MONASH University
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GENERALISED LINEAR MODELLING OF CRASHES AND INJURY SEVERITY IN THE CONTEXT OF THE SPEED-RELATED INITIATIVES IN VICTORIA DURING 2000-2002

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Abstract:

Generalised linear models of road trauma outcomes have been found to be a powerful way of representing the trends and variations over time and to explain the effects of influential factors such as countermeasure initiatives. This report covers their application to monthly casualty crash frequencies and injury severity outcomes in Victoria during 1998 to 2003. During 2000 to 2002, the mobile speed camera program in Victoria was changed by introducing "flashless" camera operations during daytime and other modifications to make the enforcement more covert and unpredictable, increasing the targeted camera operating hours from 4200 to 6000 hours per month, and reducing the speeding offence detection threshold in three stages. In December 2002, the thresholds for penalties applying to different levels of speeding offence were generally reduced by 5 km/h. Associated with the speed enforcement initiatives was a program of speed-related advertising known as the "Wipe Off 5" campaign launched in early August 2001 without specific reference to the enforcement changes. A subsequent announcement took place in late November 2001 specifically mentioning the more covert speed camera operations as well as the increase in camera hours. A third announcement took place in the print media at the end of March 2002, emphasising that the former 9 km/h speeding tolerance no longer applied. As well as the enforcement changes, the statistical models included the reduced urban speed limit in January 2001, the penalty restructure, the speed-related advertising and the announcements, plus the impact of the fixed speed camera controversy that arose in late 2003.

The study concluded that generalised linear modelling of crash outcomes as a function of potential explanatory factors needs realistic assumptions to be made about viable functional forms connecting a measure of each factor and the outcomes. The assumed functional form of the relationship between monthly speed camera hours and road trauma appears to represent this relationship well. There is doubt that the flashless speed camera initiative and the enforcement threshold reductions have been adequately represented in the monthly crash outcome models. It was concluded that the effect of these initiatives on crash outcomes is unknown at this stage. The assumed functional form of the relationship between monthly speed-related advertising levels and road trauma appears to represent this relationship well. The speed-related television advertising had a statistically significant association with a decrease in monthly casualty crash frequencies during times of increased advertising levels. In general the relationships connecting speed camera hours and levels of speed-related advertising with road trauma reductions in Victoria confirmed previous research on the effectiveness of these road safety programs as operated in the State.

Key Words:

Crash models, speed, enforcement, camera, flashless, hours, threshold, tolerance

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PREFACE

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EXECUTIVE SUMMARY

Generalised linear models of road trauma outcomes have been found to be a powerful way of representing their trends and variations over time and to explain the effects of influential factors such as countermeasure initiatives. Newstead (2005) has applied Poisson log-linear models to crash frequencies in a number of quasi-experimental design evaluations, and logistic regression models to injury severity categories of crash outcomes in studies of vehicle safety design and occupant injuries.

This report covers the application of generalised linear modelling to monthly casualty crash frequencies and injury severity outcomes in Victoria during 1998 to 2003. This period included the introduction of three speed enforcement initiatives during 2000-2002, plus a number of related changes in the area of urban speed limits, speeding offence penalties, mass-media advertising about speeding, and controversies which arose about fixed speed cameras near the end of 2003. The study attempted to include the likely effects of each of these factors in the generalised linear models, but required many assumptions about the mechanisms and timing of the effects on crash outcomes.

Another report presents the evaluation of the overall impact of the Victorian speed-related initiatives on casualty crashes and their fatal outcome during 2001 to 2004 (D'Elia, Newstead and Cameron 2006). An earlier report considered the effects on driver perceptions of speeding and speed enforcement, by examining community attitudes surveyed in October 1999 and October 2002 (Smith and Senserrick 2004).

Speed-related initiatives

During 2000 to 2002, the following changes were made to the mobile speed camera operations in Victoria:

- Staged introduction of "flashless" camera operations during daytime from December 2000, commencing in some Police Divisions, until December 2001 when it was implemented in all Divisions (following short trial periods in selected Divisions during 1999 and 2000). There was also increased use of a variety of unmarked cars, and use of new locations and times of day, all aimed at making the enforcement more covert and unpredictable to speeding drivers.

- Staged increase in camera operating hours from August 2001 to February 2002 (from 4200 to 6000 target hours per month).

- Progressive reduction in the speeding offence detection threshold from 10 km/h in excess of the speed limit in each speed zone, in steps of 1-2 km/h and at different times in each Police Region, during March to September 2002.

In addition, there was also the introduction of the 50 km/h default urban speed limit in January 2001 and, in mid-December 2002, the thresholds for penalties applying to different levels of speeding offence were generally reduced by 5 km/h.

Associated with the speed enforcement initiatives was a program of speed-related advertising carried out by the Transport Accident Commission (TAC) known as the "Wipe Off 5" campaign. This was launched in early August 2001 without specific reference to the enforcement initiatives. A subsequent announcement took place in late November 2001 and specifically mentioned the more covert speed camera operations as well as the increase in camera hours. A third announcement took place in the print media at the end of March 2002, emphasising that the former 9 km/h speeding tolerance no longer applied without giving details of the new level. The media interpreted the change as 3 km/h tolerance.

Previous research has shown that road safety announcements can have an effect on crashes in the short-term, in addition to the effects of any initiatives they are announcing. For this reason, the study included the possibility of announcement effects of one month duration in August and December 2001 and in April 2002. The influence of TAC television advertising with speed-related themes was also included. Previous research has shown that the effect on crashes is related to awareness of the advertising, measured by a function (Adstock) of television rating points. During the period, TAC speed-related advertising used emotive, instructive and enforcement-related messages. The effects of each of these styles of advertising were considered separately and in total.

The analysis initially considered crash outcomes to the end of 2002, followed subsequently by an extended analysis to the end of 2003. The analysis was extended principally to include any longer term effects of the reduced speed offence detection thresholds, as well as to examine the effects of including additional crash data in the generalised linear models. The extended analysis also included the changed structure of speeding penalties, the announcement of the penalty restructure made in September 2002, and the high-profile fixed speed camera controversy which arose publicly in November 2003.

Method

Some of the speed-related changes had been the subject of previous research in Victoria (speed camera activity and TAC advertising levels), so there was good understanding of the likely mechanisms which connect such changes with reductions in road trauma levels. Other changes (e.g., flashless camera operations and reduced speed enforcement threshold levels) were unprecedented in Victoria and it was necessary to speculate on their possible mechanisms of effect on speeds and road trauma in order to include these initiatives in the statistical models. Other factors included in the models (e.g., announcements of the initiatives) also suffered from the limited knowledge of their possible effects, and that knowledge was generally based on research from other jurisdictions. Against this background, this attempt to use generalised linear modelling to represent road crash outcomes in Victoria as a function of these and other relevant factors was ambitious.

Monthly casualty crashes and their injury severity outcome were analysed over the years 1998-2002 (and later the years 1998-2003) in the five Police Regions and 23 Divisions. The analysis also took into account the level of crashes associated with each Police area, seasonality, year and their interactions.

Poisson Regression was used to analyse the effects of the initiatives and other factors on casualty crash frequency, and Logistic Regression was used to analyse the effects on the injury severity of the casualty crashes. The severity was measured in two ways: (i) the proportion of casualty crashes which were fatal, and (ii) the proportion resulting in death or serious injury. The first of these crash severity criteria was more sensitive to the effects of the speed-related initiatives on the injury outcome of the crashes.

To test its ability to explain the variation in the casualty crash frequency and severity, the monthly hours of speed camera operation in each Region and Division were included in the regression models in continuous form, rather than in categories of levels. A logarithm transformation of the hours was used, with a negative coefficient expected to be estimated by the analysis. This was done because previous MUARC and overseas research had found that increases in speed camera activity are associated with diminishing returns as far as crash reductions are concerned. The coefficient of the logarithm-transformed camera hours measures the "elasticity" between the camera hours and crash outcomes.

All other initiatives and factors included in the regression models were analysed in categorical form. The effect of the introduction of flashless cameras was represented by a step function in the Region-Division and month in which it commenced, with the effect presumed to apply until end 2002 (at least). The first, second and third stages of the offence threshold reductions were represented by separate step functions (each relative to no threshold reduction) in the Region and from the month in which the reduction commenced, until the start of the next reduction in threshold or until the end of the analysis period.

Each of the three speed enforcement initiatives was expected to lead to an increase in the number of Traffic Infringement Notices (TINs) detected by speed cameras, at least in the short term until driver speed behaviour adapted to the new enforcement level. Previous MUARC research (Cameron, Newstead, Diamantopoulou and Oxley 2003) had shown that casualty crashes in a police district were reduced in the month following increases in the number of speeding TINs detected in the same district during a given month. The risk of fatal outcome of the casualty crashes was also reduced substantially in the following month. These delayed effects were considered to be due to the time lag in the issuing of TINs from the date the offences occurred, and the residual effect of TIN receipt over the following weeks. For these reasons, in this study the regression models analysed the effects of each speed enforcement initiative on the casualty crash frequency and severity in the month following that in which the camera hours occurred, or the flashless operation or threshold reduction applied.

The awareness of speed-related advertising, measured by Adstock of television rating points, was included in the analysis in two ways. In the initial analysis, Adstock was considered in categorical form, with the impact on crash outcomes measured relative to low levels of Adstock. Adstock was also considered in continuous form, with a logarithm transformation, in the initial analysis and only in this form in the extended analysis. This alternative, albeit less-conservative, representation of the potential effect of speed-related advertising on crashes was considered because previous research in Victoria and Queensland had provided evidence of such a functional relationship.

Results and Conclusions

Prior to the crash analysis, the changes in outputs from the mobile speed camera program were examined. Trends in speed offence detection rates and TINs issued provided indications of speeding behaviour changes. Six-monthly surveys of travel speeds by VicRoads also indicated trends. These behavioural outcome measures supported the development of the generalised linear models of the crash outcomes in Victoria. The study reached the following conclusions:

- Generalised linear modelling of monthly crash outcomes as a function of potential explanatory factors needs realistic assumptions to be made about viable functional forms connecting a measure of each factor and crash frequency and/or crash severity. The assumptions should ideally be based on previous research connecting the implementation (and, where possible, the level) of the factor with likely mechanisms of effect and the timing of the effect on road trauma. Alternatively, resources should be provided for the crash outcomes modelling to investigate a range of potential mechanisms and timings.

- The assumed functional form of the relationship between monthly speed camera hours and road trauma, included in each of the casualty crash frequency and crash severity models, appears to represent these relationships well.

- There is doubt that the flashless speed camera initiative has been adequately represented in the monthly crash outcome models. The effect of flashless operation, if it exists, has been necessarily diluted, an assumption has been made about its immediacy, and the potential interaction with the effect of the increased speed camera hours has not been taken into account. It was concluded that the effect of flashless operations on crash outcomes is unknown at this stage.

- There is doubt that the enforcement threshold reductions have been adequately represented in the monthly crash outcome models. The appropriate conclusion is that the effect of the threshold reductions is unknown at this stage because of substantial uncertainty about the timing and mechanism of effect.

- The assumed functional form of the relationship between monthly speed-related advertising levels and road trauma, included in the crash frequency model, appears to represent this relationship well. Adstock, a function of current and previous television rating points (TARPs), represents the retained awareness of advertising levels, which in turn appears to be related to casualty crash risks in the same period.

- The speed-related television advertising had a statistically significant association with a decrease in monthly casualty crash frequencies during times of increased advertising levels. During 2001-2002, when the speed enforcement initiatives were introduced, this effect appeared to be mostly due to the instructive style advertising, which was predominant in that period. When the 2003 crash data was added to the analysis, the evidence was weaker but all three styles of speed-related advertising (instructive-, emotive- and enforcement-style) appeared to have an association with decreased crash frequencies.

- The estimation of the announcement effects, if they exist at all, was influenced by the method of representing the effect of the speed-related advertising. Intensive mass-media publicity followed each announcement and, when the advertising was represented by monthly Adstock as a continuous variable, the announcements had no statistically significant association with crashes.

- The introduction of the 50 km/h default urban speed limit was statistically significantly associated with a reduction in casualty crashes. While this effect was consistent with the results of the specific evaluation by Hoareau et al (2002, 2006), doubt remains whether this initiative has been adequately represented in the crash outcome models.

1 INTRODUCTION

Generalised linear models of road trauma outcomes have been found to be a powerful way of representing their trends and variations over time and to explain the effects of influential factors such as countermeasure initiatives. Newstead (2005) has applied Poisson log-linear models to crash frequencies in a number of quasi-experimental design evaluations, and logistic regression models to injury severity categories of crash outcomes in studies of vehicle safety design and occupant injuries.

This report covers the application of generalised linear modelling to monthly casualty crash frequencies and injury severity outcomes in Victoria during 1998 to 2003. This period included the introduction of three speed enforcement initiatives during 2000-2002, plus a number of related changes in the area of urban speed limits, speeding offence penalties, mass-media advertising about speeding, and controversies which arose about fixed speed cameras near the end of 2003. The study attempted to include the likely effects of each of these factors in the generalised linear models, but required many assumptions about the mechanisms and timing of the effects on crash outcomes.

Inspiration for the study was obtained from an analysis of Queensland crash trends to evaluate the Road Safety Initiatives Package involving substantially increased hours of speed camera operation, increased hours of on-road Police enforcement to target key behaviours, increased mass-media publicity, and increased hours of Police educative activities (Newstead, Bobevski, Hosking, Delaney and Cameron 2004). Poisson regression models of crash frequencies were successfully developed incorporating a number of measures of the Police activity, mass-media publicity, relevant socio-economic factors, and seasonality and trend. Alternative models were also developed to measure the overall impact of the Package. There was good congruence between the estimated overall impact and the estimated effects on crashes of the package components, when considered cumulatively.

Another report presents the evaluation of the overall impact of the Victorian speed-related initiatives on casualty crashes and their fatal outcome during 2001 to 2004 (D'Elia, Newstead and Cameron 2007). An earlier report considered the effects on driver perceptions of speeding and speed enforcement, by examining community attitudes surveyed in October 1999 and October 2002 (Smith and Senserrick 2004).

2 BACKGROUND

2.1 The problem of speeding and factors attributed to speed choice

The term 'speeding' is used to refer to driving at a speed that is considered too fast for the prevailing conditions or at a speed greater than the posted speed limits (Zaal, 1994). Speeding has been recognised as an important factor in accident severity and accident causation. There is substantial research evidence linking speed to crash casualty and injury severity (Fildes & Lee, 1993; Zaal, 1994; Garber & Gadiraju, 1989). The energy expended at the time of impact is a function of the mass of the vehicle multiplied by the velocity squared, thus slight increases in speed lead to a much greater increase in the kinetic energy to be dissipated in a crash. Therefore the greater the speed of the vehicle, the greater the likelihood of injury, severe injury, or death (Cowley, 1987). The link between accident causation and excessive speed is less clear, although speed has been shown to play a contributory role in at least a proportion of accidents. In an extensive literature review, Fildes and Lee (1993) concluded that excessive speed was a factor in 12%-16% of motor vehicle accidents. Furthermore, Cooper (1997) reported that drivers who had committed 'excessive speed' violations, as opposed to exceeding the speed limit violations, were found to have twice the overall crash rate of drivers who exceeded the limit, as well as twice as likely to have unsafe speed associated with their crash involvement.

Both personal and environmental factors have been found to contribute to speeding. An investigation of the personal characteristics associated with driving speeds (Harrison, Fitzgerald, Pronk, & Fildes, 1998) found that faster drivers felt more comfortable driving at relatively high speeds, had a history of speeding, believed that other drivers were travelling relatively fast, were less likely to rate high speeds as dangerous, were more tolerant towards a range of illegal behaviours, and believe themselves to be safer than other drivers. Environmental factors, such as speed limits and road factors have also been found to be influential in speed choice (Harrison et al, 1998). A variety of countermeasures have been developed, including environmental traffic-management devices, punishment by way of fines, and publicity campaigns, aimed at changing community attitudes towards speed. Research evidence from evaluations of the various countermeasures has indicated that a number of factors, including various enforcement programs and public education programs, have contributed to the reduction of casualty crashes in Victoria (e.g. Cameron, Newstead, Diamantopoulou, & Oxley, 2003b; Newstead, Cameron, Gantzer, & Vulcan, 1995a; Newstead, Cameron, & Narayan, 1998). The most recent of these reviews by Cameron et al (2003b) examined the interaction between speed camera enforcement and speed-related mass media publicity in Victoria and is of special interest to the present study. The findings of Cameron et al's (2003b) study are summarised in a later section.

2.2 Speeding and enforcement

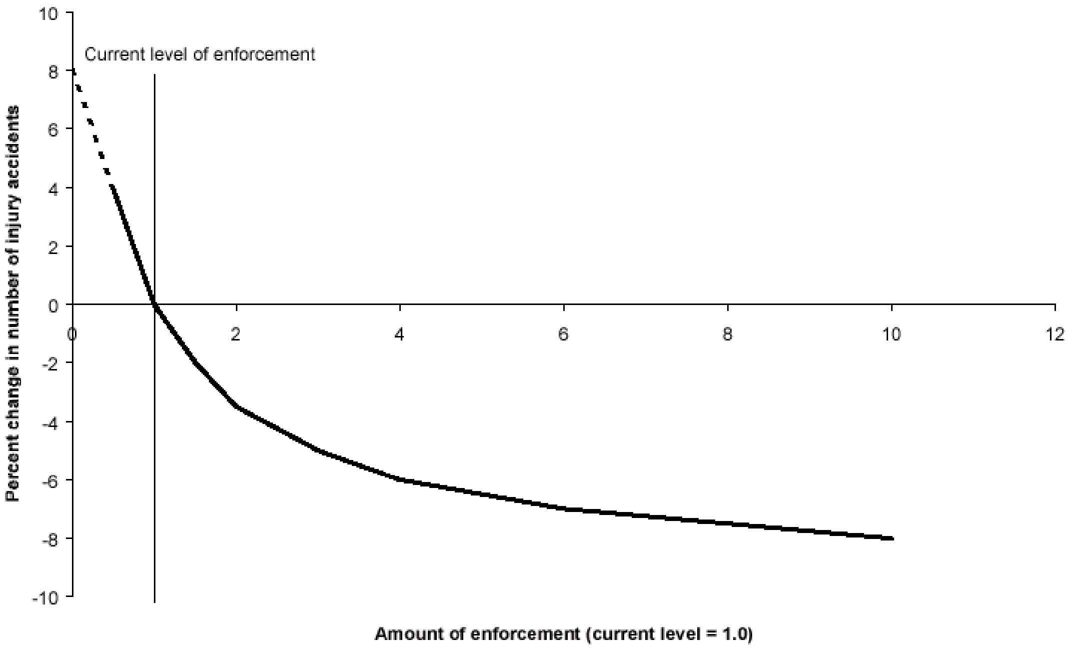
2.2.1 Enforcement mechanisms

Traffic law enforcement is defined as those activities which aim to control road user behaviour through preventative, persuasive, and punitive measures in order to effect the safe and efficient movement of traffic (OECD, 1974, cited in Zaal, 1994). The process of traffic enforcement consists of three main steps: legislation, traffic policing, and legal sanctions imposed (Rothengatter, 1990). It is the activities associated with traffic policing that are regarded as the central element of the enforcement system, as well as being the most visible and interactive aspects that form the basis for public opinion (Zaal, 1994). Traffic law enforcement methods are usually based on the mechanism of deterrence, the underlying aim of which is to modify drivers' behaviour by making them fearful of the consequences of committing an offence (Homel, 1988). Deterrence policies have so far been based on rational choice theory, which assumes that drivers will abide by the law if the expected utility of law-abiding actions is greater than the expected negative consequence of committing a particular offence (Palmer, 1977). Drivers are assumed to assess costs and benefits by weighing up three factors: the perceived risk of being caught; the fear of being caught; and the fear of the likely penalty or punishment. Thus deterrence policies aim to increase the perceived cost of offending while decreasing the perceived benefits by influencing the above three factors (Zaal, 1994). With regard to speed enforcement, it is the perceived risk of being caught, which has been identified as a crucial determinant in the decision to speed (Shinar & McKnight, 1985; cited in Zaal, 1994).

Traffic law enforcement is believed to influence driving behaviour using two processes: general deterrence and specific deterrence (Zaal, 1994). General deterrence is defined as the impact of the threat of legal punishment on the public at large. Specific deterrence is defined as the impact of a legal punishment on those who have suffered it (Homel & Wilson, 1987). According to Homel (1988), the effectiveness of general deterrence is based on having a level of enforcement that is sufficiently high and/or visible to create a perception among road users that there is a real possibility that a traffic offence will be detected. On the other hand, specific deterrence mainly has an influence on a smaller number of drivers that have received a notice or a penalty for an offence (Zaal, 1994).

Researchers have found that enforcement must be increased by a significant degree before changes in perception of enforcement occur (Ostvik & Elvik, 1990; Bjornskau & Elvik, 1992). Ostvik and Elvik (1990) have reported that increasing enforcement on a given road by less than three times does not have an impact on subjective risk of detection. A five-fold increase in enforcement has been found to increase the subjective risk of detection and to subsequently result in a reduction in the percentage of offenders and a reduction in crashes by 20-30% (Ostvik & Elvik, 1990). However, more recent research does not support the existence of marked threshold effects (Elvik, 2001). The relationship between the amount of enforcement and the number of injury accident appears to be quite smooth, with no sharp discontinuities (Figure 2.1). This relationship is non-linear. Some forms of enforcement have more powerful effects than others, but in every case the relationship with crash reductions is not linear. Because of this, there is a level of enforcement activity where the additional saving in crashes may not be worth the additional cost of extra enforcement (Gelb, Narayan, Diamantopolou, & Cameron, 2000).

Figure 2.1: General relationship between traffic enforcement and crashes (Elvik 2001)



2.2.2 Speeding related enforcement

Speed enforcement strategies, based upon the above principles of deterrence, aim to increase the risk of apprehension. The perceived risk of apprehension has been identified as a crucial determinant in the decision to speed (Shinar & McKnight, 1985). The perceived risk of detection tends to be increased when the actual probability of apprehension is increased through increased enforcement levels. Rothengatter (1982) found that increasing apparent enforcement without changing the actual levels of objective enforcement does not influence speed choice, whereas an actual increase in enforcement does have the effect of reducing speeds.

Both specific and general deterrence mechanisms are assumed to operate in speed enforcement. Specific deterrence is assumed to operate by discouraging drivers who have been apprehended and punished for speeding from re-offending. General deterrence is assumed to operate when drivers who are exposed to enforcement and informed about the risk of apprehension will modify their behaviour to avoid the risk of apprehension and its consequences (Zaal, 1994).

A comprehensive summary of the above enforcement issues can be found in Zaal (1994).

2.2.3 Speed enforcement in Victoria

Various methods of speed enforcement have been used in Victoria, invoking either one or both of the two deterrence mechanisms discussed above. Enforcement programs can be either overt or covert. Overt speed operations, which are designed to be highly visible, are thought to increase the perceived risk of detection, and thus to alter drivers' behaviour immediately in time and space. Covert operations, on the other hand, are designed to be 'invisible' in order to increase a perception that detection can occur at any location and at any time. Thus, covert operations are expected to have a more generalised effect than overt operations. Covert speed enforcement operations utilise unmarked vehicles, mobile camera units, and more recently also flashless and car mounted cameras. The cameras are operated at any one site only for short periods of time (Cameron et al, 2003a).

2.2.3.1 Covert operations with mobile speed cameras

The use of non-visible enforcement, such as unmarked cars, flashless cameras, and reductions in other aspects of the conspicuousness of the operation, acts to increase drivers' sense of uncertainty of when or where they will be detected and to prevent them from adapting their behaviour only to specific times and locations (Ostvik & Elvik, 1990). This type of enforcement is also expected to reduce the possibility that offenders will feel confident that vigilance will prevent them from being apprehended (Fildes & Lee, 1993).

Covert speed enforcement operations were introduced in Victoria in 1989, following poor results from an initial trial of an overt speed camera operation (Portans, 1988). The introduction of the covert program significantly increased the average number of infringement notices issued each month.

An evaluation of the Victorian covert operations (Cameron et al, 1992) between December 1989 and December 1991 revealed that the program had a significant effect on the reduction of crash frequency and severity. From December 1989 to March 1990, the program was found to have contributed to 15% reduction in low alcohol hour casualty crashes on arterial roads, coinciding with a period of low levels of both speed camera enforcement and speed-related publicity. Then from April 1990 to June 1990, when a publicity campaign was launched, low alcohol crashes were reduced by 34% on Melbourne arterial roads, and by 21% in country towns. Reductions in the level of injuries sustained in these crashes were also found in Melbourne during this period. From July 1990, following an increase in enforcement levels as well, low alcohol hour casualty crashes were reduced on arterial roads in Melbourne, country towns, and on rural highways by 32%, 23%, and 14% respectively. The injury severity of these crashes was also found to have decreased, although mainly in Melbourne (Cameron et al, 1992). Infringement notices and publicity were identified as driving mechanisms in the reductions of casualty crashes in Cameron et al's study. Crash frequency was related to the number of speeding infringement notices issued (generally 2-3 weeks after the offence date) and publicity levels in the same month. In regards to crash severity reductions, camera operating hours and the number of speed infringement notices were found to play a key role (Cameron et al, 1992).

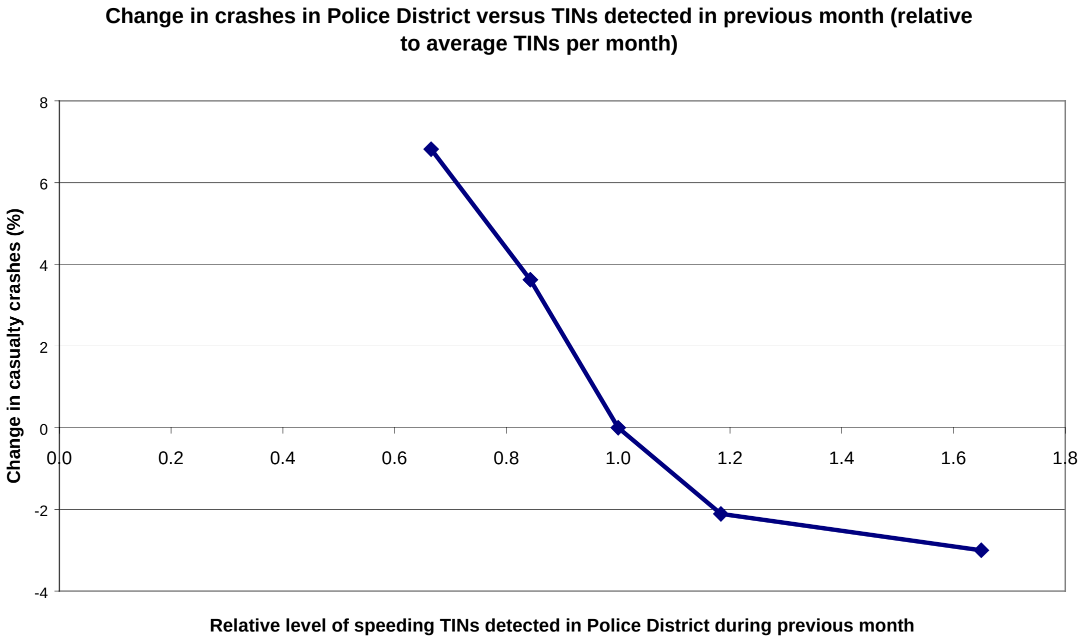
Rogerson et al (1994) also examined the impact of the mobile speed cameras program on speed. They found no significant change in mean speed from November 1989 to March 1990. However, the proportion of vehicles detected exceeding the speed limit by more than 15 km/h had decreased in 60 and 70 km/h speed zones during this period. This decrease was most evident in 60 km/h speed zones, with the proportion of vehicles exceeding the speed limit by more than 15 km/h dropping from about 11% to about 6%.

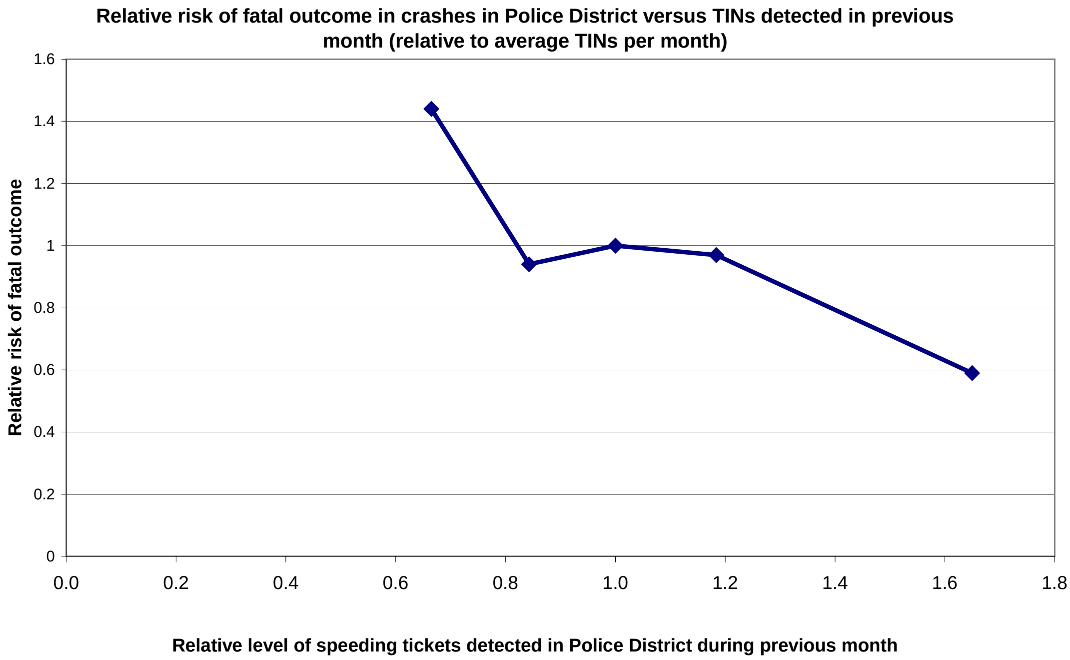
A later study of the covert program during the period from July 1990 to December 1993 (Newstead et al, 1995b) linked the casualty crash reductions in Metropolitan Melbourne to both camera operations and the receipt of infringement notices. The influence of infringement notices was evident during the three weeks following their receipt and was greatest during high alcohol hours. About 9% reduction in casualty crashes was experienced in high alcohol hours during the week following the receipt of infringement notices (Newstead et al, 1995b).

An update of the above analysis (Gelb et al, 2000), using data from January 1994 to December 1996, produced somewhat different results. Reductions in casualty crash frequency were no longer attributable to the issue of infringement notices. Moreover, the number of hours of cameras operation no longer had a positive effect on crash severity. However, crash severity was still related to the number of infringement notices issued (Gelb et al, 2000). This suggests that there may have been a change over time in the mechanisms behind the mobile speed camera program (Cameron et al, 2003a).

A more recent study by Cameron et al (2003b) has confirmed the key role of the number of speeding infringement notices detected on crash reductions in subsequent periods. During 1999, the Victoria Police varied the levels of speed camera activity substantially in four Melbourne police districts according to a systematic plan. Camera hours were increased or reduced by 50% or 100% in respective districts for a month at a time, during two separate months when speed-related publicity was present and during two months when it was absent. Monthly casualty crashes in the ten Melbourne police districts during 1996-2000 were analysed to test the effects of the enforcement, publicity, and their interaction. Monthly levels of speeding offences detected by cameras varied substantially over time in all districts, but the most extreme variations occurred in the four districts as planned. Changes in crash frequencies were found to be inversely associated with changes in the levels of speeding infringement notices detected in the same district during the previous month (Figure 2.2). This relationship is similar in shape to that identified by Elvik (2001), Figure 2.1. The risk of fatal outcome of the casualty crashes was also reduced by more than 40% when the level of speeding infringement notices detected during the previous month was at relatively high levels (65% greater than average) (Cameron et al, 2003b).

Figure 2.2: Relationships between crash outcomes and level of speeding Traffic Infringement Notices (TINs) detected by speed cameras (Cameron et al, 2003b)





Cameron et al (2003a) have summarised the main strategic principles emerging from the above research:

1. Even with low enforcement levels, high profile media activity can establish and maintain a threat of detection in the short term.
2. The intense, covert use of speed cameras can lead to long term reductions in low alcohol hour casualty crashes across a number of road types when accompanied by high profile publicity.

3. Mobile speed cameras also have a localised effect on high alcohol hour casualty crashes corresponding to the two-week period after the receipt of an infringement notice, but the exact duration of this effect is unknown.
4. The localised effect of the mobile speed camera program is also linked to the enforcement presence, although less strongly than to the receipt of a TIN.
5. The principal mechanism through which the mobile speed camera program achieves its effects on crashes is specific deterrence, operating through the actual detection and punishment of offenders.

Overseas studies of mobile speed cameras programs have been generally consistent with the research and emerging conclusions described above (e.g. in British Columbia, Canada (Chen et al, 2001); and in New Zealand (Mara et al, 1996)).

2.2.3.2 Number of hours of speed cameras operations

The number of hours of mobile camera operations plays an important role in speed enforcement. Increase in the number of hours of speed camera operation acts to intensify the level of enforcement. Increased enforcement levels are expected to result in an increased effectiveness of both general and specific deterrence for speeding. Greater enforcement efforts tend to result in a greater actual probability of detection and a higher number of apprehended drivers, and hence the greater the level of specific deterrence. Increasing the level of enforcement activity and informing the public via the media of the increased probability of detection is expected to result in greater levels of general deterrence (Zaal, 1994).

A target of 4200 hours of camera operations per month was initially set by the Victorian mobile camera program (Cameron et al, 2003a). This target was increased to 6000 hours per month in 2001, as will be discussed in the present study. Gelb et al (2000) conducted a study to evaluate whether the existing speed camera operations at the time, of about 4000 hours per month, were best practice. Gelb et al used a marginal cost/benefit analysis in terms of both hours of operation and issue of infringement notices. This analysis was limited to low alcohol hours in Melbourne and used crash data from 1987 to 1998, as well as data on the cost of running the program and the cost of casualty crashes on society in general. The analysis was based on issue of infringement notices, rather than on hours of cameras operation. Such analysis is likely to provide better estimates due to the greater variability of infringement notices issued per month. Gelb et al (2000) concluded that in order to reduce the social costs (of both cameras operations and casualty crashes), the number of infringement notices issued per month should fall within the range of 37,000 to 66,000. This corresponds to a range of 3,592 to 6,408 enforcement hours per month and an optimal average investment of 5,146 hours per month. This would be expected to result in a reduction in monthly levels of low alcohol hour casualty crashes of 13%. The program benefit cost ratio was estimated to be 6.3, meaning that by investing in about 5,146 camera hours per month the benefits obtained in reduced social costs per casualty crash would be 6.3 times the cost of investment (Gelb et al, 2000). Consistent with this economic analysis, Cameron et al's (2003b) research (described earlier in this report) found reductions in casualty crashes following at least 50% increase in camera hours in some Melbourne police districts in 1999.

2.2.3.3 Enforcement thresholds

Enforcement thresholds also play an important role in speed enforcement. An enforcement threshold is defined as the speed at or above which an infringement notice will be issued. In Victoria this speed is not identical to the posted speed limit and has changed over time. Another relevant aspect of speed enforcement is the speed tolerance, defined as the speed at which vehicles may travel without incurring a penalty. With the initial introduction of the speed camera program in Victoria, a speed tolerance of 10% of the speed limit plus 3 km/h was set. The 3 km/h allowance is a legislative tolerance because the speed camera technology may have an error of up to 3 km/h. The 10% tolerance was a discretionary tolerance adopted by the Victoria Police at that time. Therefore, in a 60 km/h zone, vehicles could travel up to the tolerance level of 69 km/h without receiving an infringement notice. In February 1993, 110 km/h speed limits were reintroduced for high quality freeways. To reduce the speed tolerance in these speed zones, a fixed 10 km/h enforcement threshold was introduced on all roads. In March 2002, Victoria Police announced further staged reductions of speed enforcement thresholds. However, the details of these reductions have not been widely publicised (Cameron et al, 2003a).

Thus, while the previous threshold was known the new one is not (Cameron et al, 2003a). Community surveys in Australia have found that in 60 km/h speed zones a speed of up to 65 km/h is considered "tolerable" (Mitchell-Taverner, 2000), so this had previously been taken as the maximum tolerated speed. Cameron et al (2003a) have estimated that if all drivers travelling of up to 6-10 km/h above the speed limit could be deterred, a reduction of up to 11% of serious casualty crashes in urban areas could be achieved.

The reduction of enforcement thresholds has not been previously assessed in Australia, but has been evaluated in Sweden. Andersson (1990) conducted a study to determine the impact of reducing tolerance levels while increasing penalties for speeding offences and implementing a speed-related publicity campaign in July 1987 in two Swedish cities (Halmstad and Jonkoping). The study also used four urban areas as control sites and measured speeds during 1986 and 1987. The study found that speeds in the treatment areas fell by approximately 0.8 to 1.2 km/h from 1986 to 1987. In contrast, in the control areas there was a slight increase of speed over the same period. Andersson (1990) suggests that the speed reduction was most likely due to the increased risk of detection caused by the lower enforcement thresholds, rather than the increased penalties or the publicity campaign. This conclusion was reached on the basis of surveys of drivers travelling through the treatment and control sites. One in three drivers reported driving slower than previously mainly due to the increased levels of police activity. Few drivers were aware of the new penalties, and only 10% of drivers who reported driving slower also reported that this was due to the publicity campaign (Andersson, 1990).

Cameron et al (2003a) concluded that reductions in enforcement threshold will increase the actual risk of detection. Then provided that this increase translates into an increase in the perceived risk of detection, reductions in the enforcement threshold may lead to positive safety outcomes.

The above conclusion is further supported by the impact of a reduction in the enforcement threshold in New Zealand. Prior to July 2000, the enforcement threshold was determined by the 85th percentile speed for each stretch of road covered by speed cameras. Following the introduction of a fixed 10 km/h enforcement tolerance applying across the road network in July 2000, the number of vehicles exceeding the speed limit at speed camera sites declined dramatically. Specifically, there was a 50% reduction in the proportion of vehicles detected exceeding the 10 km/h tolerance at camera sites in the six week following the introduction of the reduced tolerance (Robinson, 2001). This reduction has been sustained over time. The translation of this reduction in offence rates into improvements in road trauma has not been evaluated. However, the proportion of drivers travelling at over 110 km/h on rural roads (typically with 100 km/h speed limits) fell from 24-26% during 1997-1999 to 20% in 2000, 15% in 2001, and 10% in 2002 (Land Transport Safety Authority, 2003). Whether this reduction in speeding was solely due to the reduced enforcement tolerance is unclear (Cameron et al, 2003a).

2.3 Changes to the Victorian speed camera program, 2000-2002

During December 2000 to September 2002, the following changes were made to the mobile speed camera operations in Victoria:

- Staged introduction of "flashless" camera operations during daytime commencing in some Police Divisions from December 2000, until December 2001 in all Divisions (following short trial periods in selected Divisions during 1999 and 2000). There was also increased use of a variety of unmarked cars, and use of new locations and times of day, all aimed at making the enforcement more covert and unpredictable to speeding drivers.

- Staged increase in camera operating hours from August 2001 to February 2002 (from 4200 to 6000 target hours per month).

- Progressive reduction in the speeding offence detection threshold from 10 km/h in excess of the speed limit in each speed zone, in steps of 1-2 km/h and at different times in each Police Region, during March to September 2002.

In addition, in mid-December 2002, the thresholds for penalties applying to different levels of speeding offence were generally reduced by 5 km/h. While not an enforcement initiative, the increase in the penalties following detection, at most levels of speeding, could be expected to increase the effects of the speed enforcement changes, especially during 2003. Details of the penalty changes will be given in Section 2.3.2.

2.3.1 Supporting activities

Associated with the three speed enforcement initiatives was a program of speed-related advertising carried out by the Transport Accident Commission (TAC) known as the "Wipe Off 5" campaign. This was launched in early August 2001 without specific reference to the enforcement initiatives. A subsequent announcement took place in late November 2001 and specifically mentioned the more covert speed camera operations as well as the increase in camera hours. A third announcement took place in the print media at the end of March 2002, emphasising that the former 9 km/h speeding tolerance no longer applied without giving details of the new level. The media interpreted the change as 3 km/h tolerance.

Previous research has shown that road safety announcements can have an effect on crashes in the short-term, in addition to the effects of any initiatives they are announcing. The influence of TAC television advertising with speed-related themes was also likely. Previous research has shown that the effect on crashes is related to awareness of the advertising, measured by a function of television rating points.

2.3.2 Increase in penalties for speeding

In mid-December 2002, the thresholds for penalties applying to different levels of speeding offence were generally reduced by 5 km/h. The penalties applying before and after the change are given in Tables 2.1 and 2.2, respectively. The Victorian Government announced the proposed change in penalties three months before they came into effect, in early September 2002, but there is no record of a further announcement later in the year.

Table 2.1: Penalties for offences detected by speed cameras (and other speed enforcement methods) up to 15 December 2002

Offence	Fine	Demerit Points*	Licence Suspension
Speed in excess of speed limit by:			
1 – 15 km/h	$ 125	1	
16 – 29 km/h	$ 200	3	
30 – 39 km/h	$ 265	4	1 month
40 – 44 km/h	$ 360	4	4 months
45 – 49 km/h	$ 360	6	4 months
50 km/h or more	$ 430	6	6 months
Failing to nominate a driver of a corporate owned vehicle	$ 600		3 months (vehicle registration suspended)

* 12 points accumulated during any three year period leads to 3 months licence suspension or, at the driver's discretion, the option to remain demerit point free for the next year, but failing that a 6 months licence suspension

Table 2.2: Penalties for offences detected by speed cameras (and other speed enforcement methods) at 15 December 2002

Offence	Fine	Demerit Points*	Licence Suspension
Speed in excess of speed limit by:			
1 – 9 km/h	$ 125	1	
10 – 24 km/h	$ 200	3	
25 – 34 km/h	$ 265	4	1 month
35 – 44 km/h	$ 360	6	6 months
45 km/h or more	$ 430	8	12 months
Failing to nominate a driver of a corporate owned vehicle	$ 600		3 months (vehicle registration suspended)

* The penalties and options associated with the accumulation of demerit points remained unchanged.

2.3.3 Hypothesised effects of the changes

Modelling of the effects of these changes in reducing the frequency and severity level of crashes is the focus of the present study. A number of hypotheses about drivers' responses to these changes were developed to guide the crash analysis.

First, it is hypothesised that the increase in camera hours from 4200 to 6000 hours per month, and the expected subsequent increase in speeding infringement notices, would have resulted in crash reductions. This expectation is based on the previous findings (discussed earlier) suggesting that the principal mechanism through which the program achieves its effects is specific deterrence achieved through issuing infringement notices in large numbers (Cameron et al, 2003a).

Second, it is hypothesised that the implementation of more covert and less predictable camera operations would have contributed to additional crash reductions. This hypothesis is based on the Victoria Police trials of flashless camera operations, which showed that both the detection rate and the number of infringement notices issued increased by more than 50%. Similarly, the New Zealand trial showed at least a temporary increase in detection rate and an additional reduction on casualty crashes. A decrease in the predictability of camera presence is consistent with general deterrence principles and is likely to spread the general effect of the program in time and space. Thus, it is expected that these operational changes would have enhanced the effect achieved through the increase in camera operation hours (Cameron et al, 2003a).

Third, it is hypothesised that the reduction in the threshold of detection of speeding offences would have deterred additional speeding drivers and contributed to further reduction in crashes. A reduced threshold is expected to deter at least those drivers travelling between the old and the new thresholds. This expectation is consistent with the Swedish and New Zealand findings that speed reductions can be achieved through a reduction in the speeding threshold. However, the effect of the reduced threshold across the whole range of illegal speeds is unpredictable. It is possible that drivers travelling at speeds in excess of the old threshold may also have been influenced, even though the reduction in threshold is not relevant to their speed behaviour.

Fourth, it is hypothesised that the increased penalties may have added to the deterrent effect of the enforcement initiatives by increasing the threat of punishment when speeding at levels for which the penalties increased in December 2002. The penalties increased for speeds 10-15 km/h, 25-29 km/h and all categories at least 35 km/h in excess of the speed limit. However, there was no change in penalty for alleged speeds[1] in other speed ranges. It is possible that drivers travelling at speeds without increased penalties were deterred to a lesser extent by the change. Alternatively, drivers may have perceived that the penalties had generally increased, and/or applied at lower levels of speeding, and adjusted their speed behaviour generally.

[1] The alleged speed appearing on Traffic Infringement Notices for offences detected by speed cameras is 3 km/h less than the actual speed measured by the camera, and is the basis for setting the penalty applicable to the offence, not the detected speed. However, the enforcement threshold is related to the detected speed. Thus a speed 3 km/h less than the enforcement threshold can be the alleged speed.

2.3.4 Related road safety activities

On 22 January 2001, a default urban speed limit of 50 km/h was introduced in Victoria replacing the previous 60 km/h limit. This reduction in speed limit principally affected residential streets and collector roads in urban areas. The remainder of the urban road network remained zoned at 60 km/h or higher, indicated by (additional) signage. While this change technically applied only to the unsigned urban roads, it is possible that drivers may have changed their behaviour on other urban roads as well, perhaps due to confusion or uncertainty about where the new limit applied.

Commencing in April 2000, fixed speed cameras were installed in Melbourne's CityLink tunnels and at a limited number of sites on urban freeways. In November 2003, media reports expressed concern about the accuracy of the fixed cameras (but not the mobile cameras) and the Victorian Government announced that all fixed camera infringement notices would be withheld while the cameras were investigated. This controversy continued until May 2004 when the Government announced that all penalties from alleged offences detected by the fixed cameras would be refunded or reversed. While the operational problems and associated controversy were technically not relevant to the mobile speed camera program studied in this project, the distinction between the two components of the Victorian speed camera program may not have been apparent to all drivers. Hence the fixed camera controversy may have influenced the effects of the mobile speed camera program from November 2003 onwards as well. Further details of the controversy are given by Baragwanath (2004).

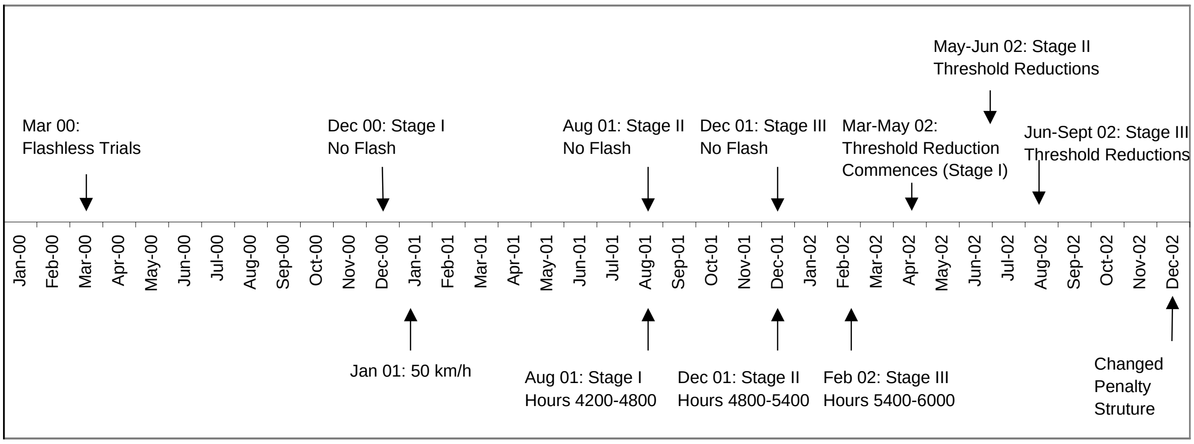
3 STUDY OUTLINE

This study attempted to model the monthly variations in crash outcomes (frequency and injury severity) in Victoria during 1998 to 2003. The monthly variations and trends were expected to be influenced by the new speed enforcement initiatives that occurred in Victoria from 2000 to 2002. The following chapter outlines the timeline and the staged introduction of the initiatives. The geographic structure of the Victoria Police regions and divisions is explained to provide a background for understanding the implication of the staged introduction of the speed enforcement initiatives.

3.1 Timeline of Initiatives

Figure 3.1 shows the time line of the introduction of the three speed enforcement initiatives. The initiatives were introduced in stages within a two-year period from December 2000, when the first stage of the use of flashless camera units began, through to the final speed enforcement threshold reductions in September 2002.

Figure 3.1: Time Line of Speed Enforcement Initiatives, Jan 2000 – Dec 2002



An attempt was made to introduce the initiatives in a staged manner as much as possible. The staged introduction involved staggering the initiatives not only in time, but also in space. Two of the three initiatives were initially introduced in only some of the Police regions and divisions, and over time more regions and divisions were included at each of the later stages. This was thought to enable a comparison of monthly crashes in areas where an initiative was active to those areas where the initiative had not been yet introduced. However, at the implementation the introduction of some initiatives overlapped in time and space. This overlap created limitations for the data analysis, as is discussed later in this report.

The geographic areas (regions and divisions) over which the staged introductions of the initiatives occurred are explained below.

3.2.1 Description of Regions and Divisions

The Victoria Police separate Victoria into five regions, four of them incorporating both metropolitan and rural areas. These regions are listed below:

Region 1: Inner Melbourne
Region 2: Southwest and West Victoria
Region 3: Northern Victoria
Region 4: Northeast and East Victoria
Region 5: Southern Victoria

Each region consists of four or five divisions, there being a total of 23 divisions. Each division is further divided into Local Government Areas (LGAs) and Traffic Management Units (TMUs). This structure is shown in Table 3.1 below.

Table 3.1: Local Government Areas and Traffic Management Units for each Region-Division (RD)

Region	Division	LGA	TMU
1	1	Melbourne	Melbourne City
	2	Yarra, Stonnington	Prahran
	3	Port Phillip, Glen Eira	St Kilda/Elsternwick
	4	Bayside, Kingston	Moorabbin
2	1	Hobson Bay, Maribyrnong, Brimbank, Melton	Melton
	2	Geelong, Queenscliff, Surf Coast, Wyndham	Geelong
	3	Ballarat	Ballarat
	4	Northern Grampians, Horsham	Horsham
	5	Southern Grampians, Corangamite, Warrnambool	S Grampians/Warrnambool
3	1	Darebin, Whittlesea	Whittlesea, Preston
	2	Hume, Moreland, Moonee Valley	Broadmeadows
	3	Greater Bendigo, Macedon Ranges	Bendigo
	4	Campaspe, Greater Shepparton	Shepparton/Echuca
	5	Mildura, Swan Hill	Mildura/Swan Hill
4	1	Banyule, Nillumbik, Manningham	Greensborough, Heidelberg
	2	Whitehorse, Boorandara, Monash	Whitehorse
	3	Knox, Maroondah, Yarra Ranges	Knox
	4	Delatite, Mitchell, Wodonga	Seymour
	5	Wangaratta	Wangaratta
5	1	Frankston, Mornington Peninsula, Wellington	Frankston
	2	Greater Dandenong, Casey, Cardinia	Dandenong
	3	Bass, Latrobe, Baw Baw	Morwell
	4	East Gippsland, Wellington	Bairnsdale

Prior to November 1999, Victoria was divided into 17 Districts by the Police, rather than Regions-Divisions (RD). Thus, in this study, data prior to November 1999 was converted from the old District structure to the corresponding RD structure.

It is expected that the effects of a speed initiative in a given region or division will extend outside those geographical boundaries and will spill over into other regions and divisions. However, it is expected that the effect of an initiative will predominantly occur in the region or division where an initiative had been active, with comparatively weaker effects in other regions or divisions.

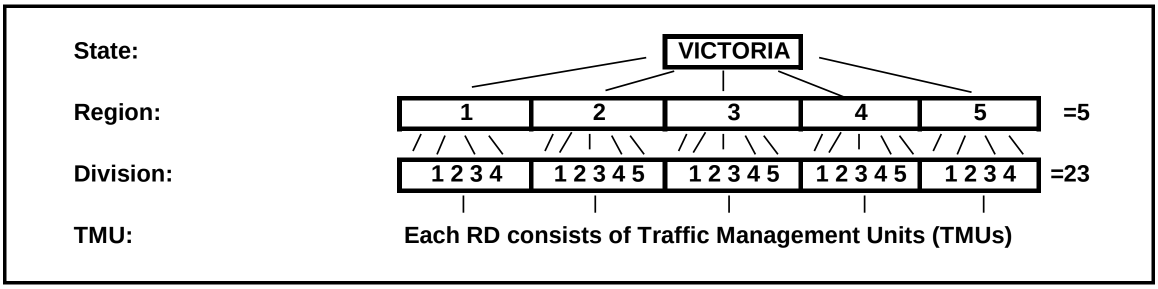
3.2 Implications of the staged introduction of initiatives for the study design

3.2.1 Implications of the staged introductions over space

The effects of the speed enforcement initiatives could be analysed at different spatial (or geographical) levels: from an overall state level, through to the smallest TMU levels. This spatial hierarchy is shown in Figure 3.2. The lowest spatial level for the initiatives' implementations was at the divisional level for the flashless cameras staging. The highest level was at the state level of increased camera hours, media announcements, and advertising.

For the purposes of the current study, the analysis was carried out at the regional and divisional levels to coincide with the smaller levels at which some of the initiatives were implemented. In this way, the individual effects of each initiative can be separately analysed in the region or division in which the initiative was implemented at a particular stage. Carrying out the analysis at the lower regional-divisional levels is especially important, because each region was not evenly represented in terms of exposure to camera hours. Therefore any effects of the initiatives from a region with a lower number of camera hours may be diluted if analysed at the overall state level.

Figure 3.2: Spatial Hierarchy



By analysing the data at the regional and divisional level, it may also be possible to investigate the combined effects of the initiatives. Some of the initiatives were introduced during the same month in a particular division. As a result, there may have been some combined effects, either additive or multiplicative. As an example, the increased hours and the threshold reductions together, may have a greater effect on crash reductions than if each is only considered individually.

3.2.2 Implications of the staged introductions over time

The analysis could be carried out not only at different spatial levels, but also at different temporal levels. For the purposes of this study, it was decided to carry out all analysis on a monthly basis.

4 SPEED ENFORCEMENT INITIATIVES

The following section describes the speed enforcement initiatives that took place from 2000 to 2002. Given that the initiatives were staged over time and space, each initiative will be described in terms of its regional and divisional implementation where applicable.

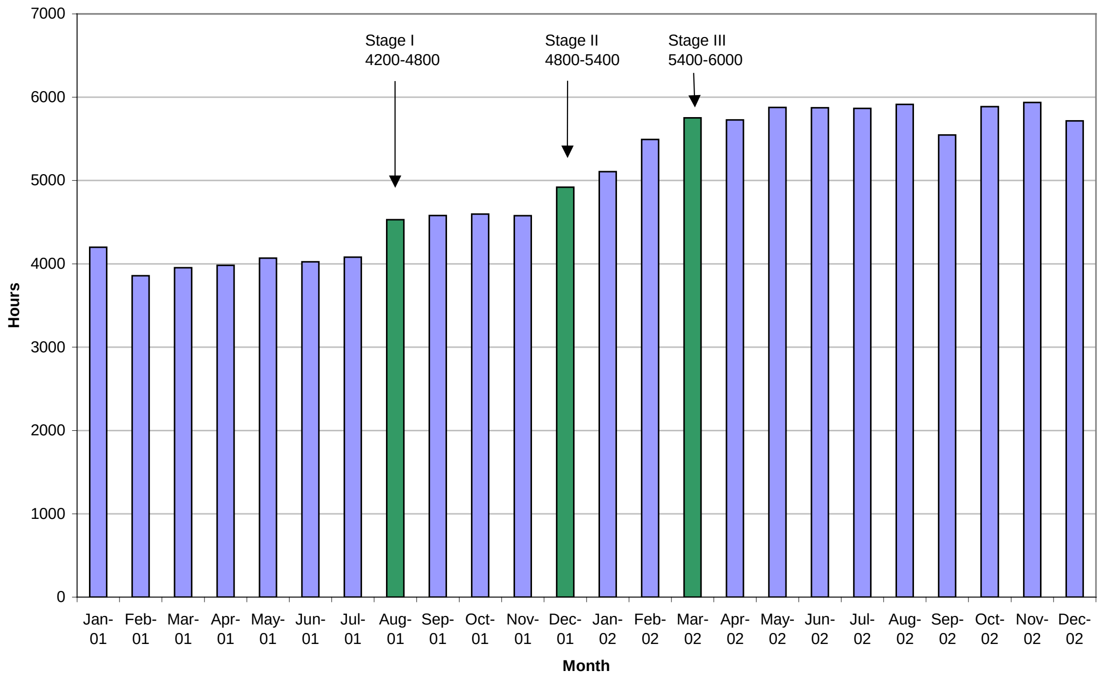
4.1 Camera Hours

Prior to 2001, speed camera target hours had been consistently set at 4200 hours per month throughout Victoria. From August 2001 to February 2002, the speed camera target hours were increased by nearly 50% in three 600-hour stages, from 4200 to 6000. Below, Table 4.1 shows the staged increase of targeted camera hour, while Figure 4.1 represents the staged increase of actual camera hours.

Table 4.1: Increase in Monthly Speed Camera Hours

Month	Increase Hours
August 2001	4200 – 4800
December 2001	4800 – 5400
February 2002	5400 – 6000

Figure 4.1: Increase in Monthly Safety Camera Hours

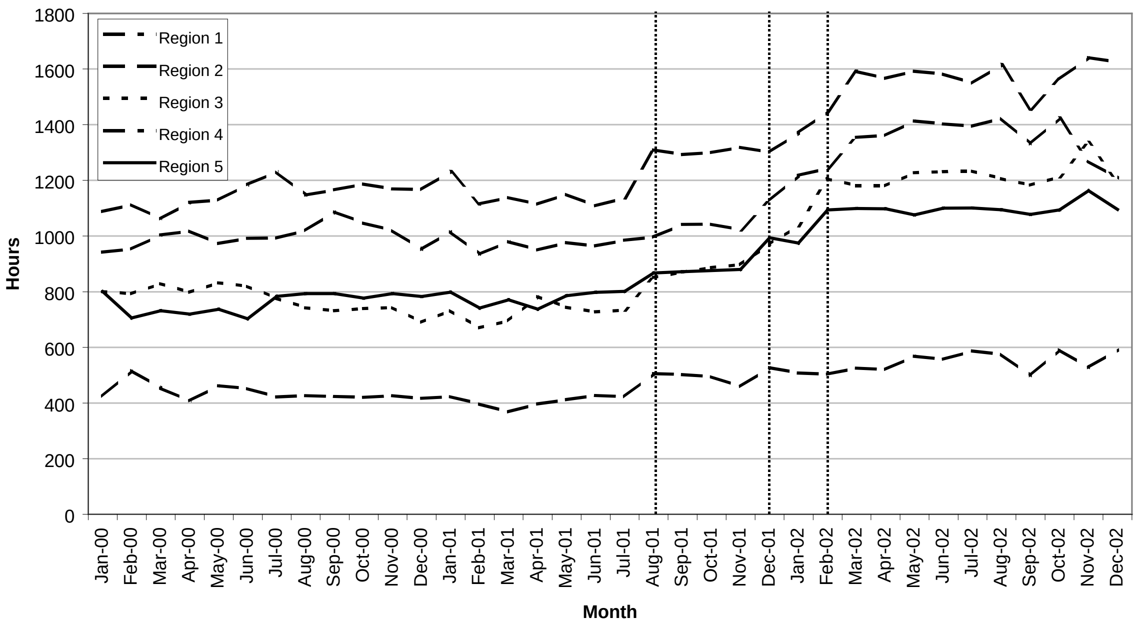


As can be seen in Table 4.1 and Figure 4.1 above, the actual hours were reasonably close to the targeted hours. However, the actual monthly camera hours were not evenly distributed over all five regions. This is shown in Table 4.2 and Figure 4.2. The prominent regions were Region 2 and Region 4, representing a yearly average of 28% and 24% of the state's total camera hours respectively. Together these two regions represented approximately half of the total hours. Region 1 represented the smallest proportion of the state's total camera hours, with a yearly average of 10%.

Table 4.2: Percentage of Camera Hours in each Region, 2000 - 2002

Region	Year			Average
	2000	2001	2002	
1	10.6	10.4	9.5	**10.1**
2	27.8	28.3	27.1	**27.7**
3	18.8	18.6	21.0	**19.6**
4	24.3	23.4	23.4	**23.6**
5	18.4	19.3	19.0	**18.9**
Total	100	100	100	**100**

Figure 4.2: Comparison of Total Camera Hours per month in each Region, January 2000 – December 2002.



Due to the regional variations described above, it is necessary to analyse the camera hours by regional, rather than by state levels. This is because if only overall state levels are considered in the analysis, the results may be disproportionately influenced by the regions with highest level of camera hours. For instance, since Regions 2 and Region 4 had the highest proportion of monthly camera hours, it is expected that these regions will also have a substantially higher proportion of TINs compared to other regions. Therefore, any effects of the increase in monthly camera hours seen at a state level may be expected to be due mainly to these more dominant regions. Any effects in Region 1, for example, may not be seen at the state level. Thus, it is important to look for effects at the regional levels.

4.2 Threshold Reductions

The speed enforcement threshold refers to the speed at or above which a vehicle will be detected by a camera. The vehicles that are detected at or above the speed enforcement threshold are referred to as offending vehicles.

The speed enforcement threshold prior to March 2002 was 10 km/h over the speed limit for all speed zones. For example, a vehicle in a 60 km/h zone would not be detected by a speed camera until it was measured travelling at 70 km/h or above. Between March 2002 to September 2002 this speed enforcement threshold was reduced in three steps of 1-2km/h over the Police regions (except in 100 km/h and 110 km/h zones where it is understood that the third step of the threshold reduction was not implemented).

The staged introduction of the speed enforcement threshold reductions is shown in Table 4.3 below. Region 1, Region 5, and Region 2 all experienced the first step of threshold reduction in March, April and May 2002 respectively, with the second step in June. Region 3 and Region 4 started off with a reduction at the level of the second step in May. The final threshold reduction (except on 100 km/h and 110 km/h zoned roads) was brought about between July and September with the reduction occurring in July for Region 1 and Region 5, in August for Region 2, and in September for Region 3 and Region 4. Thus, Region 1, Region 2, and Region 5 experienced the reduction sooner than Region 3 and Region 4. However, for the two latter regions the first reduction was steeper.

Table 4.3: Table showing kilometre threshold reductions in each month per region, March – September 2002

Region	March	April	May	June	July	August	September
1	step 1	step 1	step 1	step 2	step 3	step 3	step 3
2	-	-	step 1	step 2	step 2	step 3	step 3
3	-	-	step 2	step 2	step 2	step 2	step 3
4	-	-	step 2	step 2	step 2	step 2	step 3
5	-	step 1	step 1	step 2	step 3	step 3	step 3

According to Cameron et al (2003a), decreases in the detection threshold are expected to lead to an increase in the actual risk of detection. If this is also accompanied by an increase in the *perceived* risk of detection, associated road safety benefits would be expected. Therefore it may be reasonable to hypothesise that there will be a reduction in crashes following the reduction in thresholds.

Previous research (see section 2.2.3.3) was unhelpful about the likely timing of the effect of the reduced enforcement thresholds on crashes. For the purpose of the crash modelling it was assumed that the effect of the introduction of each step was immediate in the month and region in which it was introduced (and to remain in effect until the next step, or to the end of the analysis period). In practice, there are many alternative mechanisms which may have produced an effect on crashes due to this relatively novel initiative, such as delayed effects as drivers become more aware that surveillance has tightened, and drivers detected between the new and old thresholds change their behaviour.

4.3 Flashless Operation

The implementation of the flashless operation occurred in a staged manner at the divisional level. The flashless operation was implemented in three stages in December 2000, August 2001, and December 2001. The implementation of the flashless operation by stage and TMU is shown in Table 4.4. The first flashless stage was implemented in at least one division from each region, except for Region 3. These divisions represented 30% of all divisions. The second stage occurred in additional divisions in all regions, except for Region 4, and represented a further 30% of divisions. The final stage of the flashless implementation occurred in all remaining divisions in all regions.

The flashless operations were introduced by TMU. In consultation with Tenix, it is assumed that a TMU has jurisdiction over the entire division in which the TMU is located.

Table 4.4: Flashless Implementation Stages by TMU and corresponding Region and Division

Stage	TMU	Region	Division
Stage 1 13/12/00	Prahran	1	2
	Altona North	2	1*
	Knox	4	3
	Dandenong	5	2
	Horsham	2	4
	Seymour	4	4
	Morwell	5	3
Stage 2 01/08/01	Moorabbin	1	4
	Melton	2	1*
	Broadmeadows	3	2
	Frankston	5	1
	Geelong	2	2
	Ballarat	2	3
	Bendigo	3	3
	Bairnsdale	5	4
Stage 3 12/01	All remaining TMUs:		
	Melbourne City	1	1
	St Kilda/Elsternwick	1	3
	S Grampians/Warrnambool	2	5
	Whittlesea, Preston	3	1
	Shepparton/Echuca	3	4
	Mildura/Swan Hill	3	5
	Greensborough, Heidelberg	4	1
	Whitehorse	4	2
	Wangaratta	4	5

** This division was included in both the first and second stage of implementation.*

Prior to the flashless implementation, two flashless trials were implemented. The trial cameras were operated during October 1999 and March 2000 for a month. During October 1999, four cameras were used during daylight hours within two metropolitan and two rural areas. The camera hours were held constant. It was found that the number of offences detected and the detection rate showed a substantial increase in the metropolitan area, and a marginal increase in the rural areas. This trial was later extended in March 2000 in which eight cameras (1/3 of daily operations) were trialed in two metropolitan and two rural areas. The results were comparable to the first trial.

Therefore it can be expected that the flashless operation may have substantial effects within the Metropolitan regions and divisions. More specifically, it is expected that there would be an initial increase in detected speeding offences which in turn may be associated with a decrease in crashes. However, evidence suggests that over time the number of detected offences would reduce and return to a steady state. The expected time span between the initial increase in detected offences and then their reduction to the steady state is not known.

In addition, according to Cameron et al (2003a), the covert operation of cameras is expected to create uncertainty about camera locations and possible detection, and therefore the road safety effects could extend beyond the geographic location of camera operation.

However, the extent of the effects of the flashless operation will depend heavily on the proportion of camera sessions in which the flash is utilised. The switch from flash to flashless is done so at the discretion of the camera operator in the perceived correct conditions. No records are available of when flash or flashless cameras were used. Therefore if the proportional use of flashless cameras is low, the flashless effect may not be as strong as expected. The lack of complete information on the nature of covert operations and the frequency of flashless camera operations is a limitation of this study and must be taken into account when interpreting the results.

5 OUTPUTS FROM THE ENFORCEMENT CHANGES: OFFENCES DETECTED AND TRAFFIC INFRINGEMENT NOTICES (TINs) ISSUED

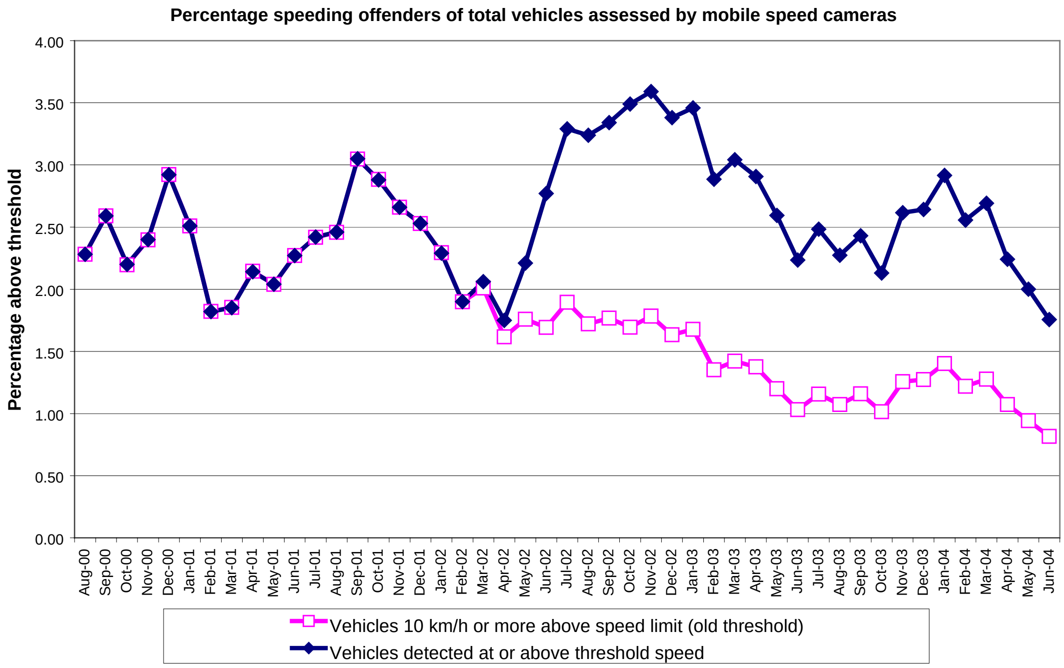
The desired outcome of the enforcement initiatives is a change in the speed behaviour of drivers, such that as many drivers as possible observe the speed limit. The speed behaviour response of drivers to changes in speed enforcement can be measured in a number of different ways. Relevant outputs from the speed camera program include the number of speeding offences detected by cameras, and the Traffic Infringement Notices (TINs) issued to drivers as a result of the offences (not all recorded offences result in Notices for a variety of operational and evidential reasons). These are described next.

5.1 Offences detected

5.1.1 Offence rates related to threshold level

The monthly number of offences detected by mobile speed cameras depends on the number of hours of operation and the number of vehicles whose speed is assessed. Offence rates, expressed as a percentage of assessed vehicles speeding at the threshold level or greater, have been used by the Victoria Police as an indicator of speeding trends for many years. This practice derives from a belief that the relatively covert operation of speed cameras rotated through many different sites in Victoria provides a reasonably representative measure of speeding behaviour. The practice also relied on the constant 10 km/h threshold applicable in all speed zones from February 1993 to February 2002. Since then, the reduced enforcement threshold has required a different approach. The Department of Justice has provided data on offences detected by mobile speed cameras, classified into those with speeds at or above the old and new enforcement thresholds, respectively (Figure 5.1).

Figure 5.1: Offence rates by threshold level



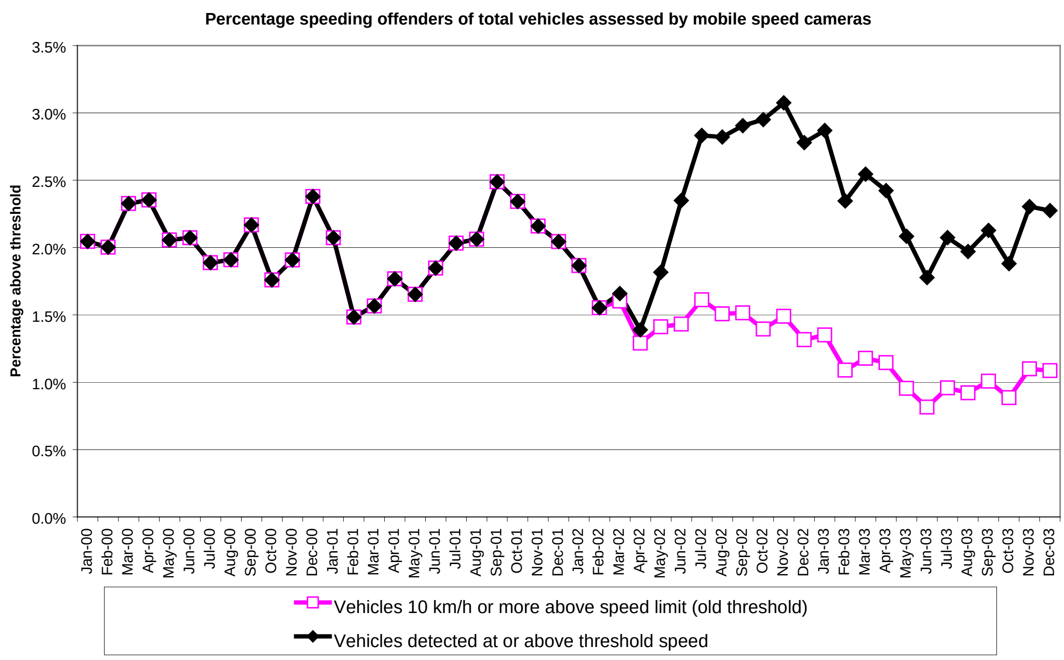
The influence of the reduced threshold can be clearly seen, approximately doubling the offence rate during July 2002 to January 2003. The percentage of drivers exceeding the old tolerance remained approximately constant during this period, then fell until October 2003. It rose during the last few months of 2003 (perhaps associated with the fixed speed camera controversy) before falling again during 2004. The overall offence rate followed a similar pattern, but the rate of offending between the old and new thresholds appears to have generally decreased over the period.

Figure 5.1 also shows that the offence rate (old threshold) fell consistently during October 2001 to February 2002, corresponding to the period during which mobile speed camera hours per month were increased. The figure also suggests a short-term increase in offence rate during December 2000, when the first stage of flashless camera operations commenced, and a reduction during February and March 2001 following introduction of the 50 km/h default urban speed limit on 22nd January.

5.1.2 Offences with Traffic Infringement Notices

During 2001-2003, 80-90% of speeding offences detected by speed cameras resulted in a Traffic Infringement Notice (TIN) being sent to the vehicle owner. Detailed information was available about the detected speed of each offence resulting in a TIN, in contrast with the information for all offences. The trend in the prosecutable offence rate, expressed as a percentage of assessed vehicles, shown in Figure 5.2 was similar to the offence rate trend shown in Figure 5.1. Thus the TIN offences were considered to be representative of trends in all offences detected by speed cameras during 2001-2003.

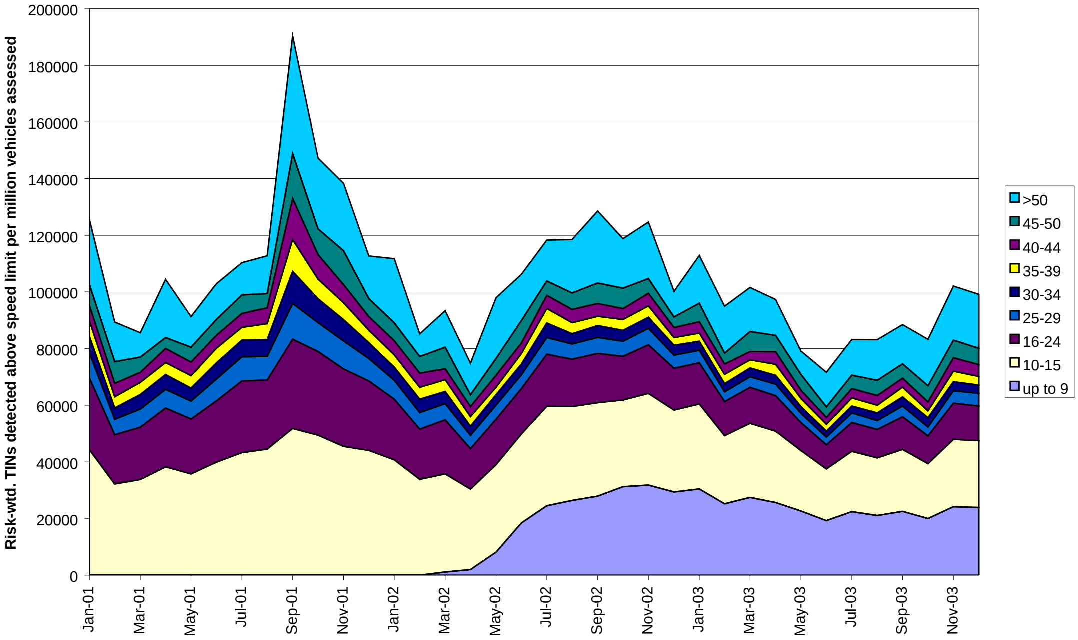
Figure 5.2: TIN offence rates by threshold level



To examine the influence of the enforcement threshold reduction on the pattern of offences at or above the old threshold (10 km/h above the limit), the detected speeds for TIN offences were classified into categories representing a mixture of the offence categories for the speeding offence penalties applying before and after 15 December 2002 (see Tables 2.1 and 2.2). This analysis also allowed the influence of the increased penalties on speeding patterns to be seen.

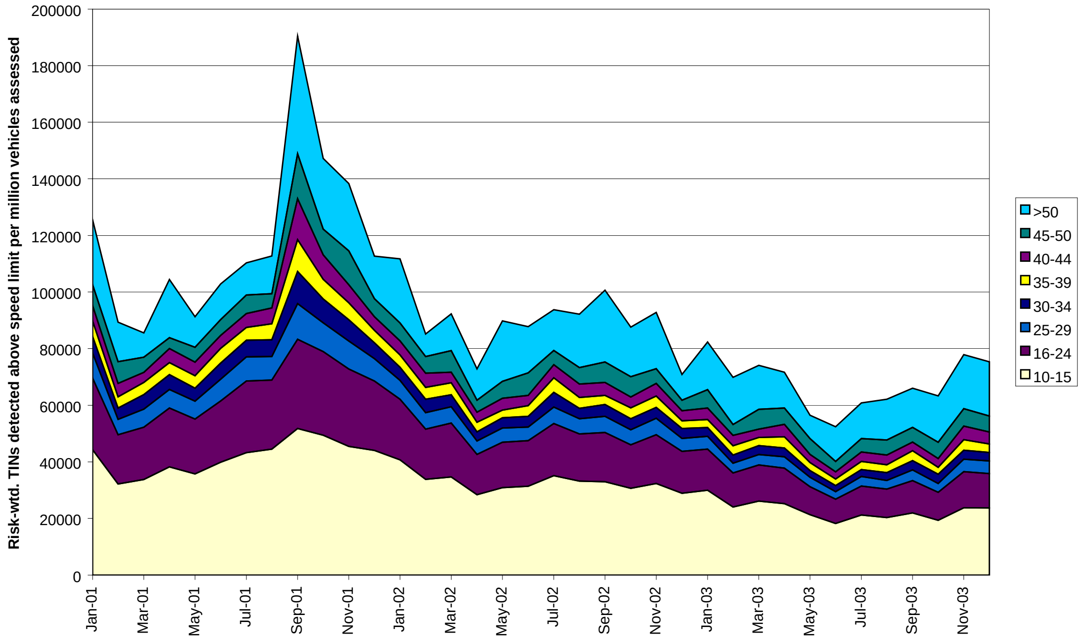
During 2001-2003, less than 0.5% of detected speeds were in the range 30-34 km/h above the limit, and less than 0.05% of speeds were in the highest speed categories. Thus the trends in offence rates for these excessive speeds could not be displayed beside the trends for lower speeds (e.g. 10-15 km/h above the limit, representing over 50% of offenders). For display purposes, it was decided to weight the offences in each speed category by their relative risk, derived from a combination of the urban and rural relative risk curves derived by the University of Adelaide (Kloeden et al 2001, 2002). The relationships represent the risk of involvement in a severe casualty crash (fatal or requiring ambulance transport and/or hospital treatment), relative to the risk when travelling at the speed limit. The weighting then reflects the relative importance of the excessive speeding offences in terms of contributing to crashes resulting in death or severe injury. The weighted TIN offences were divided by the number of vehicles assessed for speeding in the same month, to provide a risk-weighted offence rate per million vehicles (Figure 5.3).

Figure 5.3: Risk-weighted TIN offence rate by category of detected speed



The substantial reduction in risky speeding associated with the increase in mobile speed camera hours between August 2001 and February 2002 is apparent in Figure 5.3. The increase in the risk-weighted TIN offence rate during 2002 is mainly due to the inclusion of offences detected up to 9 km/h above the limit, which while they are not associated with extremely high risk, occur in relatively large number and were not detected prior to March 2002. When these offences are removed from the figure, the influence of the reduced threshold and increased penalties on higher categories of speeding can be more clearly seen (Figure 5.4).

Figure 5.4: Risk-weighted TIN offence rate by category of detected speed above old threshold of 10 km/h in excess of the speed limit



There were reductions in offence rate in all categories of speeding offence in April 2002, the month following the announcement that the enforcement threshold would be reduced. There were also reductions in all categories up to 39 km/h above the limit during August 2002, when the second step of the threshold reductions had been implemented throughout Victoria. However the pattern of changes across the speed offence categories was relatively constant during 2002. The overall impact of the threshold reduction is indicated by a comparison of the offence rates between April and November 2002, with the same months in the previous year (Table 5.1). The increased penalties came into effect in December 2002, so subsequent months were influenced by the penalty change as well as ongoing effects of the threshold reduction.

Table 5.1 shows that there were 30-40% reductions in offence rates for speeding 10-44 km/h above the limit, associated with the threshold reduction, but lesser reductions in rates of offending at higher speeds. This indicates a tendency for very excessive speeders to have been influenced less than other speeders.

Table 5.1: TIN offence rates per million vehicles assessed, by category of detected speed relative to the speed limit (km/h)

Period	Up to 9	10-15	16-24	25-29	30-34	35-39	40-44	45-50	Over 50
Apr 01-Nov 01	0	15645	4304	422	149.1	56.2	25.4	11.0	9.8
Apr 02-Nov 02	10562	11347	2793	253	83.9	34.1	15.3	8.2	8.7
Threshold reduction effect		-27.5%	-35.1%	-40.2%	-43.7%	-39.3%	-39.9%	-25.4%	-11.9%
Dec 01-Oct 02	*14771*[1]	12159	3044	272	90.8	35.7	15.7	8.6	8.0
Dec 02-Oct 03	12134	8379	1977	172	62.6	27.0	12.3	7.1	6.5
Penalty increase effect	*-17.9%*	-31.1%	-35.1%	-36.6%	-31.0%	-24.4%	-22.0%	-18.0%	-18.8%

[1] September and October 2002 only, after the reduced enforcement threshold was fully implemented throughout Victoria (all three stages of threshold reduction, where applicable)

Regarding the influence of the increased penalties in December 2002, there were reductions in offence rate in all categories of speeding during that month, further reductions in nearly all categories during February 2003, and still further reductions during May and June 2003 before offence rates generally increased again. The overall impact of the increased penalties (and perhaps also a continuing effect of the threshold reduction) is indicated by a comparison of the offence rates between December 2002 and October 2003, with the same months in the previous year (Table 5.1). November and December 2003 were excluded from this analysis because their offence rates may have been influenced by the fixed speed camera controversy.

Table 5.1 shows that there were 30-35% reductions in offence rates for speeding 10-34 km/h above the limit, associated with the penalty increase, but lesser reductions for the higher speed levels, generally decreasing with the speed category. The reductions in offence rates for two categories of speeding for which the penalties did not change (16-24 km/h and 30-34 km/h above the limit) were generally no less than the reductions in categories up to 34 km/h for which the penalties increased. The relatively small apparent reduction in the rate of offences less than 10 km/h above the limit cannot be considered reliable because the rate before the penalty increase was based on only two months data. In summary, the penalty increase appears to have had a smaller influence on the offence rate of excessive speeders (for whom the increases were substantial, especially the increased periods of licence loss) than speeders at lower levels.

5.2 Traffic Infringement Notices issued

5.2.1 Deterrence mechanism

Awareness of speed enforcement acts as a general deterrence mechanism. General deterrence is a process of influencing a potential offender against committing the offence through fear of detection and the associated consequences (Cameron and Sanderson 1982). However, the actual receipt of a TIN is a specific deterrence mechanism. Specific deterrence refers to the actual experience of detection and the associated penalties. It is expected that the receipt of a TIN will not only alter the behaviour of the recipient, but others with knowledge of the infringement as well. As a result of general and specific deterrence, drivers may experience an increase in perceived risk of detection and change their speeding behaviour. As stated by Cameron et al (2003), this relies on the assumption between perceived speed enforcement and rational behaviour.

The speed enforcement initiatives act to increase the perceived, as well as the actual risk of detection (Fildes & Lee, 1993). The use of non-visible enforcement, such as flashless cameras, acts to increase drivers' sense of uncertainty of when or where they will be detected and to prevent them from adapting their behaviour only to specific times and locations (Ostvik & Elvik, 1990). Deterrence sanctions, such as TINs, are based on the assumptions of rational choice theory, according to which drivers will abide by the law (or not exceed the speed limit in this case) if the expected utility of law-abiding actions is greater than the expected negative consequence of committing the offence (Palmer, 1977). Thus, TINs are expected to act as a deterrent by increasing the perceived cost of speeding (e.g. fines, demerit points) while decreasing the perceived benefits of speeding, so that the costs outweigh the benefits. In assessing the costs and benefits of speeding the driver is expected to weigh up the perceived risk of being caught, the fear of being caught, and the fear of likely penalty and punishment (Corbett & Simon, 1992; Zaal, 1994).

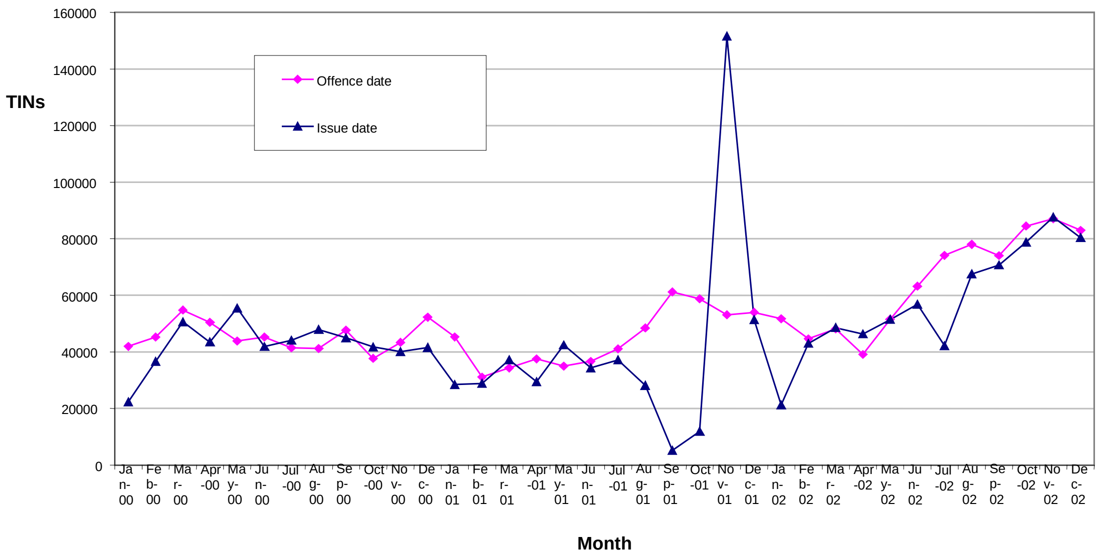
Therefore, the date of issue of TINs is a predictor of the likely timing of the behavioural response following speed enforcement. Additionally, word-of-mouth communication with others who have received TINS or heard of someone receiving TINs, may vicariously influence drivers to change their behaviour as well.

5.2.2 TINs data available

The number of Traffic Infringement Notices was available in two forms. The first was the TINs by offence date (as analysed in Section 5.2.1) and the second was by issue date (when the infringement notice was sent out).

The date of issue of TINs is expected to more accurately reflect the point of behavioural change than the actual offence date. However, the trend in TINs by issue date is not the same as the trend by date of offence (Figure 5.2). In August to November 2001 there was an industrial dispute causing a backlog of TINs from offences detected in July onwards and an approximate four-fold increase in TINs issued in November (Figure 5.5). This may have caused a delayed effect on speed behaviour and crash outcomes. However, the offence rate from September 2001 showed a consistent downward trend until February 2002 (Figure 5.2), suggesting that the delay in receipt of TINs was not perceived against the background of other substantial changes to the mobile speed camera program (increased camera hours per month, staged introduction of flashless cameras, and the high-profile announcements in August and November 2001) during the same period.

Figure 5.5: Speed Camera TINs issued by Offence Date and Issue Date, January 2000 – December 2002.



There is a lag between the offence date and the date of issue of a TIN. Hence it is expected that there would be a lag between any increase in detection of offences and the expected behavioural change, as the offending driver would not be immediately aware of the imposed penalty. Thus, any expected behavioural change and its subsequent effect on crashes will not be immediate and may be seen in later months. The form of the relationship between offence date and TIN issue date is required to determine the lag between a given offence and any expected behavioural change.

5.2.3 Relationship between offence detection and behaviour change

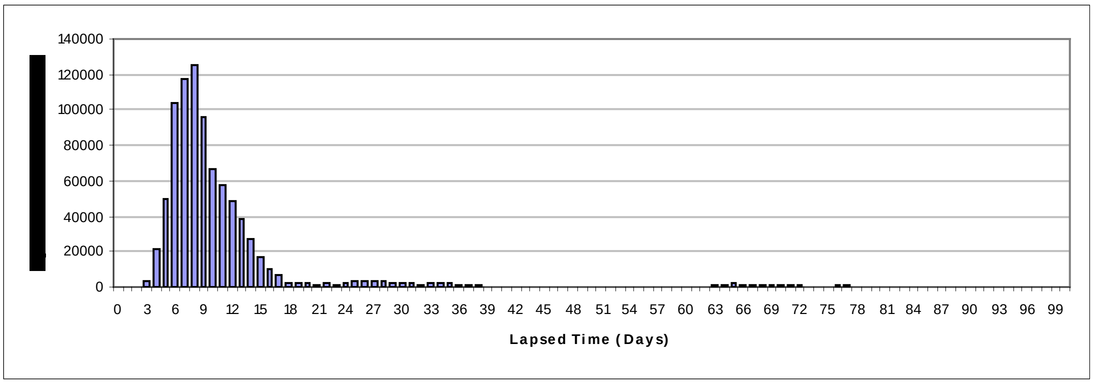
Cameron et al (2003b) found that the level of TINs derived from offences detected by speed cameras in Melbourne police districts during a given month influenced the number and severity of casualty crashes in the same district during the following month. This finding supports the assumption of delayed effects of increased mobile speed camera detections of speeders, in part due to the delay in the receipt of a TIN from the date of offence and perhaps in part due to a residual effect following that when the TIN is first received.

It is possible for a TIN to be issued more than once. The most relevant dates are the *first* issue date and *last* issue date (in many cases they will be the same). If the first TIN issued is sent to the owner of the vehicle or a company, and if they were not the driver at the time of the offence, they may nominate another driver to receive the TIN. From this another TIN is sent out to the offending driver. It is unclear whether the behavioural effects take place from the date of the first TIN issued or the last. Although the offending driver may not receive the TIN until a later date, they may find out earlier about the offence and hence behaviour modification could begin from that point. The extent of this difference in timing is examined below.

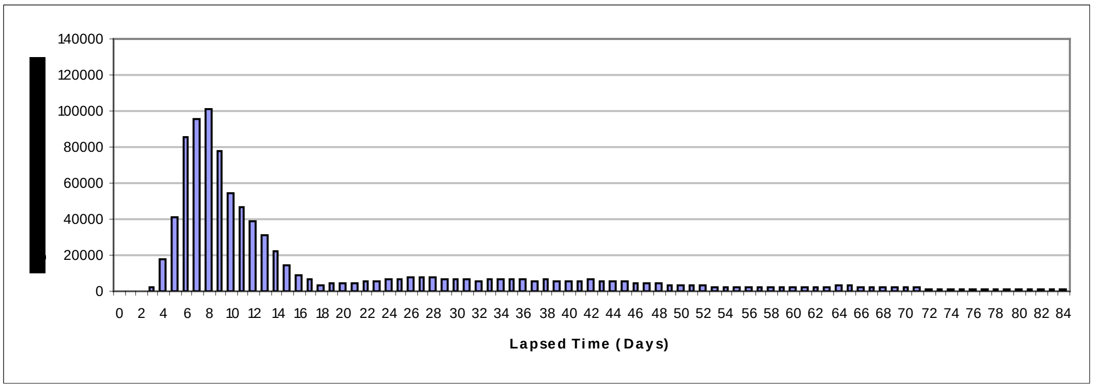
Figure 5.6 a) and b) show the 2002 distributions of lapsed time between offence date and issue date for both first and last issue date of TINs. The distributions are similar in that they are both right skewed with a long tail, but for last issue date TINs the tail is heavier, representing the longer time for TINs to reach the final offending driver. The median time in days for the TINs to reach the recipient for first issue date is eight days, while for last issued date the median is ten days. The main difference can be seen in the range of days. The central 50th percentile of first issue TINs (graph a) is between 1-2 weeks after the offence date, whereas for the last issue TINs (graph b) the central 50 percentile has a greater range of 1-4 weeks. It is unknown whether the deterrence effect begins as a result of the first TIN sent out, 1-2 weeks after the offence, or from the last TIN sent, 1-4 weeks later. One factor related to this question may be the type of vehicle owner or driver receiving the TIN.

Figure 5.6: Lapsed time between speed camera offence date and TIN issue date during 2002 (excluding lapsed times >100 days), for:

a) FIRST TINs Issue Date



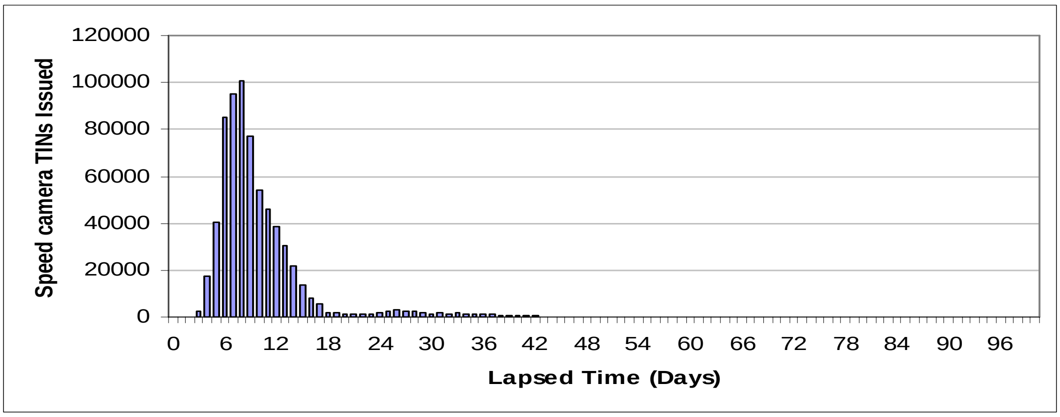
b) LAST TINs Issue Date



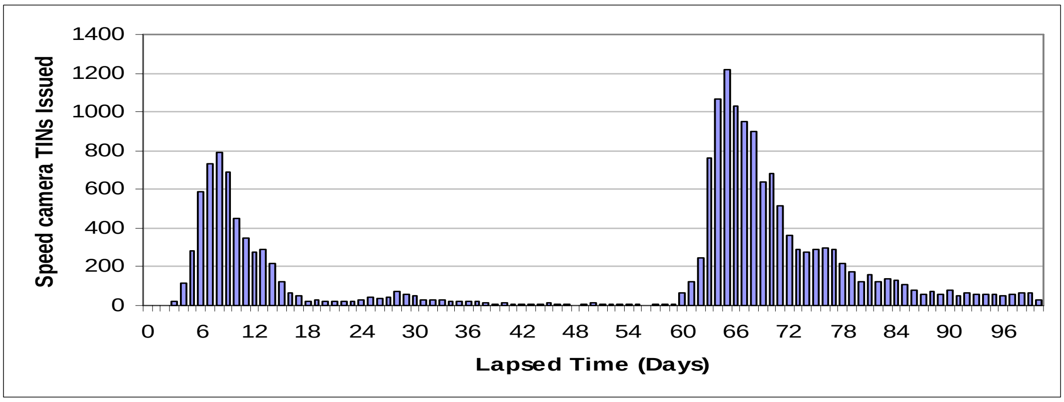
There are three possible categories into which the recipient of a TIN can fall – Owner, Company or Nominated driver. These three categories show very different distributions of the *last* TINs issued date, as shown in Figure 5.7. For the first TINs issued the form is the same as Figure 5.7, graph a, for both Owners and Companies (there are no nominated drivers in the first issue). In 2002, owners of the offending vehicle represented 74% of all last TINs issued. A further 24%, where the recipient was not the offending driver, were subsequently reissued to a nominated driver, either from a company (approximately 70%) or individual vehicle owners (approximately 20%). Only 2% are retained and paid by companies. Therefore the weight of all offences will be seen at the individual owners level, although a substantial proportion, 25%, of all offences are further nominations.

Figure 5.7: Time lapsed between offence date and LAST TIN issued, 2002, for:

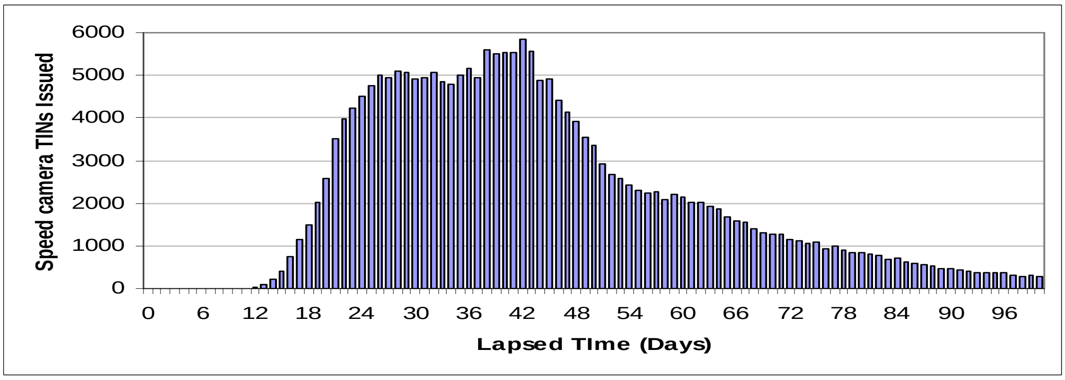
a) Individual OWNER



b) COMPANY



c) Nominated DRIVER



The distribution of TIN issue dates for owners, as seen in Figure 5.7 a), shows a similar distribution to TINs over all ownership types, with a median time lapse between offence date and last TIN issued of eight days (range 6-11 days). The issue dates of last TINs sent companies show a bimodal distribution, with peaks around one week and two months, and a median of 65 days. While the reason for this bimodality is unclear, in terms of behavioural response to the TINs it is not of a great concern as they represent only 2% of all TINs.

The main concern lies with the last TINs sent to nominated driver (24% of TINs), which shows a bell-shaped distribution, and a median lapsed time of about 6 weeks (central 50^{th} percentile range of 30-55 days or 1-2 months). This means that for a potential 25% of the speed offender population, any potential speed behaviour modification may not occur for up to 2 months after the offence. However, it is possible that the nominated driver may find out about their infringement before the subsequent notice is reissued, allowing the driver's behaviour to change sooner.

For 75% of drivers the last and first issue date will be the same. Therefore, regardless of when the TIN is issued, it appears reasonable to expect that the majority of drivers will receive their infringement notices within 1-2 weeks of the offence. Some of the remaining offending drivers will become aware soon after this that a TIN is impending, having been advised and nominated by a vehicle owner. However, some nominated drivers may not be aware of the offence for up to two months after it occurred.

Therefore, on the basis of past research and the relationships seen above, this study assumed a one month lag between the date of detection for a speeding offence and potential behaviour change leading to reduced crashes and injuries. Because of the potential two months lag in behavioural response from some nominated drivers, any measured effects may be conservative estimates, as they may have been weakened by the longer lagged behavioural response of these drivers.

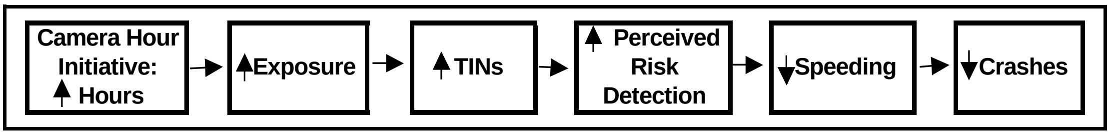
6 RELATIONSHIPS BETWEEN CRASH OUTCOMES AND INPUTS FROM THE NEW SPEED ENFORCEMENT INITIATIVES

6.1 Mechanisms of effect on crash outcomes

Each of the three speed enforcement initiatives was expected to lead to an increase in the number of offences detected by speed cameras. All other things being equal, increased hours of surveillance are expected to detect a higher number of offenders. The more covert operation of the camera units is expected to detect more of those offenders who believe they can avoid the cameras by seeing or anticipating the locations and times of the units. The reduced enforcement thresholds are expected to detect more of those offenders who speed below the old threshold but above the new.

It therefore follows that each of the three speed enforcement initiatives was expected to increase the number of TINs detected by speed cameras, at least in the short term until driver speed behaviour adapted to the new enforcement level. It was hypothesised that the relationship between a given speed enforcement initiative and the resulting effect on crashes is a chain of events. For example, the relationship between the increase in camera hours and crashes is shown in Figure 6.1.

Figure 6.1: Chain of events from the implementation of a speed initiative to the crash outcome. Example: increased speed camera hours



An increase in camera hours would lead to an increase in drivers' exposure to speed cameras. As a result, a higher absolute number of drivers would be detected offending above the threshold and receive a TIN (and associated penalties). As stated in Section 5.2.1, this would be expected to increase drivers' perceived risk of detection, and consequently, according to rational choice theory, would result in drivers decreasing their speed in order to avoid a subsequent TIN. The overall reduction in speeding would then be expected to lead to a reduction in crashes and/or the severity of crash outcomes. The subsequent offences and TINs should also fall.

As discussed previously, the introduction of more covert operation of camera units, per hour of operation, is likely to increase the detection rate per hour. The reduced enforcement threshold is also likely to increase the detection rate per camera hour. There is evidence from the outputs from the speed camera program (Section 5.1) that increases in the offence rate were associated with these initiatives. In the case of the TIN offences associated with the reduced enforcement threshold, these subsequently fell in all categories of speeding, not just in the category between the old and new threshold.

Previous MUARC research (Cameron et al 2003b) had shown that casualty crashes in a police district were reduced in the month following increases in the number of speeding TINs detected in the same district during a given month. The risk of fatal outcome of the casualty crashes was also reduced substantially in the following month. These delayed effects were considered to be due to the time lag in the issuing of TINs from the date the offences occurred, and the residual effect of TIN receipt over the following weeks. For these reasons, in the present study the effects of each speed enforcement initiative on casualty crash frequency and severity was considered in the month following that in which the speed camera hours occurred, or the flashless operation or threshold reduction applied.

6.2 Relationship between speed camera hours and crashes

Past studies have suggested a functional form relating speed camera TINs and crash frequency. The general form has been a non-linear inverse relationship with diminishing returns to scale. That is, with increased enforcement, there is a decreasing crash outcome, but at a decreasing rate. However, the nature of the relationship between speed camera hours and crashes needs to be explored.

6.2.1 Functional form

Elvik (2001) identified a functional relationship between speed enforcement and crashes (see Figure 2.1). He found a non-linear relationship, where the effect of increased enforcement diminished in terms of crashes saved. This type of relationship was confirmed for the Victorian speed camera program by Cameron et al. (2003b), where a diminishing-returns relationship was identified between TINs and casualty crashes (see Figure 2.2). The same research had also suggested a diminishing-returns relationship between TINS and the risk of fatal outcome of casualty crashes.

The form of possible relationships of this type was investigated by Smith, Cameron and Bodinnar (2001) based on experience during the growth of the Irish speed camera program. Elvik (2001) had proposed a number of potential functional forms for the relationship between enforcement and crashes, the most suitable being the logarithmic function:

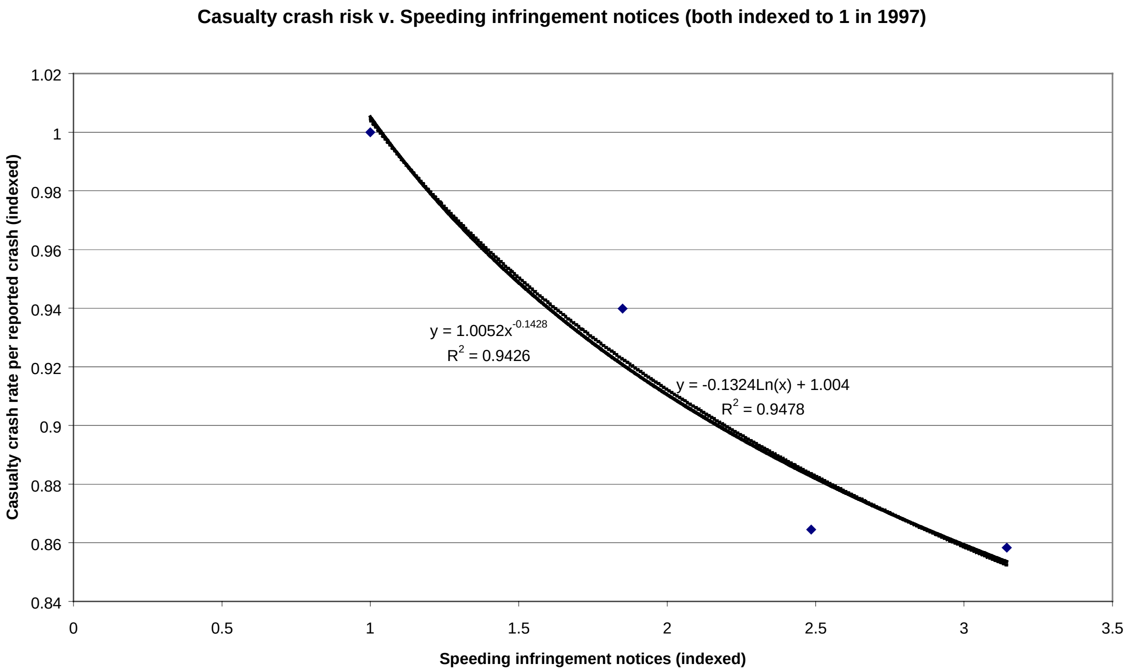
$$Y = A + B \cdot \log(X)$$

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

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

The relationship between the annual number of speeding infringement notices in Ireland during 1997-2000 and the estimated casualty crash risk (proportion of reported crashes resulting in death or injury) is shown in Figure 6.3. The two functional forms fitted to the data explain the relationship equally well.

Figure 6.3: Relationship between speeding infringement notices and casualty crash risk in Ireland, 1997-2000



Gelb et al (2000) had estimated a statistically significant relationship of the power function form connecting monthly speed camera hours and low alcohol hour casualty crashes in Melbourne during 1987-1998. Gelb et al also estimated a relationship of the same type with monthly TINs issued for offences detected by speed cameras.

There appears to be little difference in the explanatory power of either the logarithmic or power functions so far as representing the relationship between the increased inputs or outputs of the Victorian speed camera program and its effects on casualty crash outcomes. Given that the two other initiatives under evaluation (the flashless cameras and reduced speed offence thresholds) were expected to affect the system's outputs, for the purpose of this study the number of camera hours was the preferred measure directly representing the staged increase in this initiative. On the basis on previous research linking speed camera hours with casualty crashes, albeit limited, the preferred functional form was the power function described above. There was no prior experience to guide the choice of functional form linking camera hours and the injury severity of the casualty crashes (see Sections 8.1 and 8.3), but for reasons of consistency a power function was also preferred in this context as well.

7 OUTCOME MEASURES

As outlined in Section 2, research has established relationships between speeding and crashes and/or crash severity. As described, the implementation of the speed enforcement initiatives is expected to act to reduce travel speeds and the consequent crash outcomes. Both of these variables, subsequent speed behaviour and subsequent crashes, can be considered as outcomes of the process. The other speed-related road safety activities, outlined in section 2.3, are also expected to affect crash outcomes and hence need to be considered in the time series modelling of monthly crashes.

7.1 Crash outcomes

The crash estimates were obtained from the VicRoads Crash Data file, which contains information on all police reported crashes in Victoria resulting in death or injury (known as casualty crashes). Three levels of injury are recorded – fatal (death within 30 days), serious (generally severe injury resulting in hospital admission) and minor injury. The injury level of a crash refers to the highest severity of injury resulting from the crash. The two types of crash outcomes used in the analysis are:

a) **Crash Frequency:** Number of casualty crashes.

b) **Crash Severity:** Given a casualty crash, the proportion representing a given crash injury severity. Two separate analyses were carried out on each of the following severity outcomes:

   i) Fatal versus injury (serious or minor injuries)
   ii) Serious casualties (fatal or serious injury) versus minor injuries

The crash frequency is a count of monthly crashes, whereas crash severity represents a dichotomous outcome (i.e. fatal or not, or serious or not). Therefore, different statistical models were used to analyse the crash frequency and the crash severity. These models will be discussed in Section 8.

Crash frequencies and crash severities were analysed on a monthly basis per region and division in order to match the timing of the staged introduction of the enforcement initiatives. As stated in Section 6.1, it is assumed that there was a one-month lag between the impact of each enforcement initiative, through the detection additional TIN offences, and a behavioural response on travel speeds, and subsequent changes in crash outcomes.

During August to October 2001, the Police industrial dispute delayed the completion of crash report forms and there is some doubt about the accuracy of the injury severity information (except for fatal outcome) in about 20% of the reported crashes. While the influence of this crash data was expected to be small and short-lived, there was some doubt about the reliability of the second of the crash severity criteria (ii, above) and the results were viewed with caution. The first crash severity criterion (proportion of casualty crashes resulting in fatal outcome) was the preferred criterion in the time series modelling of crash outcomes.

7.2 Speeds

A second part of the outcome analysis was concerned with whether travel speeds in Victoria had changed in response to the changed enforcement and other speed-related initiatives. Speed behaviour can be measured in a number of ways. The main measures of interest used in the study were:

a) **Average and 85th percentile speed:** The average speed gives an indication of the speed the typical vehicle is driving at. The 85th percentile speed indicates the speed the fastest 15% of drivers are driving above. Average and 85th percentile speeds were calculated from VicRoads surveys of speeds on various roads in Melbourne. The surveys measured speeds under free traffic conditions, unimpeded by other traffic, during off-peak daylight hours. The survey sites were originally chosen to monitor the effects of changes to speed zones in 1994 and are not necessarily representative of traffic in Melbourne.

b) **Speed distribution:** The speed distribution indicates whether the speeding profile has shifted over time, and whether the distribution exhibits a different shape. For example, a left shift would indicate a general downward shift in the overall speeds, and a tightening of the distribution, particularly of the right tail, would indicate a decrease in high-level speeding. This indicates the behaviour change of the driving population as a whole, not just of the average driver. Speed distributions were also obtained from VicRoads free speed data.

c) **Rate of vehicles exceeding the enforcement speed limit:** This is the percentage of vehicles detected at or above the speed enforcement threshold. For the period of interest, the threshold was taken as a fixed 10 km/h above the speed limit, notwithstanding the fact that the actual threshold was reduced in stages during 2002. This allowed a consistent trend in the proportion of vehicles offending to be seen.

The data used contained information on the measured speeds of vehicles every six months from November 1994. Specific focus was given to the data matching the timeframe of the implementation of the new enforcement initiatives, i.e. May 1998 to November 2002. The speeds were generally measured at the same location at each of these six-month surveys. The locations varied over 60, 70, 80 and 100 km/h speed zones. Each site was examined in terms of its location within the Police Regions and Divisions. Unfortunately, Region 2, the second largest region in terms of camera hours, was not represented by any of the VicRoads sites.

The analysis presented below examines the three speed outcome variables within the above time frame to establish trends in the average speed, the 85th speed percentile, the distribution of speeds and the rate of vehicles above the enforcement speed limit over time, and whether any of the above varied by Region.

7.2.1 Trends in average and 85th percentile speeds

The trends in average and 85th percentile speeds in the different speed zones in Melbourne were generally constant up to November 1999, then started to decrease in all zones in May 2000 (Figures 7.1 and 7.2). This was before any of the enforcement initiatives came into effect, although there were trials of flashless cameras in October 1999 and March 2000 (the increase in offence rate associated with the second trial is apparent in Figure 5.2). All indicators had a downward trend commencing in May 2000, with some evidence of an accelerated decrease between November 2001 and May 2002, especially in the higher speed zones. This corresponded to the period when the increased camera hours and flashless operations were fully implemented, and the reduced enforcement threshold had been announced and at least the first stage was implemented. Offence rates had also fallen substantially during this period.

The downward trend continued during the remainder of 2002, and into 2003 in the higher speed zones, again consistent with the general decreasing trend in the rate of vehicles detected travelling 10 km/h or more above the speed limit (Figures 5.1 and 5.2). This general pattern of trends in the average and 85th percentile speeds in Melbourne, corresponding to reductions in offence rates associated with the introduction of the changed enforcement and other speed-related initiatives, suggests that these initiatives were a major cause of the reduction in these speed parameters during 2000-2002.

Figure 7.1: Average Speeds in 60, 70 and 80 km/h speed zones in Melbourne, November 1994 to May 2003

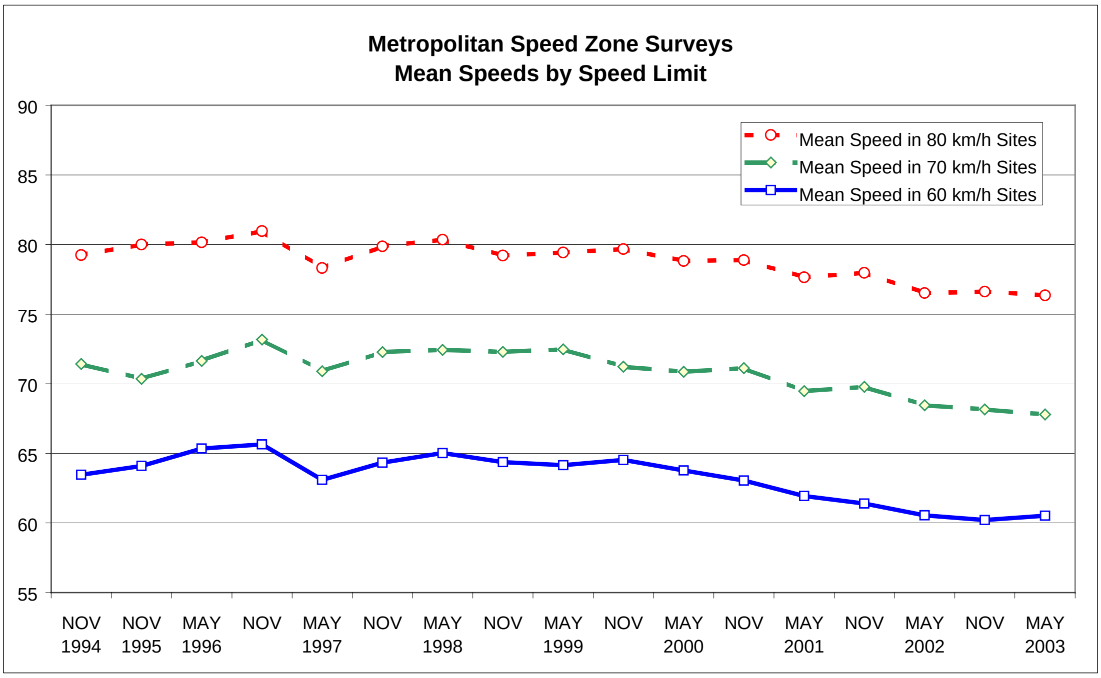
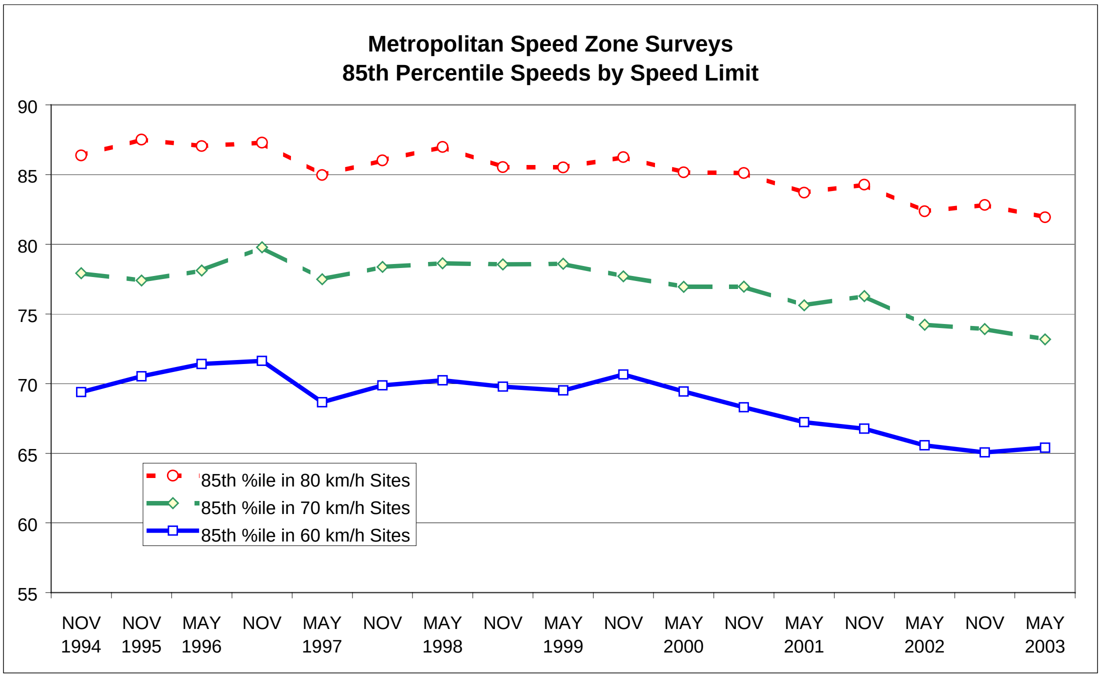


Figure 7.2: 85th Percentile Speeds in 60, 70 and 80 km/h speed zones in Melbourne, November 1994 to May 2003

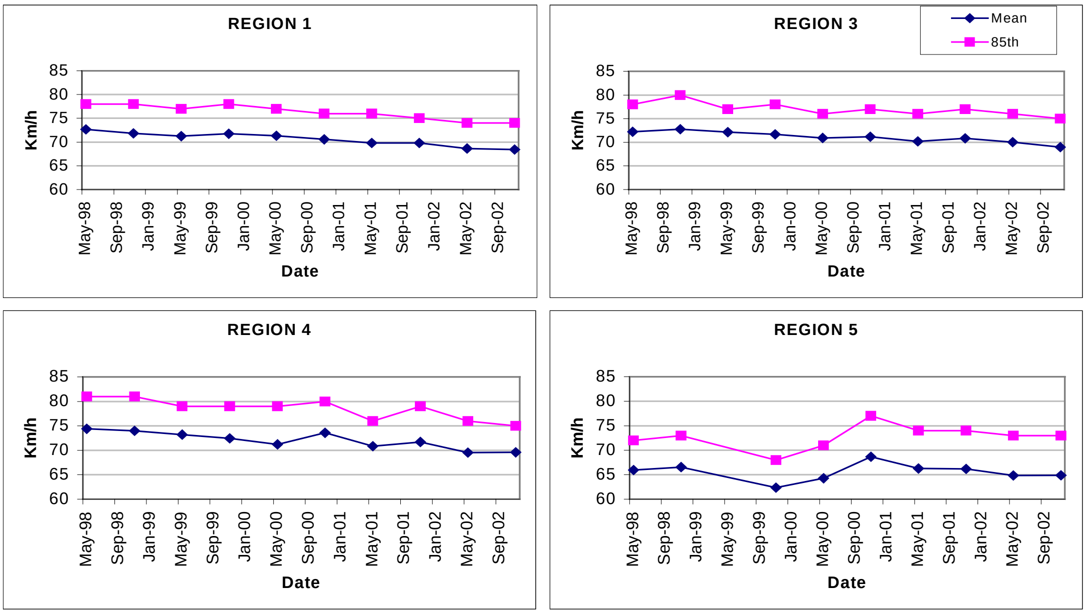


7.2.2 Average and 85th percentile speeds by Region

The average and 85th percentile speeds were analysed by region. Figure 7.3 show the average and 85th percentile speeds over time in 70 km/h speed zones for each available region. The number of sites in 70 km/h zones was adequate to provide reliable comparisons in speed trends between the regions.

All regions show a parallel trend between the mean and 85th percentile speeds. Regions 1, 3 and 4 show a downward trend over time from an overall average of 73.1 km/h in May 1998 to 69.0 km/h in December 2002. This suggests that, for 70 km/h speed zones, the average speed fell below the speed limit following implementation of the enforcement initiatives. The 85th percentile speeds reduced from 79 km/h to 75 km/h over the same period. However for Region 5 the average speed fluctuated between 62.4 and 68.7 km/h, while the 85th percentile speed fluctuated between 68 and 77 km/h. Generally, Region 5 demonstrated a lower average speed than the other regions and overall did not demonstrate the same decreasing trend in speeds as observed elsewhere.

Figure 7.3: Average and 85th Percentile Speeds in 70 km/h speed zones by Region, May 1998 to December 2002



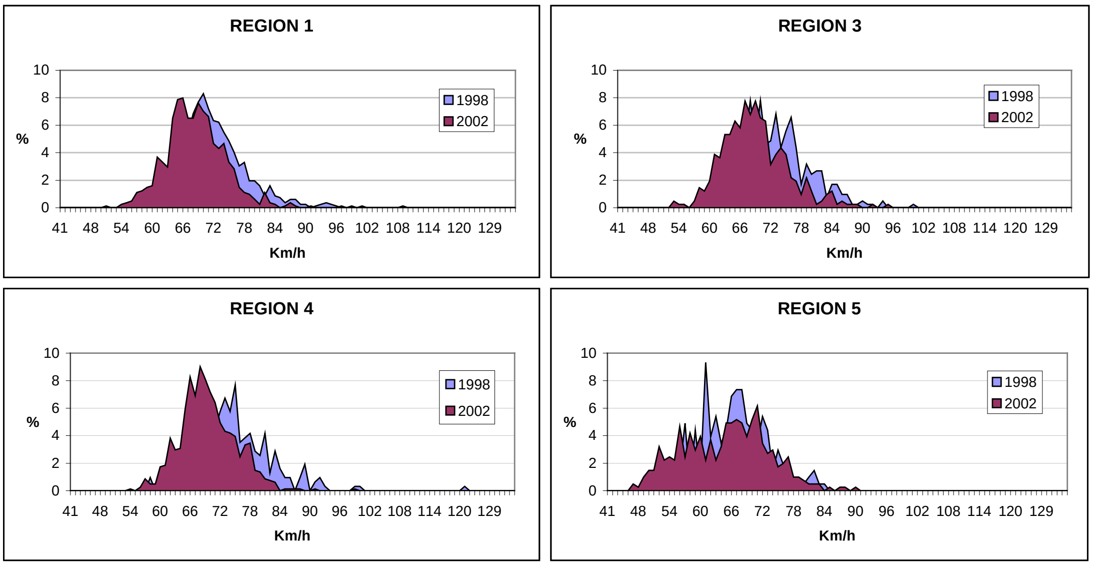
Overall, it appears that there have been similar changes (usually decreases) in both the average and 85th percentile speeds over time. This suggests that the distribution of speeds has shifted downwards, and that the shape of the distribution has stayed the same, as indicated by the parallel trend between the mean and 85th percentile. This suggests that not only are drivers driving slower on average, but the higher-level speeders have also reduced their speeds. This will be examined more closely below.

7.2.3 Speed distribution

The distributions of speeds were analysed over time to indicate whether there has been a change in the shape of the distribution. A general downward shift in the distribution would be consistent with the observed reduction in average speeds, whereas a change in the shape would indicate changes in the variability of speeding behaviour. For example, a tighter distribution would indicate less variability in speeds at the extreme ends, in particular the high-level speeders may have reduced.

Figure 7.4 shows the speed distributions in each region, for 1998 compared to 2002. Generally, the speeds appear to be approximately normally distributed. Between 1998 and 2002, regions 1, 3 and 4 indicate a downward shift in the speed distribution indicating a reduction in speeds overall. Region 5 does not appear to have shifted, but commenced with lower average speeds than the other three regions in 1998. It is difficult to determine whether there have been distinct changes in the shape of the distributions, specifically whether the distribution is less right-skewed, indicating a decrease in the extreme high-level speeders.

Figure 7.4: Comparison of the distribution of speeds per region between December 1998 and December 2002



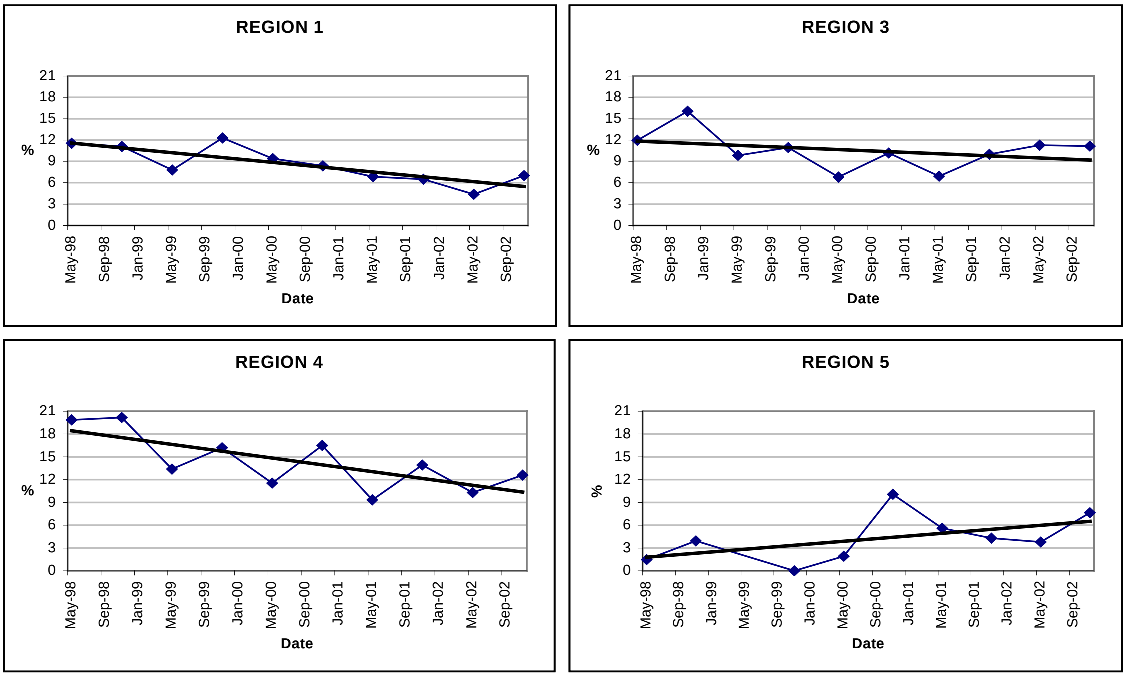
7.2.4 Rate of vehicles exceeding the enforcement speed limit

The VicRoads speed data was analysed to examine trends in the proportion of drivers exceeding or travelling at the speed enforcement threshold. It was expected that the speed camera offence rate would be lower due to drivers establishing the sites of the cameras and their ability to detect camera presence to some extent. On the other hand, the VicRoads data is collected over a shorter period of time, which may avoid any establishment effect, assuming drivers react to the speed measurement process. Therefore, the VicRoads data was considered to be more indicative of the 'true' rate of vehicles exceeding the enforcement speed limit (here taken to be a fixed 10 km/h above the limit at the speed survey site, throughout the period of the surveys).

The rates of vehicles above the enforcement speed limit over time measured by the VicRoads surveys in each region are shown in Figure 7.5. Not only was there substantial variation in the rates of vehicles above the enforcement speed limit between regions, the variations over time within a region were also variable. This variation may be due to seasonality factors, as the surveys were conducted in May and December each year. A general linear trend is imposed on the graphs. Regions 1 and 4 showed a strong downward trend in the rate of vehicles above the enforcement speed limit, whereas Region 3 showed a weak downward trend. As with the average and 85th percentile speeds, Region 5 again showed unexpected results with an increase in the rate of vehicles above the enforcement speed limit over time.

Generally, there appeared to be a steady decrease in the rate of vehicles above the enforcement speed limit over time from 1998 through to 2002, but there was considerable variation in this rate between regions.

Figure 7.5: Rate of Vehicles Observed Travelling Above the Enforcement Speed Limit, by Police Region



Note: The rates of vehicles above the enforcement speed limit in 2002 were adjusted in each region to reflect the change in the decreased threshold where applicable.

From the VicRoads speed data, the average rate of vehicles above the enforcement speed limit over all regions in December 2002 was 9.7%, approximately three times larger than the speed camera offence rate of 3.4% at the same time (Figure 5.1). Similarly, in December 2000, before the enforcement threshold had been reduced, the respective rates were 10.4% and 2.9%. The "true" rates of vehicles above the enforcement speed limit are more likely to be closer to the estimates from the VicRoads data, as the speed camera data is likely to underestimate the actual rate of vehicles travelling above the enforcement speed limit, as discussed earlier. If the VicRoads data are taken as being close approximations to the true rate of vehicles above the enforcement speed limit, it is suggested that this rate will be about three times higher than that detected by the speed camera.

In summary, the VicRoads speed data indicated that overall there was a decrease in the rate of vehicles travelling 10 km/h or more above the speed limit over time, associated with the time period that the changed enforcement and other speed-related initiatives were introduced. However, there appeared to be some regional differences and anomalies associated with Region 5. The rate of vehicles above the enforcement speed limit calculated from the VicRoads data was higher than that detected by the speed cameras by about three times over the time period of interest. This difference may in part be due to the fact that the VicRoads surveys measured only free speeds during daylight hours, and in part because the speed camera sites and/or camera operations may have produced driver reactions not applicable elsewhere.

7.2.5 Overall speed trends

Overall there appeared to have been a behavioural change over the period when the changed speed enforcement and other speed-related initiatives were introduced in both the average speeds and high-level speeds, with a downward shift towards lower speeds. This was observed over all regions, except for Region 5, which demonstrates little change over time.

The above conclusion is based on the VicRoads speed data, as the speed cameras tend to underestimate the true rate of vehicles travelling at least 10 km/h above the speed limit. Therefore the use of data on speeds detected by the cameras to estimate true speeds needs to be treated with caution. However, this underestimation does not grossly affect the analysis, but will need to be taken into account in any interpretation of trends in rates of vehicles travelling above the speed limit.

8 MODELLING OF CRASH OUTCOMES 1998 TO 2002

The aim of the crash analysis was to attempt to model the relationships between the full range of speed-related initiatives (changed speed enforcement and other factors) and the monthly crash frequencies and severities. The time period included in the initial analysis was from January 1998 to December 2002 (the extended analysis to December 2003 is described in Appendix B). The period from December 2000 to December 2002 was when the staged introduction of the enforcement initiatives occurred. Several related factors likely to have had an influence on monthly crashes were also included in the analysis: reduced default urban speed limit, media announcements related to the speed enforcement initiatives, speed-related television advertising by the TAC, and seasonal (monthly and yearly) effects. These will be discussed in more detail later. The prior period, from January 1998 to November 2000, was included in the analysis as a relatively stable pre-intervention period.

In the present study, two primary outcomes were used to measure the effect of the speed enforcement initiatives on crashes. As stated in Section 7 these were:

a) Crash Frequencies: Number of casualty crashes (crashes resulting in death or personal injury).

b) Crash Severity: Given a casualty crash, the proportion representing a given crash severity. Two different measures of crash severity were analysed:

i) Fatal crashes versus serious and minor injury crashes

ii) Serious casualty crashes (fatal or serious injury) versus minor injury crashes.

The first outcome measure represented a frequency count, while the second described a proportion or a binary outcome. Therefore these two outcome measures were analysed by two different statistical techniques. Both techniques belonged to the Generalised Linear Modelling family and are discussed in the following section.

8.1 Analysis Methodology

8.1.1 Statistical Analysis

Generalised Linear Modelling (GLM) techniques were used to estimate the effects of the speed-related initiatives and other factors on crashes. GLM is a powerful family of techniques that allows for a more flexible modelling of the response, Y_i, which can take on any distribution from the exponential family. The strength of this is that there is no assumption about a normally distributed response but can take the forms of counts, proportions, binary responses, positive continuous values, as well as Normal. Logistic, Poisson, and negative binomial regression models are three of the more common GLM family members. The use of the particular models within the GLM family is dependent on the form of the data.

As well as the probability distribution for the dependent component Y_i, it is linked to the independent variables through a link function. The GLM family of techniques allows the form of the link to be non-linear in its relationship. This is useful when modelling positive values or probabilities, so that the dependent variable is constrained to lie within set constraints. The two GLM techniques used to measure the two outcome variables are described below.

a) Crash Frequencies

Poisson regression with a log-link function was used to model the crash frequency outcome. The use of the Poisson distribution recognises that the response is indeed a count, constrained to non-negative values $Y_i \geq 0$. The log-link is used to relate the explanatory variables to the response, appropriate for non-negative count data. This is also known as log-linear modelling and takes the form:

$$\text{Log}(E(Y)) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i$$

The model is multiplicative in nature. Therefore a one unit change in any of the explanatory X variables will be associated with a multiplicative change, e^{β}, on E(Y).

One limitation of the model is the issue of over dispersion, where the variability in the response counts are greater than the mean, $\sigma^2 > \mu$. Under the Poisson model, the mean is assumed to be equal to the variance. Therefore over dispersion will underestimate the true variance expected under the Poisson model. This will cause the error variance to be too small under the Poisson, and will lead to a type I error, that is, rejecting the null hypothesis when there is no real effect. For example, stating that a particular initiative is associated with a decrease in crashes, where in actual fact, this is not true. This can be solved with a quasi-likelihood correction factor, which uses the degree of over dispersion as a scale factor to correct the model. The degree of over dispersion in the data is discussed below in Section 8.4.

The crash frequencies were analysed at the divisional level because this was the lowest geographical level at which the staged introduction of the initiatives occurred, as was explained earlier.

b) Crash Severity

Logistic regression was used to model the crash severity. Separate logistic regressions analyses were conducted to investigate the two different severity measures: (i) fatal versus serious and minor injury crashes; and (ii) serious casualty (fatal and serious) versus minor injury crashes.

Logistic regression is an appropriate technique to use, as it is able to model a binary response as a function of mixed continuous and discrete predictor variables. The equation takes the form:

$$\text{Logit}(p) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i$$

Where,

p = probability of event A occurring, that is, a fatality or serious injury in the crash (which necessarily resulted in some injury to be reported).

The logit is defined as the log odds, that is:

$$\text{Log odds} = \text{Logit}(p) = \ln(p/1\text{-}p)$$

Or

$$\text{Odds} = p/1\text{-}p = e^{\alpha} \times e^{\beta 1X1} \times e^{\beta 2X2} \times \ldots \times e^{\beta iXi}$$

Therefore, a one-unit change in the explanatory variable, Xi, will result in a multiplicative change, $e^{\beta i}$, in the odds of the outcome, all else constant. Therefore interpretation is in terms of an odds ratio (OR). For instance, an odds ratio greater than one would suggest an increase in the odds of a fatal outcome, whereas an odds ratio less than one, suggests a decrease in the odds of a fatal outcome.

Crash severity was analysed at the regional level, rather than the lower divisional level, because the average cell counts for fatalities and serious injuries at the divisional levels were too low to establish adequate statistical power.

8.2 Analysis Model

8.2.1 The statistical models

The form of the statistical models used to analyse the crash data is shown in Equation 1 below:

Equation 1: General Crash Model

$$\text{Log}(\text{crash}_{ijklmnpqrst}) = \alpha + \beta_{1i}\text{*area} + \beta_2\text{*log(hours)} + \beta_{3j}\text{*flashless} + \beta_{4k}\text{*threshold} + \beta_{5l}\text{*August announcement} + \beta_{6m}\text{*December announcement} + \beta_{7n}\text{*April announcement} + \beta_{8p}\text{*advertising Adstocks} + \beta_{9q}\text{*Month} + \beta_{10r}\text{*Year} + \beta_{11qr}\text{*(Month*Year)} + \beta_{12iq}\text{*(Area*Month)} + \beta_{13ir}\text{*(Area*Year)} + \beta_{14s}\text{*50km/hEffect}$$

A general description of the variables included in the above equation is given in Table 8.2. More detailed descriptions of the variables presented in the above table are provided next.

8.2.2 Description of the independent variables used in the analyses

The variables representing the speed enforcement initiatives are discussed first, followed by a description of the other speed-related factors included and some necessary covariates. A number of covariates which were considered likely to be also associated with crash outcomes, but which were not of main interest to this study, were included for in the analysis to control their effects.

8.2.2.1 Flashless Operation of Speed Cameras

The flashless initiative was represented as a binary variable in the analysis to indicate whether a particular area had the flashless initiative in operation or not. The reference category was the pre-initiative absence of flashless operations. Thus, a negative coefficient for the flashless initiative variable in the Poisson regression would indicate that the flashless operations were associated with decreased crash frequencies compared to the pre-initiative period**.** In the logistic regression, an odds ratio less than one would indicate that the flashless operations were associated with a reduction in crash severity (i.e. the odds of a more severe outcome are reduced) compared to the pre-initiative period.

8.2.2.2 Increase in Speed Camera Hours

The second initiative, the increase in camera hours, was coded as a continuous variable. A functional form, as described in section 6.2, was assumed for this variable. The hours variable was included in the analysis as a logarithm function, as indicated in Equation 1.

The increase in camera hours was not consistent in time and space across the divisions or the regions. Therefore, by maintaining a continuous form, as opposed to categorizing the variable, any differences in the actual hour increases between regions and divisions would be directly incorporated into the model

The interpretation of the hours variable is slightly different to the other variables. A 1% change in the monthly camera hours will be associated with a β_2% change in the crash frequency (see Equation 1). In the terminology of econometrics, β_2 is known as the 'elasticity' between camera hours and casualty crashes. Again, a negative coefficient will indicate a reduction in crash frequencies, or a reduction in the odds of a high severity level outcome (fatal or serious casualty) of the crashes.

8.2.2.3 Reduction in Speed Enforcement Threshold

For the reduction in the speed enforcement threshold variable, each of the three reduction stages was represented as a separate category, with the pre-initiative threshold used as the reference category. Thus, in the Poisson regression, for each of the three reduction categories, a negative coefficient would indicate that this particular reduction was associated with a decrease in monthly crash frequencies compared to the pre-initiative period, and vice versa. In the logistic regression, for each threshold reduction category, an odds ratio less than one would indicate that this threshold reduction was associated with a decrease in the odds of a more severe outcome.

Table 8.2: General Description of Variables and Interactions in the Generalised Linear Models

Variables	Type of Measure	Categories	Reference Category
OUTCOMES:			
Crash Frequency	Count	n/a	n/a
Crash Severity	Binary	1 = fatal 2 = injury OR 1 = serious casualty 2 = minor injury	n/a
ENFORCEMENT INITIATIVES (lagged):			
Initiative I: Flashless Operations	Binary	1 = no flashless operations 2 = flashless operations	1 = no flashless operations
Initiative II: Camera Hours	Continuous	n/a	n/a
Initiative III: Threshold Reduction	Categorical	1 = no reduction 2 = first reduction 3 = second reduction 4 = third reduction	1 = no reduction
OTHER FACTORS:			
Announcement effects - August 2001 - December 2001 - April 2002	Binary	1 = no announcement 2 = announcement made	1 = no announcement
Advertising awareness (Adstock)	Categorical	1 = low 2 = medium 3 = high	1 = Low
Regions and Divisions	Categorical	1-5 Regions 1-23 Divisions	n/a
Month	Categorical	1-12 months	n/a
Year	Categorical	1-5 years (from 1998 to 2002)	n/a
50 km/h speed limit	Binary	1 = Feb 2001 onwards 2 = Jan 1998 – Jan 2001	2 = before limit
INTERACTION TERMS:			
Month*Year	Categorical	12 months * 5 years	n/a
Month*RD	Categorical	12 months * 23 Divisions	n/a
Year * RD	Categorical	5 years * 23 Divisions	n/a

8.2.2.4 Announcements

Media announcements related to the introduction of the enforcement initiatives were expected to play a role in supporting speed camera operations. Although such announcements appear counter-productive to the covert tactic of some operations, as long as the announcements did not specify current camera locations, they are believed to play a useful role in complementing the speed-related paid advertising (Cameron et al, 2003a). Thus, in the present study, media announcement were expected to play a role in reducing crash frequencies and/or crash severity during the period (say, one month) following the date that an announcement was made, by raising drivers' awareness and anticipation of increased speed enforcement.

There were three major announcements that occurred during the initiatives implementation period. These are shown in Table 8.3.

Table 8.3: Announcements relating to the Speed Enforcement Initiatives, 2000 - 2002

Announcement	Month of Main Effect	Relevant Initiative
1	August 2001	Non-specific
2	December 2001	Hours, Flashless
3	April 2002	Threshold reduction

The first announcement occurred from 8th August 2001. This announcement was fairly non-specific and did not relate to any particular speed enforcement initiative. It was mainly concerned with the "Wipe Off 5" campaign, and the increase in crash risk from travelling at 65km/h in a 60 km/h zone. Although the announcement did not relate specifically to any speed enforcement initiative, it was still expected to have had an impact on the average speed of drivers and subsequently on crash risk. This announcement was expected to have had an effect during August.

The second announcement first occurred on 21st November 2001. This announcement specifically mentioned the flashless camera operations, as well as the increase in camera hours. The increase in camera hours was further mentioned on November 28th along with other enforcement initiatives to come into place, such as the point-to-point speed cameras. Therefore it may be expected that the effects from this announcement would be stronger than the August announcement, due to the specific nature of the announcement and the negative implications in terms of fines and demerit points. This announcement was assumed to have had an effect during December, because the timing of the announcement occurred at the end of November. It will be referred to as the December announcement in this report.

The third announcement was related to the reduction in the speed enforcement detection threshold. The announcement occurred at the end of March 2002, the month of the first staged threshold reduction. However, it was assumed that the announcement would have had an effect in April, again because it occurred at the end of March. It will be referred to as the April announcement in this report.

For analysis purposes, the announcements were assumed to have an immediate effect on crashes, for one month only, in the month that the announcement was made or in the month immediately following if the announcement was at the end of the month.

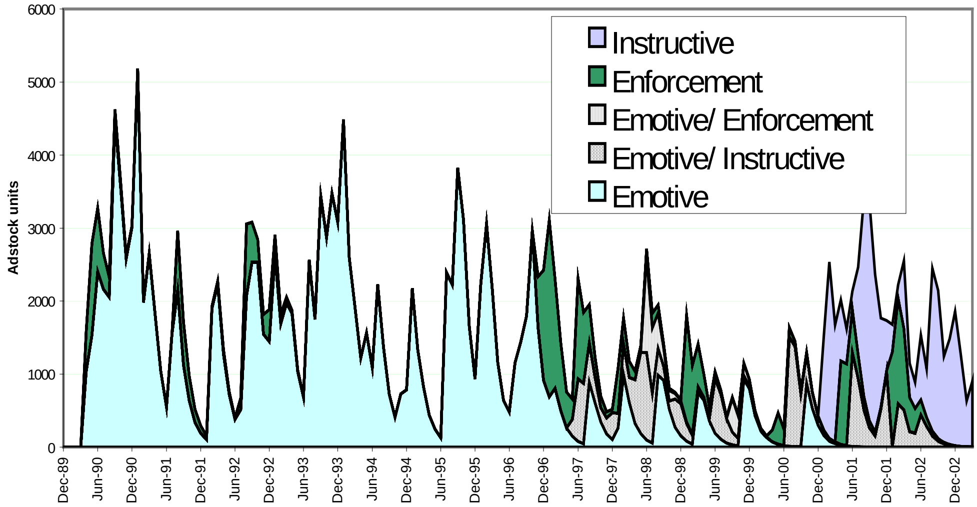
8.2.2.5 Speed-related Advertising

Speed-related television advertising by the TAC has been found to influence the frequency and severity of crashes. Cameron et al (2003b) found that high levels of awareness of TAC speed-related publicity with emotive styles produced casualty crash reductions in Melbourne during the months in which it occurred in the 1996-2000 period. In the same study it was found that there was an interaction effect on fatal casualty crash outcome when there were very high levels of speeding TINs detected in the previous month, accompanied by high levels of awareness of speed-related advertising. The reduction in risk of fatal outcome was greater than expected from effects estimated when the enforcement and advertising operated alone at these levels. Furthermore, drivers' perception of the risk of detection when speeding was found to increase during months of high levels of awareness of the speed-related advertising compared to medium level advertising (Cameron et al, 2003b).

As in previous studies (e.g. Cameron et al, 2003b; Cameron et al, 1993, 1997; Newstead et al, 1995, 1998), the advertising impact level per month from 1998 to 2002 was represented by Adstock in previous weeks, categorised into low and high, or low, medium, and high levels. Adstock is a measure developed by Broadbent (1979) describing the way that the audience's retained awareness is related to current and past levels of television advertising measured by Target Audience Rating Points (TARPs). TARPs are a measure of audience reach represented as a percentage of persons in the Target Audience in the viewing area estimated to be watching the specific television channel at the time of advertising.

During the 1998-2002 time period investigated in this study, there were several different styles of TAC speed-related advertising on television: instructive, enforcement, emotive, emotive/enforcement, and emotive/instructive. These style classifications were provided by the TAC. A graph of the level of Adstock for each style of speed-related advertising between 1989 and 2002 is presented in Figure 8.1.

Figure 8.1. Speed-related Adstock per month by style, December 1989 to December 2002



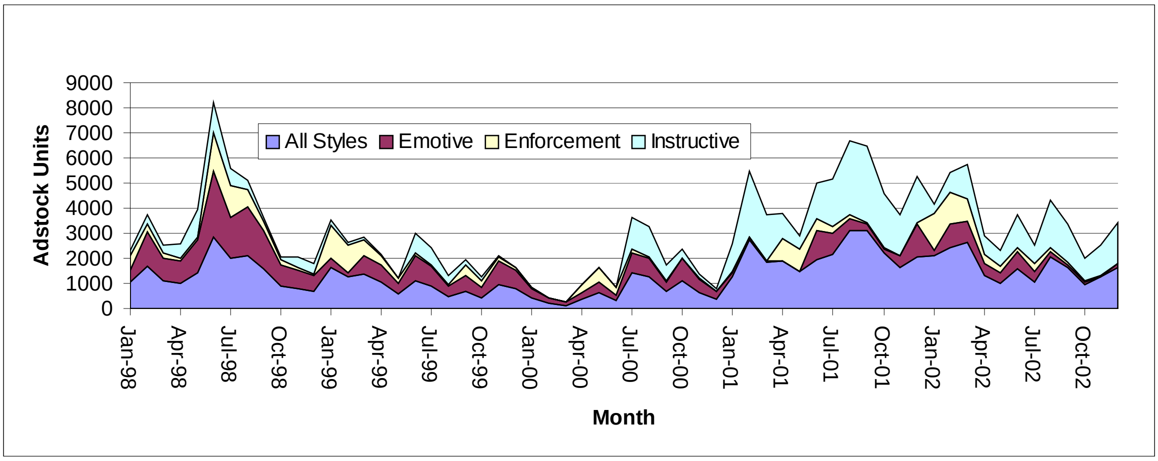
It is evident from the above figure that there was a decrease of emotive advertising over the years and an increase in instructive and enforcement styles, particularly in the period when the three new initiatives were implemented from 2000 to 2002.

For the purposes of the present study, the following categories of speed-related advertising were derived for each month of the study period:

- all styles (a sum of monthly Adstock across all of the above styles)
- emotive (a sum of monthly emotive, emotive/instructive, and emotive/enforcement Adstocks)
- instructive (a sum of monthly instructive and emotive/instructive Adstocks)
- enforcement (a sum of monthly enforcement and emotive/enforcement Adstocks)

Speed-related Adstock in these categories is shown in Figure 8.2.

Figure 8.2. Speed-related Adstock per month by style, January 1998 to December 2002.



The Adstock of the combined all styles category was categorised into low, medium, and high levels by using the 33rd and the 67th percentiles as cutoffs. As there was less variation for the individual styles, they were categorised into high and low levels using the median as a cut off. The categorisations were based on 2000-2002 levels of advertising only, in order to be able to control for even relatively small variations in advertising during the period when the new initiatives were introduced. For example, as there were much higher levels of emotive advertising in some periods prior to 2000, if the categorisation had been based on the whole 1998-2002 period much of the monthly advertising in 2000-2001 would have fallen in the low category, reducing the discrimination for this period.

As levels of advertising tend to vary somewhat between metropolitan and rural areas, all of the above Adstock estimates are based on the monthly averages of the metropolitan and rural Adstocks. The advertisements that were screened from 1998 to 2002 are described in Table A.3 in Appendix A.

Table 8.4: General Description of Advertising Sub-Models

Type of Advertising	Levels	Category Boundaries (in Adstock units)
All Styles	3	Low < 1335; Medium >= 1335 and < 2028; High >= 2028
Emotive	2	Low < 242; High>=242
Enforcement	2	Low < 116; High>=116
Instructive	2	Low<1283; High>=1283

In the main analysis, advertising was represented by including an overall "all styles" variable. However, three separate analyses were also carried where in each only one of the three advertising styles (emotive, enforcement, or instructive) was represented in order to determine if differences existed between the three styles. These analyses were carried out separately, rather than including the three advertising style variables in the same analysis, because of the overlap in the definition of the three advertising styles, as explained earlier in this section.

The "low" Adstock category was used as the reference category in the analysis. Thus, in the Poisson regression, for the "medium" and "high" categories, a negative coefficient would indicate a decrease in monthly crash frequencies compared to the "low" category, and vice versa. In the logistic regression, for the "medium" and "high" categories, an odds ratio less than one would indicate an associated decrease in the odds of a more severe outcome compared to the "low" category.

8.2.2.6 Area Effects

In order to control for regional and divisional variations in the analysis, a regional term with five levels and a divisional term with 23 levels were included in the crash frequency analysis. In the crash severity analysis, only the regional term was included because crash severity was analysed only for overall regions, as was explained earlier.

8.2.2.7 Seasonality and Yearly Effects

In the analysis it was also necessary to control for seasonality effects as it may be expected that crash frequencies would vary within different months of the same year, as well as between different years. To control for these seasonal trends, a yearly trend term, a monthly trend term, and the interaction of the yearly and monthly terms were included. Furthermore, it may be expected that seasonality trends may vary with location. Therefore, terms for the interactions between location (region/division) and month and year were also included in the analysis.

8.2.2.8 50 km/h urban speed limit

The influence of the 50 km/h speed limit was taken into account in the analysis by a simple binary variable, potentially indicating a step effect from the month after the default urban limit came into effect (i.e. from February 2001 onwards). This step variable was included in the analysis model for all Police divisions and regions, no matter whether the area was principally urban in character or not. Hence any detected effect would be an average across all areas and speed zones, and should not be seen as an alternative to the more specific estimates provided by Hoareau, Newstead and Cameron (2002, 2006) and their comprehensive evaluation of this initiative. However, given the possibility that the effect of the new limit has extended well beyond the limited roads it directly affected, the estimates provided by this study could be indicative.

8.3 Goodness of Fit

The adequacy of fit of the analysis models was measured by the ratio of deviance to degrees of freedom. For all models the ratio of deviance to degrees of freedom was approximately one. This suggested that no over-dispersion in the models.

8.4 Interpretation of the Model Results

As stated in section 8.1, the interpretation of the model coefficients is in terms of a percentage change (crash frequency) or in terms of the odds of a certain severity level of the crash (crash severity), holding all else constant. The interpretation of the percentage change or relative odds will be in relation to a reference category, as was explained earlier. For example, for the flashless initiative, the reference group will be the pre-initiative absence of flashless operations. The exception to this is the continuous hours variable, as was explained in section 8.2.2.2.

The statistical significance level, p, was not be held strictly to the 5% level of $\alpha = 0.05$, but considered worthy of reporting up to around 0.12, due to the complexity of the model and due to the possibility that the effects may have extended past the geographical boundaries, which would act to weaken the analysis. The presented significance levels are two-tailed, allowing for the possibility that the specific factor may increase or decrease crash frequency (or crash severity), but in cases where prior knowledge suggests an increase is unlikely, a one-tailed test may be considered appropriate and the significance level could be halved.

8.6 Analysis Results

8.6.1 Crash Frequency Analysis

The crash frequency analysis was performed using Poisson regression on the regional-divisional model. There were a total of 1,380 observations (12 months x 5 years x 23 regional divisions) during 1998 to 2002. Table 8.5 provides the results for the main effects.

Table 8.5: Poisson Regression Estimates for Monthly Casualty Crash Frequencies

Variables	Categories	% Change in Crash Frequencies	95% Confidence Intervals Lower	Upper	p
Camera Hours	.	-0.09 *	-0.16	-0.02	0.0096
Flashless Operations	**On**	-2.08	-8.03	4.26	0.5113
	Off	.	.	.	.
Threshold Reductions	**1st Step**	-3.80	-12.88	6.23	0.4480
	2nd Step	-10.76	-23.41	3.99	0.1445
	3rd Step	-8.08	-23.08	9.85	0.3543
	Pre-reduction	.	.	.	.
All Styles Advertising	**High**	-5.92	-16.81	6.41	0.3317
	Medium	-9.99	-18.56	-0.50	0.0396
	Low	.	.	.	.
August Announcement	**On**	-21.80	-31.89	-10.21	0.0005
	Off	0.00	0.00	0.00	
December Announcement	**On**	-10.26	-18.77	-0.87	0.0330
	Off	.	.	.	.
April Announcement	**On**	4.34	-15.40	28.69	0.6911
	Off	.	.	.	.
50 km/h limit	**On**	10.76	-16.95	47.72	0.4867
	Off	.	.	.	.

* Unlike the percentage change estimates in this column, this figure should be interpreted as the elasticity between camera hours and casualty crash frequency (see section 8.2.2.2).

As shown in Table 8.5, the Poisson regression produced results in line with the proposed hypotheses. Generally, the estimates produced coefficients that were in the expected direction, with the initiatives being generally associated with a reduced number of monthly crashes. There were four statistically significant results. Each of these will be discussed in turn below.

The increase in monthly camera hours was significantly associated with a decrease in monthly crash frequencies (p = 0.0096). This means that a 1% increase in camera hours was associated with a 0.09% decrease in casualty crashes in the following month, holding all else constant, with a 95% confidence interval ranging from 0.16% decrease to 0.02% decrease.

Based on the above results, the percentage decrease in crash frequencies associated with each stage of increase in camera hours was estimated, and is presented in Table 8.6 below.

Table 8.6: Estimates for Percentage Changes in Monthly Casualty Crash Frequencies for Stages of Increases in Monthly Camera Hours

Increase in camera hours	% Change in Crash Frequencies	95% Confidence Intervals	
		Lower	Upper
Stage 1: 4200 - 4800 hours	-1.23	-2.15	-0.30
Stage 2: 4800 - 5400 hours	-1.08	-1.90	-0.27
Stage 3: 5400 - 6000 hours	-0.97	-1.70	-0.24
Total: 4200 - 6000 hours	-3.25	-5.63	-0.80

The first stage of the camera hours increase (from 4200 hours to 4800 hours per month), represented about 14% increase in camera hours. As can be seen in Table 8.6, this corresponded to a 1.23% reduction in crashes, with a 95% confidence interval (CI) of 2.15% reduction to 0.30% reduction. The total increase from 4200 to 6000 monthly hours represented a 43% increase, and was therefore associated with a 3.25% reduction in casualty crashes (with a 95% CI from 5.63% reduction to 0.80% reduction).

Although the flashless camera operation was associated with a 2.08% reduction in monthly casualty crashes, this estimate was not statistically significant. This may in part be due to the fact that the effect of the initiative may have been diluted in practice, as speed camera operators may have been reluctant to operate without flash assistance during the poorer ambient light in winter months. No information was available to indicate whether daytime camera sessions in fact operated without the flash units after the flashless operations were deemed to have commenced.

The individual stages of the threshold reduction initiative did not show any statistically significant effects. However, all the estimates were in the hypothesised direction, with 3.80%, 10.76%, and 8.08% crash reductions associated with the first, second, and third threshold reductions respectively. It should be noted that the third step did not apply in the 100 and 110 km/h speed zones, so any effect of that stage was diluted across the crashes in all speed zones that were considered in the analysis.

While the individual stages of the threshold initiative did not produce any statistically significant results, it was possible that collectively they may. Hence, a reduced model was tested without the threshold initiative to assess the relative contribution of the initiative to the model in explaining the outcome crash frequency. The reduced model was tested by assessing the difference in scaled deviance compared to a chi-square distribution with degrees of freedom of the difference in the number of parameters in the model, that is, $(D_R - D_S) \sim \chi^2_{p-q}$. A non-significant result was obtained for the reduced model, $\chi^2_{(3)} = 2.414$, p-value = 0.491. This suggested that the threshold initiative did not make a significant contribution to the present model.

The medium level of the categorised all-styles advertising variable was significantly associated with about 10% reduction in monthly casualty crashes relative to the low level of advertising (p = 0.0396). The high level of advertising was associated with a statistically non-significant 5.92% reduction in crashes compared to the low level. The analyses for the separated advertising styles are presented later in this chapter.

The analysis presented in Table 8.5 also found two strong media announcement effects. The first was from the August 2001 announcement. This was a general announcement, which mainly focused on the instructive advertising style of the "Wipe Off 5" campaign. This announcement was significantly associated with a 21.80% reduction in casualty crashes during that month.

The second announcement that occurred at the end of November 2001, but with its effects assumed to have occurred in December, was similarly significantly associated with a 10.26% reduction in casualty crashes. This November announcement was more specific, focusing on the covert operation and increased camera hours.

The third announcement, which occurred in late March 2002 and expected to have effects in April, did not produce statistically significant results. Although the percentage estimate for this announcement was positive, its estimate was associated with a large error, thus resulting in an unreliably large confidence interval, as shown in Table 8.6.

Similarly, the introduction of the 50 km/h speed limit did not produce a statistically significant result, and the estimate was associated with a large error and a very wide confidence interval.

8.6.1.1 Analyses with the separate advertising styles

Separate analyses were also conducted for each of the three different styles of speed-related advertising (instructive, enforcement, and emotive), but otherwise using the same model as in Table 8.5. The results for each advertising style are presented in Table 8.7. The results for the other variables were very similar to those already presented in Table 8.5. As shown in Table 8.7, only the instructive style of advertising was significantly associated with crash frequency, the estimated effect being a 9.99% crash reduction. This result is very similar to that of the all-styles advertising. This is not surprising, as during the period of the implementation of the initiatives the instructive style was the most dominant of the three styles, and could thus be predominantly driving the effect of the all-styles advertising variable.

Table 8.7: Poisson Regression Estimates for Different Styles of Speed Related Advertising

Advertising Style	Category	% Change in Crash Frequencies	95% Confidence Intervals		P
			Lower	Upper	
Instructive	**High**	-9.99	-18.56	-0.50	0.0396
	Low	.	.	.	.
Emotive	**High**	-4.32	-13.49	5.12	0.3900
	Low	.	.	.	.
Enforcement	**High**	-5.12	-14.33	5.09	0.3129
	Low	.	.	.	.

Despite the lack of statistical significance of the enforcement and the emotive advertising, both these styles also exhibited a consistent trend of higher levels of advertising being negatively associated with crash frequencies. These results are summarised in Table 8.7 and the full analyses are presented in Appendix A Tables A4-A6.

8.6.1.2 Analysis with advertising Adstock as a continuous variable

The arbitrary nature of the categorisation of the advertising Adstock into low, medium, and high is a limitation of the analysis. In the present analysis, the categorisation was based on the levels of advertising during the period of the three initiatives. However, had a different period or a different categorisation method been chosen, a different pattern of estimated effects related to advertising levels may have been obtained. Furthermore, these arbitrary categories of "low", "medium", and "high" do not allow more useful estimates to be made of specific amounts of increase in Adstock levels that are associated with specific percentage changes in crashes, as was done for the continuous camera hours variable in Table 8.6. Such more precise estimates about advertising levels would be of much greater use in making future recommendations about road safety related advertising.

The reason for initially using categorised Adstock in the analysis was that if Adstock was analysed as a continuous variable a functional relationship must be assumed, similar to the issues discussed earlier regarding the camera hours (section 6.2). Although there had been previous research evidence to indicate that this relationship could be assumed for the camera hours, no definitive research appears to exist in regard to Adstock. However, a logarithmic relationship between Adstock and crashes had been assumed in the early evaluation of TAC's television advertising (Cameron et al 1993) and in Newstead et al's (1995a, 1998) modelling of factors influencing road trauma trends in Victoria. While reviewing and re-analysing these studies, White et al (2000) conducted analysis which strengthened the evidence for a relationship of the logarithmic type between speed-related Adstock and crashes. In a recent study modelling the effects of the components of the Road Safety Initiatives Package in Queensland during 2002-2003, Newstead et al (2004) included the monthly Adstock of road safety television advertising as an explanatory factor. They found Adstock (with predominantly anti-speeding and drink-driving themes) to be a highly statistically significant factor explaining monthly crash trends.

The Poisson regression analysis, described earlier in Table 8.5, was carried out again, but with a continuous Adstock variable replacing the categorised Adstock. Similar to the camera hours variable, a log function of Adstock was used in the analysis. Again, separate analysis was carried out for all-styles advertising, as well as for each of the three separate styles, but with a continuous Adstock variable used for each style. As in the earlier analyses with the categorised Adstock, the all-styles and the instructive Adstock produced statistically significant results. In fact, exactly the same coefficients were obtained for both the all-styles Adstock and for the instructive Adstock. Once more, this points to the predominance of the instructive style during the initiatives period. The results indicated that every 1% increase in all-styles or in instructive advertising Adstock was associated with 0.28% decrease in monthly crash frequencies ($p = 0.0396$; 95% confidence intervals of 0.01% reduction to 0.55% reduction). The same results were obtained for the three speed enforcement initiatives as presented in Table 8.5. A similar pattern of results was also obtained for the other factors, except that only the August announcement reached statistical significance. Thus, the effect of the media announcements appears to have been reduced when the continuous Adstock variables were used in the analysis.

The analysis with the continuous emotive style Adstock also produced statistically significant results, with every 1% increase in the emotive style of advertising being associated with 0.12% decrease in crashes (p = 0.0396). However, during the period from December 2000 to December 2002 most of the emotive style advertising also included an instructive component (emotive/instructive style). The emotive style advertising did not produce statistically significant results when analysed as a categorical variable. Thus, the emotive advertising component is less likely to have contributed to crash changes during the period of the initiatives. The full analysis results with the continuous Adstock variables are presented in Tables A7-A9.

The percentage decrease in crash frequencies associated with different amounts of increase in the all-styles Adstock was estimated, and is shown in Table 8.8 below. This is similar in character to the estimates that were presented earlier for the hours variable in Table 8.6, and a similar diminishing returns relationship is evident.

Table 8.8: Estimates for Percentage Changes in Monthly Casualty Crash Frequencies for Increases of Speed-related Advertising Adstock

Increase in Adstock	% Change in Crash Frequencies	95% Confidence Intervals Lower	Upper
500-1000	-17.88	-31.93	-0.93
1000-1500	-10.88	-20.15	-0.55
1500-2000	-7.85	-14.75	-0.39
2000-2500	-6.14	-11.65	-0.30
2500-3000	-5.05	-9.62	-0.25
3000-3500	-4.29	-8.20	-0.21
3500-4000	-3.72	-7.14	-0.18
4000-4500	-3.29	-6.33	-0.16
4500-5000	-2.95	-5.68	-0.14

During the period of the introduction of the enforcement initiatives (December 2000 to December 2002) the monthly average level of speed-related advertising was 1813.60 Adstock units, compared to 1014.16 Adstock units in the prior period (January 1998 to November 2000). This amounts to a monthly average increase in advertising of 799.44 Adstock units (78.8% increase) during the period of the initiatives. This increase was estimated to be associated with 15.23% decrease in casualty crash frequencies during the initiatives period (with a 95% confidence intervals from 0.78% to 27.57% decrease).

8.6.2 Crash Severity Analysis

The aim of the crash severity analysis was to examine the relationships between the speed-related initiatives, other relevant factors, and the relative odds of fatal outcome of casualty crashes, or the relative odds of a serious casualty outcome. Logistic regression was used for this analysis. As discussed earlier, the crash severity analysis was performed at a regional, rather than at a divisional level, to retain sufficient statistical power. A separate analysis was carried out for fatal crashes and for serious casualty crashes (in each case in comparison with less severe casualty crashes).

The serious casualty crash analysis did not produce any statistically significant results. There was also concern about the reliability of the analysis based on this crash severity criterion because of some doubt about the accuracy of the injury severity information (except for fatal outcome) in about 20% of the reported crashes during August to October 2001 (see section 7.1).

However, the fatal crash analysis did produce a number of significant results. This is consistent with the earlier research of Cameron et al (2003b), who found statistically significant reductions in the risk of fatal outcome of casualty crashes associated with increases in speed camera hours in selected police districts in Melbourne for one month at a time. It is possible that the fatal outcome of crashes may be more sensitive to a change in speed enforcement than the risk of serious injury. However, the results should be treated with caution due to the low average fatality counts per month in each region, as shown in Table 8.9 below.

Table 8.9: Average Frequencies for Fatalities and Serious Injuries per Month in Each Region

Region	Average	
	Fatal	Serious
1	3.0	88.6
2	7.1	82.9
3	6.0	83.0
4	7.3	106.8
5	7.2	76.8
Average	**6.1**	**87.6**

The regional fatal crash severity analysis produced three statistically significant main effects. Unlike the crash frequency analysis, the results were generally not in the expected direction, with the exception for the increase in speed camera hours. The results are shown in Table 8.10 below.

Table 8.10: Logistic Regression Estimates for the Odds of a Fatal Outcome Given a Casualty Crash

Variables	Categories	Odds Ratio	95% Confidence Intervals Lower	Upper	P
Camera Hours	.	-1.60 *	-3.00	-0.19	0.0256
Flashless Operations	**On**	1.70	1.11	2.60	0.0138
	Off	.	.	.	
Threshold Reductions	**1st Step**	1.10	0.48	2.51	0.8244
	2nd Step	0.94	0.29	3.00	0.9124
	3rd Step	0.78	0.20	3.02	0.7142
	Pre-Reduction	.	.	.	
All Styles Advertising	**High**	2.21	0.63	7.78	0.2170
	Medium	1.58	0.56	4.48	0.3870
	Low	.	.	.	
August Announcement	**On**	2.27	0.59	8.78	0.2355
	Off	.	.	.	
December Announcement	**On**	1.34	0.38	4.69	0.6519
	Off	.	.	.	
April Announcement	**On**	0.55	0.09	3.43	0.5231
	Off	.	.	.	
50 km/h Limit	**On**	0.21	0.01	3.29	0.2641
	Off	.	.	.	.

* Unlike the odds ratio estimates in this column, this figure should be interpreted as the elasticity between camera hours and the odds of fatal outcome from casualty crashes (see section 8.2).

As can be seen in Table 8.10, the increase in camera hours was significantly associated with a decrease in the odds of fatal outcome of the casualty crashes. The results indicate that every 1% increase in camera hours was associated with a 1.6% decrease in the odds of a fatal outcome, with a 95% confidence interval of 0.2% decrease to 3.0% decrease.

Based on the above results, the percentage decrease in the odds of a fatal outcome associated with each stage of increase in camera hours was estimated, and is presented in Table 8.11 below.

Table 8.11: Estimates of Percentage Changes in the Odds of Fatal Outcome from Casualty Crashes for Increases in Monthly Camera Hours

Increase in camera hours	% Change in Odds	95% Confidence Intervals Lower	Upper
Stage 1: 4200 - 4800 hours	-19.19	-32.99	-2.57
Stage 2: 4800 - 5400 hours	-17.14	-29.75	-2.27
Stage 3: 5400 - 6000 hours	-15.48	-27.08	-2.03
Total increase: 4200 - 6000 hours	-43.41	-65.67	-6.71

Table 8.11 shows that the increase in speed camera hours from 4200 to 6000 per month was estimated to have reduced the risk of a fatal outcome in casualty crashes by 43.41%, with 95% confidence limits on this estimate ranging from 6.71% to 65.67%.

Unlike in the crash frequency analysis, in the severity analysis in Table 8.10 the flashless initiative showed a significant result ($p = 0.0138$). However, this result was in the opposite direction to that which could be expected, with the initiative being significantly associated with an increase in the odds of a fatal outcome. This was a surprising result, given that the flashless trials were so effective in increasing the detected offence rate, and that the first stage of the initiative also showed an increase in detected offences and an apparent reduction in casualty crashes. There may be a number of explanations for this result, which are discussed later in Section 9.2.

The speed enforcement threshold reductions and the speed-related advertising were not significantly associated with the odds of fatal outcome, as neither were any of the factors considered in the above analysis.

The severity analysis was also performed with the continuous, rather than categorical Adstock variables, as discussed in the previous section. The same results were obtained for the three speed enforcement initiatives, and again none of the advertising variables reached statistical significance. This analysis is presented in Tables A10-A13.

9 DISCUSSION OF MODELLING RESULTS

Sections 9.1-9.6 provide a summary and discussion of the results of the initial modelling of monthly crash outcomes in Victoria from 1998 to 2002. This was a period of substantial change in the speed enforcement system in Victoria, accompanied by related legislative change, announcements of these initiatives, and a general escalation in speed-related mass-media advertising placed by the TAC. Section 9.7 provides a summary of an extended analysis including crash data during 2003, reported in Appendix B, as well as an outline of where the results differed.

Some of the speed-related changes had been the subject of previous research in Victoria (speed camera activity and TAC advertising levels), so there was good understanding of the likely mechanisms which connect such changes with reductions in road trauma levels. Other changes (e.g., flashless camera operations and reduced speed enforcement threshold levels) were unprecedented in Victoria and it was necessary to speculate on their possible mechanisms of effect on speeds and road trauma in order to include these initiatives in the statistical models. Other factors included (e.g., announcements of the initiatives) also suffered from the limited knowledge of their possible effects, and that knowledge was generally based on research from other jurisdictions.

Against this background, the efficacy of this ambitious attempt to use generalised linear modelling to represent road crash outcomes as a function of these and other relevant factors will be discussed. Apparent failure to adequately capture the possible or likely effect of a factor on road trauma may just as likely be due to the limited range of assumptions (usually only one) made about the mechanism of effect, rather than any evidence of the absence of an effect (or even an apparent counter-productive effect). The results for each of the speed enforcement initiatives and other factors included in the models will be discussed in turn from this perspective.

9.1 Speed camera hours

The increases in mobile speed camera hours were found to be significantly associated with decreased frequencies in monthly casualty crashes. The increase from 4200 to 6000 camera hours per month was estimated to be associated with a total of 3.25% reduction in monthly crashes (95% CLs: 0.80% to 5.63%). The increases in camera hours were also significantly associated with a reduction in the risk of fatal outcome of the casualty crashes, suggesting an estimated 43% reduction in this risk (95% CLs: 6.71% to 65.67%) due to the increased camera hours.

These results are consistent with the previous study by Cameron et al (2003b). Cameron et al classified speed camera TINs into five levels to examine an effect on crashes. They found that casualty crashes were reduced by 3.0% and the fatality risk in those crashes was reduced by 41% following months with very high levels of TINs (65% greater than the average monthly level), relative to medium levels. They identified a functional relationship between TINs and crash frequencies, such that increased levels of TINs were associated with diminishing returns in terms of reductions in crashes. A similar diminishing returns relationship had been assumed by Gelb et al (2000) in their economic analysis of potential increases in speed camera operations. The present study applied this functional form to hours of speed camera operations, a variable strongly correlated with speed camera TINs (in otherwise stable conditions). As discussed in section 6.2, this was necessary in this study because the two other enforcement initiatives included in the models (namely, flashless cameras and reduced speed offence detection thresholds) potentially changed the relationship between an hour of camera operation and the number of TINs generated from that session.

Thus, research evidence seems to point consistently to the association of increased camera hours, or increased number of TINs issued, with a reduction in casualty crash frequency and the severity of the crash outcomes. The mechanism by which the camera hours are expected to influence crash outcome is through increasing the number of detected offences and issued TINs, which in turn are expected to increase drivers' perceived as well as actual risk of detection. Consequently, according to rational choice theory, this in turn is expected to result in drivers decreasing their speed in order to avoid a subsequent penalty. The overall reduction in speeding would then be expected to lead to a reduction in crashes and/or the severity of crash outcomes.

In summary, the assumed functional form of the relationship between monthly speed camera hours and road trauma, included in each of the crash frequency and crash severity models, appears to represent these relationships well. The estimated effects of the total increase in camera hours during 2001-2002 on casualty crashes and their risk of fatal outcome should, however, be compared with the estimates of the overall impact of the full set of speed-related initiatives, given by D'Elia et al (2007). They estimated that, during August 2001 to December 2004, the speed-related package was associated with 3.8% reduction in casualty crashes (95% CLs: 2.0% to 5.6%) and a non-statistically-significant 4% reduction in the risk of fatal outcome of those crashes. However the estimated effects on both criteria varied substantially by urbanisation, speed limit zone, and number of vehicles involved in the crashes, and appeared to increase during the post-implementation period. During July-December 2004, after the speed-related package was fully implemented, it was associated with a statistically significant 10% reduction in casualty crashes and 19% reduction (which approached statistical significance) in the risk of fatal outcome. Together these estimates suggested a 27% reduction in fatal crashes (95% CLs: 6% to 48%) during the final six-month period considered in the analysis by D'Elia et al (2007). The analysis also found statistically significant reductions of similar magnitude in fatal crashes during 2003 associated with the speed-related package.

In general, bearing in mind the confidence limits on the estimates in each case, the estimated effects of the increase in speed camera hours from 4200 to 6000 hours per month, and the estimated overall impact of the speed-related package when fully implemented, appeared to be consistent so far as casualty crashes are concerned and not inconsistent in terms of the effect on the risk of fatal outcome of those crashes. The estimated effects of the increase in speed camera hours were also consistent, on both crash outcome criteria, with the estimated effects when speed camera TINs were increased by 65% in selected Melbourne police districts during months in 1999 (Cameron et al 2003b; see section 2.2.3.1).

The relationships between speed camera operational hours and crash frequency and severity identified in this study could be used to examine the policy implications of further increases in mobile speed camera operations in Victoria. An economic analysis of the benefits from further crash and injury reductions, compared with the costs of the increased camera operations and offence processing, could be conducted using methods similar to Gelb et al (2000).

9.2 Flashless speed camera operation

The flashless camera operations were estimated to be associated with a 2.1% decrease in monthly casualty crash frequencies, although this estimate was not statistically significant. However, contrary to expectations, the flashless operations were significantly associated with an increase in the odds of fatal outcome of the crashes. This was a surprising result given that the flashless trials were so effective in increasing the detected offence rate, and that the first stage of the initiative also showed an increase in detected offences and an apparent reduction in crashes. There may be a number of explanations for the above results, as discussed below.

The actual proportion of camera operations that did not use a flash is in fact unknown. Therefore, while the trials were effective in increasing the detected offence rate, this was apparently achieved with a universal flashless camera operation. Furthermore, the first stage of the initiative implementation occurred in the summer month of December 2000. There may have been a higher proportion of flashless operations due to better light conditions in the summer months. However, the second stage of the flashless initiative occurred in August 2001, when light conditions may have been poorer. Moreover, with the pressure on camera operators to maintain a high prosecutable photo rate, an operator may opt to use the flash in order to err on the side of caution and reduce the chance of a failed session. This means that the analysis may have attempted to represent the effect of the initiative that took place in circumstances where any potential effects were mixed and could only be measured in a diluted state.

The unknown proportion of flashless camera hours is a major limitation of the evaluation of this particular initiative. Unfortunately this information is not currently recorded in any form. A co-operation with those responsible for speed camera operations to record and provide this information in future would be most valuable.

In addition, the second and third stage of the flashless operations occurred respectively at the same time as the first and second stages of the camera hour increase. It is possible that because the increased camera hours were so strongly associated with crash changes, any flashless effect may be confounded by the camera hours effect.

A further limitation in assessing the outcomes of the flashless initiative is that the initiative in fact also involved various other measures to make the camera operations less conspicuous. This involved purchasing new, less conspicuous vehicles, and placing the vehicles with the cameras on the road in a less conspicuous ways. Unfortunately, due to the lack of documentation available regarding how each operation was carried out, the assessment of this initiative remains limited.

In summary, there is doubt that the flashless speed camera initiative has been adequately represented in the monthly crash outcome models. The effect of flashless operation, if it exists, has been necessarily diluted, an assumption has been made about its immediacy, and the potential interaction with the effect of the increased speed camera hours has not been taken into account. Therefore, the appropriate conclusion is that the effect of flashless operations on crash severity is unknown at this stage. There is suggestive evidence that the flashless operations may have reduced casualty crash frequencies by about 2%, but the estimate is unreliable and not statistically significant.

An investigation determining the extent of use of flashless cameras is recommended to help determine the true impact of flashless operations on crashes. This could be achieved by either recording details for each camera session, or by surveys of camera operators in both summer and winter.

9.3 Speed enforcement threshold reductions

There was no statistically significant evidence of an association between changes in crash frequencies or crash severity and the speed offence threshold reductions. While not significant, in the crash frequency analysis, the estimates for each stage of the threshold decreases were negative, indicating that each threshold decrease was associated with a decrease in casualty crashes in the following month. However, a further analysis to test for the contribution of the initiative as a whole (rather than as separate stages) to crash changes, indicated that it did not make a statistically significant contribution.

Unlike the increased speed camera hours initiative, and to some extent the flashless camera operations, there was no precedent in Victoria of research on the effects of reduced speed enforcement thresholds to provide any guidance on the likely mechanism of effect on road trauma (see section 2.3.3). It had to be assumed that the reduced threshold would result immediately in increased offences detected (at least for speeds between the old and new thresholds) and TINs issued, and that, based on previous research, road trauma reductions would soon follow due to that mechanism. Thus the models made assumptions about the timing of effect without any knowledge about driver perceptions of the implications of the change for general deterrence, and whether a specific deterrence mechanism would be impactful for drivers caught at lower speeding levels than previously.

It is possible that no significant association was found between the threshold reductions and crash outcomes in the initial analysis, because it may take longer for this relationship to become apparent. The final step of the threshold reduction took place in September 2002, very close to the end of the period that was initially analysed (December 2002). There is evidence that a change in the pattern of speeding offences, particularly those detected at speeds in excess of the previous threshold, did not take place until early months in 2003. Therefore, the effect of the threshold reductions may not be evident until 2003. A reduction in crashes at the beginning of 2003, as well as a reduction in TINs, would be indicative of an adjustment to the reduced enforcement threshold. Further crash analysis covering at least the first half of 2003 may help to determine the true extent of the effect from the threshold reduction initiative. This was done in the extended analysis reported in Appendix B (see summary in forthcoming section 9.7).

In the interim, there is doubt that the enforcement threshold reductions have been adequately represented in the monthly crash outcome models to the end of 2002. The appropriate conclusion is that the effect of the threshold reductions is unknown at this stage because of substantial uncertainty about the timing and mechanism of effect, and the possibility that any effect may not have manifested itself until 2003.

9.4 Speed-related advertising

Speed-related advertising was expected to be an important factor in the crash outcome models. Speed-related Adstock units were included in the analysis, as previous research has linked levels of speed-related advertising measured in this way to changes in monthly crashes (Cameron et al, 2003b). Adstock was initially included in the analysis models in categorical form, involving no assumption about the functional relationship with crashes, and then as a continuous variable with an assumed logarithmic relationships with casualty crashes and with crash severity. As outlined in section 8.6.1.2, past research had suggested that this was a not unreasonable assumption, albeit less conservative than the analysis based on categorical levels of Adstock.

During the time period that the three speed enforcement initiatives were introduced (from December 2000 to December 2002), there was a decrease in the emotive advertising style favoured in the previous period, and instead the instructive style became predominant. In the initial analysis for this study, increased levels of total speed-related Adstock (all styles), as well as of the instructive style by itself, were found to be significantly related to reductions in monthly casualty crash frequencies. The results produced for the all-styles and the instructive styles were very similar, most probably because of the dominance of the instructive style. Increased levels of the emotive style advertising were also related to crash reductions when the emotive style Adstock was analysed as a continuous variable. However, during the period of the three initiatives most of the emotive advertising also included an instructive component. Thus, the pure emotive advertising component is less likely to have contributed to crash changes during the period of the initiatives.

The above results are consistent with those of Cameron et al (2003b), who found levels of speed-related advertising to be associated with similar magnitudes of changes in monthly casualty crashes. However, in the present study neither the total advertising Adstock, nor the individual styles, were significantly associated with changes in the odds of fatal outcome of casualty crashes.

In summary, the assumed functional form of the relationship between monthly speed-related advertising levels and road trauma, included in the crash frequency model, appears to represent this relationship well. Adstock, a function of current and previous television rating points (TARPs), represents the retained awareness of advertising levels, which in turn appears to be related to casualty crash risks in the same period. A number of studies have now established that relationship for speed-related advertising, at least at the levels practiced in Victoria and Queensland.

9.5 Announcements

During 2001-2002, three media announcements occurred that might have influenced monthly crashes. Such announcements are believed to play a useful role in increasing drivers awareness of increased enforcement levels, and thereby playing a role in monthly crash changes (e.g. Cameron et al, 2003b). The three media announcements were included in the analysis on the basis of having potential effects for one month if at the beginning of the month, or for the next month if at the end of the previous month.

The first announcement, which occurred in August 2001 and was related to the "Wipe off 5" campaign, was significantly associated with a decrease in monthly casualty crashes. This association was weaker, but still significant when the speed-related Adstock was analysed as a continuous variable, rather than a categorical one.

The second announcement occurred at the end of November 2001 and was related to the flashless camera operations and the increased camera hours. This announcement was found to be significantly associated with a decrease in monthly crash frequencies during December 2001 when the advertising Adstock was included in the analysis as a categorical variable, but not when the Adstock was analysed as continuous. This instability in the announcements' estimates indicates that the estimated effects of the media announcements may not be independent from the effects of the speed-related advertising campaign.

The third announcement, which occurred in April 2002 and related to the threshold reductions was not significantly associated with changes in crash frequencies. Furthermore, none of the announcements were associated with changes in the odds of a fatal outcome of the casualty crashes.

In summary, announcement effects, assumed to affect casualty crash risks for no more than one month duration, can be adequately represented in monthly crash frequency models as simple "spike" functions (i.e. taking value 1 in the month affected by the announcement, and 0 otherwise). Since announcements may be followed by intensive mass-media publicity, the estimated impact of the announcement on crash risk may be contaminated by the estimation of the impact of the advertising (if this factor is also included in the model), and vice versa.

9.6 50 km/h default urban speed limit

The suggested impact of the 50 km/h urban speed limit on casualty crash frequency was associated with very wide confidence limits and could not be considered reliable. In addition, the representation of its potential effect in the crash outcome models was simplistic, bearing in mind that many of the crashes analysed for Regions 2 to 5 occurred in rural areas where the limit did not apply. A more focused study was undertaken to measure the impact of this initiative (Hoareau et al 2002, 2006). The present study must be inconclusive about whether the initiative has been adequately represented in the crash outcome models.

9.7 Results from the extended analysis

As outlined earlier, following the initial analysis of crashes during 1998-2002, the modelling analysis was extended to include crashes during 2003. This was done principally to include any longer term effects of the reduced speed offence detection thresholds, as well as to examine the effects of including additional crash data in the generalised linear models. The extended analysis required that the models include possible effects of the changed structure of speeding penalties, the announcement of the penalty restructure, and the high-profile fixed speed camera controversy which arose publicly in November 2003 (see Appendix B for details).

Overall, very similar results were obtained for the three speed enforcement initiatives in the extended 1998-2003 analysis, compared to the analysis for the earlier 1998-2002 period. In particular for the threshold reductions, very similar estimates were obtained compared to those of the earlier analysis, in both direction and magnitude, but the estimated effects remained statistically non-significant even though they were based on an additional year's crash data.

While for the 1998-2002 analysis the instructive style of advertising appeared to be predominant in its effect, in the extended analysis all three advertising styles (instructive, emotive, and enforcement) were close to statistical significance. As described in Appendix B, there were some differences in the advertising styles and levels in 2003 compared to the earlier period, which may have contributed to these differences in the results.

In the extended analysis the August 2001 announcement did not have a statistically significant association with monthly crash frequencies, unlike the earlier analysis. This may have been because the nature of the estimated associations between monthly advertising Adstock and crash frequencies had changed and had captured the apparent announcement effect found in the earlier analysis.

The extended analysis found that the introduction of the 50 km/h urban speed limit was significantly associated with casualty crash frequency, with an estimated effect of 13.5% reduction in these crashes. This estimated effect is consistent with the results of the specific evaluation by Hoareau et al (2002, 2006). However there must still be doubt whether this initiative has been adequately represented in the crash outcome models by a simple step reduction in risk throughout Victoria.

10 CONCLUSIONS

This study attempted to model the likely effects of three speed enforcement initiatives (increased speed camera hours, flashless camera operations, and decreased speed offence detection thresholds) plus some other speed-related changes in Victoria on monthly casualty crash frequencies and severities. The study reached the following conclusions:

- Generalised linear modelling of monthly crash outcomes as a function of potential explanatory factors needs realistic assumptions to be made about viable functional forms connecting a measure of each factor and crash frequency and/or crash severity. The assumptions should ideally be based on previous research connecting the implementation (level) of the factor with likely mechanisms of effect and the timing of the effect on road trauma. Alternatively, resources should be provided for the crash outcomes modelling to investigate a range of potential mechanisms and timings.

- The assumed functional form of the relationship between monthly speed camera hours and road trauma, included in each of the crash frequency and crash severity models, appears to represent these relationships well.

- There is doubt that the flashless speed camera initiative has been adequately represented in the monthly crash outcome models. The effect of flashless operation, if it exists, has been necessarily diluted, an assumption has been made about its immediacy, and the potential interaction with the effect of the increased speed camera hours has not been taken into account. It was concluded that the effect of flashless operations on crash outcomes is unknown at this stage.

- There is doubt that the enforcement threshold reductions have been adequately represented in the monthly crash outcome models. The appropriate conclusion is that the effect of the threshold reductions is unknown at this stage because of substantial uncertainty about the timing and mechanism of effect.

- The assumed functional form of the relationship between monthly speed-related advertising levels and road trauma, included in the crash frequency model, appears to represent this relationship well. Adstock, a function of current and previous television rating points (TARPs), represents the retained awareness of advertising levels, which in turn appears to be related to casualty crash risks in the same period.

- The speed-related television advertising had a consistent and strong association with a decrease in monthly casualty crash frequencies during times of increased advertising levels. During 2001-2002, when the speed enforcement initiatives were introduced, this effect appeared to be mostly due to the instructive style advertising, which was predominant in that period. When the 2003 crash data was added to the analysis, the evidence was weaker but all three styles of speed-related advertising (instructive-, emotive- and enforcement-style) appeared to have an association with decreased crash frequencies.

- The estimation of the announcement effects, if they exist at all, was influenced by the method of representing the effect of the speed-related advertising. Intensive mass-media publicity followed each announcement and, when the advertising was represented by monthly Adstock as a continuous variable, the announcements had no statistically significant association with crashes.

- The introduction of the 50 km/h default urban speed limit was statistically significantly associated with a reduction in casualty crashes. While this effect was consistent with the results of the specific evaluation by Hoareau et al (2002, 2006), doubt remains whether this initiative has been adequately represented in the crash outcome models.

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12 TERMINOLOGY

High-Level Speeding	Vehicles detected at >25 km/h above the speed limit (c.f. low-level speeding).
Low-Level Speeding	Vehicles detected at <10 km/h above the speed limit (c.f. high level speeding).
Offence Rate	Number of vehicles detected above the threshold as a proportion of all drivers, that is: $\text{Offence Rate} = \frac{\text{Vehicles Detected}}{\text{Vehicles Assessed}} * 100$
Offending Vehicles	Vehicles detected at or above the threshold speed (=vehicles detected)
RD	Region and Division e.g. RD 4-2 refers to Region 4 Division 2. See Graph X.X for description of RD structure.
State Level	Analysis at the state level incorporates all Regions and Divisions, which sum to all state.
TINs	Traffic Infringement Notice. Defined by offence date and issue date.
Vehicles assessed	All vehicles counted by a camera, offending and non-offending.
Vehicles detected	Vehicles detected at or above the threshold speed (=offending vehicles)

APPENDIX A: ANALYSIS CODING AND DETAILED RESULTS

Speed-related Advertising Coding

Table A.1 refers to the coded levels of advertising for each of the 4 advertising styles:

Style a) = All Styles
Style b) = Emotive
Style c) = Enforcement
Style d) = Instructive

Style a) is coded into 3 levels, Low, Medium, High, while the other 3 styles b) – d) have 2 levels, Low and High.

Table A.2 shows the total number of months at each coded advertising level.

Table A.1: Speed Related Advertising Levels per month January 1998 – December 2000, Metropolitan and Rural Victoria Combined.

Month	Advertising Sub-Model				Month	Advertising Sub-Model			
	a)	b)	c)	d)		a)	b)	c)	d)
Jan-98	L	H	H	L	Jul-00	M	H	H	L
Feb-98	M	H	H	L	Aug-00	L	H	L	L
Mar-98	L	H	H	L	Sep-00	L	H	L	L
Apr-98	L	H	L	L	Oct-00	L	H	L	L
May-98	M	H	L	L	Nov-00	L	H	L	L
Jun-98	H	H	H	L	Dec-00	L	H	L	L
Jul-98	M	H	H	L	Jan-01	L	L	L	L
Aug-98	H	H	H	L	Feb-01	H	L	L	H
Sep-98	M	H	H	L	Mar-01	M	L	L	H
Oct-98	L	H	H	L	Apr-01	M	L	H	L
Nov-98	L	H	L	L	May-01	M	L	H	L
Dec-98	L	H	L	L	Jun-01	M	H	H	H
Jan-99	M	H	H	L	Jul-01	H	H	H	H
Feb-99	L	L	H	L	Aug-01	H	H	H	H
Mar-99	M	H	H	L	Sep-01	H	L	L	H
Apr-99	L	H	H	L	Oct-01	H	L	L	H
May-99	L	H	H	L	Nov-01	M	H	L	H
Jun-99	L	H	L	L	Dec-01	M	H	L	H
Jul-99	L	H	L	L	Jan-02	H	H	H	L
Aug-99	L	H	L	L	Feb-02	H	H	H	L
Sep-99	L	H	H	L	Mar-02	H	H	H	H
Oct-99	L	H	H	L	Apr-02	M	H	H	L
Nov-99	L	H	H	L	May-02	L	H	H	L
Dec-99	L	H	L	L	Jun-02	M	H	H	H
Jan-00	L	H	L	L	Jul-02	L	H	H	L
Feb-00	L	L	L	L	Aug-02	H	H	H	H
Mar-00	L	L	L	L	Sep-02	M	L	L	H
Apr-00	L	H	H	L	Oct-02	L	L	L	L
May-00	L	H	H	L	Nov-02	L	L	L	L
Jun-00	L	L	H	L	Dec-02	M	L	L	H

Table A.2: Number of observations in each advertising style and category.

Coded Level	Advertising Sub-Model			
	a)	**b)**	**c)**	**d)**
High	11	45	33	14
Med	17	0	0	0
Low	32	15	27	46
TOTAL	**60**	**60**	**60**	**60**

Table A.3 Advertisement Styles from 1998 to 2003

TITLE	MESSAGE	LAUNCH DATE	STYLE
Golf	Older Drivers	March 1998	Emotive
Twelve days of Xmas	Drink-drive	November 1998	Emotive
Blame	Speed	November 1999	Emotive
Skids	Learners	May 2000	Emotive
Never	Drink-drive	December 2000	Emotive
WO5 - Post Mortem	Speed	February 2002	Emotive
Double whammy	Drink-drive	January 1998	Enforcement
Waiting Game	Drink-drive	September 1998	Enforcement
Back Streets	Drink-drive	September 1998	Enforcement
On the Buses	Drink-drive	September 1998	Enforcement
1000+Booze	Drink drive	September 1999	Enforcement
Stop	Drink-drive	August 2000	Enforcement
Consequences	Speed	July 2000	Enforcement
Map	Speed	January 2001	Enforcement
Enforcement	Speed	November 2001	Enforcement
Enhanced enforcement	Drink-drive	December 2001	Enforcement
Guillotine	Speed	December 2002	Enforcement
WO5 - Mean Business	Speed	May 2002	Enforcement
Guillotine	Speed	December 2002	Enforcement
Guillotine	Mobiles	December 2002	Enforcement
Rachel (Broken bones)	Speed	July 2002	Enforcement
Powernap	Fatigue	March 1999	Emotive/Instructive
Pinball	Seatbelts	June 1999	Emotive/Instructive
P Plates	Youth	August 1999	Emotive/Instructive
Crash Cause	Youth	November 1999	Emotive/Instructive
Black	Fatigue	March 2002	Emotive/Instructive
Vice Versa	Motorcycle	September 2002	Emotive/Instructive
John & Jessica	Drink-drive	February 1998	Emotive/Enforcement
Young Cops	Speed	June 1998	Emotive/Enforcement
P-Plates	Speed	August 1999	Instructive
P's	P-Plates	August 1999	Instructive
Words	Learners	May 2000	Instructive
Map	Speed	January 2001	Instructive
Little Girl	Speed	January 2001	Instructive
Wipe Off 5	Speed	August 2001	Instructive
WO5 – Mean Business	Speed	May 2002	Instructive
WO5- Slo-Mo	Speed	August 2002	Instructive
Guillotine	Mobile	December 2002	Instructive

Table A.4 Poisson Regression Estimates for Monthly Crash Frequencies - Emotive advertising (Categorical variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.09	-0.16	-0.02	0.0096
Flashless Operations	**On**	-2.08	-8.03	4.26	0.5113
	Off	0.00	0.00	0.00	.
Threshold Reductions	**Step 1**	-3.80	-12.88	6.23	0.4448
	Step 2	-10.76	-23.41	3.99	0.1444
	Step 3	-8.08	-23.08	9.85	0.3543
	Off	0.00	0.00	0.00	.
Emotive Advertising	**High**	-4.32	-13.49	5.82	0.3900
	Low	0.00	0.00	0.00	.
August Announcement	**On**	-16.88	-26.26	-6.31	0.0025
	Off	0.00	0.00	0.00	.
December Announcement	**On**	-0.32	-9.87	10.25	0.9511
	Off	0.00	0.00	0.00	.
April Announcement	**On**	2.60	-19.64	31.01	0.8365
	Off	0.00	0	0	.
50 k limit	**On**	2.48	-20.35	31.86	0.8492
	Off	0.00	0	0	.

Table A.5 Poisson Regression Estimates for Monthly Crash Frequencies - Enforcement advertising (Categorical variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.09	-0.16	-0.02	0.0096
Flashless Operations	**On**	-2.08	-8.03	4.26	0.5113
	Off	0.00	0.00	0.00	.
Threshold Reductions	**Step 1**	-3.80	-12.88	6.23	0.4448
	Step 2	-10.76	-23.41	3.99	0.1444
	Step 3	-8.08	-23.08	9.85	0.3543
	Off	0.00	0.00	0.00	.
Enforcement Advertising	**High**	-5.11	-14.33	5.09	0.3129
	Low	0.00	0.00	0.00	.
August Announcement	**On**	-13.13	-22.85	-2.17	0.0203
	Off	0.00	0.00	0.00	.
December Announcement	**On**	-0.32	-9.87	10.25	0.9511
	Off	0.00	0.00	0.00	.
April Announcement	**On**	-6.07	-22.89	14.43	0.5341
	Off	0.00	0	0	.
50 k limit	**On**	-1.13	-20.59	23.09	0.9189
	Off	0.00	0	0	.

Table A.6 Poisson Regression Estimates for Monthly Crash Frequencies – Instructive advertising (Categorical variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.093	-0.16	-0.02	0.0096
Flashless Operations	**On**	-2.078	-8.03	4.26	0.5113
	Off	0.000	0.00	0.00	.
Threshold Reductions	**Step 1**	-3.796	-12.88	6.23	0.4448
	Step 2	-10.756	-23.41	3.99	0.1444
	Step 3	-8.075	-23.08	9.85	0.3543
	Off	0.000	0.00	0.00	.
Instructive Advertising	**High**	-9.986	-18.56	-0.50	0.0396
	Low	0.000	0.00	0.00	.
August Announcement	**On**	-21.800	-31.89	-10.21	0.0005
	Off	0.000	0.00	0.00	.
December Announcement	**On**	-10.264	-18.77	-0.87	0.0330
	Off	0.000	0.00	0.00	.
April Announcement	**On**	4.342	-15.40	28.69	0.6911
	Off	0.000	0	0	.
50 k limit	**On**	4.206	-16.27	29.68	0.7117
	Off	0.000	0	0	.

Table A.7 Poisson Regression Estimates for Monthly Crash Frequencies for continuous Emotive advertising.

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.093	-0.163	-0.02	0.0096
Flashless Operations	**On**	-2.078	-8.031	4.26	0.5113
	Off	0.000	0.000	0.00	.
Threshold Reductions	**Step 1**	-3.796	-12.879	6.23	0.4448
	Step 2	-10.756	-23.408	3.99	0.1444
	Step 3	-8.075	-23.077	9.85	0.3543
	Off	0.000	0.000	0.00	.
Emotive Ads	**.**	-0.118	-0.231	-0.01	0.0396
August Announcement	**On**	-21.054	-30.932	-9.76	0.0005
	Off	0.000	0.000	0.00	.
December Announcement	**On**	-2.293	-10.927	7.18	0.6224
	Off	0.000	0.000	0.00	.
April Announcement	**On**	22.961	-9.200	66.51	0.1813
	Off	0.000	0.000	0	.
50 k limit	**On**	8.741	-14.100	37.66	0.4860
	Off	0.000	0.000	0	.

Table A.8 Poisson Regression Estimates for Monthly Crash Frequencies for continuous Enforcement advertising.

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.093	-0.163	-0.02	0.0096
Flashless Operations	**On**	-2.078	-8.031	4.26	0.5113
	Off	0.000	0.000	0.00	.
Threshold Reductions	**Step 1**	-3.796	-12.879	6.23	0.4448
	Step 2	-10.756	-23.408	3.99	0.1444
	Step 3	-8.075	-23.077	9.85	0.3543
	Off	0.000	0.000	0.00	.
Enforcement Ads	**.**	-3.992	-14.065	6.08	0.4373
August Announcement	**On**	-13.125	-22.854	-2.17	0.0203
	Off	0.000	0.000	0.00	.
December Announcement	**On**	-0.319	-9.872	10.25	0.9511
	Off	0.000	0.000	0.00	.
April Announcement	**On**	-82.436	-99.758	1174.40	0.4262
	Off	0.000	0.000	0	.
50 k limit	**On**	1.6E+06	-100.000	7.2E+16	0.4394
	Off	0.000	0.000	0	.

Table A.9 Poisson Regression Estimates for Monthly Crash Frequencies for continuous Instructive advertising.

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.093	-0.163	-0.02	0.0096
Flashless Operations	**On**	-2.078	-8.031	4.26	0.5113
	Off	0.000	0.000	0.00	.
Threshold Reductions	**Step 1**	-3.796	-12.879	6.23	0.4448
	Step 2	-10.756	-23.408	3.99	0.1444
	Step 3	-8.075	-23.077	9.85	0.3543
	Off	0.000	0.000	0.00	.
Instructive Ads	**.**	-0.284	-0.555	-0.01	0.0396
August Announcement	**On**	-11.379	-21.735	0.35	0.0566
	Off	0.000	0.000	0.00	.
December Announcement	**On**	-2.274	-10.909	7.20	0.6256
	Off	0.000	0.000	0.00	.
April Announcement	**On**	-5.541	-22.414	15.00	0.5706
	Off	0.000	0.000	0	.
50 k limit	**On**	-15.794	-33.910	7.29	0.1641
	Off	0.000	0.000	0	.

Table A.10 Logistic Regression Estimates for the Odds of a Fatality Given an Injury Crash - Emotive Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**Odds Ratio**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-1.60	-3.00	-0.19	0.0256
Flashless Operations	**On**	1.70	1.11	2.60	0.0138
	Off				.
Threshold Reductions	**Step 1**	1.10	0.48	2.51	0.8244
	Step 2	0.94	0.29	3.00	0.9124
	Step 3	0.78	0.20	3.02	0.7142
	Off				.
Emotive Ads	**.**	-9.19	-30.01	11.63	0.3870
August Announcement	**On**	0.00	0.00	18441.67	0.4115
	Off				.
December Announcement	**On**	0.18	0.00	6.55	0.3472
	Off				.
April Announcement	**On**	1.1E+09	0.00	4.8E+29	0.3906
	Off				.
50 k limit	**On**	7.1E+04	0.00	1.5E+16	0.4017
	Off				.

Table A.11 Logistic Regression Estimates for the Odds of a Fatality Given an Injury Crash - Enforcement Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**Odds Ratio**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-1.60	-3.00	-0.19	0.0256
Flashless Operations	**On**	1.70	1.11	2.60	0.0138
	Off				.
Threshold Reductions	**Step 1**	1.10	0.48	2.51	0.8244
	Step 2	0.94	0.29	3.00	0.9124
	Step 3	0.78	0.20	3.02	0.7142
	Off				.
Enforcement Ads	**.**	0.33	-0.42	1.09	0.3870
August Announcement	**On**	1.43	0.59	3.47	0.4254
	Off				.
December Announcement	**On**	0.84	0.42	1.71	0.6369
	Off				.
April Announcement	**On**	1.00	0.21	4.77	0.9968
	Off				.
50 k limit	**On**	0.32	0.03	3.49	0.3505
	Off				.

Table A.12 Logistic Regression Estimates for the Odds of a Fatality Given an Injury Crash - Instructive Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**Odds Ratio**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-1.60	-3.00	-0.19	0.0256
Flashless Operations	**On**	1.70	1.11	2.60	0.0138
	Off				.
Threshold Reductions	**Step 1**	1.10	0.48	2.51	0.8244
	Step 2	0.94	0.29	3.00	0.9124
	Step 3	0.78	0.20	3.02	0.7142
	Off				.
Instructive Ads	**.**	0.35	-0.44	1.13	0.3870
August Announcement	**On**	1.40	0.58	3.39	0.4585
	Off				.
December Announcement	**On**	0.86	0.43	1.76	0.6863
	Off				.
April Announcement	**On**	0.87	0.19	3.97	0.8533
	Off				.
50 k limit	**On**	0.83	0.17	3.96	0.8103
	Off				.

Table A.13 Logistic Regression Estimates for the Odds of a Fatality Given an Injury Crash – All Styles Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**Odds Ratio**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-1.60	-3.00	-0.19	0.0256
Flashless Operations	**On**	1.70	1.11	2.60	0.0138
	Off				.
Threshold Reductions	**Step 1**	1.10	0.48	2.51	0.8244
	Step 2	0.94	0.29	3.00	0.9124
	Step 3	0.78	0.20	3.02	0.7142
	Off				.
All Styles Ads	**.**	0.75	-0.95	0.87	0.3870
August Announcement	**On**	1.38	0.57	3.36	0.4783
	Off				.
December Announcement	**On**	0.86	0.42	1.75	0.6830
	Off				.
April Announcement	**On**	0.88	0.19	4.03	0.8680
	Off				.
50 k limit	**On**	0.56	0.11	2.88	0.4877
	Off				.

Table A.14 Poisson Regression Estimates for 2003 Analysis of Monthly Crash Frequencies - Emotive Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.092	-0.153	-0.03	0.0033
Flashless Operations	**On**	-1.892	-7.730	4.32	0.5430
	Off				.
Threshold Reductions	**Step 1**	-2.897	-11.893	7.02	0.5533
	Step 2	-9.616	-22.201	5.01	0.1865
	Step 3	-6.424	-21.419	11.43	0.4559
	Off				.
Emotive Ads	**.**	-0.249	-0.562	0.06	0.1186
August Announcement	**On**	-14.862	-35.698	12.72	0.2614
	Off				.
December Announcement	**On**	7.380	-11.871	30.84	0.4800
	Off				.
April Announcement	**On**	103.196	-15.738	390.00	0.1144
	Off				.
September Announcement	**On**	18.258	5.758	32.23626196	0.0033
	Off				.
50 k limit	**On**	-26.007	-46.316	1.98	0.0658
	Off				.
Restruct	**On**	12.008	-12.176	42.85157955	0.3607
	Off				.
Controversy	**On**	-3.700	-16.407	10.93918696	0.6018
	Off				.
Offence Rates	**On**	19.913	6.526	34.983721	0.0026
	Off				.

Table A.15 Poisson Regression Estimates for 2003 Analysis of Monthly Crash Frequencies - Enforcement Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.092	-0.153	-0.03	0.0033
Flashless Operations	**On**	-1.892	-7.730	4.32	0.5430
	Off				.
Threshold Reductions	**Step 1**	-2.897	-11.893	7.02	0.5533
	Step 2	-9.616	-22.201	5.01	0.1865
	Step 3	-6.424	-21.419	11.43	0.4559
	Off				.
Enforcement Ads	**.**	-0.793	-1.789	0.20	0.1186
August Announcement	**On**	1056.751	-44.098	23835.98	0.1132
	Off				.
December Announcement	**On**	-10.399	-18.954	-0.94	0.0319
	Off				.
April Announcement	**On**	686.561	-39.549	10134.36	0.1151
	Off				.
September Announcement	**On**	53.541	8.575	117.1304198	0.0153
	Off				.
50 k limit	**On**	0.743	-14.063	18.10	0.9268
	Off				.
Restruct	**On**	-10.264	-18.944	-0.65544254	0.037
	Off				.
Controversy	**On**	-7.568	-17.242	3.235644514	0.163
	Off				.
Offence Rates	**On**	1235.112	-35.466	27521.29151	0.0936
	Off				.

Table A.16 Poisson Regression Estimates for 2003 Analysis of Monthly Crash Frequencies - Instructive Advertising (Continuous variable)

			95% confidence intervals		
Variables	**Categories**	**% Change**	**Lower**	**Upper**	**p**
Camera Hours	**.**	-0.092	-0.153	-0.03	0.0033
Flashless Operations	**On**	-1.892	-7.730	4.32	0.5430
	Off				.
Threshold Reductions	**Step 1**	-2.897	-11.893	7.02	0.5533
	Step 2	-9.616	-22.201	5.01	0.1865
	Step 3	-6.424	-21.419	11.43	0.4559
	Off				.
Instructive Ads	**.**	-0.198	-0.447	0.05	0.1186
August Announcement	**On**	14.259	-4.106	36.14	0.1358
	Off				.
December Announcement	**On**	-4.572	-12.936	4.60	0.3176
	Off				.
April Announcement	**On**	-6.695	-25.758	17.26	0.5523
	Off				.
September Announcement	**On**	32.591	10.519	59.07156352	0.0024
	Off				.
50 k limit	**On**	-1.390	-14.670	13.96	0.8491
	Off				.
Restruct	**On**	-3.188	-12.226	6.779951193	0.5173
	Off				.
Controversy	**On**	-5.852	-16.723	6.438375725	0.3353
	Off				.
Offence Rates	**On**	29.823	11.178	51.59404417	0.001
	Off				.

APPENDIX B: EXTENDED ANALYSIS OF CRASH OUTCOMES 1998-2003

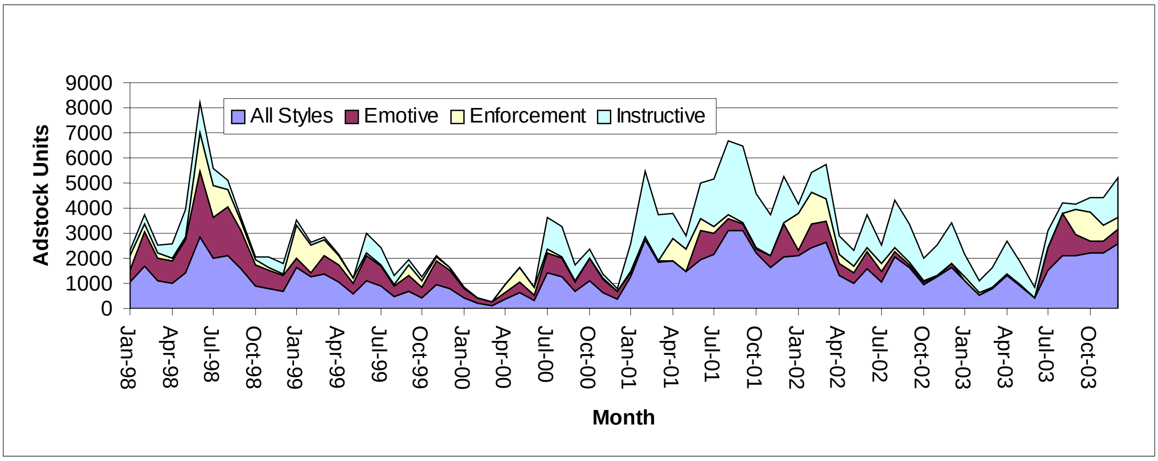
The analyses described in chapters 8 and 9 were extended to include data until the end of 2003, in order to better represent the longer term effects of the three speed enforcement initiatives: increase in camera hours, flashless camera operations, and decreased speed offence detection thresholds. The longer term analysis is of particular relevance to the offence detection thresholds, for which the final step of decrease did not occur until near the end of 2002. Therefore it is possible that the full effect of this initiative on crash outcomes may not have been evident until 2003. This appendix describes the background, results, and discussion of the extended analysis.

B.1 Relevant changes in 2003

During 2003, no further speed enforcement-related changes occurred. That is, the monthly target for camera hours remained at a total of 6000 a month, the flashless operation continued, and there were no further offence threshold changes.

The total speed-related advertising Adstock levels were overall lower in 2003 than in the 2001-2002 period, although they picked up in the second half of 2003. The instructive advertising style was still predominant in the first half of 2003, but in the second half of the year the emotive style became prominent as well. A graph of the various styles of advertising Adstock is presented below in Figure B.1.

Figure B.1. Speed-related Adstock per Month by Style for Victoria, January 1998 to December 2003.



Several events took place at the end of 2002 and during 2003 that could have influenced monthly crashes, and therefore needed to be accounted for in the extended analysis. The thresholds of penalties applying to different levels of speeding were generally decreased by 5 km/h in mid-December 2002. This was preceded by a media announcement of the proposed changes in September 2002. Both the penalties changes and the announcement were expected to increase the effect of enforcement. The details of the penalty changes were described in Section 2.3.2.

Another relevant event was the fixed speed camera controversy described in Section 2.3.4. The controversy started in November 2003 and continued until May 2004. While this controversy solely concerned the fixed cameras, the distinction between the fixed and mobile components of the Victorian speed camera program may not have been apparent to drivers. Therefore, the controversy may have influenced the effectiveness of the mobile speed camera program from November 2003 onwards.

Yet another event that may have influenced crash outcomes was an observed substantial drop in offence rates, particularly for speeds 15-39 km/h in excess of limits, in August 2002 (see section 5.1). The reason for this observation remains unknown.

All of the changes described above were included as variables in the extended analysis, otherwise the statistical models were the same as those outlined in section 8.3 and analysed in the same way as the results presented in section 8.6.

B.2 Extended analysis of crash frequencies and crash severity

The extended analyses carried out until the end of 2003 were identical to those described earlier for the 1998-2002, but with the extra year's crash data included. Once again, Poisson regression was carried out to examine the effects of the speed-related initiatives and other factors on casualty crash frequencies, and logistic regression was conducted to examine the effects on the odds of fatal outcome given that a casualty crash has occurred.

The form of the statistical model used for the extended analysis was the same as Equation 1 in Section 8.3.3, but with the addition of four additional variables representing the four relevant events described in the previous section. Each of the new variables was included in the analysis as a binary variable, which could in turn represent a step effect (either positive or negative) of the event on crash outcomes if such an effect was real. The results of the analyses are described in the next sections.

B.3 Results of the extended crash frequency analysis from 1998-2003

Poisson regression was used to analyse the association between each of the speed-related factors and changes in monthly crash frequencies. As in the analysis described in Section 8.6, several factors in addition to speed enforcement initiatives continued to be included: speed-related television advertising by the TAC, three media announcements, and the introduction of the 50 km/h limit. In addition to these factors, four new factors were also relevant to the extended 2003 analysis: the restructuring of the speeding penalties which occurred in December 2002, another media announcement in September 2002 relating to the penalties restructure, the controversy about the fixed speed cameras from November 2003 onwards, and the observed drop in offence rate in August 2002. The advertising Adstock was treated in the extended analysis as a continuous variable with a logarithmic transformation, as was discussed in Section 8.6.1.2 for the earlier analysis. The results of the crash frequency analysis for the period from 1998 to 2003 are shown in Table B.1 below.

Table B.1: Poisson Regression Estimates for Monthly Casualty Crash Frequencies

Variables	Categories	% Change in Crash Frequencies	95% Confidence Intervals Upper	Lower	p
Camera Hours	.	-0.09 [1]	-0.15	-0.30	0.0033
Flashless Operations	**On**	-1.89	-7.73	4.32	0.5430
	Off	.	.	.	.
Threshold Reductions	**1st Step**	-2.90	-11.89	7.02	0.5533
	2nd Step	-9.62	-22.20	5.01	0.1865
	3rd Step	-6.42	-21.42	11.43	0.4559
	Pre-Reduction	.	.	.	.
All-Styles Advertising	**.**	-0.25 [2]	-0.57	0.06	0.1186
August Announcement	**On**	15.13	-4.02	38.10	0.1288
	Off	.	.	.	.
December Announcement	**On**	-2.25	-12.04	8.62	0.6720
	Off	.	.	.	.
April Announcement	**On**	12.31	-10.39	40.76	0.3132
	Off	.	.	.	.
Penalties Announcement	**On**	25.99	9.83	44.51	0.0010
	Off	.	.	.	.
50 km/h Limit	**On**	-13.52	-26.41	1.64	0.0782
	Off	.	.	.	.
Penalties Restructure	**On**	-1.31	-11.67	10.27	0.8153
	Off	.	.	.	.
Fixed Cameras Controversy	**On**	-11.72	-20.03	-2.56	0.0134
	Off	.	.	.	.
Aug 2002 Drop in Offence Rate	**On**	30.77	11.31	53.64	0.0011
	Off	.	.	.	.

[1] Unlike the percentage change estimates in this column, this figure should be interpreted as the elasticity between camera hours and casualty crash frequency (see section 8.2).

[2] Unlike the percentage change estimates in this column, this figure should be interpreted as the elasticity between advertising Adstock and casualty crash frequency (see section 8.6.1.2).

As can be seen in Table B.1 above, the increased camera hours were significantly associated with a decrease in crashes, with every 1% increase in hours being associated with a 0.09% decrease in casualty crash frequencies. The percentage decrease in crash frequencies associated with each stage of increase in camera hours was estimated from the above results and is presented below in Table B.2. While the estimated reductions in crashes are the same as in Table 8.6, the confidence limits on the estimates in Table B.2 are narrower. This is because the additional 12 months crash data included in the extended analysis has made the estimates more reliable.

Table B.2: Estimates of Percentage Changes in Monthly Casualty Crash Frequencies for Increases in Monthly Camera Hours

Increase in Camera Hours	% Change in Crash Frequencies	95% Confidence Intervals	
		Upper	Lower
Stage 1: 4200 - 4800 hours	-1.23	-2.00	-0.45
Stage 2: 4800 - 5400 hours	-1.08	-1.77	-0.40
Stage 3: 5400 - 6000 hours	-0.97	-1.58	-0.36
Total increase: 4200 – 6000 hours	-3.25	-5.25	-1.20

Table B.2 indicates that the total increase of targeted camera hours from 4200 to 6000 per month was associated with 3.25% (95% confidence intervals from 1.20% to 5.25%) decrease in crash frequencies. Since the last stage of this change in February 2002, the targeted camera hours have remained at a constant 6000 hours per month. Therefore, no further crash changes in association with the camera hours are expected to have occurred in 2003.

Returning to the results in Table B.1, the threshold reductions and the flashless initiative did not reach statistical significance, although the coefficients were in the expected direction, indicating a non-significant association between these initiatives and reductions in casualty crash frequencies. The flashless initiative was associated with 1.89% non-significant reduction in casualty crash frequencies. The first, second, and third stages of the threshold reduction initiative were non-significantly associated with 2.90%, 9.62%, and 6.42% crash reductions, respectively.

For the all-styles advertising Adstock, every 1% increase in Adstock was associated with 0.25% reduction in casualty crashes. This association was not statistically significant at the 5% level for the two-sided hypothesis (p = 0.1186). However, if the less conservative one-sided alternative is considered, it approaches significance (p = 0.0593). Separate analyses were also performed for each of the three individual styles of advertising: instructive, emotive, and enforcement. The estimated elasticities are presented in Table B.3 below. The full analyses are presented in Appendix A Tables A14-A16.

Table B.3: Estimated Elasticity with Monthly Casualty Crash Frequencies For Different Styles of Speed-related Adstock

Advertising Style	Estimated Elasticity	95% Confidence Intervals		p
		Upper	Lower	
Instructive	-0.20	-0.45	0.05	0.1186
Emotive	-0.25	-0.56	0.06	0.1186
Enforcement	-0.79	-1.79	0.20	0.1186

As can be seen in Table B.3, similarly to the all-styles analysis, a 1% increase in each of the instructive, emotive, and enforcement styles was associated with 0.20%, 0.25%, and 0.79% decrease in crash frequencies, respectively. Again, these association approached significance at the one-tailed 5% level (p = 0.0593).

The percentage decrease in crash frequencies associated with different amounts of increase in all-styles Adstock was estimated, and is shown in Table B.4 below.

Table B.4: Estimates of Percentage Changes in Monthly Casualty Crashes for Increases in Monthly Speed-related Adstock (All Styles)

Increase in Adstock	% Change in Crash Frequencies	95% Confidence Intervals Upper	Lower
500-1000	-16.13	-32.75	4.60
1000-1500	-9.78	-20.72	2.67
1500-2000	-7.04	-15.18	1.88
2000-2500	-5.51	-11.99	1.46
2500-3000	-4.52	-9.91	1.19
3000-3500	-3.84	-8.45	1.01
3500-4000	-3.33	-7.36	0.87
4000-4500	-2.95	-6.52	0.77
4500-5000	-2.64	-5.85	0.69

During the extended period in which the enforcement initiatives were in effect (December 2000 to December 2003) the monthly average level of advertising was 1707.19 Adstock units, compared to 1014.16 Adstock units in the prior period (January 1998 to November 2000). This amounts to a monthly average increase in advertising of 693.03 Adstock units (68.3% increase) during the period of the evaluation. This increase was estimated to be associated with a 12.38% decrease in casualty crash frequencies during the extended period (but with a wide 95% confidence interval from 3.44% increase to 25.78% decrease in crashes). This crash benefit is somewhat weaker than that estimated in section 8.6.1.2 for the shorter period December 2000 to December 2002, because the total level of advertising decreased during 2003 compared with 2001-2002.

Among the new factors considered in the extended analysis, the media announcement which occurred in September 2002 and related to the subsequent increase in penalties, was significantly associated with 25.99% increase in casualty crash frequencies (95% CI from 9.83% to 44.51% increase). This result is surprising, as such media announcements have been usually associated with a decrease in crashes. The reason for this result is unclear, although the very large confidence interval indicates a large error associated with this estimate. The estimated effect for the actual penalty restructure commencing December 2002, on the other hand, was in the expected direction, although non-significant, indicating a 1.31% decrease in casualty crashes. The other three media announcements were not significantly associated with crash changes in this extended analysis, though the announcements in August and December 2001 had been significant in the earlier analysis (Table 8.5).

The fixed camera controversy in November and December 2003 was significantly associated with 11.72% decrease in casualty crashes, but with very wide 95% confidence intervals from 2.56% decrease to 20.03% decrease. It is not clear how this controversy may have influenced the camera program, but it was speculated that the distinction between the fixed and mobile components of the program may not have been apparent to all drivers, and perhaps undermined the effectiveness of the mobile camera program. (An increase in offence rate for the mobile speed cameras was observed during the last two months of 2003; see section 5.1.1.) Rather, the opposite effect to that expected was indicated by the crash analysis results.

The drop in detected mid-range speeding offences in August 2002 was significantly associated with 30.77% increase in casualty crashes, but with a very wide 95% confidence interval of 10.65% increase to 53.64% increase. This coefficient may be in the expected direction, as a drop in the detection rate of offences is expected to lead to a decrease in the perceived, as well as the actual risk of detection, and subsequently to less safe driving behaviours. However, unless the mobile speed camera sites and sites changed substantially during August 2002, the drop in offence rate during that month is suggestive of improved behaviour which, in contrast, could be expected to be associated with a decrease in casualty crashes.

The estimate for the introduction of the 50 km/h speed limit was nearly significant at the 5% level ($p = 0.0782$), with an estimated 13.52% reduction in casualty crash frequencies (95% CIs: from 1.64% increase to 26.41% reduction in crashes). This estimate was more reliable than that obtained in the earlier analysis (Table 8.5), as indicated by the relative width of the confidence limits. Based on the finding of a reduction in casualty crashes found in a specific evaluation of the 50 km/h limit (Hoareau, Newstead and Cameron 2002, 2006), a one-sided alternative hypothesis (decrease in crashes compared with unchanged) would not have been unfounded. In which case, the p value for this estimate could be halved (i.e. $p = 0.0391$) suggesting that the estimated effect of the 50 km/h limit was statistically significant.

B.4 Results of the extended crash severity analysis from 1998-2003

The aim of the crash severity analysis was to examine the association between each of the speed-related factors and changes in the odds of fatal outcome of the casualty crashes. Logistic regression was used for this analysis. The crash severity analysis was performed at a regional, rather than at a divisional level, to retain sufficient statistical power. The outcome that was analysed was the proportion of fatal crashes versus the proportion of injury crashes, coded as a binary outcome. Previous research (e.g. Cameron at al., 2003b), as well as the initial analysis to the end of 2002 (section 8.6.2), have shown that fatal crashes appear to be more sensitive to changes in speed-related factors than serious injury crashes. However, the results should be treated with caution due to the low average fatality counts per month in each region. The results of the severity analysis are presented in Table B.5 below.

Table B.5: Logistic Regression Estimates for the Odds of a Fatal Outcome Given a Casualty Crash

Variables	Categories	Odds Ratio	95% Confidence Intervals Upper	Lower	p
Camera Hours	.	-2.03 [1]	-3.16	-0.89	0.0005
Flashless Operations	**On**	1.75	1.15	2.64	0.0084
	Off				.
Threshold Reductions	**1st Step**	1.19	0.53	2.70	0.6715
	2nd Step	1.14	0.36	3.57	0.8202
	3rd Step	1.00	0.26	3.79	0.9954
	Pre-Reduction	.	.	.	.
All-Styles Advertising	**.**	0.78 [2]	-0.92	2.49	0.3674
August Announcement	**On**	0.90	0.28	2.90	0.8608
	Off	.	.	.	.
December Announcement	**On**	0.69	0.33	1.47	0.3408
	Off	.	.	.	.
April Announcement	**On**	0.84	0.16	4.33	0.8315
	Off	.	.	.	.
Penalties Announcement	**On**	1.02	0.39	2.67	0.969
	Off	.	.	.	.
50 km/h Limit	**On**	0.85	0.29	2.53	0.7735
	Off	.	.	.	.
Penalties Restructure	**On**	0.82	0.37	1.78	0.6094
	Off	.	.	.	.
Fixed Cameras Controversy	**On**	0.87	0.38	1.98	0.736
	Off	.	.	.	.
Aug 2002 Drop in Offence Rate	**On**	0.70	0.23	2.13	0.5263
	Off	.	.	.	.

[1] Unlike the odds ratio estimates in this column, this figure should be interpreted as the elasticity between camera hours and the odds of fatal outcome from casualty crashes (see section 8.2).
[2] Unlike the odds ratio estimates in this column, this figure should be interpreted as the elasticity between Adstock and the odds of fatal outcome from casualty crashes (see section 8.6.1.2).

Table B.5 shows that every 1% increase in camera hours was significantly associated with a 2.03% reduction in the risk of a fatal outcome of casualty crashes. The percentage decrease in odds of fatal outcome of the crashes, associated with specific amounts of increases in camera hours, were estimated and are presented in Table B.6 below.

Table B.6: Estimates of Percentage Changes in the Odds of a Fatal Crash Outcome for Increases in Monthly Camera Hours

Increase in Camera Hours	% Change in Odds	95% Confidence Intervals Upper	Lower
Stage 1: 4200 – 4800 hours	-23.69	-34.43	-11.20
Stage 2: 4800 - 5400 hours	-21.22	-31.08	-9.95
Stage 3: 5400 - 6000 hours	-19.21	-28.32	-8.95
Total increase: 4200 - 6000 hours	-51.44	-67.61	-27.19

As shown in Table B.6, the total increase in camera hours from 4200 to 6000 was associated with a 51.4% decrease (95% confidence intervals from 27.2% to 67.6%) in the risk of a fatal outcome of the casualty crashes.

The only other factor for which a statistically significant association was observed was the flashless camera operations, as seen in Table B.5. However, the estimate was in the opposite direction to that expected, in fact suggesting an association with an increase in the odds of a fatal crash outcome. This is similar to the results obtained for the earlier analysis until the end of 2002, and possible reasons for these estimates were discussed earlier in this report. The appropriate conclusion, once more, is that the effect of flashless operations on crash severity is unknown at this stage.

None of the other factors included in the analysis in Table B.5 reached statistical significance. Separate logistic regression analyses were also carried out for each advertising style: instructional, emotive, and enforcement, but similarly no other statistically significant results were observed.

B.5 Summary of results from the extended analysis

Overall, very similar results were obtained for the three speed enforcement initiatives in the extended 1998-2003 analysis, compared to the analysis for the earlier 1998-2002 period. The results are summarised and compared below.

In the 1998-2003 analysis, the increased camera hours were significantly and consistently related to both a decrease in monthly casualty crash frequencies and a decrease in the odds of a fatal outcome of these crashes. These results are very similar in both direction and magnitude to those obtained for the earlier 1998-2002 analysis.

In the 1998-2003 analysis, the flashless camera initiative was associated with a decrease in crashes. Although this association was in the expected direction, it did not reach statistical significance. As before, the 1998-2003 analysis indicated that the flashless operations were associated with an increase in the odds of a fatal crash outcome.

For the threshold reductions, also very similar results were obtained in the extended analysis to those of the earlier analysis, in both direction and magnitude, but they remained statistically non-significant even though the estimated effects were based on an additional year's crash data.

There remains doubt that either the flashless initiative or the threshold reductions have been adequately represented in the monthly crash outcome models.

While for the 1998-2002 analysis the instructive style of advertising appeared to be predominant in its effect, in the extended analysis all three advertising styles (instructive, emotive, and enforcement) were close to statistical significance. As described earlier in this Appendix, there were some differences in the advertising styles and levels in 2003 compared to the earlier period, which may have contributed to these differences in the results.

In the extended analysis the August 2001 announcement did not have a statistically significant association with monthly crash frequencies, unlike the earlier analysis. This may have been because the nature of the estimated associations between monthly advertising Adstock and crash frequencies had changed and had captured the apparent announcement effect in the earlier analysis.

The extended analysis found that the introduction of the 50 km/h urban speed limit was significantly associated with casualty crash frequency, with an estimated effect of 13.5% reduction in these crashes. While this estimated effect is consistent with the results of the specific evaluation by Hoareau et al (2002, 2006), doubt remains whether this initiative has been adequately represented in the crash outcome models.