Per 10 000 non-camera tickets	-0.8%	(-1.0%, -0.6%)
Per 10 000 speed camera tickets	-0.7%	(-1.2%, -0.1%)

4.6 Higher speed vehicles

The results of fitting the same model to the percentage of vehicles travelling at speeds over 110 km/h are shown in Table 2, using data from 1996-2002.

Table 2: Estimated change in percentage of vehicles travelling at more than 110km/h, for every 10 000 tickets issued 1996-2002

	Estimated change in %vehicles over 110km/h	95% confidence interval
Per 10 000 non-camera tickets	-23%	(-28%, -18%)
Per 10 000 speed camera tickets	-11%	(-22%, 2%)

Table 3: Estimated change in 85th percentile speed, for every 10 000 tickets issued 1996-2002

	Estimated change in 85th percentile speed	95% confidence interval
Per 10 000 non-camera tickets	-1.6%	(-2.3%, -0.9%)
Per 10 000 speed camera tickets	-1.1%	(-3.1%, 1.0%)

4.7 Speed-crash relationship

The model described in section 3 was fitted to the series of open road injury crashes in low alcohol hours from 1996-2002. Waikato, Bay Of Plenty and Eastern Police districts were excluded from the analysis. 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 reduction in crashes of 6% per year was also found.

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 4. A significant decrease in injuries was found, associated with changes in mean speeds. Numbers of fatal and serious crashes and injuries were too small to enable detection of an effect associated with changes in the mean speed.

Table 4: Estimated change in open road injury crashes and injuries during low alcohol hours, NZ excluding Midland

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%	(-18%, -6%)	- 7%	(-10%, -3%)
…fatal & serious injury crashes	- 7%	(-17%, 3%)	- 3%	(- 8%, 3%)
…fatal & serious injuries	- 7%	(-18%, 6%)	- 3%	(- 9%, 4%)

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 tickets, particularly to vehicles travelling at speeds between 111 and 120 km/h. Enforcement activity has been accompanied 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. The shift in perceptions coincides with a reduction in open road speeds, providing evidence of this 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. As the percentage changes are small, an additive (linear) model yields very similar results over this range of data.

Both mean and 85th percentile speeds have shown a significant decrease associated with the increase in enforcement activity. Over the period studied, the mean speed decreased by 0.8% for every 10 000 non-speed camera tickets issued, and by 0.7% for every 10 000 speed camera tickets issued. (That is, if the number of camera tickets was held constant, and the number of non-speed camera tickets increased by 10 000, we would predict a 0.8% decrease in the mean speed, and similarly a 0.7% decrease in the mean speed if the number of camera tickets increased by 10 000 with no change in non-speed camera tickets.) Vehicles travelling at higher speeds were the most affected, with a reduction in the 85th percentile speed of 1.6% for every 10 000 non-camera tickets 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 reduction of 12% in injury crashes and 13% in injuries and deaths was found to be associated with a 1km/h reduction in mean speed. This 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, lower-volume roads studied by Nilsson. It is expected 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 speeds and ticketing rates evaluated, or with major changes to the enforcement environment, is invalid and may generate nonsensical 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 strategy were 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. The effect of enforcement is a function of many factors, including the number of enforcement hours taken to issue tickets, locations on the network where the activity takes place, and the speed thresholds at which tickets may be issued. In this paper, these issues are not directly addressed, but all are legitimate areas for investigation. Further refinement of this analysis is planned.

7 Acknowledgements

Thanks to Paul Phipps for the graph of the speed and non-camera ticket distributions, and to Malcolm Benseman of the Police Infringement Bureau for supplying enforcement data.

8 References

Cameron, M.H., Cavallo, A., & 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.* Monash University Accident Research Centre, Report Number 42. Clayton, Victoria.

Corbett, C. (1995). Road traffic offending and the introduction of speed cameras in England: The first self report survey. *Accident Analysis and Prevention*, 27(3), 345-354.

Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record*, 1595, 14-19.

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

Kloeden, C.N., McLean, A.J., Moore, V.M. & Ponte, G. (1997). *Travelling speed and the risk of crash involvement*. NHRMC Road Accident Research Unit, University of Adelaide.

Kloeden, C.N., Ponte, G. & McLean, A.J. (2001). *Travelling speed and the risk of crash involvement on rural roads*. Road Safety Report CR204, Australian Transport Safety Bureau.

LTSA (2002). *Public attitudes to road safety, highlights of the 2002 survey*. Land Transport Safety Authority, www.ltsa.govt.nz .

Mara, M.K., Davies, R.B. & Frith, W.J. (1996). Evaluation of the effect of compulsory breath testing and speed cameras in New Zealand. Roads '96: *Combined 18th ARRB Transport Research Conference and Transit NZ Land Transport Symposium*, Christchurch, NZ, 2-6 September 1996.

Newstead, S.V., Mullan, N.G. and Cameron, M.H. (1995). Evaluation of the speed camera program in Victoria 1990-1993. Phase 5: Further investigation of localised effects on casualty crash frequency. Report 78, Monash University Accident Research Centre.

Redelheimer, Donald A., Tibshirani, Robert J., and Evans, Leonard (2003). Traffic-law enforcement and risk of death from motor-vehicle crashes: case-crossover study. *Lancet*, 28 June 2003, **361**: 2177-2182.

SAS Institute (1996). SAS/Stat software changes and enhancements through release 6.11.

Zaal , D. (1994). *Traffic law enforcement: A review of the literature*. Monash University Accident Research Centre, report No 53. Prepared for Federal Office of Road Safety, Canberra and Institute for Road Safety Research (SWOV), The Netherlands.