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OVERALL IMPACT DURING 2001-2004 OF VICTORIAN SPEED-RELATED PACKAGE

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Title:

Overall Impact During 2001-2004 of Victorian Speed-Related Package

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Abstract:

From December 2000 until July 2002, three new speed enforcement initiatives were implemented in Victoria. These initiatives were introduced in stages and involved the following key components: More covert operations of mobile speed cameras, including flash-less operations; 50% increase in speed camera operating hours; and lowering of cameras' speed detection threshold. In addition, during the period 2001 to 2002, the 50 km/h General Urban Speed Limit (GUSL) was introduced (January 2001), there was an increase in speed-related advertising including the "Wipe Off 5" campaign, media announcements were made related to the above enforcement initiatives and there was a speeding penalty restructure. The above elements combine to make up a package of speed-related initiatives and factors. The broad aim of this study was to evaluate the overall effectiveness of the speed-related package. This report presents the results of the overall impact during 2001-2004 of the speed-related initiatives on crash outcomes.

Evaluation of the crash effects of the Victorian speed-related package has shown clear reductions in the number of casualty crashes associated with its implementation. The package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.8%. This reduction was due largely to the highly statistically significant 4.6% estimated reduction in casualty crashes in metropolitan Melbourne. Analysis of the proportion of casualty crashes that were fatal suggested a possible reduction in the risk of fatal outcome in casualty crashes with a non-statistically significant estimated relative crash injury severity of 0.96 whilst analysis of the proportion of fatal or serious injury crashes that were fatal showed a statistically significant reduction in the risk of fatal outcome in the serious casualty crash subset with an estimated relative crash injury severity of 0.86. Both measures of severity showed non-statistically significant estimated reductions in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the post-implementation period.

Since the key component initiatives were implemented in a staggered way, the overall results were partitioned by time in order to assess changes in the crash outcomes over time during the post-implementation period. Because of the staggered implementation, it could be argued that the final partitioned period of July 2004 to December 2004 inclusive best reflects the full effect of the speed-related package on crash outcomes. This period showed a highly statistically significant estimated crash reduction of 10% in casualty crashes, with a non-statistically significant estimated relative crash injury severity of 0.81 occurring for the proportion of casualty crashes resulting in fatal outcome. Compounding these results gave a statistically significant estimated reduction in fatal crashes of 27% with a 95% confidence interval of (5.9%, 48%). Given that 136 fatal crashes were observed during this 6 month period, the number of fatal crashes *that would have been expected* if the speed-related package had not been implemented was estimated to be 186 (145, 259); this equates to a saving of just over 8 (1, 21) fatal crashes per month.

Key Words:

Speed, Enforcement, Impact Evaluation, Statistical Analysis

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EXECUTIVE SUMMARY

From December 2000 until July 2002, three new speed enforcement initiatives were implemented in Victoria. These initiatives were introduced in stages and involved the following key components:

1. More covert operations of mobile speed cameras, including flash-less operations;
2. 50% increase in speed camera operating hours; and
3. Lowering of cameras' speed detection threshold.

In addition, during the period 2001 to 2002, the 50km/h General Urban Speed Limit (GUSL) was introduced (January 2001), there was an increase in speed-related advertising including the "Wipe Off 5" campaign, media announcements were made related to the above enforcement initiatives and there was a speeding penalty restructure.

The above elements combine to make up the package of speed-related initiatives and factors. The broad aim of this study was to evaluate the overall effectiveness of the speed-related package. This report documents the increased speed camera activity and presents the results of assessment of the overall impact during 2001-2004 of the speed-related initiatives on crash outcomes. The methodology used for the crash analysis took into account as far as possible non-speed enforcement initiatives and socio-economic factors which have influenced crash outcomes in parallel to the speed-related package. This report also includes an examination of speed trends in Melbourne and on Victorian rural highways, especially the proportions of vehicles travelling at excessive speeds.

Speed Camera Activity

Victoria Police have provided data on mobile speed camera activity by speed zone for 1999 to 2004. Speed camera hours increased by around 1200 hours (or 46%) in Melbourne and by about 800 hours (or 54%) in the rest of Victoria between 1999-2000 and 2003-2004. In Melbourne, the camera hours on 50 and 60 km/h roads increased by approximately 750 hours (or 39%) (the 50 km/h roads were generally zoned 60 km/h prior to January 2001), but the hours on Melbourne roads zoned at 80 km/h or higher increased by around 300 hours (or 87%) between 1999-2000 and 2003-2004. In the rest of Victoria, camera hours on 50 and 60 km/h roads increased by about 70 hours (or 7%) only, whereas they more than tripled (by around 650 hours or 223%) on 100 and 110 km/h roads albeit from a much lower base.

Effects on Crashes

Crash effects of the speed-related package were assessed using an explanatory Poisson regression model of monthly crash data series from January 1999 to December 2004. This model measured the overall effect of the package after adjusting as far as possible for the effects of changes in the non-speed road safety initiatives and socio-economic factors on crash outcomes. By not including measures of specific components of the speed-related package, the model was designed to measure the overall effect of the package over its implementation period, without regard to the mechanisms producing the effect. In addition, two levels of crash injury severity were measured, namely the proportion of casualty crashes that were fatal, and the proportion of fatal or serious injury crashes that were fatal.

Evaluation of the crash effects of the Victorian speed-related package has shown clear reductions in the number of casualty crashes associated with its implementation. The package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.8%. This reduction was in large part due to the highly statistically significant 4.6% estimated reduction in casualty crashes for metropolitan Melbourne, in contrast with a non-statistically significant estimated increase in casualty crashes of 1.5% occurring for the non-metropolitan location. Analysis of crash outcomes by speed limit at crash location and crash type showed highly statistically significant casualty crash reductions of 6.1% and 4.9% associated with casualty crashes that occurred in 40, 50 or 60 km/h speed zones and where more than one vehicle was involved respectively. The latter result is similar to the estimated reduction in casualty crashes for the metropolitan region. This is consistent with the fact that 84% of casualty crashes involving more than one vehicle occurred in metropolitan Melbourne (2004 data).

The analysis of crash effects for the proportion of casualty crashes that were fatal suggested a possible reduction in the risk of fatal outcome in casualty crashes over the post-implementation period with a non-statistically significant estimated relative crash injury severity of 0.96. A model where the post-implementation period was partitioned by time showed a statistically significant reduction in estimated severity for a partition in the latter part of the package period however. Analysis of the proportion of fatal or serious injury crashes that were fatal showed a statistically significant reduction in the risk of fatal outcome in the serious casualty subset of the crash population with an estimated relative crash injury severity of 0.86. For the same measure, analysis of severity changes by speed limit at crash location and crash type estimated a statistically significant 29% reduction in crash injury severity in 40, 50 or 60 km/h speed zones and a nearly statistically significant reduction of 18% in the severity of crashes where there was more than one vehicle involved. Both measures of severity showed non-statistically significant estimated reductions in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the entire post-implementation period.

Since the key component initiatives were implemented in a staggered manner over time it could be argued that the full effect of the speed-related package was not achieved until some time later after all of the speed-related initiatives had been fully implemented. To investigate this prospect, the overall results were partitioned by time after implementation in order to obtain a more informative view of the crash outcomes over the post-implementation period. Because of the staggered implementation, it may be fair to conclude that the final period of July 2004 to December 2004 inclusive best reflects the full effect of the speed-related package on crash outcomes. This period showed a highly statistically significant estimated crash reduction of 10% in casualty crashes, with a non-statistically significant estimated relative crash injury severity of 0.81 occurring for the proportion of casualty crashes resulting in fatal outcome. Compounding these results gave a statistically significant estimated reduction in fatal crashes of 27% with a 95% confidence interval of (5.9%, 48%). Given that 136 fatal crashes were observed during this 6 month period, the number of fatal crashes *that would have been expected* if the speed-related package had not been implemented is estimated to be 186 (145, 259); this equates to 50 (9, 123) less fatal crashes occurring over the six month period or just over 8 (1, 21) less fatal crashes per month.

Speed Observation Data

In order to evaluate the effect of the speed-related package on speed trends and investigate the link between speed trends and crash outcomes in Victoria, speed observation data was obtained from VicRoads. Speed observation data was included because of its role as an intermediate measure between the implementation of the speed-related package and the crash outcomes. Sufficient knowledge of the link between travel speed and casualty crash risks in urban and rural areas exists to make an approximate estimate of the expected magnitude of the reduction in casualty crashes from a change in the on-road speed distribution, especially the change in the proportion of vehicles exceeding the speed limit. On this basis, it was possible to analyse the speed observation data, especially the proportions of vehicles travelling above certain excessive speed levels, weighting the speed levels by the appropriate risk of a casualty crash, to estimate the changes in casualty crashes that could be expected from the speed behaviour changes.

Risk-weighted proportions of vehicles observed in metropolitan speed zones indicate that a reduction in the number of casualty crashes should be expected over the evaluation period. The risk-weighted proportions of vehicles observed in the 60 km/h speed zone illustrated that the total expected casualty crash risk associated with speed appears to have fallen substantially during 2000, before the speed-related initiatives commenced, but then decreased again by 17% between November 2001 and May 2002 when most of the speed-related initiatives had come into effect. The crash analysis showed a reduction in the number of casualty crashes in 40, 50 or 60 km/h speed zones of 6.1% (and a reduction of 4.6% in metropolitan Melbourne) associated with the speed-related package. Therefore the expected reduction in casualty crashes estimated from the speed behaviour changes would appear to be larger than those estimated from the crash analysis.

In contrast with the risk-weighted proportions of vehicles observed in metropolitan speed zones, the data for rural speed zones do not give a clear indication of whether a reduction in the number of casualty crashes should be expected. In fact the risk-weighted speed observation data for rural speed zones was generally stable or showed small reductions over the evaluation period and seems to be in contrast with the crash analysis, which showed an estimated increase in casualty crashes of 1.5% for the non-metropolitan region, however this result was non-statistically significant. On the other hand, the disaggregated casualty crash results for 100 or 110 km/h roads, which showed a statistically significant estimated reduction in casualty crashes of 4.9%, do seem to be consistent with the risk-weighted speed observation data if we consider that a majority of casualty crashes on these roads occurred in the non-metropolitan location (2004 data).

In terms of crash injury severity, it should be expected that casualty crashes involving pedestrians (which mainly occur in Melbourne) should benefit from a reduction in excessive speed, as our knowledge of biomechanical tolerances suggests that such crashes are associated with greater decreases in serious injury risk for a given decrease in impact speed. For both measures of severity, the estimated reduction in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the post-implementation period seems to be consistent with this hypothesis however these results are non-statistically significant.

Conclusions

Evaluation of the crash effects of the speed-related package showed clear reductions in the number of casualty crashes associated with its implementation. The package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.8%. This reduction was in large part due to the highly statistically significant 4.6% estimated reduction in casualty crashes for the metropolitan rather than non-metropolitan location which showed a non-statistically significant estimated increase in casualty crashes. In addition, disaggregation of crash outcomes showed a highly statistically significant crash reduction of 6.1% associated with casualty crashes that occurred in 40, 50 or 60 km/h speed zones which are mostly situated in metropolitan Melbourne. This result was consistent with the analysis of increased speed camera activity, a key element of the package, which indicated that in metropolitan Melbourne the largest increase in camera hours occurred on 50 and 60 km/h roads. An analysis of excessive speed weighted by risk showed that for metropolitan speed zones, a reduction in the number of casualty crashes should have been expected over the evaluation period. In particular the risk-weighted proportions of vehicles observed in the 60 km/h speed zone showed large reductions in the total expected casualty crash risk associated with speed after most of the speed-related initiatives had come into effect.

In contrast, an analysis of excessive speed weighted by risk for rural speed zones did not give a clear indication of whether a reduction in the number of casualty crashes should have been expected. The total expected risk of a casualty crash in the 80 km/h rural speed zone was generally stable, with the expected risk showing small reductions over the evaluation period for 100 and 110 km/h rural speed zones. This seemed to be in contrast with the crash analysis, which showed an estimated increase in casualty crashes of 1.5% for the non-metropolitan region, however this result was non-statistically significant. On the other hand, the disaggregated casualty crash results for 100 or 110 km/h roads, which showed a statistically significant estimated reduction in casualty crashes of 4.9%, did seem to be consistent with the risk-weighted speed observation data if we consider that a majority of casualty crashes on these roads occurred in the non-metropolitan location. The estimated crash reduction of 4.9% was also consistent with the analysis of increased speed camera activity which showed that the second largest increase in camera hours occurred on rural 100 and 110 km/h roads.

For crash injury severity, the analysis of crash effects for the proportion of casualty crashes that were fatal suggested a possible reduction in the risk of fatal outcome in casualty crashes over the post-implementation period with a non-statistically significant estimated relative crash injury severity of 0.96. A model where the post-implementation period was partitioned by time did show a statistically significant estimated reduction of 30% in this severity measure for the period July 2003 to December 2003 inclusive. Analysis of the proportion of fatal or serious injury crashes that were fatal showed a statistically significant reduction in the risk of fatal outcome in the serious casualty subset of the crash population in the entire post-implementation period with an estimated relative crash injury severity of 0.86. The same measure stratified by location also showed a statistically significant result for the metropolitan region with an estimated relative crash injury severity of 0.82. For the proportion of fatal or serious injury crashes resulting in fatal outcome, disaggregation by crash outcomes estimated a statistically significant 29% reduction in crash injury severity in 40, 50 or 60 km/h speed zones. On the whole, a general trend towards a reduction in the level of severity seemed to occur over time for both measures.

1 BACKGROUND AND OBJECTIVES

1.1 VICTORIAN SPEED-RELATED INITIATIVES

From December 2000 until July 2002, three new speed enforcement initiatives were implemented in Victoria. These initiatives were introduced in stages and involved the following key components:

1. More covert operations of mobile speed cameras, including flash-less operations;
2. 50% increase in speed camera operating hours; and
3. Lowering of cameras' speed detection threshold.

In addition, during the period 2001 to 2002, the 50 km/h General Urban Speed Limit (GUSL) was introduced (January 2001), there was an increase in speed-related advertising including the "Wipe Off 5" campaign, media announcements were made related to the above enforcement initiatives and there was a speeding penalty restructure.

The above elements combine to make up a package of speed-related initiatives and factors. The effect of these changes in terms of public perceptions has been assessed by Smith and Senserrick, 2004.

1.2 OBJECTIVES: OVERALL EVALUATION

This project aimed to evaluate the overall effectiveness of the speed-related package. The project objectives were:

- to document the increased speed camera activity in each speed limit zone and in Melbourne compared with the rest of Victoria;
- to evaluate the overall effect on crash outcomes of the package;
- to account as far as possible for the effect on crash outcomes of non-speed road safety initiatives and socio-economic factors, which would otherwise influence the speed-related package evaluation; and
- to examine speed trends in Melbourne and on Victorian rural highways, especially the proportions of vehicles travelling at excessive speeds.

2 INCREASED SPEED CAMERA ACTIVITY BY SPEED ZONE

Victoria Police have provided data on mobile speed camera activity by speed zone for 1999 to 2004. Figure 2.1 shows mobile speed camera hours per month by speed zone for Melbourne and Figure 2.2 shows mobile speed camera activity for the rest of Victoria. Speed camera hours increased by around 1200 hours (or 46%) in Melbourne and by about 800 hours (or 54%) in the rest of Victoria between 1999-2000 and 2003-2004. In Melbourne, the camera hours on 50 and 60 km/h roads increased by approximately 750 hours (or 39%) (the 50 km/h roads were generally zoned 60 km/h prior to January 2001), but the hours on Melbourne roads zoned at 80 km/h or higher increased by around 300 hours (or 87%) between 1999-2000 and 2003-2004. In the rest of Victoria, camera hours on 50 and 60 km/h roads increased by about 70 hours (or 7%) only, whereas they more than tripled (by around 650 hours or 223%) on 100 and 110 km/h roads albeit from a much lower base.

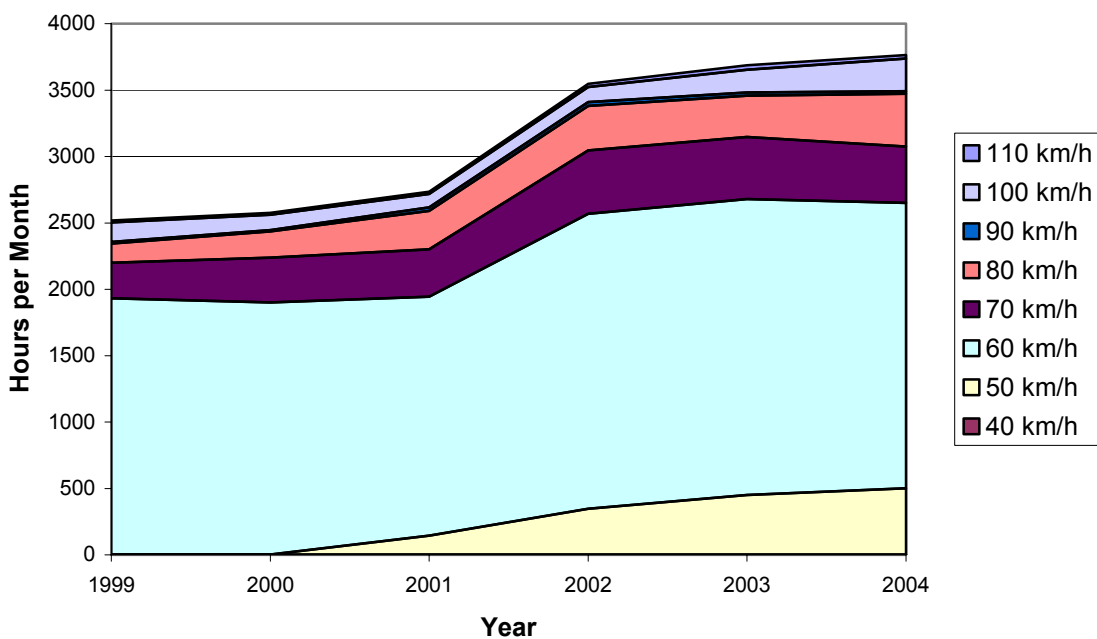


Figure 2.1: Mobile Speed Camera Hours by Speed Zone – Melbourne

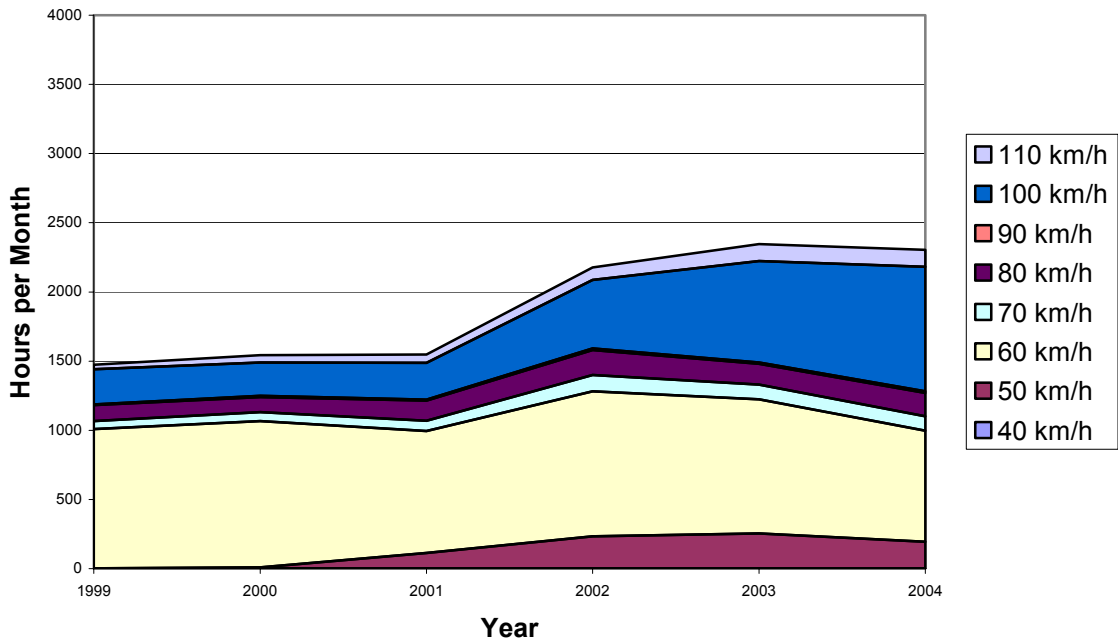


Figure 2.2: *Mobile Speed Camera Hours by Speed Zone – Rest of Victoria*

The speed camera activity information above has provided an initial indication of the parts of the Victorian road system where the strongest effects of the increased speed camera activity on speeding and crash outcomes could be expected. It was also used to guide the crash analysis presented in Section 3 which considered crashes in each of three categories of speed zone. The categories reflect the major speed zones specifically (as opposed to crashes in each Police region/division as a whole).

3 CRASH ANALYSIS

3.1 OVERALL EVALUATION DESIGN

The number of initiatives and factors included in the speed-related package and the reach of these elements over the crash population did not lend themselves to an explicit crash-based evaluation employing an experimental or quasi-experimental design framework. The coverage of crashes throughout Victoria by the elements of the package across all times of day and all road users, did not result in any crash type which could be considered unaffected by the package and hence potentially useful for taking into account the influence of non-speed road safety initiatives and socio-economic factors as a “control” group in a quasi-experimental setting.

As the best alternative design, the evaluation of speed-related package crash effects has sought to identify a relationship between the overall effect of the package and the outcomes in terms of a time trend in observed monthly crashes through statistical regression modelling. The success of such an approach relies on the ability to effectively represent the majority of other factors that have influenced observed crash counts over an extended time period in order to be able to measure the pure effects of the speed-related package. To do this, it is necessary to have accurate measures of the other influential factors and to model the crash data for a period sufficiently long enough to allow accurate associations between the available measures and the crash outcomes to be firmly established. This has required crash trends to be modelled over a time period including the period during which the package took place but also for a significant time period beforehand.

The basic idea of the modelling approach is to accurately represent as far as possible crash trends in the pre-package period by the non-package factors included in the regression model and then measure the perturbation from the pre-implementation crash trends once the package took place. The perturbation is then inferred to represent the overall effect of the package on crashes. That is, the approach models the perturbation on the crash series associated with the package as a single global effect.

The specific structure of the statistical regression model used in the evaluation will be discussed in detail later but is classed as a Poisson regression model, a class of Generalised Linear Models (GLMs) (McCullagh and Nelder, 1989). The use of GLMs in the context of this evaluation has been successfully demonstrated in other evaluations of crash outcomes in Monash University Accident Research Centre (MUARC) research examining the interaction between speed camera enforcement and mass media publicity (Cameron et al. 2003a) and in research examining the effects of a road safety initiatives package implemented in Queensland during 2003-2004 (Newstead et al., 2004). A paper summarising the method as applied in the first study has been peer-reviewed before publication (Cameron et al., 2003b).

3.1.1 Analysis Stratification and Disaggregation

Stratification

Data on non-speed road safety initiatives and socio-economic factors was generally available by location, e.g. metropolitan versus non-metropolitan. It is possible that the influence of these factors on crash outcomes may vary in the different parts of the state. Where possible, non-speed road safety initiatives and socio-economic factors were

stratified by location along with the crash outcome variable. In this way, the evaluation model is able to accommodate any influence by location that these factors may exert.

Disaggregation

It had been hypothesised that the effect on crash outcomes of an across-the-board reduction in the speed distribution on Victoria's roads, should be greater in certain crash circumstances (e.g. collisions involving more than one vehicle such as side impacts at intersections, which occur mostly in Melbourne) and to certain road users (e.g. pedestrians). Knowledge of biomechanical tolerances suggests such crashes are associated with greater increases in serious injury risk for a given increase in impact speed. It had also been hypothesised that the effects of the speed-related package may be greater in Melbourne, and on roads with a 50 or 60 km/h speed limit, if speed enforcement activity has been focused on those roads.

In addition, Cameron et al. (2003a) found that during 1999, Melbourne Police districts with relatively high monthly levels of speeding tickets detected by speed cameras were associated with a reduction in the frequency and severity of casualty crashes during the following month. However it is thought that the effect on crash outcomes of the increases in monthly speed camera hours within each Police region and division during 2000-2002 may vary between metropolitan and non-metropolitan regions of Victoria or the speed limit of the crash location. This could occur when the increase in speed camera hours is applied differently in Melbourne or on roads with a 50 or 60 km/h speed limit for example.

Also, random breath tests, one of the non-speed road safety initiatives whose effect on crash outcomes is to be taken into account in the analysis, are expected to have a strong effect on High Alcohol Hour crashes, but not on the remainder of the crash population. High Alcohol Hours of the week are defined as those times and days when alcohol involvement in crashes is much higher than at other times. In Victoria, Harrison (1990) found that during High Alcohol Hours, 38% of drivers killed or admitted to hospital had illegal blood alcohol concentration (BAC), whereas only 4% of such drivers had illegal BACs at other times.

Therefore, in addition to an overall model, separate models were developed for crash criteria related to speed limit of crash location, crash type and alcohol hours via a disaggregation of crash outcomes along these lines. A model only dealing with casualty crashes involving pedestrians was also developed. As mentioned in the section on stratification above, crash outcomes were already stratified by location into metropolitan versus non-metropolitan regions of Victoria. The disaggregation of crash outcomes was as follows:

Speed limit of crash location

The speed limit of the crash location was used to disaggregate crash outcomes into the following categories:

- 40, 50 or 60 km/h;
- 70, 80 or 90 km/h;
- 100 or 110 km/h.

Crash Type

The number of vehicles involved in a crash was used to disaggregate crash outcomes into the following categories:

- One vehicle involved;
- More than one vehicle involved.

Alcohol Hours

Crash outcomes were disaggregated into two times of the week (High versus Low Alcohol Hours). The High Alcohol Hours defined by Harrison (1990) are:

- 4 p.m. Sunday to 6 a.m. Monday;
- 6 p.m. to 6 a.m. Monday to Thursday nights;
- 4 p.m. Friday to 8 a.m. Saturday;
- 2 p.m. Saturday to 10 a.m. Sunday.

Low alcohol hours are the residual times of the week.

Where appropriate, the estimated effect of the speed-related package in “target” circumstances (i.e. 40, 50 or 60 km/h speed limit; more than one vehicle involved) were compared with the estimated effect in the complementary circumstances. A statistically significant difference in these estimates indicated the circumstances in which the impact of the speed-related package is greater. This information may assist conclusions about the cause-and-effect of any reduction in crash outcomes found to be associated with the package.

3.2 DATA FOR THE OVERALL EVALUATION

3.2.1 Crash Data and Crash Outcomes

MUARC holds crash data supplied by VicRoads covering the analysis period of January 1999 to December 2004. As only crashes involving death or injury are required to be reported to Police in Victoria, the crash data only includes reported injury crashes over that period with each unit record in the data representing a person involved in a casualty crash. Prior to the analysis, the crash data was reduced so that each unit record in the data represented a reported casualty crash. Each record contained the following information:

- Crash severity;
- Crash date;
- Crash time of day;
- Police region and division of crash location;
- Speed limit of crash location;
- Number of vehicles involved;
- Road user type.

Injury outcome in Police reported crashes in Victoria is classified into one of three levels, namely fatal, serious injury (where taken to hospital) and other injury. The severity of a crash is defined by the most serious injury level sustained by any person involved in the crash. The fields listed above allowed each level of injury outcome to be stratified by location and disaggregated by speed limit of crash location, number of vehicles involved and alcohol hours as described in Section 3.1.1. The road user type field allowed crashes involving pedestrians to be identified.

Monthly crash data series are shown in Figures 3.1 to 3.3. Figure 3.1 shows the monthly crash series for casualty crashes by the metropolitan versus non-metropolitan stratification. Figures 3.2 and 3.3 show the monthly crash series stratified by location for serious injury and fatal crashes respectively.

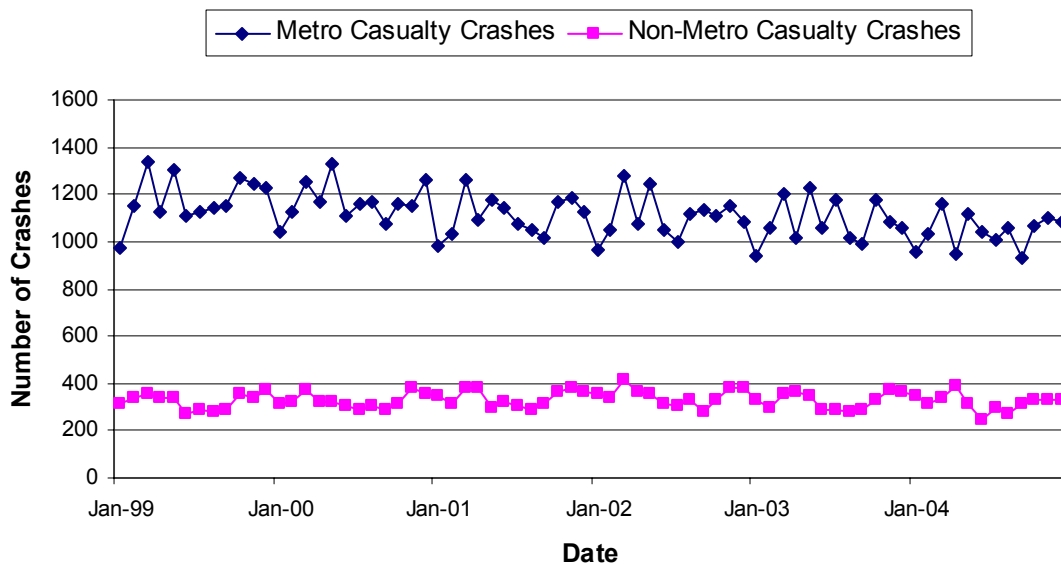


Figure 3.1: Monthly Crash Data: Casualty Crashes by Location

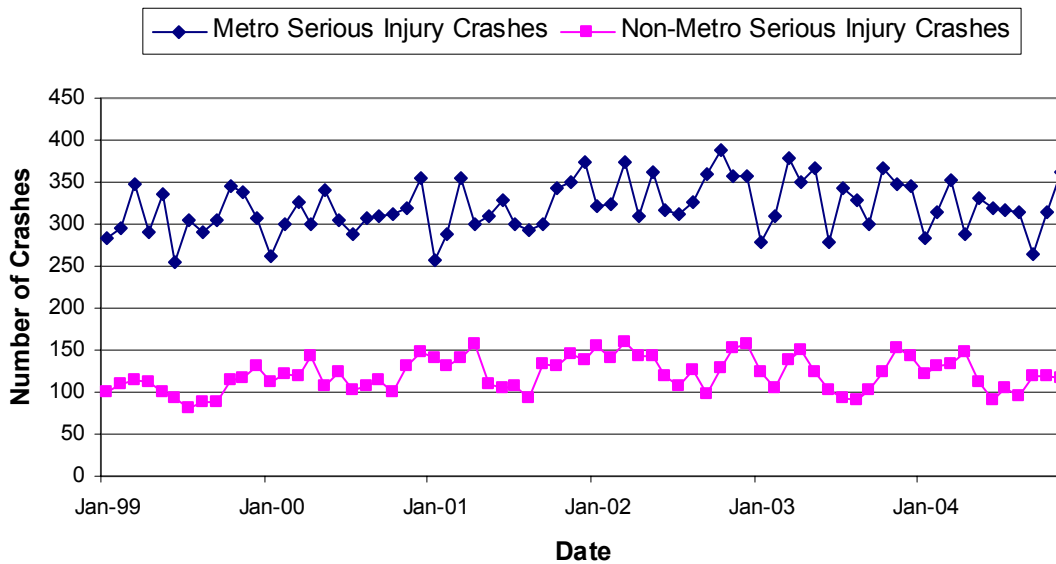


Figure 3.2: *Monthly Crash Data: Serious Injury Crashes by Location*

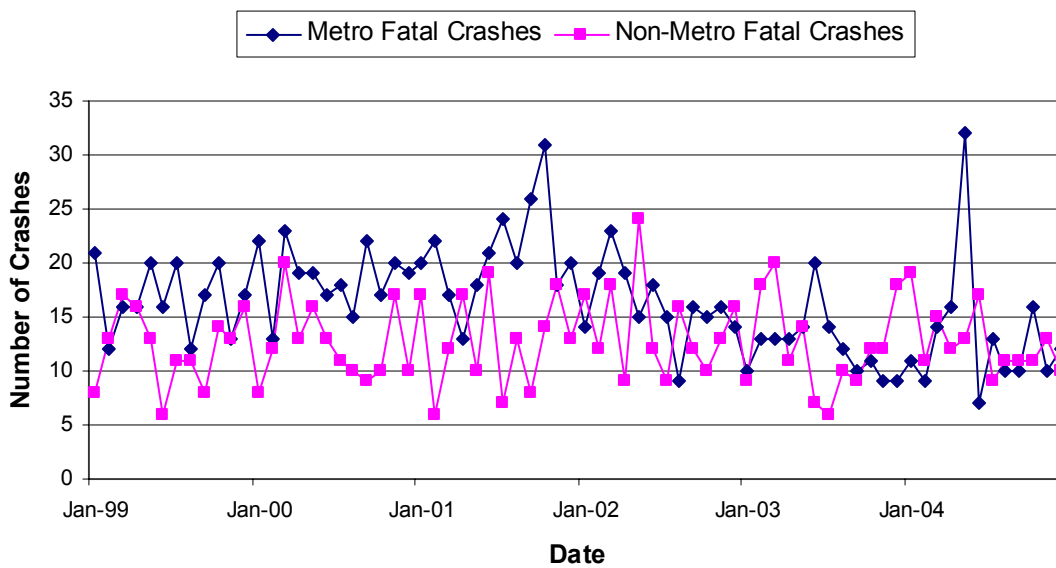


Figure 3.3: *Monthly Crash Data: Fatal Crashes by Location*

3.2.2 Speed-Related Package

The speed-related package consists of speed-related initiatives and factors. Brief descriptions of elements of the package including implementation timing follow. It was not the purpose of this study to evaluate the components separately, rather these elements were assessed as a package overall.

Covert Operations

Covert operation of mobile speed cameras includes the use of non-visible enforcement such as unmarked vehicles and flash-less cameras. In particular, flash-less operation was introduced in three stages from December 2000 to December 2001.

Camera Operating Hours

From August 2001 to February 2002, mobile speed camera operating hours per month were increased from a target of 4200 hours to a target of 6000 hours. This is almost a 50% increase and occurred in three 600 hour stages.

Speed Detection Threshold

Lowering of cameras' speed detection threshold took place in three stages from March to September 2002. Speed detection threshold refers to the difference between the speed limit and the speed at or above which a vehicle will be detected as speeding by a camera.

General Urban Speed Limit (GUSL)

During January 2001, a state-wide 50 km/h GUSL was introduced. That is, a 50 km/h speed limit became default in built-up areas except where otherwise signed. Most major arterial roads and some local collector streets in urban areas were signed at 60 km/h after the change so that they retained their previous 60 km/h limit.

Speed-Related Advertising

From August 2001, an increase in speed-related advertising including the "Wipe Off 5" campaign was carried out by the Transport Accident Commission (TAC).

Media Announcements

Associated with the increase in speed-related advertising, a media announcement was made in August 2001 regarding the "Wipe Off 5" campaign. In addition, media announcements were made in late November 2001 and March 2002 in relation to covert operations and increased camera operating hours, and speed detection thresholds respectively.

Speeding Penalty Restructure

In December 2002, the thresholds for penalties applying to different levels of speeding offence were generally reduced by 5 km/h including the threshold resulting in automatic licence suspension. A media announcement regarding this change was made in September 2002.

Based on a broad consideration of the implementation timing of the above elements, for the purpose of assessing its overall impact, the speed-related package was defined to start from August 2001. That is, the speed-related package was deemed to be the initiatives and factors commencing during or after August 2001 and excluding the first stage of covert operations and the GUSL, both of which affected a relatively small part of the Victorian road system and crashes thereon. In particular, the first stage of covert operations was implemented in police divisions representing around 30% of all divisions.

3.2.3 Non-Speed Road Safety Initiatives

Non-speed road safety initiatives were likely to have had an effect on observed monthly crash levels and consequently the presence of each needed to be reflected in the evaluation statistical model. Modelling only reflects the effects of major road safety initiatives with significant monthly variation on overall crash outcomes. Significant monthly variation in the factors is required for the factor to be successfully linked to monthly crash outcomes in the statistical model used. Including factors in the statistical models that vary smoothly is generally not successful and leads to interpretation problems with the model. The effects of these slow varying factors are reflected by general terms in the statistical model although the specific relationship between each of these slow varying factors and crash outcomes will not be known.

A review of road safety activity over the evaluation period identified random breath tests and non-speed-related advertising as the major non-speed road safety initiatives that occurred with significant monthly variation. Therefore the factors reflected in the model were as follows: number of random breath tests, exceeding prescribed concentration of alcohol and non-speed-related Adstock (see below).

Random Breath Tests

The number of monthly random breath tests conducted from booze buses and other stationary vehicles. Available by Police region and division.

Exceeding Prescribed Concentration of Alcohol

The monthly number of offences detected of drivers exceeding the legally prescribed blood alcohol concentration for their category of licence.

Non-Speed-Related Adstock

Non-speed-related advertising impact level per month as represented by Adstock. Adstock is a measure developed by Broadbent (1979, 1984) describing the way that an audience's retained awareness is related to current and past levels of television advertising. Available by metropolitan Melbourne and regional areas of Victoria.

3.2.4 Socio-Economic Factors

Changes in socio-economic factors are known to have effects on observed road trauma. Like the non-speed initiatives, it was necessary to include measures of socio-economic effects in the statistical models to accurately describe trends in the crash data driven by factors other than the speed-related package. The following socio-economic factors were taken into account in the evaluation statistical model: estimated kilometres travelled, fuel sales, alcohol sales, unemployment rate and population. Unemployment rate and population are available by Melbourne statistical division and the rest of Victoria. The socio-economic factors included in the model are known to reflect differences in total exposure to crash risk, each in a subtly different way. These factors were used in the research mentioned earlier which examined the effects of the road safety initiatives package implemented in Queensland during 2003-2004 (Newstead et al., 2004) and in previous work by Newstead et al. (1995) and Cameron et al. (1993) examining Victorian road trauma trends. These projects identified the important socio-economic factors to include in the analysis, following earlier work by Thoresen et al. (1992) which investigated linking the Victorian road toll with economic, road safety, social and other factors.

3.3 STATISTICAL ANALYSIS METHODS

3.3.1 Minimisation of Co-Linearity between Independent Variables

In order to build a statistical regression model that was robust and easily interpreted the first step in the statistical modelling process was to test for co-linearity between the regression input (independent) variables. The presence of co-linearity between potential independent variables in the regression model has been investigated through analysing the correlations between the variables. Variables with a raw correlation coefficient higher than 0.5 were considered to have a sufficiently high co-linearity to cause concern in interpreting analysis results. In order to minimise the co-linearity problem, highly correlated independent variables were removed from the regression equation. Any variable remaining in the model could be considered to represent the effect of itself as well as the removed correlated variable/s associated with it.

3.3.2 Poisson Regression Model

General Model Structure

The analysis model used in this evaluation to relate the overall effect of the speed-related package and non-speed initiatives and socio-economic factors to observed monthly crash counts was a Poisson Regression model. The general form of the Poisson regression model is given by Equation 3.1.

$$\ln(y) = \beta X + \varepsilon \quad (3.1)$$

In Equation 3.1, y is the dependent variable, in this case monthly crash counts, β is the vector of model parameters or regression coefficients, X is the matrix of input or independent variables and ε is the random error of the dependent variable. In a Poisson regression model, the crash counts are assumed to vary randomly according to a Poisson distribution.

Use of the Poisson regression model for evaluating the crash effects of the speed-related package was appropriate for a number of reasons. First, it is widely assumed that monthly crash count data follow a Poisson distribution (Nicholson, 1985; Nicholson, 1986) which is reflected in the Poisson structure of the Poisson regression model dependent variable. The log-linear structure of the model ensures that fitted values from the model are non-negative, a property required of predicted crash counts. The log-linear structure of the model also reflects previous findings that the effects of many road safety countermeasures affect crash outcomes in a multiplicative rather than additive way. In practice this means that the absolute crash savings achieved by a countermeasure will be dependent on the initial size of the crash population on which it acts.

The Poisson regression model is also particularly useful for building predictive models of crash outcomes as required here, because the model structure lends itself to ready interpretation of the relationships between input and outcome variables and the statistical significance testing of these relationships. It is also relatively robust to some element of misspecification, in the form of less than perfect model fit, arising when not all the factors driving the observed crash outcomes are available and can be measured. This is because the Poisson distribution is a one parameter distribution, the mean being equal to the variance. As the variance is not estimated independently in the modelling process, the statistical significance estimates of the model parameters will not be compromised by less

than perfect model fit. The only threat to the validity of relationships between input and outcome measures predicted by the model structure in the case of misspecification is when the factors not included in the model are not independent of the key model inputs that are being assessed. Whilst Poisson regression models are not useful for forecasting, providing crash forecasts was not the objective of the study.

Poisson regression models have been applied in many studies evaluating crash data, for example by Maher and Summersgill (1996). Furthermore, Poisson regression models have been effectively applied to evaluate both the Random Road Watch (Newstead et al., 2001) and Speed Camera (Newstead and Cameron, 2003) programs in Queensland, the evaluation methods of the former study being peer reviewed for publication.

The overall purpose of the Poisson regression analysis model is to assess the level and statistical significance of association between the speed-related package and observed crash outcomes. As such, the model provides the tool for formal statistical hypothesis testing of this association. The generic null hypothesis being tested is that there is no association between the speed-related package and observed crash outcomes. This is tested against the two-sided alternative hypothesis that the speed-related package has a significant association with the number of observed monthly crashes. The two-sided hypothesis gives a more conservative significance level on the estimates of crash effects because it does not make a presumption about the direction in which the crash frequencies will be associated with the package (i.e. whether the monthly numbers of crashes will be decreased or increased).

In the following descriptions of the precise form of the statistical model fitted, a shorthand notation for each variable included in the model has been used. A summary of the shorthand notations as well as an indication of the structure and treatment of the variable in the models is given in Table 3.1.

Table 3.1: Summary of Modelling Variable Shorthand Names and Structures

Variable Grouping	Variable Description	Shorthand Name	Structure in Modelling Process
Crash data	Monthly casualty crash counts	CASUALTY	Count variable
	Monthly fatal injury crash counts	FATAL	Count variable
	Monthly fatal or serious injury crash counts	FAT_SER	Count variable
Stratification variables	Metropolitan and non-metropolitan regions	LOCATION	Categorical (1=metro, 0=non-metro)
	Month of crash	MONTH	Categorical (1-12)
Non-speed road safety initiatives	Number of random breath tests	RBT	Continuous Numeric
	Non-speed-related Adstock	AD-NONSP	Continuous Numeric
	Exceeding prescribed concentration of alcohol	EX_PCA	Continuous Numeric
Socio-economic factors	Kilometres travelled	KMS	Continuous Numeric
	Fuel sales	FUEL	Continuous Numeric
	Alcohol sales	ALCOHOL	Continuous Numeric
	Unemployment rate	UNEMP_R	Continuous Numeric
	Population	POPLN	Continuous Numeric

Assessment of Overall Package Effect

The Poisson regression model was specified to include all relevant factors aside from those associated with elements of the speed-related package. By not including measures of specific components of the package, the model was designed to measure the overall effect of the package over its implementation period, without regard to the mechanisms producing the effect. To assist with understanding the form of the regression model, the form used is given below in simplified notation similar to that used in programming the model in SAS. A brief note on the purpose of each model term is also included.

$$\begin{aligned}
\ln(\text{Crashes}) = & \text{LOCATION (Metropolitan versus non-metropolitan)} \\
& + \text{RBT} + \text{AD_NONSP (Non-speed road safety initiative variables)} \\
& + \text{UNEMP_R} + \text{ALCOHOL (Socio-economic factor variables)} \\
& + \text{RBT*LOCATION} + \text{AD_NONSP*LOCATION (Non-speed road safety initiatives by location)} \\
& + \text{UNEMP_R*LOCATION} + \text{ALCOHOL*LOCATION (Socio-economic factors by location)} \\
& + \text{MONTH*LOCATION (Seasonal term by location)} \\
& + \text{OVERALL_EFFECT (Speed-related package overall effect)}
\end{aligned}$$

The package implementation term (*OVERALL_EFFECT*) was defined as a categorical step function stepping at August 2001. To measure the overall effect of the speed-related package by location, the last term of the above model was interacted with the categorical LOCATION variable.

A more formal definition of the analysis model used is given by Equation 3.2.

$$\begin{aligned}
\ln(\text{Crashes}_i) = & \alpha + \beta^{\text{LOCATION}} I_{\text{LOCATION}} \\
& + \beta^{\text{RBT}} \text{RBT} + \beta^{\text{AD_NONSP}} \text{AD_NONSP} + \beta^{\text{UNEMP_R}} \text{UNEMP_R} + \beta^{\text{ALCOHOL}} \text{ALCOHOL} \\
& + \beta_i^{\text{RBT}} \text{RBT} + \beta_i^{\text{AD_NONSP}} \text{AD_NONSP} + \beta_i^{\text{UNEMP_R}} \text{UNEMP_R} + \beta_i^{\text{ALCOHOL}} \text{ALCOHOL} + \beta_i^{\text{MONTH}} \text{MONTH} \\
& + \beta^{\text{OVERALL_EFFECT}} I_{\text{OVERALL_EFFECT}}
\end{aligned} \tag{3.2}$$

In Equation 3.2,

- l is the index for LOCATION;
- α, β are parameters of the model;
- I is an indicator function being 1 if the factor is active and 0 otherwise.

The package implementation term is the final term in Equation 3.2. It is defined as 0 prior to August 2001 and 1 from the time the speed-related package was deemed to have been implemented. It is included as a categorical variable in the analysis model and is the key term for assessing the overall effect of the speed-related package on crash outcomes.

Separate analysis models were fitted to the monthly crash counts to measure the overall effect and the overall effect by location. The models were fitted using the SAS statistical software.

Estimation of Percentage Crash Change

Estimates of percentage crash change associated with a factor included in the Poisson regression model can be derived directly from the model parameter β , associated with that factor via Equation 3.3.

$$\%Change = (1 - \exp(\beta)) \times 100\% \tag{3.3}$$

For a binary categorical variable such as the speed-related package's overall effect term in the model specified above, Equation 3.3 gives the net percentage crash change due to the implementation of the package. In the above, positive percentage change estimates indicate crash reduction, whilst negative percentage change estimates indicate a crash increase. Statistical confidence limits can be placed on the estimated percentage changes by using the parameter standard error to estimate confidence limits on the parameter and then transforming the confidence limits into percentage changes using Equation 3.3.

3.3.3 Estimation of Effects on Crash Severity

Assessment has also been made as far as possible of the effects of the speed-related package on crash severity. Changes in crash severity have been measured through examining two principal measures of severity. They were:

- The proportion of casualty crashes that were fatal;
- The proportion of fatal or serious injury crashes that were fatal.

The same study design as that used for assessing changes in monthly crash counts was used for assessing crash severity changes apart from two key differences. First, instead of modelling monthly crash counts, the monthly proportions as defined above were modelled. Second, the form of the statistical model described in Equation 3.1 was altered to become a logistic regression model. The logistic model has the following general form:

$$\text{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \beta X + \varepsilon \quad (3.4)$$

In Equation 3.4, p is the dependent variable, in this case the monthly crash proportion, β is the vector of model parameters or regression coefficients, X is the matrix of input or independent variables and ε is the random error of the dependent variable. In a logistic regression model it is the binomial distribution that describes the distribution of the errors.

As for the crash count analysis, the crash severity analysis has considered the overall effect of the speed-related package on crash severity. The structure of the linear form of input measures for the logistic regression models is the same as used for the Poisson crash count model described in Equation 3.2.

Separate analysis models were fitted to the monthly data series of each of the crash severity levels considered in the evaluation. The models were fitted using the SAS statistical software.

3.4 RESULTS

3.4.1 Minimisation of Co-Linearity between Independent Variables

In order to build a statistical regression model that was robust and could be easily interpreted, it was first necessary to test for co-linearity between the regression input (independent) variables. The presence of co-linearity between potential independent variables in the regression model has been investigated through analysing the Pearson correlations between the variables over the months for which the analysis was performed. Variable pairs with a raw correlation co-efficient higher than 0.5 were considered to have a

sufficiently high co-linearity to cause concern in interpreting analysis results. Variable pairs with high correlations were as follows with the level of correlation indicated:

- Victorian population with random breath tests (0.571);
- Victorian population with exceeding prescribed concentration of alcohol (0.697);
- Victorian population with fuel sales (0.782);
- Victorian population with kilometres travelled (0.700);
- Victorian population with unemployment rate (-0.703);
- Random breath tests with exceeding prescribed concentration of alcohol (0.642);
- Random breath tests with fuel sales (0.565);
- Exceeding prescribed concentration of alcohol with fuel sales (0.574);
- Exceeding prescribed concentration of alcohol with unemployment rate (-0.508);
- Alcohol sales with fuel sales (0.518);
- Fuel sales with kilometres travelled (0.810);
- Fuel sales with unemployment rate (-0.637); and
- Kilometres travelled with unemployment rate (-0.654).

The full variable correlation matrix is given in Appendix A.

To overcome the model co-linearity problems, a number of variables were excluded from the analysis. Because of the high correlation, the effect of the excluded variable is represented by the correlated variable included in the analysis. The following variables were excluded, whilst the variable representing the effect of each excluded variable is indicated in brackets.

- Exceeding prescribed concentration of alcohol (in favour of random breath tests);
- Fuel sales (in favour of unemployment rate);
- Kilometres travelled (in favour of unemployment rate); and
- Victorian population (in favour of unemployment rate).

3.4.2 Results of Crash Frequency Analysis

Estimates of the overall effects of the speed-related package resulting from fitting the regression model described in Equation 3.2 are given in Table 3.2. The estimated crash reductions shown in Table 3.2 are derived from the model parameter estimates using Equation 3.3. Given along with the estimated crash reductions associated with the package are 95% confidence limits on the estimates as well as the statistical significance in each case. Low statistical significance values indicate the crash effect is unlikely to have arisen through chance variation in the data.

Table 3.2: *Estimated Crash Reductions Associated with the Speed-Related Package*

Crash Outcome	Estimated Crash Reduction*	Lower 95% Confidence Limit	Upper 95% Confidence limit	Statistical Significance
Casualty Crashes	3.80%	2.00%	5.57%	< 0.0001
<i>Metropolitan</i>	4.62%	2.69%	6.50%	< 0.0001
<i>Non-Metropolitan</i>	-1.53%	-6.76%	3.45%	0.5549

* Negative percentage crash reduction estimates indicate an estimated percentage crash increase

For casualty crashes occurring in the metropolitan location, the regression model fitted to the raw data is shown in Figure 3.4 with 95% confidence limits. Figure 3.5 shows the fitted model with and without the OVERALL EFFECT term included. The difference in Figure 3.5 reflects the highly statistically significant 4.62% estimated reduction in casualty crashes associated with the speed-related package for the metropolitan location (Table 3.2). Table 3.2 also shows a non-statistically significant estimated crash reduction of -1.53% for the non-metropolitan location. This indicates a non-statistically significant estimated percentage crash *increase* in casualty crashes of 1.53% for the non-metropolitan region.

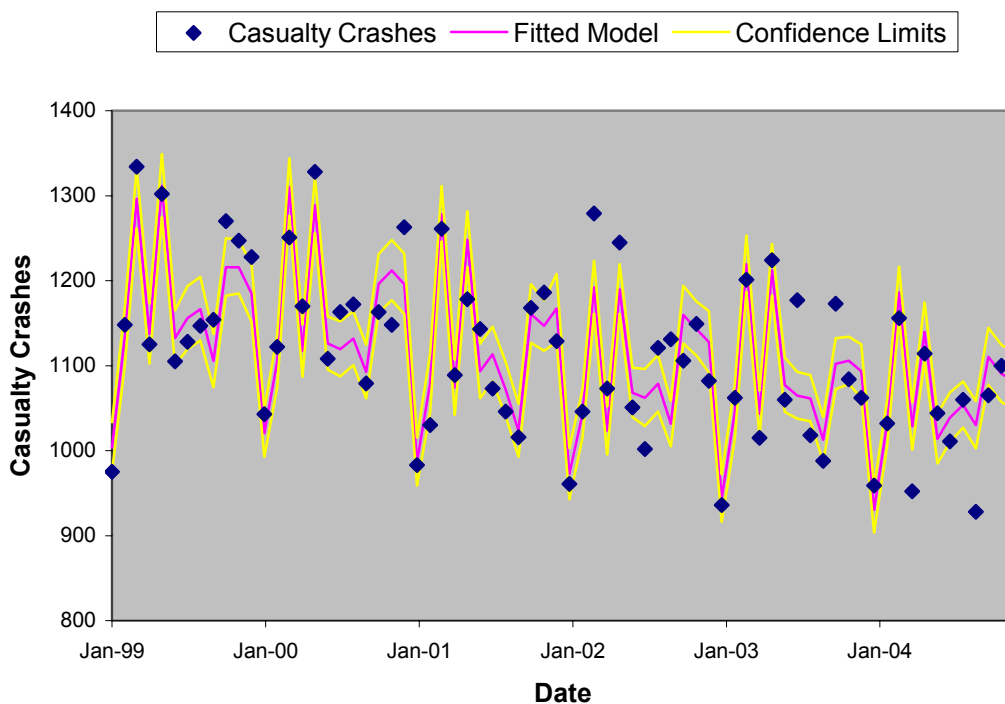


Figure 3.4: *Metropolitan Casualty Crashes – Fitted Model with 95% Confidence Limits*

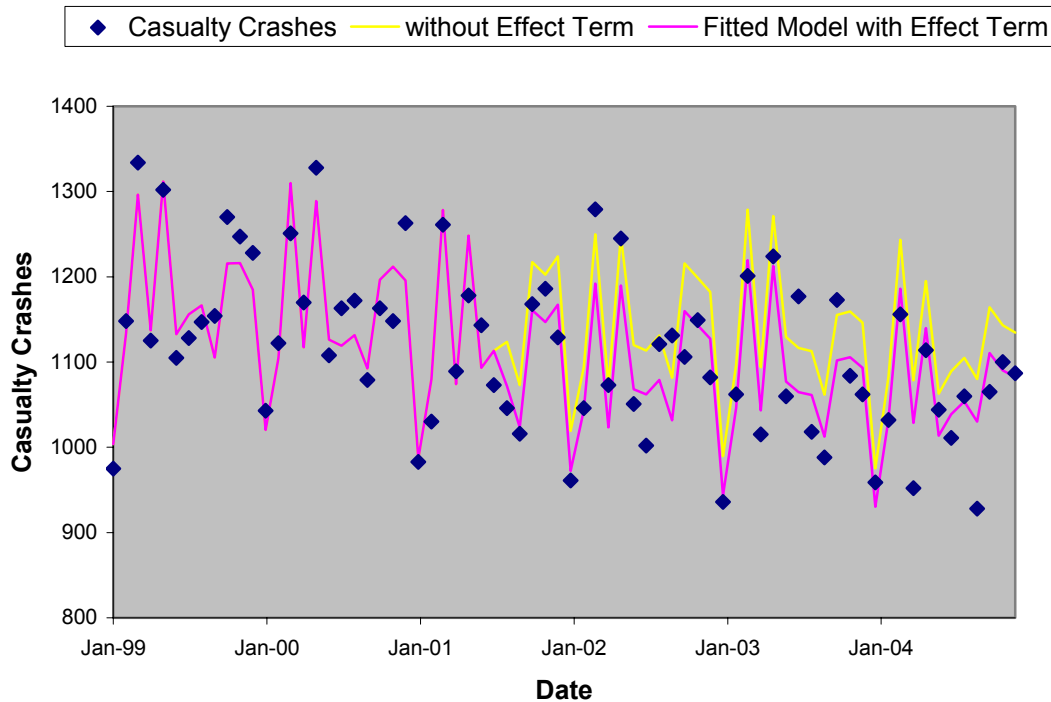


Figure 3.5: *Metropolitan Casualty Crashes – Fitted Model with and without the OVERALL EFFECT Term*

For the regression model fitted to the metropolitan casualty crash data shown in Figure 3.4, model fit was assessed by comparing observed and fitted values. This comparison was made through the use of standardised Pearson residuals which reflect the difference between the observed and fitted values. Figure 3.6 shows the standardised residuals that resulted from the model. Standardised Pearson residuals fluctuate randomly around zero, are independent and follow an approximate standard normal distribution when the model fit is adequate. Therefore standardised residuals larger than around 2 should be noted however some values of this size (around 1 in 20) are to be expected by chance alone. From Figure 3.6, the even fluctuation of residuals around zero shows that there is no systematic bias in the model. It can also be seen that most of the residuals fall within the range of around -2 to +2 indicating that the model fit is reasonable.

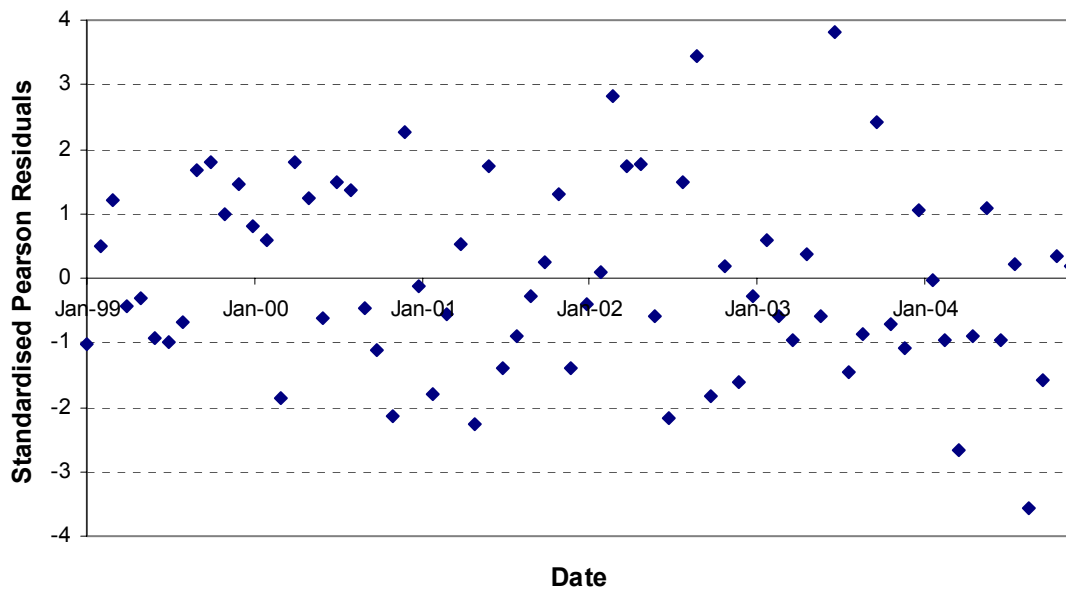


Figure 3.6: *Metropolitan Casualty Crashes – Standardised Pearson Residuals*

Estimates of the overall effects of the speed-related package resulting from fitting the regression model described in Equation 3.2 to disaggregated crash outcomes are given in Table 3.3. An estimate of the overall effect on crashes involving pedestrians is shown in Table 3.4.

Table 3.3: *Estimated Crash Reductions Associated with the Speed-Related Package (Disaggregated Results for Casualty Crashes)*

Disaggregation Category	Estimated Crash Reduction*	Lower 95% Confidence Limit	Upper 95% Confidence limit	Statistical Significance
40, 50 or 60 km/h	6.14%	3.92%	8.31%	< 0.0001
70 or 80 km/h	-1.82%	-5.92%	2.14%	0.3725
100 or 110 km/h	4.93%	0.10%	9.53%	0.0456
More than one vehicle involved	4.92%	2.77%	7.03%	< 0.0001
One vehicle involved	1.37%	-1.95%	4.58%	0.4138
Low Alcohol Hours	4.01%	1.65%	6.32%	0.0010
High Alcohol Hours	3.53%	0.72%	6.25%	0.0141

* Negative percentage crash reduction estimates indicate an estimated percentage crash increase

Table 3.4: *Estimated Crash Reduction Associated with the Speed-Related Package (Casualty Crashes Involving Pedestrians)*

Crash Outcome	Estimated Crash Reduction	Lower 95% Confidence Limit	Upper 95% Confidence limit	Statistical Significance
Involving Pedestrians	1.19%	-4.62%	6.70%	0.6806

Table 3.2 shows that the estimated overall reduction in casualty crashes associated with the speed-related package was 3.80%. The estimate was highly statistically significant. From Table 3.3 it can be seen that statistically significant estimated crash reductions were also obtained for both categories of alcohol hours, where the effects of the package by time of week (high compared with low alcohol hours) were not statistically significantly different. Disaggregation of crash outcomes by speed limit at the crash location shows that a reduction in casualty crashes associated with the speed-related package was 6.14% for 40, 50 or 60 km/h speed zones. The estimate was highly statistically significant and is also significantly different from its complementary category of 70 or 80 km/h. The third speed limit category of 100 or 110 km/h was associated with a statistically significant crash reduction of 4.93%. Disaggregation by crash type was associated with a highly statistically significant crash reduction of 4.92% for crashes where more than one vehicle was involved. Table 3.4 shows that for casualty crashes involving pedestrians a statistically significant estimate of crash reduction was not observed.

3.4.3 Results of Crash Severity Analysis

Estimated effects on relative crash severity associated with the speed-related package have been assessed using the logistic regression model as detailed in Section 3.3.3. Results of the analysis are presented in Table 3.5 for the two measures of crash severity that have been considered. Each crash severity measure is the proportion of fatal crashes in the total reported casualty crashes or the serious casualty subset of the crash population. The analysis outcome measure presented is the relative risk. It essentially gives an estimate of the relative injury severity of crashes in the speed-related package period relative to that expected from pre-package trends and the influence of other factors included in the logistic regression model. For example, the proportion of casualty crashes that were fatal in the package period was estimated to be only 96 percent of the proportion expected (Table 3.5). Table 3.5 also gives 95 percent confidence limits on the estimated relative risk as well as the statistical significance level of the estimate.

Table 3.5: *Estimated Relative Crash Severity Associated with the Speed-Related Package*

Crash Severity	Relative Risk	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Statistical Significance
Fatal / Casualty Crashes	0.96	0.83	1.10	0.5166
<i>Metropolitan</i>	<i>0.92</i>	<i>0.78</i>	<i>1.08</i>	<i>0.3017</i>
<i>Non-Metropolitan</i>	<i>1.06</i>	<i>0.82</i>	<i>1.37</i>	<i>0.6796</i>
Fatal / Fatal + Serious	0.86	0.75	0.99	0.0357
<i>Metropolitan</i>	<i>0.82</i>	<i>0.69</i>	<i>0.97</i>	<i>0.0189</i>
<i>Non-Metropolitan</i>	<i>0.97</i>	<i>0.74</i>	<i>1.27</i>	<i>0.8310</i>

Similarly, estimated effects of the speed-related package on the crash severity proportion Fatal / Casualty Crashes resulting from fitting the logistic regression model detailed in Section 3.3.3 to disaggregated crash outcomes are given in Table 3.6. An estimate of the effect on the crash severity proportion resulting from fitting the logistic regression model to casualty crashes involving pedestrians is shown in Table 3.7.

Table 3.6: *Estimated Relative Crash Severity Associated with the Speed-Related Package (Disaggregated Results for Fatal / Casualty Crashes)*

Disaggregation Category	Relative Risk	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Statistical Significance
40, 50 or 60 km/h	0.79	0.63	1.01	0.0568
70 or 80 km/h	0.98	0.75	1.28	0.8847
100 or 110 km/h	1.10	0.88	1.38	0.4051
More than one vehicle involved	0.95	0.78	1.17	0.6476
One vehicle involved	0.95	0.78	1.14	0.5671
Low Alcohol Hours	0.96	0.78	1.18	0.6809
High Alcohol Hours	0.95	0.79	1.15	0.5974

Table 3.7: *Estimated Relative Crash Severity Associated with the Speed-Related Package (Casualty Crashes Involving Pedestrians for Fatal / Casualty Crashes)*

Crash Severity	Relative Risk	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Statistical Significance
Involving Pedestrians	0.80	0.59	1.10	0.1664

Also, estimated effects of the speed-related package on the crash severity proportion Fatal / Fatal + Serious resulting from fitting the logistic regression model detailed in Section 3.3.3 to disaggregated crash outcomes, are given in Table 3.8. An estimate of the effect on the crash severity proportion resulting from fitting the logistic regression model to casualty crashes involving pedestrians is shown in Table 3.9.

Table 3.8: *Estimated Relative Crash Severity Associated with the Speed-Related Package (Disaggregated Results for Fatal / Fatal + Serious)*

Disaggregation Category	Relative Risk	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Statistical Significance
40, 50 or 60 km/h	0.71	0.56	0.90	0.0044
70 or 80 km/h	0.88	0.67	1.15	0.3577
100 or 110 km/h	1.02	0.80	1.29	0.8963
More than one vehicle involved	0.82	0.67	1.01	0.0589
One vehicle involved	0.90	0.74	1.10	0.3064
Low Alcohol Hours	0.86	0.70	1.07	0.1705
High Alcohol Hours	0.86	0.71	1.04	0.1197

Table 3.9: *Estimated Relative Crash Severity Associated with the Speed-Related Package (Casualty Crashes Involving Pedestrians for Fatal / Fatal + Serious)*

Crash Severity	Relative Risk	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Statistical Significance
Involving Pedestrians	0.80	0.59	1.10	0.1722

Results of the severity analysis based on the measure Fatal / Casualty Crashes suggest a possible reduction in the risk of fatal outcome in casualty crashes (Table 3.5) however this result did not achieve statistical significance. The result of the severity analysis based on the measure Fatal / Fatal + Serious did see a statistically significant result occur for all of

Victoria and for the metropolitan location however. For all of Victoria the proportion of fatal or serious crashes that were fatal in the speed-related package period was estimated to be only 86 percent of the proportion expected (an estimated 14% reduction). This became an estimated 18% reduction in the risk of fatal outcome in serious casualty crashes for the metropolitan region. The results in Table 3.8 suggest that these estimated reductions were principally due to the reduction in crash severity in 40, 50 or 60 km/h speed zones (estimated 29% reduction) and in crashes where more than one vehicle was involved (estimated 18% reduction). There was no apparent difference in the effect of the speed-related package by time of week (high compared with low alcohol hours). The estimates for the reduction in fatal outcome in casualty crashes (Table 3.6) followed the pattern in Table 3.8, except that the apparent effects were weaker. Tables 3.7 and 3.9 show that for casualty crashes involving pedestrians, non-statistically significant estimated reductions of 20% in the risk of fatal outcome over the post-implementation period occurred for both measures of severity.

3.5 OVERALL EFFECT PARTITIONED BY TIME

The results presented in Section 3.4 represent the overall effect of the speed-related package on crash outcomes. The analysis model used is given by Equation 3.2, where the final term in the equation is defined as 0 prior to August 2001 and 1 from the time the speed-related package was deemed to have been implemented. It is included as a categorical variable in the model and is the key term for assessing the overall effect of the package.

Whilst the estimated crash reduction of 3.80% was highly statistically significant for the frequency analysis (Table 3.2) and the estimated relative crash severity of 0.86 was found to be statistically significant for the severity measure Fatal / Fatal + Serious (fourth line of Table 3.5), the estimated relative crash severity of 0.96 was found to be non-statistically significant for the measure Fatal / Casualty Crashes (first line of Table 3.5). Given that the speed-related package was deemed to be the initiatives and factors commencing *during or after* August 2001 (Section 3.2.2), it was of interest to assess the results in the post-implementation period in more detail by partitioning the period by time. The first partition was defined as August 2001 to December 2001 inclusive and the remaining post-implementation period of January 2002 to December 2004 inclusive was evenly divided into six partitions of 6 months. Blocks of 6 months were chosen as smaller partitions would potentially diminish the statistical power and larger partitions wouldn't allow the presence of any trends to be clearly ascertained. In the analysis model, the overall effect term in Equation 3.2 was replaced by seven terms, one for each partition. Each term was included as a categorical variable defined as 1 during the relevant period and 0 otherwise.

The results of this analysis are presented in Figure 3.7 for the frequency analysis and in Figures 3.8 and 3.9 for the severity analysis. In each figure, the full post-implementation period results from Section 3.4 are indicated as a dashed line, with lower and upper 95% confidence limits shown as dotted lines. For clarity, the results of the time-partitioned analysis have been shown as single points placed in the mid-section of each partition. Lower and upper 95% confidence limits have also been shown. Whereas the model assessing overall effectiveness measures the perturbation from the expected crash trends that occurs during or after August 2001, the model partitioned by time measures the perturbation separately for each package period segment. This gives an indication of the effectiveness of the speed-related package as it occurs over time.

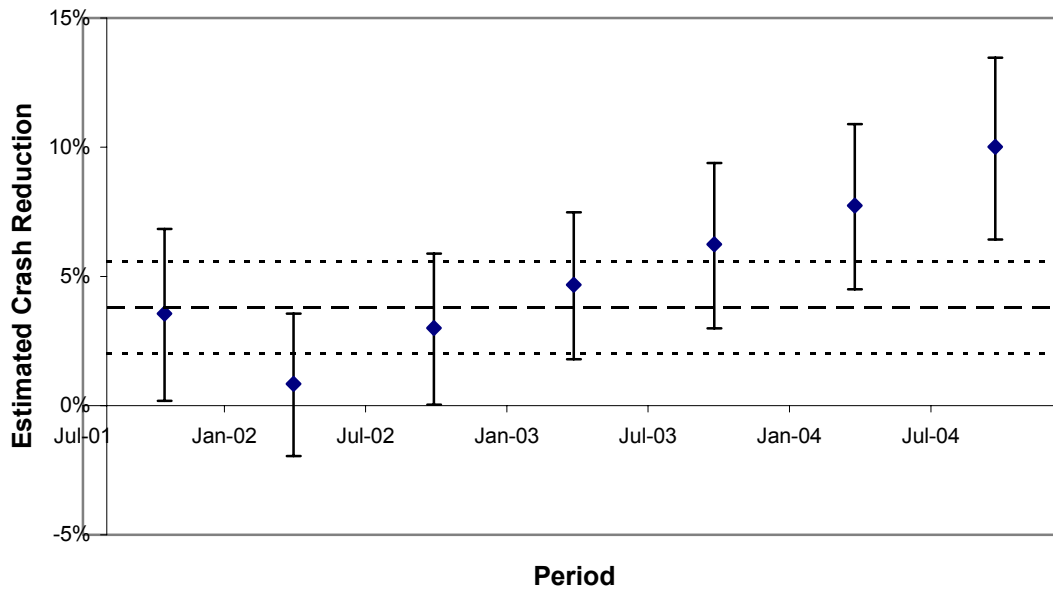


Figure 3.7: Overall Crash Reduction Partitioned by Time (Casualty Crashes)

For the crash frequency analysis, Figure 3.7 shows that the estimated overall crash reduction of 3.80% was statistically significant (the confidence interval is above 0%). Results from the time-partitioned model suggest that statistically significant estimated crash reductions were associated with most of the six monthly periods in the post-implementation period and indicate that crash reductions associated with the package have been increasing over time. Figure 3.7 shows that the periods August 2001 to December 2001 inclusive and July 2002 to December 2002 inclusive have estimates which are only marginally significant however (the lower confidence limit lies just above 0%).

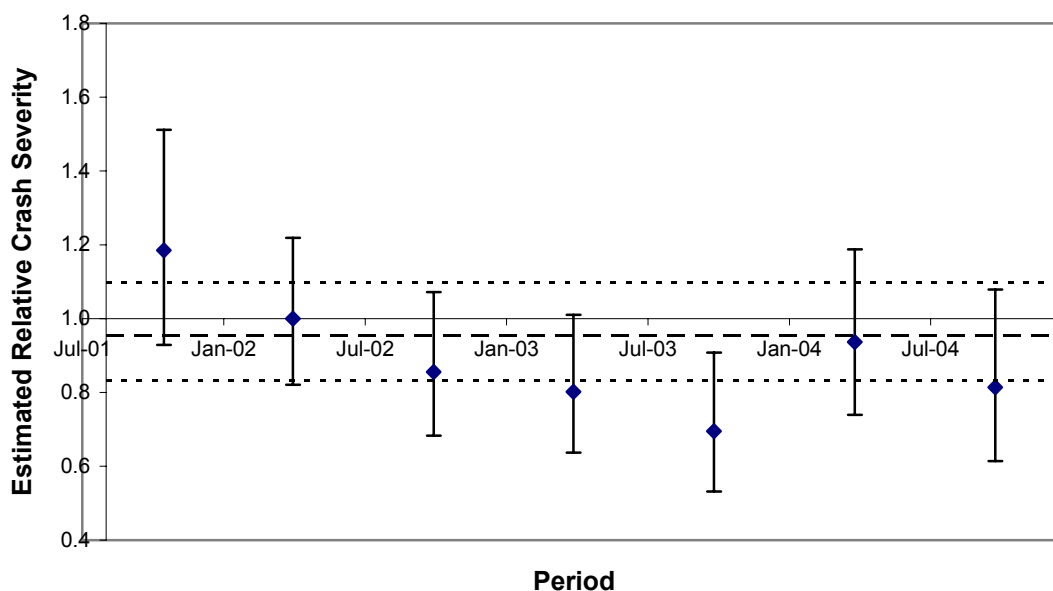


Figure 3.8: Overall Relative Crash Severity Partitioned by Time (Fatal / Casualty Crashes)

For the crash severity analysis, it can be seen from Figure 3.8 that the estimated overall relative crash severity of 0.96 for the measure Fatal / Casualty Crashes was not statistically significant (the upper confidence limit is above 1) whilst in Figure 3.9 it can be seen that the estimated overall relative crash severity of 0.86 for the measure Fatal / Fatal + Serious was statistically significant (the upper confidence limit is below 1). An estimated relative crash severity of 1 indicates no change in the level of severity. Results from the time-partitioned model indicate that estimated relative crash severities were generally not statistically significant for the measure Fatal / Casualty Crashes (Figure 3.8) however a statistically significant estimated relative crash severity of 0.70 did occur for the period July 2003 to December 2003 inclusive. For the measure Fatal / Fatal + Serious (Figure 3.9) the time-partitioned results are mostly statistically significant with the greatest reduction in severity occurring for the same period of July 2003 to December 2003 inclusive. The estimated relative crash severity for this period was 0.62. On the whole, a general trend towards a reduction in the level of severity seemed to occur over time for both measures.

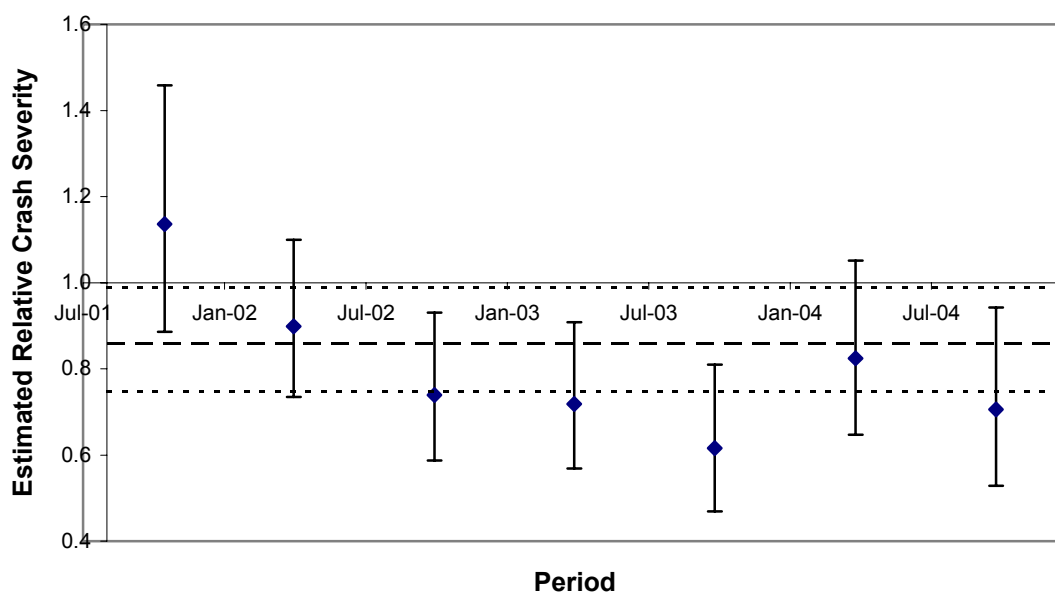


Figure 3.9: Overall Relative Crash Severity Partitioned by Time (Fatal / Fatal + Serious)

3.6 COMPOUNDED RESULTS (FATAL CRASHES)

Results for casualty crashes and for the severity measure Fatal / Casualty Crashes can be compounded to obtain information on fatal crashes. Specifically, the estimated fatal crash reduction can be calculated by combining the estimated casualty crash reduction with the corresponding estimated relative crash severity based on the measure Fatal / Casualty Crashes.

Estimated crash reductions for fatal crashes are shown in Figure 3.10 and were produced by combining the point estimates shown in Figure 3.7 for casualty crashes with those shown in Figure 3.8 for the severity measure Fatal / Casualty Crashes. As a result, Figure 3.10 shows the overall estimated fatal crash reduction partitioned by time. Confidence limits were placed on the point estimates through the use of an approximation formula for determining the variance of a non-linear function of random variables.

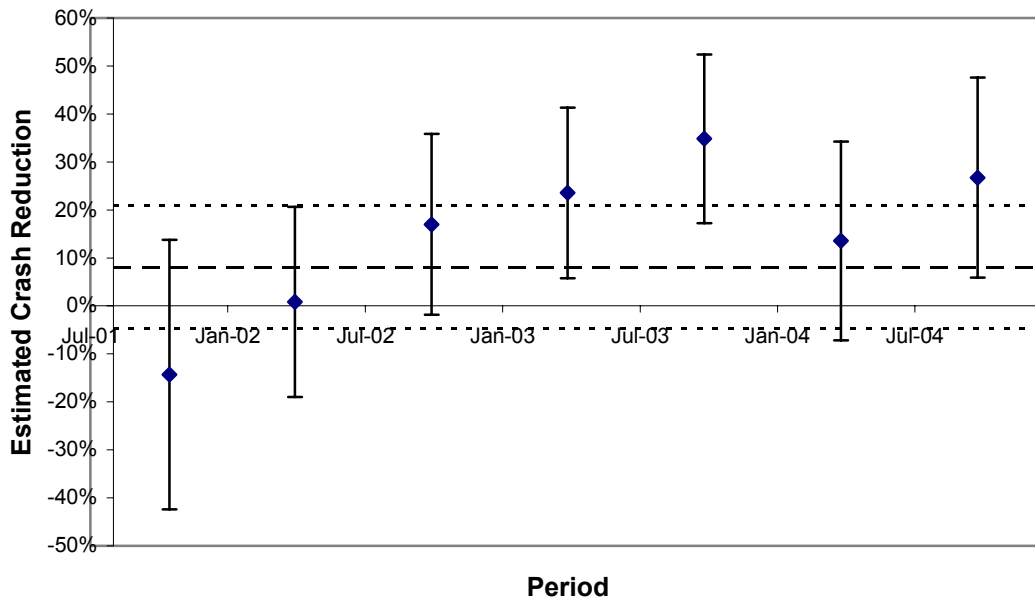


Figure 3.10: Overall Crash Reduction Partitioned by Time (Fatal Crashes)

Figure 3.10 suggests that the estimated overall fatal crash reduction of 8.09% is not statistically significant (the confidence interval encompasses 0%). Alternatively the time-partitioned results suggest that statistically significant fatal crash reductions occur during the period January 2003 to December 2003 inclusive, which contains the highest estimated fatal crash reduction of 34.83%, and for the period July 2004 to December 2004 inclusive, which shows an estimated reduction in fatal crashes of 26.74%.

3.7 DISCUSSION ON THE CRASH EFFECTS EVALUATION

Evaluation of the crash effects of the Victorian speed-related package has shown clear reductions in the number of casualty crashes associated with its implementation. The package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.80%. This reduction was in large part due to the highly statistically significant 4.62% estimated reduction in casualty crashes for metropolitan Melbourne, in contrast with a non-statistically significant estimated increase in casualty crashes of 1.53% occurring for the non-metropolitan location. In addition, disaggregation of crash outcomes showed highly statistically significant crash reductions of 6.14% and 4.92% associated with casualty crashes that occurred in 40, 50 or 60 km/h speed zones and where more than one vehicle was involved respectively. The earlier result suggests that the speed-related package may have been more effective in reducing casualty crashes that occurred where the speed limit was 40, 50 or 60 km/h. The latter result is similar to the estimated reduction in casualty crashes for the metropolitan region. This is consistent with the fact that 84% of casualty crashes involving more than one vehicle occurred in metropolitan Melbourne (2004 data).

The analysis of crash effects for the severity measure Fatal / Casualty Crashes suggested a possible reduction in the risk of fatal outcome in casualty crashes over the post-implementation period with a non-statistically significant estimated relative crash severity of 0.96. A model where the post-implementation period was partitioned by time did show a

statistically significant estimated reduction of 30% in this severity measure for the period July 2003 to December 2003 inclusive. Analysis of the severity measure Fatal / Fatal + Serious showed a statistically significant reduction in the risk of fatal outcome in the serious casualty subset of the crash population in the entire post- implementation period with an estimated relative crash severity of 0.86. The same measure stratified by location also showed a statistically significant result for the metropolitan region with an estimated relative crash severity of 0.82. For the measure Fatal / Fatal + Serious, disaggregation by crash outcomes estimated a statistically significant 29% reduction in crash severity in 40, 50 or 60 km/h speed zones and a nearly statistically significant reduction of 18% in the severity of crashes where there was more than one vehicle involved. As per the frequency analysis the latter result is consistent with that for the metropolitan region. Both measures of severity showed non-statistically significant estimated reductions in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the entire post-implementation period.

It is not known to what extent the difference in estimated risk of fatal outcome between the two severity measures examined were due to suspected biases in reporting of serious injury crashes during the initiatives period (Hoareau et al., 2006) or whether they represent differential effects of the speed package between serious injury and minor injury crashes. It is possible that both measures of severity are potentially biased by crash reporting changes. However it is likely that the proportion Fatal / Casualty Crashes would be a more robust measure because it is less affected by the more substantial biases resulting from suspected increased reporting of serious injury crashes. In any event, the results for both measures seem to point to a general trend towards a reduction in the risk of fatal outcome over the post-implementation period even if the point estimate and level of statistical significance is somewhat unclear.

The analysis presented in this report considered the overall impact of the speed-related package on crash outcomes. For this purpose the package was deemed to be the initiatives commencing during or after August 2001 (Section 3.2.2). It could be argued that the full effect of the speed-related package was not achieved until some time later after all of the speed-related initiatives had been fully implemented since the key component initiatives were implemented in a staggered manner over time. To investigate this prospect, the overall results were partitioned by time after implementation in order to obtain a more informative view of the crash outcomes over the post-implementation period. Because of the staggered implementation, it may be fair to conclude that the final period of July 2004 to December 2004 inclusive best reflects the full effect of the speed-related package on crash outcomes. This period showed a highly statistically significant estimated crash reduction of 10.02% in casualty crashes (Figure 3.7), with a non-statistically significant estimated relative crash severity of 0.81 occurring for the measure Fatal / Casualty Crashes (Figure 3.8) and a statistically significant estimated relative crash severity of 0.71 occurring for the measure Fatal / Fatal + Serious (Figure 3.9).

It was also of interest to consider the results in terms of the estimated reduction in the number of fatal crashes associated with the speed-related package. Section 3.6 describes how earlier results were compounded to produce estimated fatal crash reductions with confidence limits (Figure 3.10). Once again considering the final time-partitioned period of July 2004 to December 2004 inclusive, Figure 3.10 shows a statistically significant estimated reduction in fatal crashes of 26.74% with a 95% confidence interval of (5.90%, 47.59%). Given that 136 fatal crashes were observed during this 6 month period, the number of fatal crashes *that would have been expected* if the speed-related package had not been implemented is estimated to be 186 (145, 259); this equates to 50 (9, 123) less fatal

crashes occurring over the six month period or just over 8 (1, 21) less fatal crashes per month.

The results for crash effects within 40, 50 or 60 km/h speed zones are consistent with the hypothesis presented earlier that the effects of any speed-related package may be greater on roads with a 50 or 60 km/h speed limit, if speed enforcement activity has been focused on those roads. The analysis of increased speed camera activity presented in Section 2 indicates that in Melbourne between 1999-2000 and 2003-2004, the camera hours on 50 and 60 km/h roads increased by approximately 750 hours per month (or 39%), whilst in the rest of Victoria camera hours on 50 and 60 km/h roads increased by about 70 hours (or 7%). Considering that most 40, 50 or 60 km/h roads are situated in Melbourne, the 750 camera hour increase on metropolitan roads seems to be consistent with the crash effects results. In addition, Section 2 indicates that the next largest increase in camera hours occurred on rural 100 and 110 km/h roads where camera hours more than tripled (by around 650 hours or 223%). The focus of speed enforcement activity on these roads may help to explain the statistically significant estimated crash reduction of 4.93% on all 100 or 110 km/h roads given that a majority of the casualty crashes that occurred on these roads were in the non-metropolitan region (2004 data).

It was also hypothesised that the effect on crash outcomes of an across-the-board reduction in the speed distribution on Victoria's roads should be greater in collisions involving more than one vehicle and to certain road users such as pedestrians. The crash effects results are generally consistent with this hypothesis. More specifically, as 84% of casualty crashes involving more than one vehicle and 86% of casualty crashes involving pedestrians occurred in metropolitan Melbourne (2004 data), the results are consistent with a hypothesis which refers to a reduction in the speed distribution on *metropolitan* Melbourne's roads. This more specific hypothesis is also consistent with the crash results for 40, 50 or 60 km/h roads which are mainly situated in the metropolitan location. The non-statistically significant estimated increase in casualty crashes occurring for the non-metropolitan region should be noted when considering any changes that occurred in the speed distribution in the non-metropolitan region over the evaluation period.

3.8 CRASH EFFECTS EVALUATION ASSUMPTIONS AND QUALIFICATIONS

Results of the crash effects analysis of the speed-related package presented are subject to a number of assumptions and qualifications. These are as follows:

- It is assumed that all the data supplied for the evaluation is correct and measures both evaluation inputs and outcomes as described.
- It is assumed that the form of the statistical analysis model used, including the functional relationship between dependant and independent variables and the distribution of random error, is appropriate.
- It is assumed that estimates of the crash effects are not biased through measures missing from the statistical models that are associated with the speed-related package.
- Derivation of the crash effects were made using the assumed functional forms of the analysis regression equations and hence are dependent on those functional forms. The real "dose-response" relationship between the independent and dependent variables may be different to that assumed.

4 SPEED OBSERVATION DATA

In order to evaluate the effect of the speed-related enforcement package on speed trends and investigate the link between speed trends and crash outcomes in Victoria, speed observation data was obtained from VicRoads. Raw data for 60, 70, 80, 90 and 100 km/h zones was received for metropolitan Melbourne and aggregated raw data was acquired for 60, 70, 80, 90, 100 and 110 km/h speed zones for rural Victoria. In metropolitan Melbourne, small samples (100-130) of vehicles travelling at free speed have been measured at sites during weekday off-peak daylight hours. This has occurred in May and November of each year since November 1994. In rural Victoria, there are 64 permanent counting telemetry sites where on-road speed data is continuously collected. Data has been collected for rural strategic traffic monitoring programs since 1998 however data in standardised speed bins is only available from 2001 onwards. Due to the large quantity of information, the raw data was aggregated into 6 month periods of January to June inclusive and July to December inclusive prior to being received.

4.1 LINKAGE BETWEEN CRASH EFFECTS AND CHANGES IN SPEED

An important step in establishing a conclusion of “cause and effect” between any speed reduction which can be associated with the speed-related package, and any reduction in crash outcomes during the post-implementation period, is an assessment of whether the road trauma reductions are consistent with the speed reductions. It may not be sufficient to say that there was a speed reduction and a road trauma reduction during the post-implementation period, therefore the speed reduction caused all of or most of the road trauma reduction.

We have sufficient knowledge of the link between travel speed and casualty crash risks in urban and rural areas to make an approximate estimate of the expected magnitude of the reduction in casualty crashes from a change in the on-road speed distribution, especially the change in the proportion of vehicles exceeding the speed limit. Kloeden et al. (2002) has established the relationship for the risk of involvement in a casualty crash in urban 60 km/h speed zones, and Kloeden et al. (2001) has quantified the relationship between rural travel speeds and the risk of involvement in a casualty crash in 80 km/h or greater speed zones.

On this basis, it is possible to analyse the speed observation data, especially the proportions of vehicles travelling above certain excessive speed levels, weighting the speed levels by the appropriate risk of a casualty crash, to estimate the changes in casualty crashes that could be expected from the speed behaviour changes. This type of analysis is likely to provide more sensitive estimates than could be expected from an analysis of the road trauma effects of changes in mean speed by appealing to Nilsson’s (1984) laws. In addition, numerous MUARC studies of the introduction of new speed limits and speed enforcement programs have found substantial reductions in severe crashes at the time of little or no reduction in mean speeds, but substantial reductions in excessive speeds.

4.2 METROPOLITAN SPEED OBSERVATION DATA

The available Melbourne speed observation data is limited. There are relatively few sites and they have not been chosen to be representative of traffic in Melbourne. Only 60, 70 and 80 km/h speed zones are represented adequately. The small samples may explain why only mean and 85th percentile speeds are published. (Other speed parameters, such as 95th

percentiles, would be unreliable indicators at each site.) Figure 4.1 shows the published mean speeds and Figure 4.2 shows the published 85th percentile speeds for the evaluation period of 1999-2004.

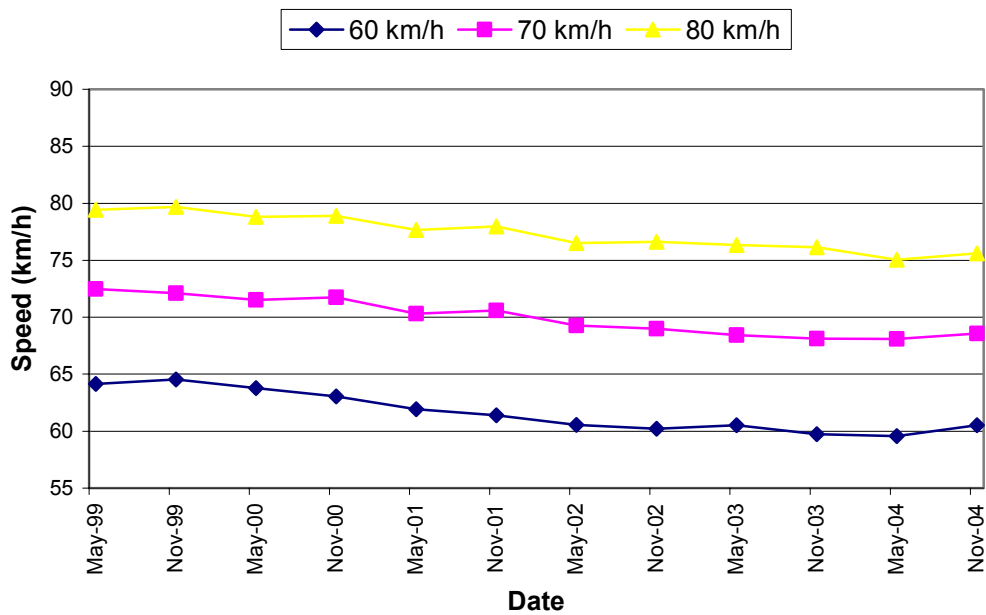


Figure 4.1: Metropolitan Mean Speeds by Speed Limit

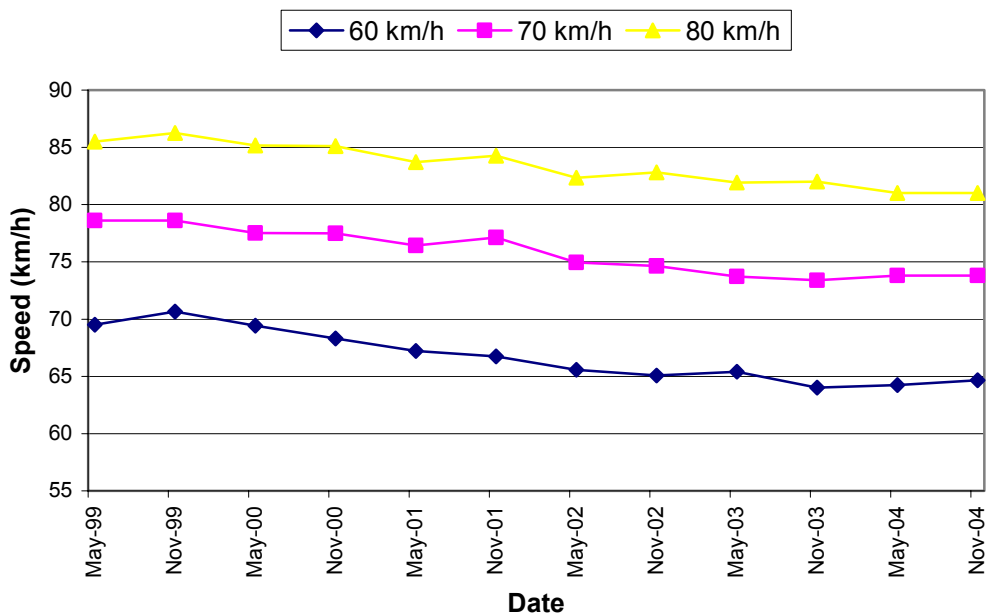


Figure 4.2: Metropolitan 85th Percentile Speeds by Speed Limit

In addition to mean and 85th percentile speeds, the proportion of vehicles observed in the speed categories of 1-9, 10-14, 15-19, 20-24, 25-29 and 30+ km/h above the speed limit were compiled for each speed zone (Appendix B). Figure 4.3 shows these proportions and the proportion of vehicles not exceeding the speed limit after each category was risk-weighted using the relationship established by Kloeden et al. (2002) for urban 60 km/h speed zones. The “Not Exceeding” category was given a risk-weighting of 1, whilst the excessive speed categories were given risk-weightings based on the mid-point of their respective speed ranges except for the category “30+ km/h” where the risk-weighting was based on a speed of 30 km/h above the limit.

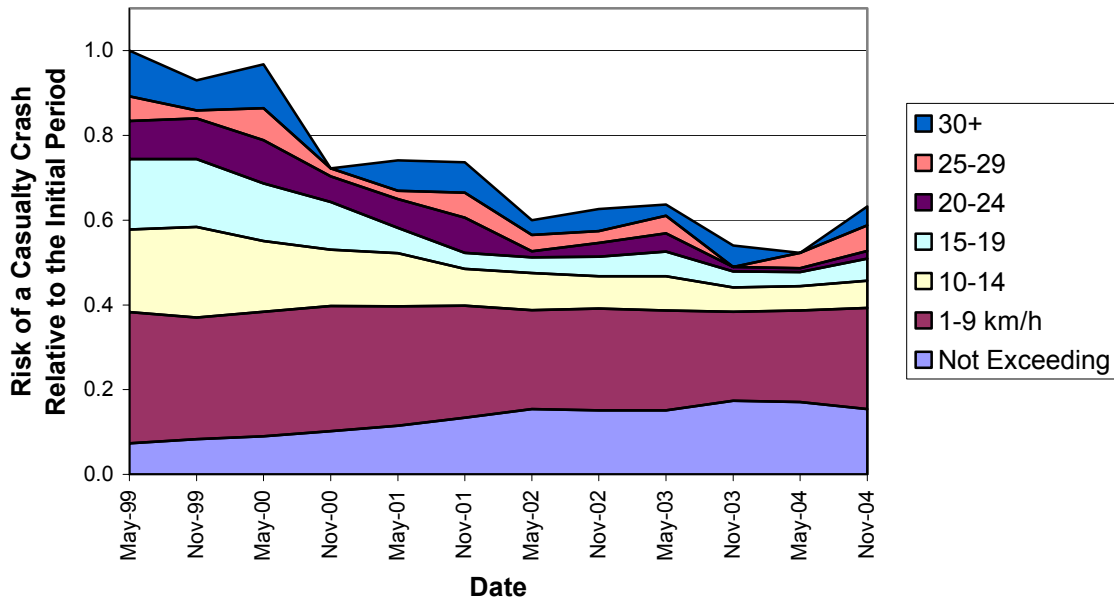


Figure 4.3: Risk-Weighted Proportions of Vehicles Observed in the 60 km/h Speed Zone

Figures 4.4 and 4.5 show risk-weighted proportions for 70 and 80 km/h speed zones respectively. It is important to note that the relationship established by Kloeden et al. (2002) was derived for an urban 60 km/h speed environment. However in order to obtain an approximate indication of the possible effect of speed changes on crash outcomes in 70 and 80 km/h metropolitan speed zones, it was desirable to apply risk-weightings to the speed categories for these zones also. The most direct way to do this was to apply the same risk-weightings to the equivalent speed categories for 70 and 80 km/h speed zones as were calculated for the 60 km/h speed zone, i.e. the shape of the risk curve was maintained, but the reference point was shifted from 60 km/h to 70 or 80 km/h as appropriate.

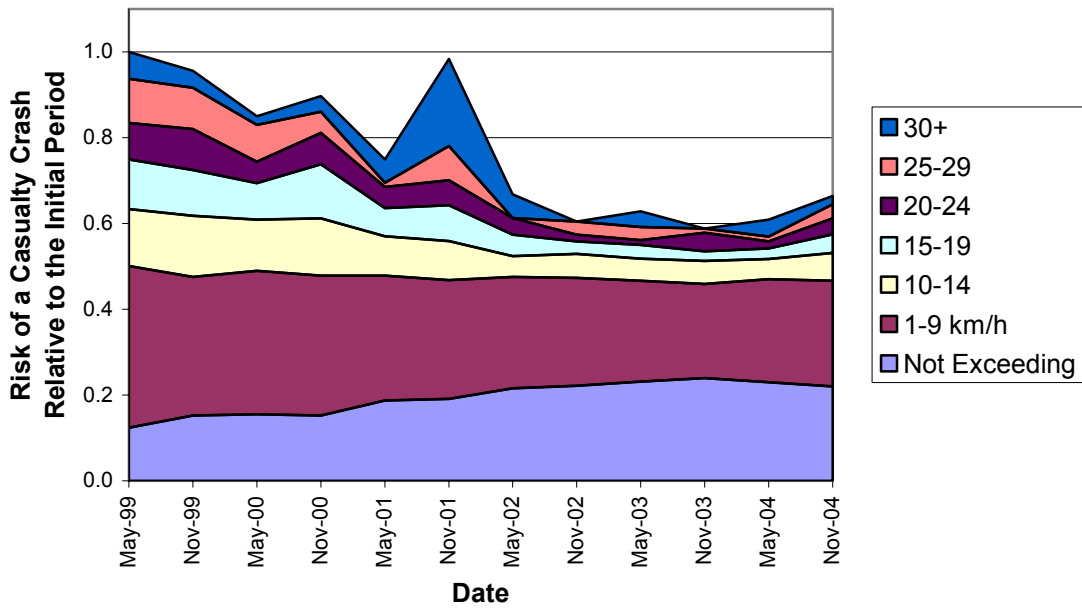


Figure 4.4: Risk-Weighted Proportions of Vehicles Observed in the 70 km/h Speed Zone

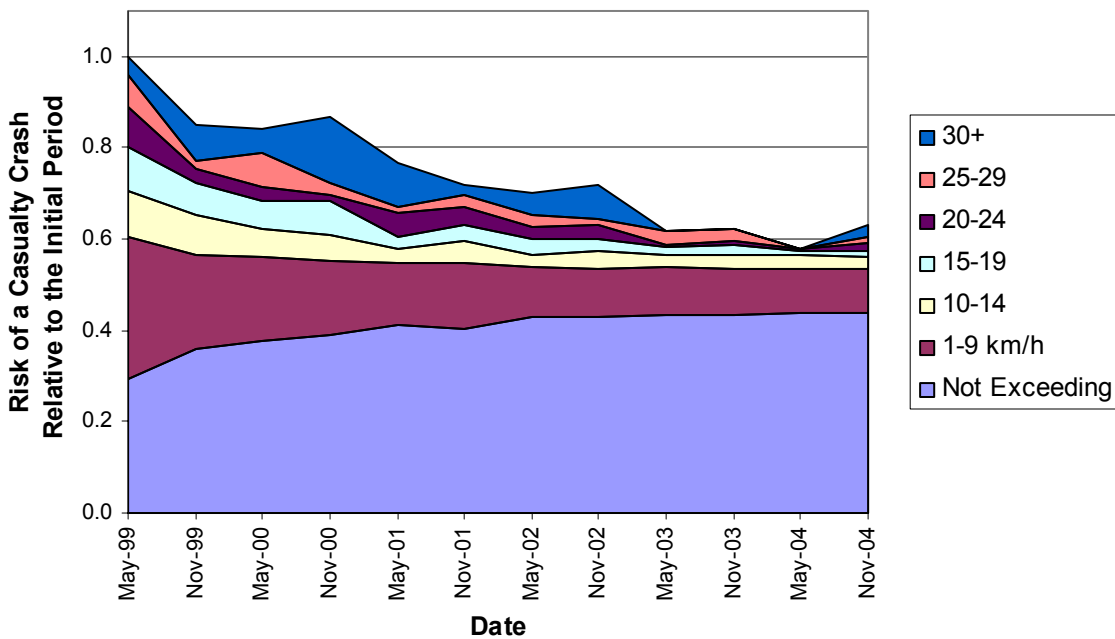


Figure 4.5: Risk-Weighted Proportions of Vehicles Observed in the 80 km/h Speed Zone

4.3 VICTORIAN RURAL SPEED OBSERVATION DATA

The available Victorian rural speed observation data is greater in volume than the metropolitan data, but the representativeness of the sites is unknown. Only 80, 100 and 110 km/h speed zones are represented adequately. Figure 4.6 shows the median speeds and Figure 4.7 the 85th percentile speeds for 80, 100 and 110 km/h speed zones for the evaluation period of 1999-2004.

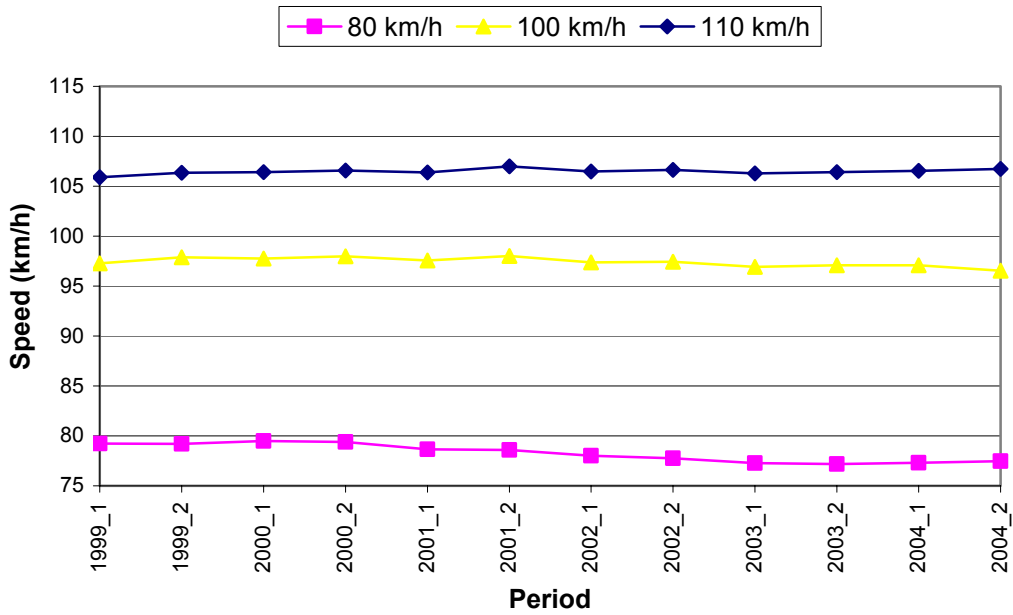


Figure 4.6: Victorian Rural Median Speeds by Speed Limit

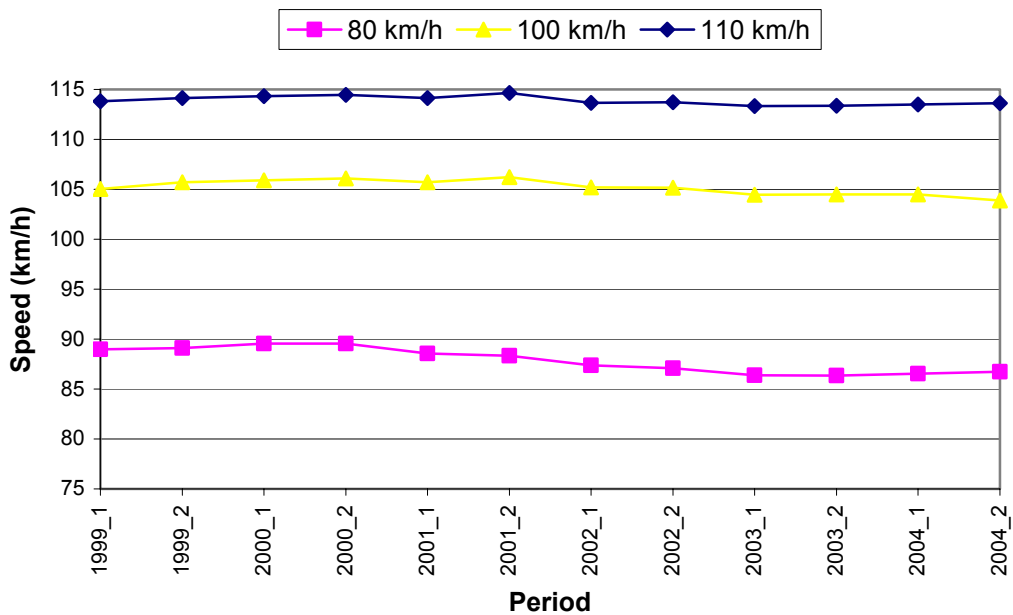


Figure 4.7: Victorian Rural 85th Percentile Speeds by Speed Limit

In addition to median and 85th percentile speeds, the proportion of vehicles observed in the speed categories of 1-5, 6-9, 10-14, 15-19, 20-24, 25-29 and 30+ km/h above the speed limit were assembled for each speed zone (Appendix B). Figure 4.8 shows these proportions and the proportion of vehicles not exceeding the 80 km/h speed limit after each category was risk-weighted using the relationship established by Kloeden et al. (2001) for rural speed zones. The “Not Exceeding” category was given a risk-weighting of 1, whilst

the other speed categories were given risk-weightings based on the mid-point of their respective speed ranges except for the category “30+ km/h” where the risk-weighting was based on an excessive speed of 30 km/h. Similarly, Figures 4.9 and 4.10 show risk-weighted proportions for 100 and 110 km/h speed zones respectively. It should be noted that median rather than mean speeds were used in the application of the risk function.

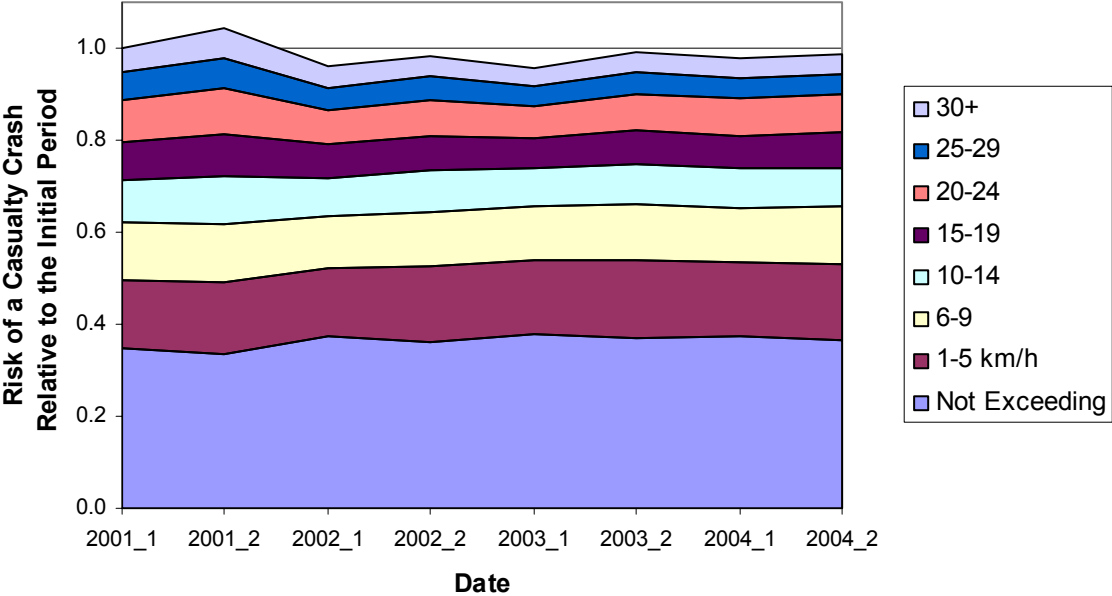


Figure 4.8: Risk-Weighted Proportions of Vehicles Observed in the 80 km/h Speed Zone

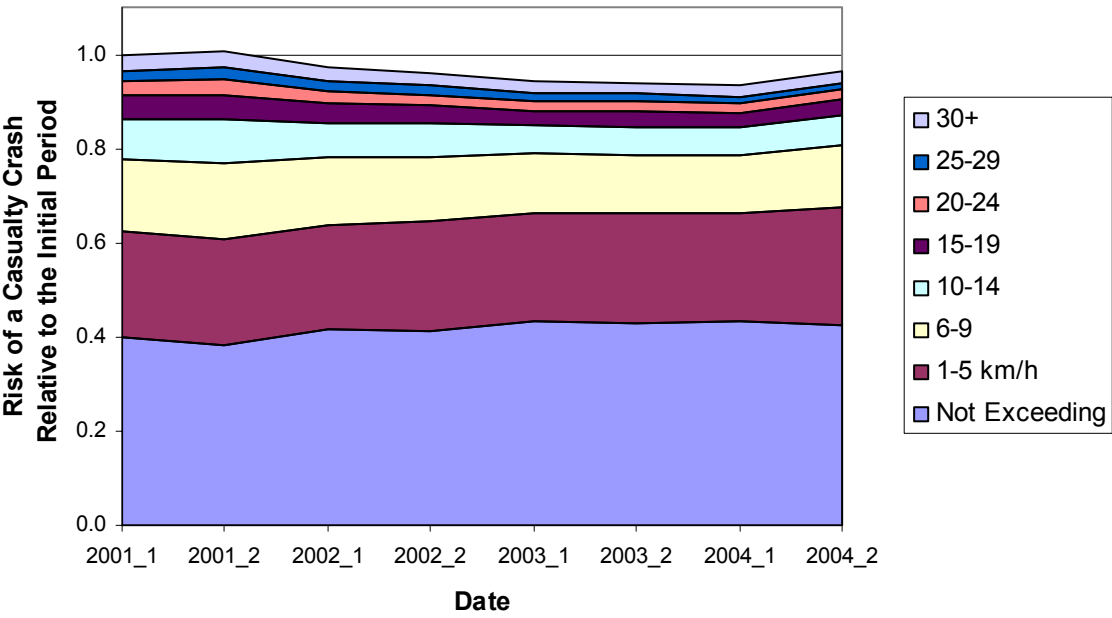


Figure 4.9: Risk-Weighted Proportions of Vehicles Observed in the 100 km/h Speed Zone

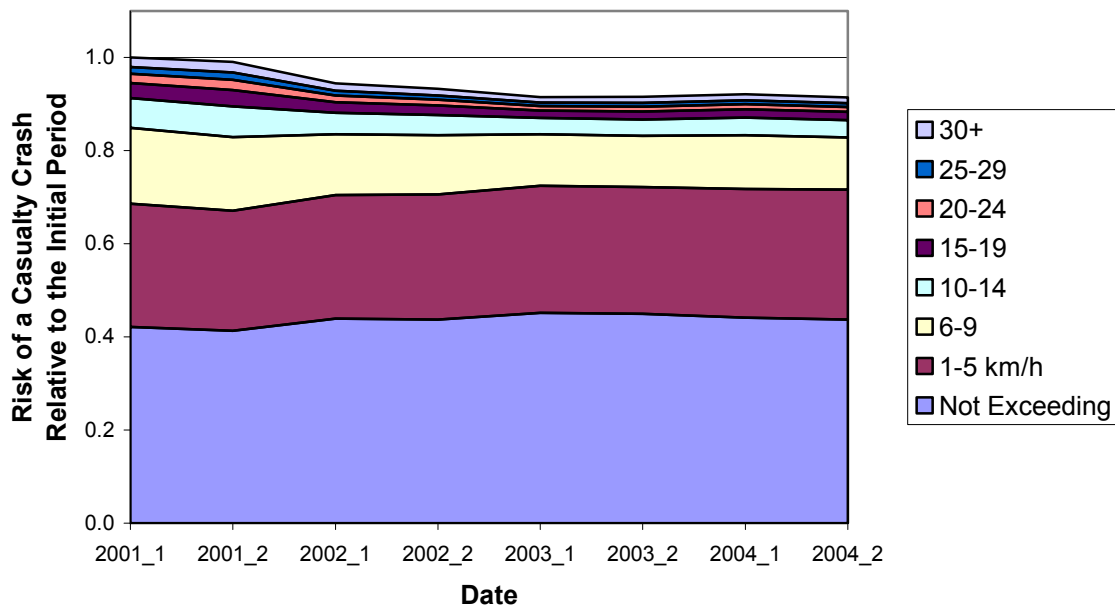


Figure 4.10: Risk-Weighted Proportions of Vehicles Observed in the 110 km/h Speed Zone

4.4 DISCUSSION ON THE ANALYSIS OF SPEED OBSERVATION DATA

Speed observation data was included in the evaluation because of its role as an intermediate measure between the implementation of the speed-related package and the crash outcomes. It could be expected that the package achieved its effects on road trauma via changes in speed behaviour. Failure to show this would cast doubt on the cause-and-effect mechanism.

Vehicles travelling at increasingly excessive speeds are known to be associated with substantially increased risks of severe casualty crashes. This is because the force of vehicle crashes increases exponentially with the speed of a vehicle. Therefore, any reductions in the relatively small proportion of vehicles exceeding the speed limit are considered important.

For metropolitan speed zones, the data presented above seems to provide evidence of a reduction in the mean and 85th percentile speeds (Figures 4.1 and 4.2 respectively). However for rural speed zones, the median and 85th percentile speeds, presented in Figures 4.6 and 4.7 respectively, have either remained steady or show smaller reductions. For the metropolitan data, a downward trend in mean and 85th percentile speeds is apparent over the evaluation period for all of the speed zones. Hence it would be difficult to argue that the speed-related package achieved its effects during 2001-2004 through a reduction in mean and 85th percentile speeds because a downward trend was already present.

Clearly an analysis of excessive speed weighted by risk is important in attempting to assess the link between changes in speed and crash effects. The risk-weighting takes into account the exponential rise in the risk of involvement in a casualty crash that occurs according to Kloeden et al. (2001) and Kloeden et al. (2002) as the level of excessive speed increases. Figures 4.3 to 4.5 show that for metropolitan speed zones, a reduction in the number of casualty crashes should be expected over the evaluation period. The risk-weighted

proportions of vehicles observed in the 60 km/h speed zone (Figure 4.3) illustrates that the total expected casualty crash risk associated with speed appears to have fallen substantially during 2000, before the speed-related initiatives commenced, but then decreased again by 17% between November 2001 and May 2002 when most of the speed-related initiatives had come into effect.

The crash analysis (Section 3) showed a reduction in the number of casualty crashes in 40, 50 or 60 km/h speed zones of 6.14% (and a reduction of 4.62% in metropolitan Melbourne) associated with the speed-related package. Therefore the expected reduction in casualty crashes estimated from the speed behaviour changes would appear to be larger than those estimated from the crash analysis. However it is difficult to draw a conclusion from this result if we note the following points. Firstly there are relatively few speed observation sites and they have not been chosen to be representative of traffic in Melbourne. Secondly the risk curves developed by Kloeden et al. (2001) for an urban 60 km/h speed limit environment were developed for South Australia and were mostly based on the crash types oncoming vehicle turning right across the path of the free travelling speed vehicle and vehicle turning right from the side street on the left of the free travelling speed vehicle. In Victoria however the most common type of casualty crashes in 60 km/h speed zones (which are predominantly located in metropolitan Melbourne) are rear end crashes followed by those involving vehicles turning right across the path of another vehicle.

In contrast with the risk-weighted proportions of vehicles observed in metropolitan speed zones (Figures 4.3 to 4.5), Figures 4.8 to 4.10 for rural speed zones do not give a clear indication of whether a reduction in the number of casualty crashes should be expected. The total expected risk of a casualty crash in the 80 km/h rural speed zone (Figure 4.8) is generally stable, with Figures 4.9 and 4.10 for 100 and 110 km/h rural speed zones respectively showing a small reduction over the evaluation period except for late 2004 for the 100 km/h speed zone (Figure 4.9). The risk-weighted speed observation data for rural speed zones appears to be in contrast with the crash analysis (Section 3), which showed an estimated increase in casualty crashes of 1.53% for the non-metropolitan region, however this result was non-statistically significant. On the other hand, the disaggregated casualty crash results for 100 or 110 km/h roads, which showed a statistically significant estimated reduction in casualty crashes of 4.93%, do seem to be consistent with the risk-weighted speed observation data if we consider that a majority of casualty crashes on these roads occurred in the non-metropolitan location (2004 data). Exactly how representative the rural speed observation data is of overall rural speeds is unknown, however it is greater in volume than the metropolitan data and for this reason might be expected to be more reliable. However an assessment of whether the risk curves developed by Kloeden et al. (2002) for South Australia should be applied to Victorian data should be made before any conclusions are drawn.

As mentioned above, the crash effects analysis presented in Section 3 showed a highly statistically significant 4.62% estimated reduction in casualty crashes for the metropolitan location associated with the implementation of the speed-related package. Certainly the downward trend in mean and 85th percentile travel speeds and a general reduction in the number of vehicles exceeding the speed limit in the metropolitan region seem to have contributed to the estimated reduction. In terms of crash severity, it should be expected that casualty crashes involving pedestrians (which mainly occur in Melbourne) should benefit from a reduction in excessive speed, as our knowledge of biomechanical tolerances suggests that such crashes are associated with greater decreases in serious injury risk for a

given decrease in impact speed. For both measures of severity, the estimated reduction in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the post-implementation period seems to be consistent with this hypothesis however these results are non-statistically significant.

5 CONCLUSIONS

This project has evaluated the overall impact of the Victorian speed-related package on crash outcomes whilst accounting as far as possible for the effect of non-speed road safety initiatives and socio-economic factors, which would otherwise have influenced the evaluation. In addition, the project examined speed trends in Melbourne and on Victorian rural highways, especially the proportions of vehicles travelling at excessive speed, and documented the increase in speed camera activity by speed zone across the state.

Evaluation of the crash effects of the speed-related package showed clear reductions in the number of casualty crashes associated with its implementation. The package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.80%. This reduction was in large part due to the highly statistically significant 4.62% estimated reduction in casualty crashes for the metropolitan rather than non-metropolitan location which showed a non-statistically significant estimated increase in casualty crashes. In addition, disaggregation of crash outcomes showed a highly statistically significant crash reduction of 6.14% associated with casualty crashes that occurred in 40, 50 or 60 km/h speed zones which are mostly situated in metropolitan Melbourne. This result was consistent with the analysis of increased speed camera activity, a key element of the package, which indicated that in metropolitan Melbourne the largest increase in camera hours occurred on 50 and 60 km/h roads. An analysis of excessive speed weighted by risk showed that for metropolitan speed zones, a reduction in the number of casualty crashes should have been expected over the evaluation period. In particular the risk-weighted proportions of vehicles observed in the 60 km/h speed zone showed large reductions in the total expected casualty crash risk associated with speed after most of the speed-related initiatives had come into effect.

In contrast, an analysis of excessive speed weighted by risk for rural speed zones did not give a clear indication of whether a reduction in the number of casualty crashes should have been expected. The total expected risk of a casualty crash in the 80 km/h rural speed zone was generally stable, with the expected risk showing small reductions over the evaluation period for 100 and 110 km/h rural speed zones. This seemed to be in contrast with the crash analysis, which showed an estimated increase in casualty crashes of 1.53% for the non-metropolitan region, however this result was non-statistically significant. On the other hand, the disaggregated casualty crash results for 100 or 110 km/h roads, which showed a statistically significant estimated reduction in casualty crashes of 4.93%, did seem to be consistent with the risk-weighted speed observation data if we consider that a majority of casualty crashes on these roads occurred in the non-metropolitan location. The estimated crash reduction of 4.93% was also consistent with the analysis of increased speed camera activity which showed that the second largest increase in camera hours occurred on rural 100 and 110 km/h roads.

For crash severity, the analysis of crash effects for the measure Fatal / Casualty Crashes suggested a possible reduction in the risk of fatal outcome in casualty crashes over the post-implementation period with a non-statistically significant estimated relative crash severity of 0.96. A model where the post-implementation period was partitioned by time did show a statistically significant estimated reduction of 30% in this severity measure for the period July 2003 to December 2003 inclusive. Analysis of the severity measure Fatal / Fatal + Serious showed a statistically significant reduction in the risk of fatal outcome in the serious casualty subset of the crash population in the entire post-implementation period with an estimated relative crash severity of 0.86. The same measure stratified by location also showed a statistically significant result for the metropolitan region with an estimated

relative crash severity of 0.82. For the measure Fatal / Fatal + Serious, disaggregation by crash outcomes estimated a statistically significant 29% reduction in crash severity in 40, 50 or 60 km/h speed zones. On the whole, a general trend towards a reduction in the level of severity seemed to occur over time for both measures.

6 REFERENCES

Broadbent, S. (1979). One way T.V. advertisements work. *Journal of the Market Research Society*, Vol. 21, No. 3, London.

Broadbent, S. (1984). Modelling with Adstock. *Journal of the Market Research Society*, Vol. 26, No. 4, London.

Cameron, M., Haworth, N., Oxley, J., Newstead, S. and Le, T. (1993). *Evaluation of Transport Accident Commission road safety television advertising*. Report No. 52, Monash University Accident Research Centre.

Cameron, M., Newstead, S., Diamantopoulou, K., and Oxley, P. (2003a). *The interaction between speed camera enforcement and speed-related mass media publicity in Victoria*. Report No. 201, Monash University Accident Research Centre.

Cameron, M., Newstead, S., Diamantopoulou, K., and Oxley, P. (2003b). *The interaction between speed camera enforcement and speed-related mass media publicity in Victoria, Australia*. Proceedings, 47th Annual Scientific Conference, Association for the Advancement of Automotive Medicine, Lisbon, Portugal.

Harrison, W. A. (1990). *Update of alcohol times as a surrogate measure of alcohol involvement in accidents*. Research Note, Monash University Accident Research Centre.

Hoareau, E., Newstead, S. and D'Elia, A. (2006). *An Analysis of Injury Severity Trends in Transport Accident Commission Claims: 2000-2004*. Draft final report, Monash University Accident Research Centre.

Kloeden, C. N., Ponte, G. & McLean, A. J. (2001) *Travelling Speed and the Risk of Crash Involvement in Rural Roads*, Report No. CR 204, Australian Transport Safety Bureau.

Kloeden, C. N., McLean, A. J. & Glonek, G. (2002) *Reanalysis of Travelling Speed and the Risk of Crash Involvement in Adelaide and South Australia*, Report No. CR 207, Australian Transport Safety Bureau.

Maher, M. J. and Summersgill, I., (1996). A Comprehensive Methodology for the Fitting of Predictive Accident Models. *Accident Analysis and Prevention*, 28(3), pp. 281-296.

McCullagh, P. and Nelder, J. A. (1989). *Generalized linear models*. 2nd ed., Chapman and Hall, London.

Newstead, S., Bobevski, I., Hosking, S. and Cameron, M. H. (2004). *Evaluation of the Queensland road safety initiatives package*. Unpublished report, Monash University Accident Research Centre.

Newstead, S. and Cameron, M. (2003). *Evaluation of the crash effects of the Queensland speed camera program*. Report No. 204, Monash University Accident Research Centre.

Newstead, S., Cameron, M., Gantzer, S. and Vulcan, P. (1995). *Modelling of some major factors influencing road trauma trends in Victoria 1989-93*. Report No. 74, Monash University Accident Research Centre.

Newstead, S., Cameron, M. and Leggett, M. (2001). The crash reduction effectiveness of a network-wide traffic Police deployment system. *Accident Analysis and Prevention*, 33(3), pp. 393-406.

Nicholson, A. J., (1985). The Variability of Accident Counts. *Accident Analysis and Prevention*, 17(1), pp. 47-56.

Nicholson, A. J., (1986). The Randomness of Accident Counts. *Accident Analysis and Prevention*, 18(3), pp. 193-198.

Nilsson, G. (1984). *Speeds, accident rates and personal injury consequences for different road types*. Rapport 277, Swedish National Road and Transport Research Institute (VTI), Sweden.

Smith, G. and Senserrick, T. (2004). *Public perceptions of Victorian speed enforcement initiatives*. Report No. 224, Monash University Accident Research Centre.

Thoresen, T., Fry, T., Heiman, L. and Cameron, M. (1992). *Linking economic activity, road safety countermeasures and other factors with the Victorian road toll*. Report No. 29, Monash University Accident Research Centre.

APPENDIX A – CORRELATIONS OF INDEPENDENT VARIABLES

	Victorian population	Random breath tests	Exceeding prescribed concentration of alcohol	Alcohol sales
Victorian population	1			
Random breath tests	0.571	1		
Exceeding prescribed concentration of alcohol	0.697	0.642	1	
Alcohol sales	0.119	0.405	0.238	1
Fuel sales	0.782	0.565	0.574	0.518
Kilometres travelled	0.700	0.489	0.359	0.495
Unemployment rate	-0.703	-0.451	-0.508	-0.164
Non-speed related Adstock	0.063	0.219	-0.064	0.155

	Fuel sales	Kilometres travelled	Unemployment rate	Non-speed related Adstock
Victorian population				
Random breath tests				
Exceeding prescribed concentration of alcohol				
Alcohol sales				
Fuel sales	1			
Kilometres travelled	0.810	1		
Unemployment rate	-0.637	-0.654	1	
Non-speed related Adstock	0.176	0.328	-0.134	1

APPENDIX B – PROPORTION OF VEHICLES OBSERVED EXCEEDING THE SPEED LIMIT

Metropolitan 60 km/h Speed Zone

		Period											
		May 1999	Nov 1999	May 2000	Nov 2000	May 2001	Nov 2001	May 2002	Nov 2002	May 2003	Nov 2003	May 2004	Nov 2004
Excessive Speed Range	1-9 km/h	55.9%	51.6%	53.0%	53.2%	50.8%	47.7%	42.1%	43.4%	42.5%	37.8%	39.0%	43.0%
	10-14	13.3%	14.6%	11.4%	9.1%	8.6%	5.9%	6.0%	5.2%	5.5%	3.9%	3.9%	4.4%
	15-19	5.1%	5.0%	4.2%	3.5%	1.8%	1.2%	1.1%	1.4%	1.8%	1.2%	1.0%	1.6%
	20-24	1.2%	1.2%	1.3%	0.8%	0.9%	1.1%	0.2%	0.4%	0.6%	0.1%	0.1%	0.2%
	25-29	0.3%	0.1%	0.4%	0.1%	0.1%	0.3%	0.2%	0.1%	0.2%	0.0%	0.2%	0.3%
	30+	0.3%	0.2%	0.3%	0.0%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%

Metropolitan 70 km/h Speed Zone

		Period											
		May 1999	Nov 1999	May 2000	Nov 2000	May 2001	Nov 2001	May 2002	Nov 2002	May 2003	Nov 2003	May 2004	Nov 2004
Excessive Speed Range	1-9 km/h	55.3%	47.3%	49.0%	47.8%	42.6%	40.6%	38.1%	36.9%	34.5%	32.2%	35.2%	36.0%
	10-14	7.4%	7.9%	6.6%	7.4%	5.1%	5.1%	2.7%	3.1%	2.9%	3.0%	2.6%	3.6%
	15-19	2.9%	2.7%	2.1%	3.2%	1.6%	2.1%	1.3%	0.7%	0.8%	0.6%	0.6%	1.1%
	20-24	0.9%	1.0%	0.5%	0.8%	0.5%	0.6%	0.4%	0.2%	0.1%	0.4%	0.2%	0.4%
	25-29	0.4%	0.4%	0.3%	0.2%	0.0%	0.3%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%
	30+	0.1%	0.1%	0.0%	0.1%	0.1%	0.4%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%

Metropolitan 80 km/h Speed Zone

		Period											
		May 1999	Nov 1999	May 2000	Nov 2000	May 2001	Nov 2001	May 2002	Nov 2002	May 2003	Nov 2003	May 2004	Nov 2004
Excessive Speed Range	1-9 km/h	34.2%	22.6%	20.3%	17.9%	14.9%	16.1%	12.2%	11.8%	12.0%	11.3%	10.5%	10.7%
	10-14	4.4%	3.7%	2.6%	2.5%	1.3%	1.9%	1.2%	1.7%	1.0%	1.2%	1.2%	1.2%
	15-19	1.8%	1.4%	1.1%	1.4%	0.4%	0.7%	0.6%	0.5%	0.4%	0.4%	0.2%	0.2%
	20-24	0.7%	0.3%	0.3%	0.1%	0.4%	0.3%	0.2%	0.2%	0.0%	0.1%	0.0%	0.1%
	25-29	0.2%	0.0%	0.2%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%
	30+	0.1%	0.1%	0.1%	0.2%	0.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%

Victorian Rural 80 km/h Speed Zone

		Period							
		2001_1	2001_2	2002_1	2002_2	2003_1	2003_2	2004_1	2004_2
Excessive Speed Range	1-5 km/h	18.6%	19.1%	17.5%	18.8%	17.9%	18.8%	17.9%	19.0%
	6-9	10.7%	10.8%	9.2%	9.5%	8.9%	9.1%	9.0%	9.5%
	10-14	5.4%	6.1%	4.6%	4.7%	4.1%	4.4%	4.3%	4.4%
	15-19	3.0%	3.2%	2.4%	2.4%	2.1%	2.2%	2.2%	2.4%
	20-24	1.9%	2.0%	1.4%	1.5%	1.2%	1.4%	1.4%	1.5%
	25-29	0.7%	0.8%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%
	30+	0.4%	0.5%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%

Victorian Rural 100 km/h Speed Zone

		Period							
		2001_1	2001_2	2002_1	2002_2	2003_1	2003_2	2004_1	2004_2
Excessive Speed Range	1-5 km/h	22.5%	23.3%	22.2%	23.2%	21.9%	22.8%	22.5%	23.2%
	6-9	10.7%	11.8%	9.7%	9.4%	8.1%	8.2%	8.2%	8.3%
	10-14	4.0%	4.3%	3.3%	3.2%	2.6%	2.6%	2.5%	2.6%
	15-19	1.3%	1.5%	1.1%	1.1%	0.9%	0.9%	0.8%	0.8%
	20-24	0.5%	0.6%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%
	25-29	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%
	30+	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%

Victorian Rural 110 km/h Speed Zone

		Period							
		2001_1	2001_2	2002_1	2002_2	2003_1	2003_2	2004_1	2004_2
Excessive Speed Range	1-5 km/h	23.8%	24.3%	24.0%	24.5%	24.2%	24.4%	25.1%	25.8%
	6-9	9.9%	10.2%	8.0%	7.9%	6.7%	6.8%	7.2%	7.1%
	10-14	2.6%	2.8%	1.9%	1.8%	1.4%	1.4%	1.5%	1.5%
	15-19	0.8%	0.9%	0.6%	0.5%	0.4%	0.4%	0.4%	0.4%
	20-24	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%
	25-29	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	30+	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%