OVERALL IMPACT OF SPEED-RELATED INITIATIVES AND FACTORS ON CRASH OUTCOMES

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ABSTRACT

From December 2000 until July 2002 a package of speed-related initiatives and factors took place in Victoria, Australia. The broad aim of this study was to evaluate the overall impact of the package on crash outcomes. Monthly crash counts and injury severity proportions were assessed using Poisson and logistic regression models respectively. The model measured the overall effect of the package after adjusting as far as possible for non-speed road safety initiatives and socio-economic factors. The speed-related package was associated with statistically significant estimated reductions in casualty crashes and suggested reductions in injury severity with trends towards increased reductions over time.

From December 2000 until July 2002, three new speed enforcement initiatives were implemented in Victoria, Australia. 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 package represents a broad, long term program by Victorian government agencies to reduce speed based on three linked strategies: more intensive Police enforcement of speed limits to deter potential offenders, i.e. the three new speed enforcement initiatives just described - supported by higher penalties; a reduction in the speed limit on local streets throughout Victoria from 60 km/h to 50 km/h; and provision of information using the mass media (television, radio and billboard) to reinforce the benefits of reducing low level speeding - the central message of “Wipe Off 5”. These strategies were implemented across the entire state of Victoria with the intention of covering as many road users as possible.
This study aimed to evaluate the overall effectiveness of the speed-related package. The study 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. This paper presents the results of the evaluation of the overall impact on crash outcomes associated with the speed-related package, after adjusting as far as possible for the effect of non-speed road safety initiatives and socio-economic factors. D’Elia, Newstead and Cameron (2007) document the study results in full.

METHODS

OVERALL EVALUATION 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, such as non-speed road safety initiatives and socio-economic 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.

Data Stratification - The population of Victoria as at 2004 was around 5 million, with approximately 3.6 million living in the statistical division of Melbourne and the remainder living in rural Victoria. The majority of Victoria’s traffic is carried on the declared road network of freeways and arterial roads. This network links centres of activity in rural and metropolitan areas and is comprised of 22,300 kilometres of roads.
managed by the Roads Corporations (VicRoads). In 2004, 16,323 casualty crashes were reported to Police of which 5,492 were fatal or serious injury crashes. Of the 16,323 casualty crashes, 77% occurred in the metropolitan region.

In general, data on non-speed road safety initiatives and socio-economic factors was available by location, e.g. Melbourne metropolitan region versus rest of Victoria. 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.

Analysis 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, Newstead, Diamantopoulou et al. (2003) 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.

Therefore, in addition to an overall model, separate models were developed for crash criteria related to speed limit of crash location and crash type 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 (40, 50 or 60 km/h; 70, 80 or 90 km/h; 100 or 110 km/h) and Crash Type (One vehicle involved; More than one vehicle involved).
DATA FOR THE OVERALL EVALUATION - Crash Data and Crash Outcomes - The Accident Research Centre holds crash data supplied by the Roads Corporation (VicRoads) covering the analysis period of January 1999 to December 2004. As only casualty crashes, i.e. crashes involving death or injury, are required to be reported to Police in Victoria, the crash data only includes these crashes.

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.

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. An examination of the individual components has been undertaken by a separate study, the results of which are currently unpublished. Covert Operations: Covert operation of car-based 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, aimed at dispelling the belief that exceeding the limit by 5 to 10 km/h is “safe”, 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.

**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. 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 (RBT), exceeding prescribed concentration of alcohol (EX-PCA) and non-speed-related Adstock (AD-NONSP). Brief descriptions of these follow.

**Random Breath Tests:** The number of monthly random breath tests conducted from booze buses and other stationary vehicles. It is 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. It is available by metropolitan Melbourne and regional areas of Victoria.

**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 (KMS), fuel sales (FUEL), alcohol sales (ALCOHOL), unemployment rate (UNEMP_R) and population (POPLN). 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 research which examined the effects of the road safety initiatives package implemented in Queensland.
during 2003-2004 [Newstead, Bobevski, Hosking et al., 2004] and in previous work by Newstead, Cameron, Gantzer et al. (1995) and Cameron, Haworth, Oxley et al. (1993) examining Victorian road trauma trends. These studies identified the important socio-economic factors to include in the analysis, following earlier work by Thoresen, Fry, Heiman et al. (1992) which investigated linking the Victorian road toll with economic, road safety, social and other factors.

STATISTICAL ANALYSIS METHODS - 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.

Poisson Regression Model - 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 1.

\[ \ln(y) = \beta X + \epsilon \]  

In Equation 1, \( y \) is the dependent variable, in this case monthly crash counts, \( \beta \) is the vector of model parameters or regression coefficients, \( X \) is the matrix of input or independent variables and \( \epsilon \) 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.

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, Cameron and Leggett, 2001] and speed camera [Newstead and Cameron, 2003] programs in Queensland, and the interaction between the speed camera program and speed-related mass-media publicity in Victoria [Cameron, Newstead, Diamantopoulou et al. 2003].

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 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. The model was fitted using the SAS/STAT® software. To assist with understanding the form of the regression model, the form used is given below (Equation 2) in simplified notation similar to that used in programming the model. A brief note on the purpose of each model term is also included.
\[
\ln(\text{Crashes}) = \text{LOCATION (Metropolitan versus non-metropolitan)}
\]
\[
+ \text{RBT} + \text{AD_NONSP (Non-speed road safety initiative variables)}
\]
\[
+ \text{UNEMP}_R + \text{ALCOHOL (Socio-economic factor variables)}
\]
\[
+ \text{RBT*LOCATION} + \text{AD_NONSP*LOCATION (Non-speed road safety initiatives by location)}
\]
\[
+ \text{UNEMP}_R*\text{LOCATION} + \text{ALCOHOL*LOCATION (Socio-economic factors by location)}
\]
\[
+ \text{MONTH*LOCATION (Seasonal term by location)}
\]
\[
+ \text{OVERALL\_EFFECT (Speed-related package overall effect)}
\]

(2)

The package implementation term (OVERALL\_EFFECT) was defined as a categorical step function stepping at August 2001. It is the key term for assessing the overall effect of the speed-related package on crash outcomes. In a separate analysis 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.

**Estimation of Effects on Crash Injury Severity** - Assessment has also been made as far as possible of the effects of the speed-related package on crash injury severity. Changes in injury severity have been measured through examining two principal measures of severity. They were the proportion of casualty crashes that were fatal and the proportion of fatal or serious injury crashes that were fatal. This paper presents results for the former measure which was considered to be more robust. D’Elia et al. (2007) documents the results for both measures.

The same study design as that used for assessing changes in monthly crash counts was used for assessing injury 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 1 was altered to become a logistic regression model. The logistic model has the following general form:
In Equation 3, \( p \) is the dependent variable, in this case the monthly crash proportion with fatal outcome, \( \beta \) is the vector of model parameters or regression coefficients, \( X \) is the matrix of input or independent variables and \( \varepsilon \) 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 injury severity analysis has considered the overall effect of the speed-related package on injury severity. The structure of the linear form of input measures for the logistic regression model is the same as used for the Poisson crash count model described in Equation 2.

RESULTS

Minimisation of Co-Linearity between Independent Variables - To overcome the model co-linearity problems, a number of variables were excluded from 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). The use of unemployment rate is consistent with the work by Thoresen, Fry, Heiman et al. (1992) who considered the use of many different factors to measure the economic activity in Victoria and discovered that unemployment had a better association with the road toll than vehicle travel.

Crash Frequency Analysis - Estimates of the overall effects of the speed-related package resulting from fitting the regression model described in Equation 2 are given in Table 1. 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.

Table 1 shows that the estimated overall reduction in casualty crashes associated with the speed-related package was 3.8%. The estimate was highly statistically significant. For casualty crashes occurring in metropolitan Melbourne, Table 1 shows a highly statistically significant 4.6% estimated reduction in casualty crashes. Table 1 also shows a non-statistically significant estimated crash increase of 1.5% for the non-metropolitan region.
Table 1 - Estimated Crash Reductions Associated with the Speed-Related Package

<table>
<thead>
<tr>
<th>Region</th>
<th>Estimated Crash Reduction</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Victoria</td>
<td>3.80%</td>
<td>2.00%</td>
<td>5.57%</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>4.62%</td>
<td>2.69%</td>
<td>6.50%</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Non-Metropolitan</td>
<td>-1.53%</td>
<td>-6.76%</td>
<td>3.45%</td>
<td>0.5549</td>
</tr>
</tbody>
</table>

Note: Negative percentage crash reduction estimates indicate an estimated percentage crash increase

Estimates of the overall effects of the speed-related package resulting from fitting the regression model described in Equation 2 to disaggregated crash outcomes are given in Table 2. An estimate of the overall effect on casualty crashes involving pedestrians is shown in Table 3.

Table 2 - Estimated Crash Reductions Associated with the Speed-Related Package (Disaggregated Results)

<table>
<thead>
<tr>
<th>Disaggregation Category</th>
<th>Estimated Crash Reduction</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>40, 50 or 60 km/h</td>
<td>6.14%</td>
<td>3.92%</td>
<td>8.31%</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>70 or 80 km/h</td>
<td>-1.82%</td>
<td>-5.92%</td>
<td>2.14%</td>
<td>0.3725</td>
</tr>
<tr>
<td>100 or 110 km/h</td>
<td>4.93%</td>
<td>0.10%</td>
<td>9.53%</td>
<td>0.0456</td>
</tr>
<tr>
<td>More than one vehicle involved</td>
<td>4.92%</td>
<td>2.77%</td>
<td>7.03%</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>One vehicle involved</td>
<td>1.37%</td>
<td>-1.95%</td>
<td>4.58%</td>
<td>0.4138</td>
</tr>
</tbody>
</table>

Note: Negative percentage crash reduction estimates indicate an estimated percentage crash increase

Table 3 - Estimated Crash Reduction Associated with the Speed-Related Package (Casualty Crashes Involving Pedestrians)

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Estimated Crash Reduction</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involving Pedestrians</td>
<td>1.19%</td>
<td>-4.62%</td>
<td>6.70%</td>
<td>0.6806</td>
</tr>
</tbody>
</table>
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 6.1% 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 4.9%. Disaggregation by crash type was associated with a highly statistically significant crash reduction of 4.9% for crashes where more than one vehicle was involved. Table 3 shows that for casualty crashes involving pedestrians a statistically significant estimate of crash reduction was not observed.

Crash Injury Severity Analysis - Estimated effects on relative injury severity associated with the speed-related package have been assessed using the logistic regression model as detailed above. Results of the analysis are presented in Table 4 for the proportion of casualty crashes resulting in fatal outcome. 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 4). Table 4 also gives 95 percent confidence limits on the estimated relative risk as well as the statistical significance level of the estimate.

Table 4 - Estimated Relative Injury Severity Associated with the Speed-Related Package

<table>
<thead>
<tr>
<th>Region</th>
<th>Relative Risk</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Victoria</td>
<td>0.96</td>
<td>0.83</td>
<td>1.10</td>
<td>0.5166</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>0.92</td>
<td>0.78</td>
<td>1.08</td>
<td>0.3017</td>
</tr>
<tr>
<td>Non-Metropolitan</td>
<td>1.06</td>
<td>0.82</td>
<td>1.37</td>
<td>0.6796</td>
</tr>
</tbody>
</table>

Similarly, estimated effects of the speed-related package on the proportion of casualty crashes resulting in fatal outcome resulting from fitting the logistic regression model to disaggregated crash outcomes are given in Table 5. An estimate of the effect on the injury severity proportion resulting from fitting the logistic regression model to casualty crashes involving pedestrians is shown in Table 6.
Table 5 - Estimated Relative Injury Severity Associated with the Speed-Related Package (Disaggregated Results)

<table>
<thead>
<tr>
<th>Disaggregation Category</th>
<th>Relative Risk</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>40, 50 or 60 km/h</td>
<td>0.79</td>
<td>0.63</td>
<td>1.01</td>
<td>0.0568</td>
</tr>
<tr>
<td>70 or 80 km/h</td>
<td>0.98</td>
<td>0.75</td>
<td>1.28</td>
<td>0.8847</td>
</tr>
<tr>
<td>100 or 110 km/h</td>
<td>1.10</td>
<td>0.88</td>
<td>1.38</td>
<td>0.4051</td>
</tr>
<tr>
<td>More than one vehicle involved</td>
<td>0.95</td>
<td>0.78</td>
<td>1.17</td>
<td>0.6476</td>
</tr>
<tr>
<td>One vehicle involved</td>
<td>0.95</td>
<td>0.78</td>
<td>1.14</td>
<td>0.5671</td>
</tr>
</tbody>
</table>

Results of the severity analysis suggest a possible reduction in the risk of fatal outcome in casualty crashes (Table 4) however this result did not achieve statistical significance. A potentially larger although non-statistically significant estimated reduction in the risk of fatal outcome in casualty crashes for the metropolitan region is also suggested by Table 4. The results in Table 5 suggest that any larger estimated reduction in metropolitan Melbourne might be due to the nearly statistically significant reduction in injury severity in 40, 50 or 60 km/h speed zones (estimated 21% reduction). Table 6 shows that for casualty crashes involving pedestrians, a non-statistically significant estimated reduction of 20% in the risk of fatal outcome over the post-implementation period occurred.

Table 6 - Estimated Relative Injury Severity Associated with the Speed-Related Package (Casualty Crashes Involving Pedestrians)

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Relative Risk</th>
<th>Lower 95% C. L.</th>
<th>Upper 95% C. L.</th>
<th>Stat. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involving Pedestrians</td>
<td>0.80</td>
<td>0.59</td>
<td>1.10</td>
<td>0.1664</td>
</tr>
</tbody>
</table>
OVERALL EFFECT PARTITIONED BY TIME - Given that the speed-related package was deemed to be the initiatives and factors commencing during or after August 2001, 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 would not allow the presence of any trends to be clearly ascertained. In the analysis model, the overall effect term in Equation 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.

![Graph showing overall crash reduction partitioned by time](image)

Note: Negative percentage crash reduction estimates indicate an estimated percentage crash increase

Figure 1 - Overall Crash Reduction Partitioned by Time (Casualty Crashes)

The results of this analysis are presented in Figure 1 for the frequency analysis and in Figure 2 for the severity analysis. In each figure, the full post-implementation period results (Tables 1 and 4; Victoria) 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.

For the crash frequency analysis, Figure 1 shows that the estimated overall crash reduction of 3.8% 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. The final period of July 2004 to December 2004 inclusive shows a highly statistically significant estimated crash reduction of 10% in casualty crashes. Figure 1 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 2 - Overall Relative Injury Severity Partitioned by Time (Fatal Outcome in Casualty Crashes)

For the injury severity analysis, it can be seen from Figure 2 that the estimated overall relative injury severity of 0.96 was not statistically significant (the upper confidence limit is above 1). An estimated relative injury severity of 1 indicates no change in the level of severity. Results from the time-partitioned model indicate that estimated relative injury severities were generally not statistically significant however a statistically significant estimated relative injury severity of 0.70 did occur for the period July 2003 to December 2003 inclusive.
DISCUSSION

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 in metropolitan Melbourne, in contrast to a non-statistically significant estimated increase in casualty crashes of 1.5% occurring in the non-metropolitan region. However it is not possible to draw strong conclusions regarding the effect of the speed-related package in the non-metropolitan region of Victoria due to the lack of statistically significant results for both crash frequency and injury severity. Disaggregation of crash outcomes showed highly statistically significant 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 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 based on an analysis of 2004 crash data.

In evaluating the overall impact of the speed-related package on crash outcomes, the number of individual elements of the package and the reach of these elements over the crash population did not lend themselves to evaluation using the strongest available study designs. Like so many road safety programs, implementation based on the most robust randomised treatment-control design was not carried out. Furthermore, the next best option in employing a quasi-experimental evaluation study design with carefully matched controls was also not possible given the coverage of the program. The coverage of crashes throughout Victoria by the elements of the package included all times of day, all areas and all road users. This resulted in no 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. In addition, the use of another Australian state as a potential “control” group was not feasible due to the considerably different road and traffic environments and combinations of other factors affecting road trauma outcomes.

Consequently, the next best alternative analysis design was employed in this study in the form of a time series based before-after implementation analysis adjusted for other key measurable factors other than the speed program known to affect road trauma outcomes. The
evaluation of speed-related package crash effects presented 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 basic idea of the modelling approach was 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 was implemented. The perturbation is then inferred to represent the overall effect of the package on crashes.

The success of such an approach relies on the ability to effectively represent the majority of factors other than the intervention of interest that have influenced observed crash counts over the full analysis time period in order to be able to measure the pure effect of the intervention. Assessing the success of the model in capturing long term trends requires focus on the model fit to the data, particularly in the pre-intervention period. One way to assess model fit is through the use of model residuals, which reflect the difference between observed and fitted values. Figure 3 shows standardised Pearson residuals resulting from the model for casualty crashes in metropolitan Melbourne. The residuals appear to fluctuate randomly around zero in an independent manner suggesting a lack of systematic bias in the model, particularly during the pre-implementation period.

The assessment of model fit suggests that crash trends including underlying long-term trends have been adequately captured using the analysis approach, however limitations do exist. This includes the reliance on effectively representing the majority of other factors that have
influenced crash counts over an extended period of time. Despite validating model fit, there are always possible sources of bias in the analysis design used. These include changing relationships between key model factors and the outcome measure over time that are compensated for by the intervention term to produce apparently good model fit effects of some unconsidered factor that may have come into play at the same time as the intervention. Whilst every effort has been made to avoid such biases in the current study through a carefully considered modelling approach, there is still some finite chance that such biases exist. As for all statistical modelling processes, it is also important to note that the models establish levels of association between factors and not cause-and-effect between intervention and measured outcome.

The analysis of crash effects for the proportion of casualty crashes resulting in fatal outcome suggested a possible reduction in the risk of fatal outcome in reported casualty crashes over the post-implementation period with a non-statistically significant estimated relative 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 injury severity for the period July 2003 to December 2003 inclusive. This measure of severity showed a non-statistically significant estimated reduction in the risk of fatal outcome of 20% for casualty crashes involving pedestrians over the entire post-implementation period.

With regards to the assessment of changes in injury severity, it is acknowledged that the reliance on Police-reported injury outcome limits the range of injury severity that can be assessed to measures based on the crude gradients of injury outcome classified by Police (death, hospitalisation, other injury, no injury). The availability of an injury scale such as AIS would enable subtle changes in injury severity to be investigated however classification of injury using such a scale is generally not possible from Police-reported crash data and certainly not from that reported in Victoria. In addition, the measurement of serious injury, defined as “taken to hospital”, is known to be relatively inaccurate in Victorian crash data. In contrast, classification of a fatality is less subject to error hence the injury severity measure of principal focus in this study was the proportion of casualty crashes that were fatal. The proportion of fatal or serious injury crashes that were fatal was examined but not presented because the measure was not considered to be robust.

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 documented by D’Elia et al. (2007) 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, D’Elia et al. (2007) found 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 4.9% 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 region.

ASSUMPTIONS AND QUALIFICATIONS - Results of the analysis of the speed-related package presented are subject to a number of assumptions and qualifications. It is assumed that all the data supplied for the evaluation is correct and measures both evaluation inputs and outcomes as described; that the form of the statistical analysis model used, including the functional relationship between dependent and independent variables and the distribution of random error, is appropriate; that estimates of the crash effects are not biased through measures missing from the statistical models that are associated with the speed-related package; and that 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. In addition, for those models which utilised subsets of the data, the potential loss of statistical power should be noted.

CONCLUSIONS

This study has evaluated the overall impact of a package of speed-related initiatives and factors on crash outcomes including more covert operations of mobile speed cameras, an increase in speed camera operating hours and lowering of cameras’ speed detection threshold. The
package was associated with a highly statistically significant estimated overall reduction in casualty crashes of 3.8% which was in large part due to the estimated reduction in casualty crashes for metropolitan Melbourne rather than the rest of Victoria. In particular, 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 which indicated that in Melbourne the largest increase in camera hours occurred on 50 and 60 km/h roads. For injury severity, the analysis suggested a possible reduction in the risk of fatal outcome in reported casualty crashes over the post-implementation period with a non-statistically significant estimated relative injury severity of 0.96. In addition, a model where the post-implementation period was partitioned by time showed trends towards increased reductions in casualty crashes and in the risk of fatal outcome of those crashes over time.

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