M O N A S H   U N I V E R S I T Y

CRASH-BASED EVALUATION OF SPEED CAMERA PROGRAM IN VICTORIA 1990-1991

PHASE 1: GENERAL EFFECTS.

PHASE 2: EFFECTS OF PROGRAM MECHANISMS

by

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Abstract:

A major speed camera program was launched in April 1990 in Victoria which involved a dramatic increase in the detection of speeding offenders and a multi-million dollar, Statewide publicity campaign through all mass media. This report describes Phases 1 and 2 of an evaluation study examining its effects on crashes. Phase 1 examined the general effects Victoria-wide, in Melbourne, and in the rest of the State separately, and Phase 2 attempted to link the effects to the various speeding deterrence mechanisms (both specific and general deterrence) associated with the program.

The results of Phase 1 indicated that the speed camera program in Victoria has been associated with decreases in the frequency of reported casualty crashes which occur in low alcohol times of the week and also decreases in their injury severity. These decreases have been calculated as departures from expected values based on past trends and seasonal patterns, changes in unemployment rate, and using the comparable areas of New South Wales as a control. The program appears to have had its greatest effects (in terms of decreases in the frequency of casualty crashes) on arterial roads in Melbourne and on 60 km/h roads in rural Victoria, where the majority of the speed camera operations have taken place within the respective Melbourne and country areas. This pattern of results provides further evidence that the observed effects relate to the speed camera program. The results of Phase 2 suggested that the reductions in the frequency of casualty crashes (in low alcohol hours) appeared to be linked with speed camera TINs (Traffic Infringement Notices) issued to detected drivers, Transport Accident Commission (TAC) road safety publicity in general and TAC speed related publicity in particular (lower level of significance). Reductions in the injury severity of casualty crashes (in low alcohol hours) appeared to be associated with speed camera TINs issued and hours of camera operation.

It is planned to undertake two further Phases of evaluation: Phase 3 will attempt to examine the localised effects in time and space related to the camera operations, while Phase 4 will attempt to link the observed effects with changes in speed behaviour.

Key Words:

speed & evaluation (assessment), injury, collision, road trauma, traffic regulations, statistics, research report, publicity, speed camera, speed enforcement, time series analysis

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EXECUTIVE SUMMARY

A speed camera program was gradually introduced in Victoria since December 1989 to reduce traffic speeds and hence road trauma. The program involved the progressive introduction of 54 speed cameras between December 1989 and January 1991 across the State, and was supported by an intensive Statewide mass media publicity campaign. The publicity aimed to increase the perception of the level of camera operations and their legitimacy, as well as building a community agenda about speeding and safety. The major launch of the enforcement and publicity occurred in April 1990.

The current evaluation study attempts to quantify the effects of the program on the incidence and severity of road crashes between December 1989 and December 1991. This report describes Phase 1 of the evaluation, which examined the general effects Victoria-wide, in Melbourne, and in the rest of the State separately, and Phase 2 which links the effects to the various speeding deterrence mechanisms (both specific and general deterrence) associated with the program. It is planned that Phase 3 will examine the localised effects in time and space related to the camera operations. Phase 4 will link the observed effects with changes in speed behaviour.

Program Description

Speed cameras were developed to detect and photograph speeding vehicles. A slant radar measures the speeds of passing vehicles, while a camera control unit provides photographic evidence of the vehicle at the scene of the offence and records the time, date, location and speed of travel. Speed cameras can be set so that both receding and/or approaching vehicles can be monitored. The speed cameras are capable of taking two photographs per second and can be operated at any time of the day (or night).

Cameras can be mounted on tripods outside the vehicle or used in a less obvious manner from inside the vehicle, as is generally the case. Generally unmarked police vehicles have been used to reduce the visibility of operations. Warning signs are not displayed specifically in relation to camera operations to alert drivers of the camera's presence. However, some general warning signs were erected at a number of locations, including every major road coming into Victoria. Through such operations, the program aimed to increase drivers' perceptions about the chances of being caught, and hence increase compliance with speed limits generally, by detecting a large proportion of offenders.

An automated Traffic Infringement Notice (TIN) penalty system was also introduced to allow efficient processing of offences and issuing of TINs, given the dramatic increase in detection rates. A TIN informs the vehicle owner of the details of the offence such as the date, place and time of the offence and the penalties for the level of the offence. Penalties increase with the level of speeding over the posted speed limit, with combinations of fines, licence demerit points, and immediate licence suspension, depending on the severity of the offence. The registered owner of the vehicle is liable for these penalties unless he/she nominates the driver of the vehicle at the time of the offence.

Low levels of local publicity began in December 1989/January 1990 with the trialing of 4 speed cameras at a small number of sites in Melbourne. The official mass media publicity launch occurred in April 1990. Speed cameras were used at substantial levels from July 1990 when the automated TIN processing system commenced. The program resulted in a dramatic increase in **all** speeding offenders detected from a level of around 20,000 per month before July 1990 to 40,000 - 80,000 per month over the operation of the program.

Speed cameras have been used mainly on arterial roads in 60 km/h speed zones in both the metropolitan and country areas. There has also been greater use of speed cameras in the metropolitan area.

Phase 1: General Effects

Phase 1 of the evaluation attempted to determine the area-wide effects of the program on casualty crash frequency and injury severity (evaluation criteria), as it operated in different periods during 1990 and 1991. This approach was undertaken because it was considered possible that the program could have generalised or dispersed effects beyond immediate speed camera sites and times, given that speed cameras are often not obvious, are used at many sites, use has been maintained at high levels (especially relative to previous speed enforcement), and related publicity has also been intensive.

The program was characterised by three distinct periods to the end of 1991:

T1a: a period of low level camera trialing and localised low level publicity from December 1989 to March 1990

T1b: a period characterised by a high profile media launch of speed cameras and intensive publicity relating to speed-related crash risk, but little speed camera enforcement (ie. after an intense 9 day burst of camera use, negligible levels of speed camera use, offence detection and hence TINs issued) between April and late June 1990,

T2: the subsequent period in which enforcement increased dramatically, and thus also the detection and punishment of speed offenders, and was maintained at high levels, as was speed publicity, from July 1990 onwards. (This period was later split into T2a and T2b for analysis reasons).

Speed cameras have been used to a different extent in the Melbourne metropolitan area and rural areas in the State, and to differing extents on different zoned roads, therefore analyses were undertaken for each of the following treated areas:

↗arterial roads (all zones)
Melbourne
↗ ↘arterial roads (60 km/h zones)
Victoria
↘ ↗arterial (open) roads (100km/h limit)
Rural Victoria
↘roads in rural towns (60 km/h zones)

Method

The estimated percentage change in the evaluation criteria (casualty crash frequency and casualty crash severity) in each area during each of the post-intervention periods (T1a, T1b, and T2) was adjusted by the parallel estimated percentage change in the comparable area in New South Wales (comparison areas) for the same periods. Taking into account parallel changes in comparison areas is a method for excluding the effects of extraneous influences on evaluation criteria in the treatment areas, so that estimates reflect the impact solely of the program.

Multivariate time series models for each of the evaluation criteria were developed for each of the treatment and comparison areas, so that the changes (relative to what was expected) during each of the post-intervention periods could be estimated for each series. Casualty crash severity was measured by the ratio of fatal plus serious injury crashes to crashes involving minor injury only. The respective unemployment rates in each area were included in the models fitted, to take into account the differential changes in treatment and comparison areas, and because it was considered that unemployment rates provided a measure for differential changes in driving exposure (vehicle travel).

Percentage changes in each area of Victoria were then contrasted with the corresponding area of NSW, allowing the ***net percentage changes*** in each treatment area to be estimated. The net change provided an estimate of the percentage change in each of the two crash measures that is attributable to the speed camera program, after other factors have been taken into account (measured by experience in NSW).

Periods T1a and T1b essentially represent an introductory period prior to the major change in speed enforcement practices, and as such are a "one-off" occurrence for the program. The T2 period was divided into the time between July 1990 and February 1991 (T2a) and March to December 1991 (T2b) because of the commencement of a speed camera program in NSW in March 1991. Net percentage changes in T1a, T1b and T2a therefore represent the effects of the Victorian program, whilst the net percentage change for T2b represents the effects of the Victorian program relative to that in NSW.

Only casualty crashes in "low alcohol hours" of the week (mainly daytime) were examined given the parallel operation of a major Random Breath Testing (RBT) initiative primarily in high alcohol times. Thus the results pertain to the effects of the speed camera program during "low alcohol hours" only (ie. Monday - Thursday 6am to 6pm, Friday 6am to 4pm, Saturday 8am to 2pm, Sunday 10am to 4pm). During "low alcohol hours" in 1988 and 1989, the percentage of drivers killed or admitted to hospital with a blood alcohol content exceeding 0.05%, was below 4%. Hence, even a large reduction in drink driving could have only a very small effect on the frequency of serious crashes in those "low alcohol hours".

Results

Figures 1 and 2 show the actual values of the two evaluation criteria in each month of 1983-1991, for Victoria as a whole. The Figures also show the expected post-intervention trends (from the models) if the speed camera program had not been introduced. Two expected trends are displayed; one based on the model for Victoria, excluding the effect of other factors not implicit in the model, and the second trend including the effect of other factors, as measured by the experience in NSW. The difference between the expected trend (including other factors) and the actual represents the apparent effect of the program.

Figure 1
Number of Casualty Crashes per month in low alcohol times 1983-1991
Victoria

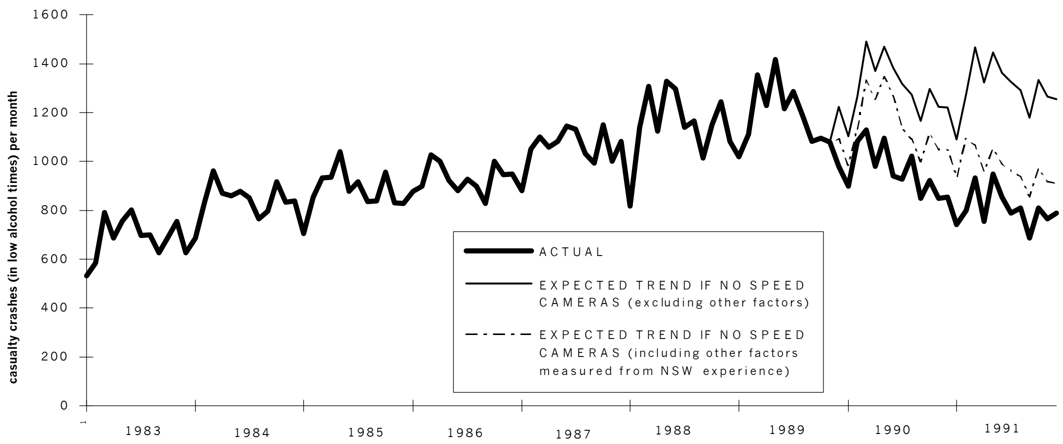
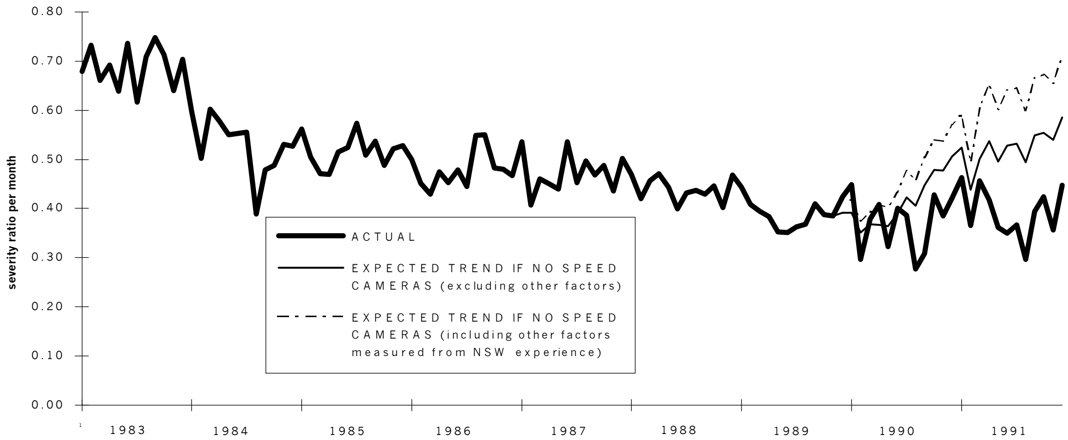


Figure 2
Casualty Crash Severity per month in low alcohol times 1983-1991, Victoria
(ratio of fatal & serious injury crashes to crashes involving minor injury only)



Figures 3-6 provide a summary of the percentage reductions measured for the two evaluation criteria, together with the 95% confidence limits on each estimate. Both statistically significant (shaded) and non-significant estimates are shown, because the non-significant reductions indicate time trends in the effects, although individually they do not represent scientific evidence of an effect in the specific phase of the speed camera program.

The effects on Melbourne's 60 km/h arterial roads are reflected on all Melbourne arterial roads, so only the results for the latter roads are given in Figure 3. Figure 4 shows the effects over all Melbourne roads, which are generally smaller than on the arterial roads (reflecting relatively smaller effects on residential roads). The apparent effects on rural 100 km/h highways were generally non-significant and disparate in magnitude and direction, so for these reasons they are not presented in a Figure. The effects on rural 60 km/h roads were more consistent over the program phases than those on the 100 km/h rural roads and are presented in Figure 5 (however because of the inconsistency between the results for these two types of rural roads, the apparent effects for rural Victoria as a whole are not presented in a Figure). Although the Victoria-wide effects are obviously an amalgam of a number of different effects operating on different roads during different months, they are summarised in Figure 6 to provide an overall view of effects of the program.

Frequency of casualty crashes (in low alcohol hours)
A consistent significant drop from what would have been expected in the **number of (low alcohol hour) casualty crashes** across all treated areas was observed for the periods corresponding to the publicity launch (T1b) and the increase in speed camera enforcement (T2a), except for 100 km/h rural open roads where there was a significant drop in T2a only. The largest of these reductions (around 30%) occurred on arterial roads in Melbourne. During T1a the reduction (14%) was confined only to arterial roads in Melbourne. Rural 60 km/h roads experienced a statistically significant drop relative to the respective rural NSW areas in T2b, when NSW also had a speed camera program operating.

Injury severity of casualty crashes (in low alcohol hours)
The Melbourne area (as a whole and on arterials roads specifically) experienced increasing reductions over time from what would have been expected in the **severity of (low alcohol hour) casualty crashes.** No significant changes were observed on 60 km/h rural roads, although 100 km/h rural roads experienced a significant increase in casualty crash severity during T1b (this unexpected result may in fact be a chance anomaly which has arisen because of the large number of significance tests conducted in this study). The overall changes in severity for Victoria as a whole were significant reductions in the T2a (28%) and T2b (40%) periods.

It should be noted that the estimated percentage reductions in the injury severity of casualty crashes apply to the severity ratio defined earlier (page iii) and not to the more traditional measure of injury severity, namely the ratio of fatal plus hospitalisation crashes to all casualty crashes (ie. those involving death or any level of injury). The former ratio is likely to show larger changes than the latter; for example, the estimated 28% reduction in the Victoria-wide severity ratio during T2a is equivalent to a 21% reduction in the traditional measure.

In addition, the estimated percentage reductions in the injury severity of casualty crashes are derived from models which take into account the effects of changes in unemployment rate. In practice this means that the estimated net effects are based on the expectation that casualty crash severity (in low alcohol hours) would have increased in Melbourne and Victoria, given the increase in unemployment rate that occurred during the intervention period, had the speed camera program not been introduced. Therefore, the estimated percentage reductions are not reflected in the actual trend in the casualty crash severity ratio during the intervention period.

Pattern of effects corresponding to the level of speed camera enforcement
In terms of **casualty crash frequency in low alcohol times**, the pattern of results suggested that there were stronger reductions on 60km/h arterial roads and all arterial roads in Melbourne (around 30%) as compared with Melbourne as a whole and in rural 60km/h zones (around 20%) and also as compared with the weakest effect observed in rural 100km/h zones (14% drop in one period only). This pattern of effects corresponds with the level of speed camera enforcement in these different areas:

- speed camera operations were conducted almost exclusively on arterial roads,

- a greater number speed camera operations were conducted in Melbourne than in rural areas (70% of total sessions on average have been conducted in Melbourne),

- most (80-90%) camera sessions have been conducted in 60 km/h zones in both the respective metropolitan and rural parts of the State.

The pattern of results therefore provided greater confidence that the observed reductions in the frequency of casualty crashes (in low alcohol hours) were related to the speed camera program.

In terms of the **injury severity of casualty crashes**, reductions were observed in the Melbourne areas but not in any of the rural areas, again corresponding to the greater level of speed camera enforcement in Melbourne compared with country Victoria. There was no substantial difference between the effects on Melbourne arterial roads only and all Melbourne roads, except that they appeared somewhat greater on the arterials (as could be expected).

Figure 3
Estimated Percentage Reductions (with 95% confidence limits) in Casualty Crash Frequency and Injury Severity in Low Alcohol Hours during Phases of the Speed Camera Program - Melbourne Arterial Roads - Dec 89 - Dec 91

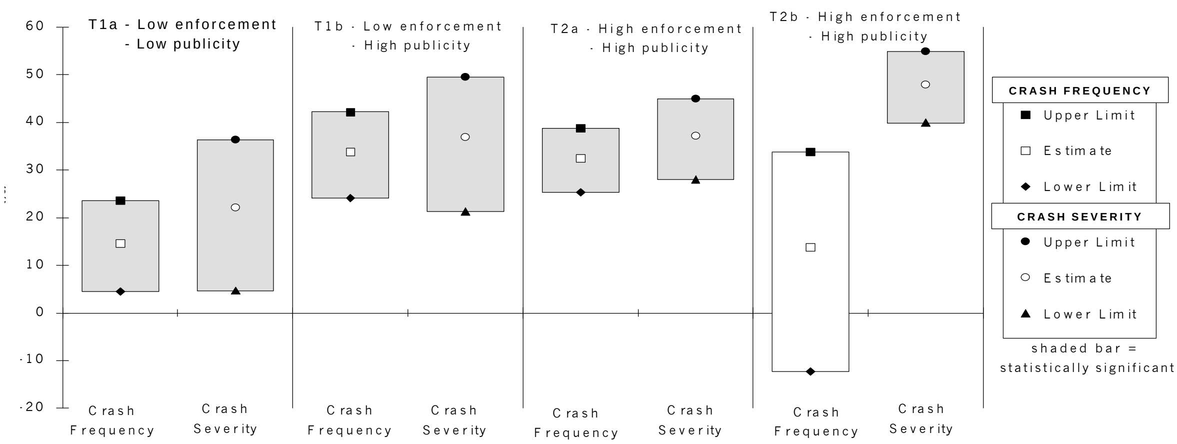


Figure 4
Estimated Percentage Reductions (with 95% confidence limits) in Casualty Crash Frequency and Injury Severity in Low Alcohol Hours during Phases of the Speed Camera Program - Melbourne - Dec 89 - Dec 91

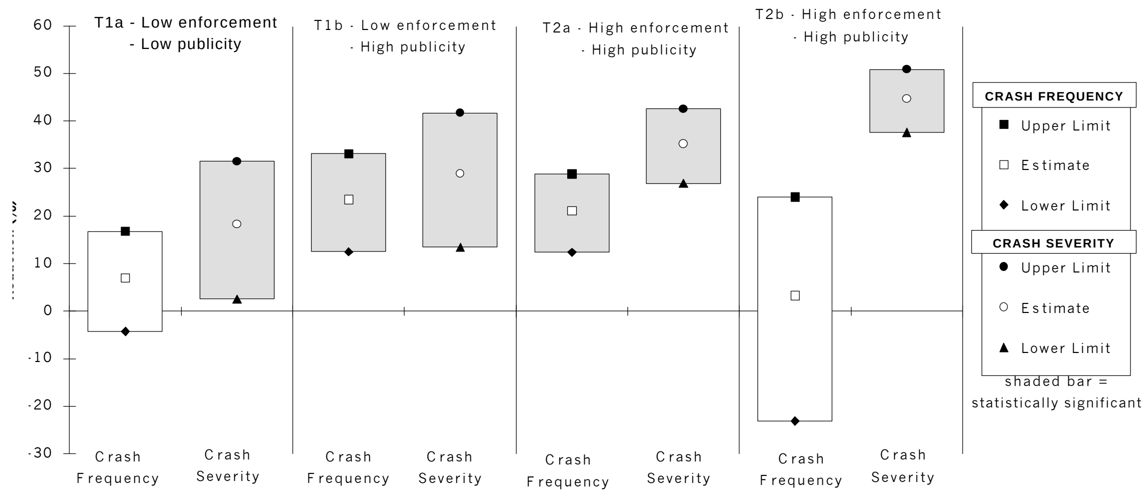


Figure 5
Estimated Percentage Reductions (with 95% confidence limits) in Casualty Crash Frequency and Injury Severity in Low Alcohol Hours during Phases of the Speed Camera Program - Rural Victoria 60kmh - Dec 89 - Dec 91

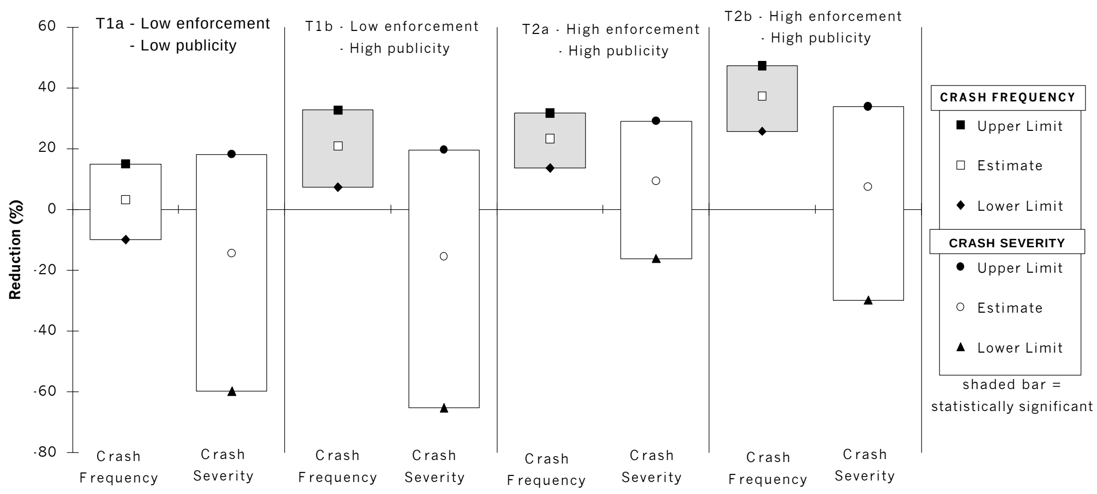
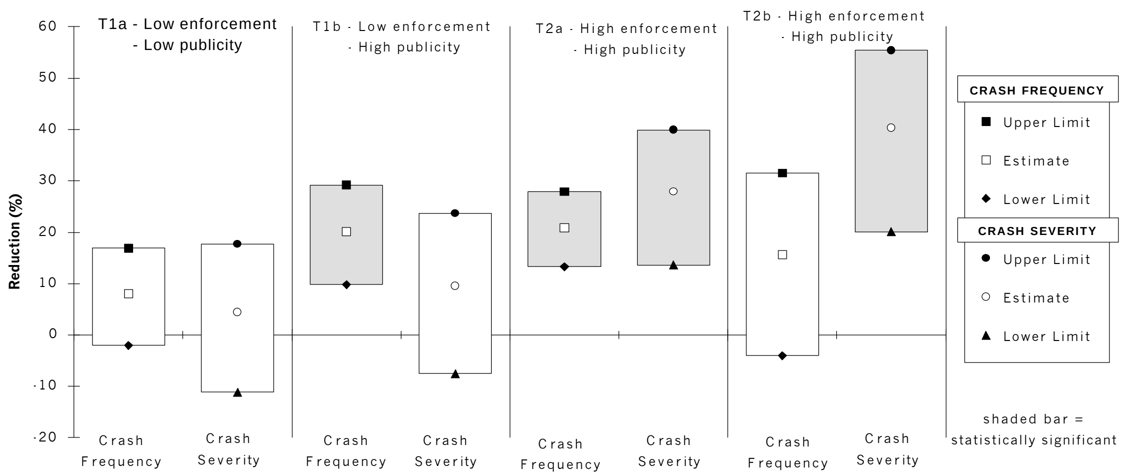


Figure 6
Estimated Percentage Reductions (with 95% confidence limits) in Casualty Crash Frequency and Injury Severity in Low Alcohol Hours during Phases of the Speed Camera Program - Victoria - Dec 89 - Dec 91



This phase of the evaluation tested for simultaneous reductions in casualty crash frequency and their injury severity (in low alcohol times) with the introduction of the various phases of the program (represented by intervention variables). Reductions were estimated after taking into account the effects of other influences; namely long-term trends in casualty crash risk and severity, seasonal trends and unemployment, and also changes in the evaluation criteria in NSW, which served as a comparison area. The effects observed in Phase 1 are strongly suggestive of a coincidental effect of the program on the evaluation criteria. However, it does not directly link the program to the observed effects, and hence it is possible that other influences, which are not accounted for, could have caused these observed effects.

Phase 2: Effects Of Program Mechanisms

Phase 2 of this evaluation attempts to further understand and estimate the impact of the program by modelling the various deterrence mechanisms of the program against the evaluation criteria (casualty crash incidence and severity during low alcohol times of the week). The measured mechanisms are represented quantitatively and are assessed for their relative impact on the evaluation criteria. The purpose of this is two-fold:

1. to attempt to link more directly the program mechanisms with observed reductions in crash criteria, and hence better establish the "cause-and-effect" of the program,

2. to attempt to indicate which of the program mechanisms appear to be most strongly associated with changes in the crash criteria.

A range of mechanisms which potentially affected drivers' perceptions and hence speed behaviour have operated through the speed camera program. Measures of speed camera TINs issued, TAC speed related publicity only, all TAC road safety publicity, and hours of camera operation were available on a monthly basis, whilst other measures were not. Therefore an attempt was made to determine the relationship (if any) between the evaluation criteria and the quantified deterrence mechanisms.

Method

The relationships between the evaluation criteria (casualty crash incidence and severity during low alcohol times of the week) in Melbourne and the different program measures were determined using multivariate time series analysis models.

Results

Significant inverse relationships were found between some of the measures of the program and the frequency and injury severity of casualty crashes which occurred in low alcohol times, in 1990 and 1991. These were:

Frequency of casualty crashes (low alcohol times)	Injury severity of casualty crashes (low alcohol times)
• Speed camera TINs issued to drivers • All TAC road safety publicity • TAC Speed related publicity (sig. at 0.07 level only)	• Speed camera TINs issued to drivers • Speed camera operation hours

The effects of speed camera TINs issued to drivers was consistently related to both crash frequency and injury severity, with stronger effects observed on arterial roads for both criteria. The direct effects of speed camera operations themselves (basically the immediate effects of the cameras operating) appeared to be confined to casualty crash injury severity only. This may indicate that:

- drivers are not aware of cameras operating because they are generally not obvious and hence cannot react to operations directly, or

- exposure to camera operations is not sufficient to modify speed behaviour to the degree required to reduce the risk of a casualty crash occurring but receipt of a TIN and punishment for speeding is effective in reducing crash risk.

Alternatively, the high intercorrelations between variables and estimates for the variables, especially for camera operations and other significant variables, may have masked the relationship between camera operations and casualty crash frequency. In addition, the casualty injury severity measure may be a more specific and more sensitive criterion related to speed than casualty crash frequency.

In relation to the findings for publicity, similar comments apply for the relationship between speed related publicity and casualty crash frequency. The estimate for this variable was correlated with the estimates for other significant variables. On the other hand, the stronger significant effect of all road safety publicity rather than speed related publicity on casualty crash frequency may reflect that casualty crash frequency is a general measure of the risk of all types of (low alcohol hour) crashes and it is not confined to "speed-related" crashes (which could reasonably be expected to be affected by the speed-related publicity).

It appears that publicity (speed related only or all publicity) was not related to casualty crash injury severity.

Qualifications of this Research

The research design involved a number of assumptions. These include:

Interstate control (Phase 1)
The conceptualisation of the effects of this program as being generalised across broad areas for phase 1 of the evaluation led to the absence of any untreated area, time or other crash group in the respective Victorian metropolitan and rural areas to provide an acceptable comparison group. This meant that the use of an interstate comparison group was unavoidable. Although the most similar State to Victoria was chosen for this role, it is not known how well it provided control for other (exogenous) factors present over time in Victoria (although unemployment rates were explicitly taken into account in the analysis of each State's crash data). It is therefore assumed that net changes in T1a, T1b and T2a represent the effects of the program, rather than other factors. The net changes in T2b are assumed to represent the effects of the program in Victoria relative to the effects of speed cameras introduced in NSW.

Unemployment rate as a measure of low alcohol hour vehicle travel (Phases 1 & 2)
The use of unemployment rate as a covariate to control for changes in low alcohol hour travel cannot be directly validated. There were substantial changes in the trends in total travel almost coinciding with the program and these changes differed between Victoria and NSW. Explicitly controlling for changes in exposure was considered to be important for estimating effects of the program on crash frequency.

A significant statistical relationship was found between unemployment rate and injury severity of casualty crashes in Melbourne and in Sydney, but not in rural Victoria nor rural NSW, suggesting that increases in unemployment rate is associated with increases in the injury severity of crashes. One possible explanation for this is that when traffic congestion is reduced in times of economic recession, the opportunity to travel at higher speeds also increases (especially in urban areas) which leads to greater injury severity of those crashes which occur. This warranted the retention of unemployment rate in the models so it could be accounted for in estimating the effects of the program on crash severity. The estimates of the program in Melbourne and State-wide Victoria are therefore influenced by the presence of the unemployment variable in these models, because of its statistically significant role in these models of casualty crash severity.

Efficacy of the Phase 1 models
The validity of the results for casualty crash severity are tentative given that the models fitted may be inadequate from a statistical perspective. These models were characterised by high intercorrelations between estimates for the predictors, in particular between those

for unemployment rate, trend and T2b, which may have affected the estimates of the program variables. It was also assumed that the correlations between some parameter estimates in the (ARIMA) modelling of casualty crash frequency did not affect the estimates for the intervention periods.

The approach used in the modelling was such that a specific test was made for a step change or reduction with the introduction of the program. This assumes that the nature of the effects of the program are immediate and maintained. If, for example, effects were initially small and increased incrementally over time, the current estimates will only be an average of these varying effects. Although this is a shortcoming, it is because of the unclear nature of the effects of the program over time that alternative frameworks were not used.

Efficacy of the Phase 2 models

The models were found to fit the crash data well (around 84% and 66% of the variance in the casualty crash frequency and casualty crash severity criteria, respectively, was accounted for by these models). However, intercorrelations between coefficient estimates for casualty crash frequency models (in particular) and casualty crash injury severity models indicated that there were high correlations between many estimates. Such intercorrelations may mean that the estimated relationships reported are unreliable, particularly that indicated for the relationship between camera operations (and to a lesser extent that for speed publicity) and casualty crash frequency, given its high correlations with the estimates for other significant variables (ie. TINs issued, unemployment rate and trend).

Low alcohol hour crashes (Phases 1 &2)

The results described here apply only to casualty crashes occurring during the low alcohol hours of the week (mainly daytime). This is because of the influence of a concurrent RBT initiative in high alcohol times.

Difficulties in linking program mechanisms (Phase 2)

One of the major practical difficulties with attempting to model the specific aspects of the program is the reliance on available quantified measures of the program and representing it validly. The lack of monthly time series data for other program mechanisms meant that a full model was not developed. On the other hand, while this was theoretically desirable, in practice it may have been impossible to develop a full model and disaggregate each mechanism's sole contribution to observed reductions in the crash criteria, given that the mechanisms are unavoidably interrelated.

Problems with the feasibility of this aim include the statistical problems of collinearity between the measures, and between the measures and other influences, the appropriate representation and quantification of the mechanisms within the model, and the fact that correlational relationships between the program and crashes does not prove causality absolutely. For these reasons, statistically significant effects which seem related to a particular program mechanism cannot definitively be attributed to that particular part of the program only, given that it operated in the presence of the other mechanisms (quantified and unquantified) and other unknown factors. Indeed, the relative importance of the various mechanisms in drivers' perceptions, speed choice and speed behaviour and the extent to which these have altered cannot be understood through this quantitative approach.

Further Research

It is now planned to undertake Phase 3 of this evaluation, as outlined in section 5.0. This should provide more definitive evidence of a cause-and-effect link between the speed camera operations and the general effects observed in Phase 1 of the evaluation. This phase should also provide further understanding of the key factor affecting the deterrent effect of the program, so that future camera operations of the program can be optimised. An additional Phase which attempts to examine existing traffic speed data over time to provide additional supporting evidence linking the observed effects to the speed camera program will also be attempted. It may not, however, replace the evidence that should be provided by the proposed Phase 3 of the evaluation, given the paucity of traffic speed data over the relevant time period. Additional research areas and data requirements emerged from the study and are outlined in the report.

Conclusions

The introduction of the speed camera program and supporting publicity in Victoria has been associated with decreases in the frequency of reported casualty crashes which occur in low alcohol times of the week and also decreases in their injury severity. These decreases have been calculated as departures from expected values based on past trends and seasonal patterns, changes in unemployment rate, and using the comparable areas of NSW as a control. The magnitudes of these decreases have varied with the region of the State and nature of the program operated during different periods. The program appears to have had its greatest effects (in terms of the frequency of casualty crashes) on arterial roads in Melbourne and on 60 km/h roads in rural Victoria, where the majority of the speed camera operations have taken place within the respective Melbourne and country areas. This pattern of results provides further evidence that the observed effects relate to the speed camera program.

The results of Phase 2 suggest that the reductions in the frequency of casualty crashes (in low alcohol hours) appeared to be linked with speed camera TINs issued to detected drivers, TAC road safety publicity in general and TAC speed related publicity (lower level of significance). Reductions in the injury severity of casualty crashes (in low alcohol hours) appeared to be associated with speed camera TINs issued and hours of camera operation.

On the basis of the analyses in this report, it is clear that the speed camera program (enforcement and supporting publicity) has been effective.

1.0 INTRODUCTION

A speed camera program was gradually introduced in Victoria since December 1989 to reduce traffic speeds and hence road trauma. The program involved the progressive introduction of 54 speed cameras between December 1989 and January 1991 across the State, and was supported by an intensive Statewide mass media publicity campaign. The publicity aimed to increase the perception of the level of camera operations and their legitimacy, as well as building a community agenda about speeding and safety. The major launch of the enforcement and publicity occurred in April 1990.

Up until this time speed enforcement was conducted at a relatively low level given the high resource demands required without an automated surveillance system. A few speed cameras were used and trialed in the late 1980's. Speed cameras were developed to detect and photograph speeding vehicles. A slant radar is used to measure speeds of passing vehicles, while a camera control unit provides photographic evidence of the vehicle at the scene of the offence and records the time, date, location and speed of travel. A full record of each session of operation is therefore available with information, such as the number of vehicles checked, the number of vehicles travelling at different speeds, the time and date of the operation. Speed cameras can be set so that both receding and/or approaching vehicles can be monitored. The speed cameras are capable of taking two photographs per second and can be operated at any time of the day (or night).

Cameras can be mounted on tripods outside the vehicle or used in a less obvious manner from inside the vehicle, as is generally the case. Generally unmarked police vehicles are used to reduce the visibility of operations. Warning signs are not displayed specifically in relation to camera operations to alert drivers of the camera's presence. However, some general warning signs were erected at a number of locations, including every major road coming into Victoria. This type of speed enforcement is predicated on the underlying belief that such operations (which result in larger proportions of drivers being detected and punished) are the best way to increase drivers' perceptions about the chances of being caught, and thus to increase compliance with speed limits generally.

An automated Traffic Infringement Notice (TIN) penalty system was also introduced through the establishment of a speed camera office to allow efficient processing of offences and issuing of TINs, given the dramatic increase in detection rates. A TIN informs the vehicle owner of the details of the offence such as the date, place and time of the offence and the penalties for the level of the offence. Penalties are commensurate with the level of speeding over the posted speed limit, with combinations of fines, licence demerit points, and licence suspension, depending on the severity of the offence. The registered owner of the vehicle is liable for these penalties unless he/she nominates the driver of the vehicle at the time of the offence.

The current evaluation study attempts to quantify the effects of the program on the incidence and severity of road crashes for different periods between December 1989 and December 1991.

This report outlines:

- available research relating to the role of speed and speed enforcement on crashes
- the mechanisms which could lead to changes in speed behaviour

- quantification of the mechanisms and description of the program
- evaluation study of the effects on crashes of the program

This report describes Phase 1 of the evaluation, which examined the general effects Victoria-wide, in Melbourne, and in the rest of the State separately, and Phase 2 which links the effects to the various speeding deterrence mechanisms (both specific and general deterrence) associated with the program. It is planned that Phase 3 will examine the localised effects in time and space related to the camera operations. Phase 4 will link the observed effects with changes in speed behaviour.

2.0 THE ROLE OF SPEED IN CRASHES

Reviews of studies which have investigated the relationships between travel speed and crashes (eg. Cowley, 1980, 1983, 1987; OECD, 1982; Sanderson & Cameron, 1982; Social Development Committee, 1991) have found that the nature of the relationship between crash incidence and speed is still not well understood. This is mainly because of the difficulty in estimating the pre-crash speeds of vehicles, and the dependency of involvement rate on different crash types, traffic and road characteristics (Sanderson & Cameron, 1982). On the other hand, basic data on crash dynamics as well as those studies which address secondary safety issues (Cowley, 1987) consistently demonstrate that the severity of injury in the event of a crash increases with crash speed.

Research conducted to date has almost exclusively been undertaken overseas and is mainly limited to rural highway environments. The studies fall into two methodological groups (Cowley, 1987):

a) those which examine changes in traffic speed distribution characteristics (average speed, speed variance, 85th percentile speed, skewness, etc.) and corresponding changes in both numbers of crashes and injury levels, generally after a change in posted speed limits

b) those which examine the crash involvement rates for different vehicle speeds, compared with the speeds of vehicles in the (corresponding) traffic stream, to identify speeds which are associated with higher crash risk, (with only Solomon [1964] giving attention to the relationship between speed and crash severity).

Generally, European studies have used the first approach whilst the second approach has mainly been used in early US studies (mainly in the 1960's). The literature is summarised below.

2.1 STUDIES OF SPEED LIMIT CHANGES

In reviewing studies of speed limit changes the general conclusions have been that reductions in speeds are associated with reductions in crash rates and crash severities whilst inversely, increasing speeds generally increases crash occurrences (OECD, 1982; Cowley, 1987). Nilsson (1981) describes Swedish studies since the 1960's of the effects of lowering speed limits and concludes that decreases in speed limits led to decreases in traffic speeds and consequently decreases in crash and casualty rates. Other Scandinavian and Danish studies confirm these findings (Cowley, 1987). The OECD (1982) provided a quantification of these effects outside built-up areas (based on the findings of Swedish research to that date, and taking into consideration the estimates from other countries): the percentage reduction in crash rates equals 'n' times the percentage drop in mean speed, where 'n'=4 for fatal crashes, 'n'=3 for personal injury crashes and 'n'=2 for all crashes.

A recent study of the speed limit reduction from 110km/h to 90km/h during the summer period of 1989 in Sweden, estimated that personal injury crashes decreased by 27% and the number of persons killed or injured fell by 21% (Nilsson, 1990). Motorways experienced the largest reductions. The estimates are based on comparisons with the relative change on 70 km/h roads, to provide a base, although it was stated that speeds on these roads also fell and so the estimates may be conservative. A Danish evaluation of the effect of the introduction of a 50km/h limit in built-up areas, found that injury crashes dropped by 9% and fatalities by 24% (Engel & Thomson, 1988).

In the US, Wagenaar, Streff & Schultz (1990) evaluated, using a time series approach, the effects of raising the speed limit, from 55 to 65 mph, on Michigan's rural interstate highways in 1988. Using time series analyses, including covariates, they found an increase of 48.4% in fatalities, 31.8% in serious injuries, 30.3% in moderate injuries, no change in minor injuries and a 27.3% increase in property damage only crashes. There were no changes on rural highways on which speed limits did not change, except for an increase in fatalities on 55 mph limited access freeways. Garber & Graham (1990) evaluated the increase from 55 to 65 mph on rural interstate highways in all states, and found conflicting results for different states. On the whole, however, they concluded that the increase in speed limit led to a greater number of fatalities.

In addition, in reviewing European studies of speed limit/travel speed changes, OECD (1982) found evidence of a relationship between speed dispersion and crash risk, for homogeneous traffic only, that is, not where there is a mix of heavy and light vehicles.

2.2 STUDIES OF RELATIVE CRASH RISK FOR VARYING TRAVEL SPEEDS

Studies conducted in the US, which have used approach (b) (section 2.0) to examine travel speed and crash risk, support the finding that speed variance is related to crash risk but do not find average or median travel speeds important in determining crash involvement. Solomon (1964) found a U shaped relationship between speed dispersion and crash risk: crash involvement increasing with increasing departure from average traffic speeds, particularly for night-time crashes. Solomon's work uses mainly third party estimates of pre-crash speeds. Research Triangle Institute (1970) and West & Dunn (1971) reported a flatter U shaped relationship between crash risk and departures from average traffic speeds, with departures of 25 km/h or more only related to an eight-fold increase in crash risk. These studies, particularly that by West & Dunn (1971), estimate the pre-crash speeds of crash-involved vehicles better, although the samples studied are smaller. These studies, however, are extremely dated and it has been questioned whether they apply to the current situation, particularly in Australia.

A more recent US study (Garber & Gardirau, 1988) examined the inter-relationships between highway types, road characteristics (in particular design speeds), travel speed characteristics (average travel speeds and speed variance), and crash rates. Thirty-six sites were used consisting of a sample of Interstates (rural, urban, expressways/freeways), urban and rural Arterials, and rural Collectors, which had minimal differences in posted speed limits, generally at 55 miles per hour.

Unlike previous studies which examined the relationship between speed and crashes by estimating the pre-crash speed of crash-involved vehicles and quantifying the crash risk of each speed category relative to its occurrence in the traffic stream, this study examines the relationship between overall crash rates with the characteristics listed above. The assumption in this approach is that the speed characteristics of the traffic stream cause the observed crash rates, without directly determining the specific crash risk of each speed category. In addition, mathematical models using regression analysis were used to determine the relationships between the different factors. However, as noted in the report, there was some correlation between factors, namely design speed and average speed, and average speed and speed variance. Therefore in attempting to dissociate the independent relationships between these characteristics and crash risk, some of the results may actually represent the importance of the other factor(s). Nevertheless, the following results can be drawn from this study:

- average travel speeds increase as the design speed of the roadway increases, suggesting that drivers travel faster on highways with better geometric characteristics (regardless of the posted speed limit)

- speed variance decreases as average travel speed increases (although the inter-relationship between average speed and design speed means that design speed could be the important factor, although this is not tested in the study)

- speed variance is lowest when the difference between the design speed and posted speed limit is between 5 and 10 miles per hour

- the relationship between average speed and crash rate could not be assessed because of the inter-relationship between design speed (ie. geometric characteristics) and average speed

- crash rate increases as speed variance increases for each highway type in the study (varying design speeds and average speeds were not taken into account in this analysis and therefore these other factors may have confounded the analysis, although separate analyses for each road type were undertaken).

2.3 OTHER EVIDENCE FOR THE RELATIONSHIP BETWEEN INJURY LEVELS AND SPEED

According to the law of physics, speed and energy dissipation in a crash are directly related: for a given vehicle mass, the kinetic energy to be dissipated in a crash increases by the square of the impact speed; that is, if speed is doubled, four times the energy will be absorbed in the crash. For this reason, it is said that increased speed leads to increased crash severity, and probably increased injury severity to the vehicle occupants.

Studies of speed limit changes, outlined in section 2.1, have found effects on injury rates with changes in travel speeds. In addition, Solomon's (1964) study also found that higher travel speeds are associated with greater injury risk. Bohlin (1967) reported a curvilinear relationship between crash speed and injury risk to drivers from a comprehensive Swedish study. The rate of increase in injury risk was greater at higher impact speeds. The results also showed that the probability of injury was greater for unbelted drivers although the relationship was still clear for drivers wearing seat belts. Data on crash dynamics and findings from other studies conducted in the US in the 1960's clearly showed the trend of increasing probability of fatality occurrence with increased vehicle speed (Cowley, 1987).

Some reports warn of the applicability of the results of these studies to current Australian conditions, given high seat belt wearing rates and some improvements in vehicle design, such as collapsible steering columns and impact-absorbing chassis (Social Development Committee Inquiry, 1991). The consistent findings of the various types of studies, however (including more recent speed limit evaluation studies in the US and Sweden), as well as basic principles of crash dynamics indicate the importance of speed in injury outcome, when a crash occurs.

As was pointed out in the Social Development Committee Inquiry (1991), injury or death can occur for unprotected road users at relatively low speeds, given that motorcyclists, pedestrians and bicyclists account for around 60% of deaths in 60 km/h zones. Forty-five percent of all fatal crashes occur in 60 km/h zones. Yet such statistics often confuse the possible dual role of travel speed as a factor in crash incidence (particularly the possible importance of speed dispersion) and crash severity, and is not adjusted for any exposure data to test injury ***risk*** by vehicle crash speeds. Additionally, factors other than speed and/or speed characteristics are important in crash risk. The other point made by the Social Development Committee (1991) is that freeways have substantially lower casualty rates than undivided roads, regardless of their higher speed limits and travel speeds. However, this may indicate their inherent safety due to geometric properties and low interaction and conflict levels with other traffic and road users, as opposed to the travel speeds characteristic of these environments.

2.4 AUSTRALIAN STUDIES

Australian studies have generally attempted to quantify the proportion of crashes in which speed is a factor through analysis of mass crash data and other sources. Such estimates are derived from subjective judgements and data which are thought to be speed related. Objective measures of speeds are not available.

It would appear that, on the basis of the weight of the evidence available from existing studies, vehicle speed is an important factor in both primary and secondary safety. However, it must be realised that the results of these studies may not be applicable to Australian conditions, they are almost exclusively based on rural roads and highways, and that the precise role speed has in contributing or causing crashes and their severity is still unclear. As stated in the Social Development Committee report (1991): "There is no doubt that speed is a contributing factor in road crashes. Whether or not speeding, however defined, is an important factor is yet to be proven." (p.175).

3.0 EFFECTS OF ENFORCEMENT ON SPEED BEHAVIOUR & CRASH RISK

There are four published trials of speed cameras available. Dreyer & Hawkins (1979) reported on a 3 month trial on 4 different roads (residential, rural, urban and urban thoroughfare) in Arlington Texas using a van-mounted ORBIS III photomechanical device. They reported that the greatest effect was on urban, densely travelled roadways during 'high' levels of enforcement where the proportion of "speeders" decreased throughout the 0.5 mile test segments. Reductions at residential and rural sites were less dramatic, but were detected at the van and post-ORBIS III locations; lower levels of enforcement appeared to be effective at these sites. Speed distributions were not greatly affected however, with small shifts in average travel speed of the order of 1 mph. They also reported that the effects on travel speeds were maintained for some time after the device was removed in the immediate area.

A study of photo radar on a West German autobahn to increase compliance with a 100km/h limit in the late 1970's (Blackburn & Glanz, 1984, cited in Freedman, Williams & Lund, 1990) reported increased compliance with the limit and resulted in a reduction from 300 crashes, 80 injuries and 7 deaths to 9 crashes, 5 injuries and no deaths.

In Victoria, a trial of speed cameras used from manned, unmarked stationary vehicles, with and without warning signs, was undertaken between 1985 and 1987. The study found that greater reductions in travel speeds resulted with the presence of highly visible warning signs compared with sites without warning signs (Portans, 1988). The data also indicated that the "halo" effect around the sites was limited, although no indication is given as to the size of the halo achieved. The "halo effect" is a term used to describe the effect on traffic behaviour beyond the point where enforcement is applied (Dart & Hunter, 1976, cited in Portans, 1988). Portans (1988) also concluded that media publicity is also an important factor for reducing speeds.

Speed enforcement studies have generally found that drivers respond to highly visible Police vehicles by suppressing vehicle speeds for up to a maximum of 5 km after the enforcement symbol, and this can occur regardless of whether the initial vehicle speed was over the limit (Portans, 1988). Leggett (1988) demonstrated that on 3 rural highways in Tasmania, low levels of highly visible but ***random*** placement of marked Police vehicles can increase the halo effect to 21 km and result in significant reductions in crash rates. Brackett & Edwards (1978, cited in Leggett, 1988) found a similar effect with such randomised enforcement. Most of these studies have been undertaken on highway stretches with little attention to effects of speed enforcement in urban areas. Most studies indicate however, that the effects of highly visible and limited speed enforcement are highly localised and temporary.

Armour (1984) reported an experiment at 2 urban sites in Sydney primarily to investigate memory effects of speed enforcement. A memory effect is defined as reduction of travel speeds at sites where enforcement symbols had previously been operating, even when it is longer present. A memory effect of at least 2 days after the enforcement symbol was removed was found for commuter drivers, whilst no memory effect was found for afternoon (non-commuter) situations. The study also suggested that drivers returned to their normal driving behaviour soon after passing a police vehicle, and a halo effect was achieved only while the police operation was visible to the driver. A Canadian study (Hauer, Ahlin & Bowser, 1982) reported a 3 day effect after one enforcement period and that this increased to 6 days after repeated enforcement. They found no difference between drivers who occasionally passed the site and those who passed it daily. A Swedish study (Engdahl & Nilsson, 1983; cited in Bjornskau & Elvik, 1990) claimed an effect of about 14 days when passing the same (enforcement) site. The effects did not differ if drivers had passed more than one enforcement site. No lasting effects were found for enforcement from unmarked vehicles.

The current program under evaluation is somewhat similar to the Victorian speed camera trial (1985 to 1987) to the extent that unmarked police vehicles and no warning signs are used, but is on a much larger scale and is supported by much more extensive publicity than any previous enforcement program in Victoria. The current type of enforcement program leads to a much larger number of drivers being detected and punished (specific deterrence), compared to highly visible enforcement which attempts to deter exposed drivers by the fear of being detected by increasing their belief that they will be caught (general deterrence). Traditional deterrence theory postulates that deterrence to committing offences occurs through either of these two mechanisms.

The assumption is that if enough drivers are detected speeding and there is widespread awareness of the program through publicity, a generalised effect on crashes is possible; that is, through a high level of specific deterrence supplemented by publicity enough offending drivers who have been punished will change behaviour elsewhere, and indirectly deter other non-punished drivers from speeding through word of mouth and publicity. To date there is no evidence in the research literature that speed enforcement effects generalise to other than the immediate vicinity of the actual enforcement (Portans, 1988), but the authors of this report are unaware of a program of this scale having been evaluated previously. In addition, the postulation of two global deterrence concepts, specific and general, needs to take into account the more common response to risk of detection and punishment, particularly in relation to speed enforcement, of ***restrictive*** deterrence where drivers curtail rather than entirely refrain from their violations of the law, to avoid getting caught (Gibbs, 1975; cited in Homel, 1980).

Deterrence literature generally is concerned with understanding the process of deterrence, whether deterrence truly occurs and if so how. The process is complex involving theories of decision-making processes and the various factors (psychological and social) which impinge upon it. The general model underlying modern deterrence theory is that legal threat (perceived likelihood of being detected and punished) is one of many factors which influence drivers' risk taking behaviour, and that these factors do not necessarily pertain, as thought previously, to rational cost benefit weighting of options. Personal and extra legal factors can weaken the impact of legal factors. Many factors other than laws, enforcement and punishment, which are not necessarily 'rational', may intervene to encourage or discourage propensity to offend.

The question however, still remains as to how to enhance legal sanctions and programs to give this factor the maximum possible impact on the maximum number of drivers. Past experience in other road safety programs suggest that in order to obtain maximum effect publicity campaigns should accompany legal programs, enforcement should be maintained over time and be deployed in such a way as to maximise (exaggerate) drivers' perceptions of being detected and punished (the best example of this is Random Breath Testing). It is theorised that such programs pave the way for social attitudes and beliefs to change about the behaviour, which in turn reinforce the negative consequences of this behaviour and act to maintain behavioural changes.

On the surface this may appear simple but the transient nature and pervasiveness of speeding, the widely held belief that this behaviour is not necessarily unsafe, and the fact that speeds are often selected to match the surrounding road and traffic conditions means that speeding is not easy to deter, except temporarily, as suggested by past experience and research. A recent review of law enforcement evaluations and studies (Bjornskau & Elvik, 1990) did not reveal evidence of programs with long-term effects. Additionally, they estimated that actual enforcement needs to be increased substantially to impact upon drivers' perceptions of enforcement levels and the risk of being detected.

4.0 PROGRAM MECHANISMS INFLUENCING SPEED BEHAVIOUR

The speed camera program in Victoria may have generated several mechanisms via which drivers could have responded to reduce travel speeds. These include:

1. Receipt of a speeding TIN and associated demerit points (specific deterrence)

2. Receipt of multiple TINs, demerit points and/or licence suspension (specific deterrence)

3. Knowledge of other drivers who have received TINs (general deterrence)

4. Knowledge of actual speed camera operations (general deterrence)

5. Publicity about speed cameras and the risks of speeding (general deterrence)

At the very least this information helps to describe the characteristics of the program, and to interpret the results of the formal evaluation study. The information can also be used as described under section 5.0, phase 2 of the evaluation study to link the effects on primary and secondary safety of the program mechanisms. The program mechanisms are described in turn below.

4.1 SPECIFIC DETERRENCE

4.1.1 Receipt of a TIN

Specific deterrence refers to the modification of behaviour by direct punishment so that the individual avoids re-punishment. Drivers who have received TINs are possibly deterred from "speeding" to avoid further penalties.

Figure 1 shows the number of speed camera offences Victoria-wide over time. Figure 2 shows the number of all other speed offences Victoria-wide over time. As shown in Figure 1, punishment of drivers for exceeding speed limits overall has increased dramatically relative to pre-program levels (speed cameras had been operating at extremely low levels since 1987, and trialed between 1985 and 1987). The monthly level of offences through the Speed Camera Program rose 2 to 4 times the level achieved by traditional speed enforcement methods, with around 20,000 speeding offenders in all detected per month before July 1990 to 40,000 - 80,000 per month over the operation of the program.

It should be noted however, that whilst speed camera operations have been conducted across the whole of Victoria, the level of camera operations have not been uniform across regions and speed zones; a far greater number of operations have been conducted in Melbourne compared with the rest of the State (refer section 4.2.2).

It should also be noted that the monthly number of TINs issued via speed camera detection (Figure 1) between April and June 1990 are not directly reflected by the monthly level of speed camera operations in this period, given that negligible use of speed cameras occurred between mid April to late June.

Figure 1
Monthly number of Traffic Infringement Notices Issued for Speeding Offences Detected by Speed Cameras Victoria 1989-1991

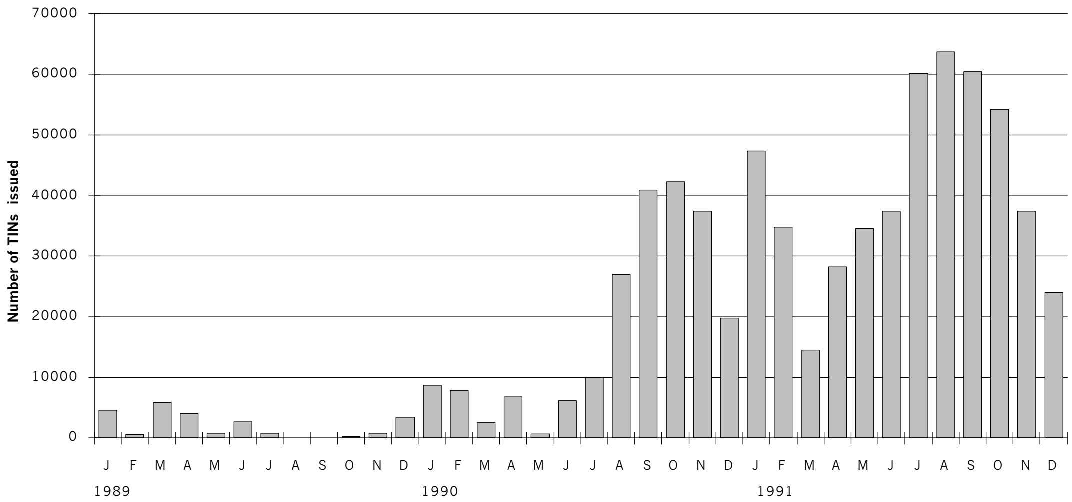
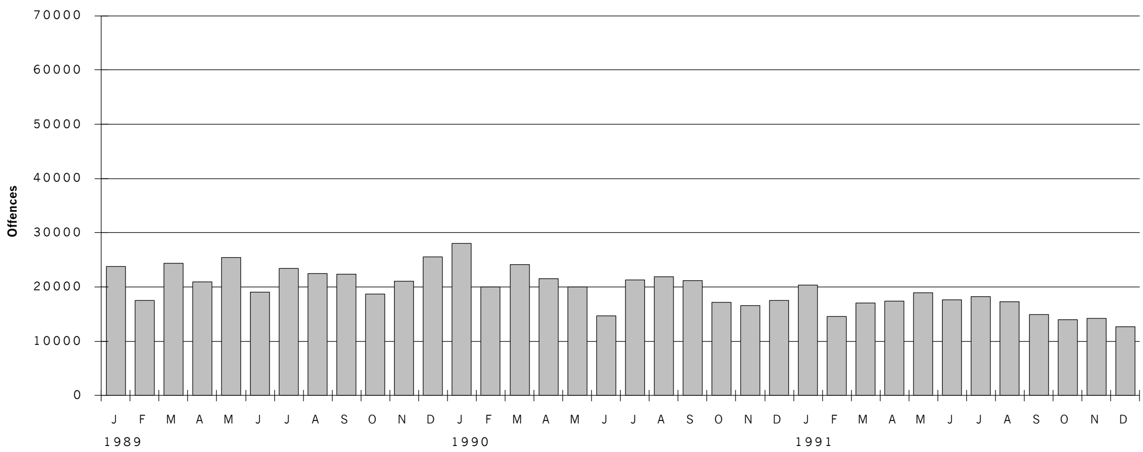


Figure 2
Non Speed Camera Speeding Offences, 1989-1991 Victoria



4.1.2 Receipt of multiple TINs

Drivers who have received multiple TINs may be further deterred given the approaching increase in penalty severity (ie. licence suspension) as licence demerit points are accumulated; and at a particular point re-offenders and/or excessive speeders are 'incapacitated' by licence suspension.

A maximum of 12 points in any three year period is permitted, after which a driver can choose between the following options: a 3 month licence suspension or an attempt at no extra points in the following 12 month period (if breached a six month licence suspension is invoked). More severe offences also incur higher penalties which results in faster accumulation of demerit points or even direct licence suspension. The penalties are as follows:

Offence	Fine	Demerit Points	Licence Suspension
Speed in excess of that permitted:			
1 - 15 km/h	$105	1	
16 - 29 km/h	$165	3	
30 - 39 km/h	$220	4	1 month
40 - 44 km/h	$300	4	4 months
45 - 49 km/h	$300	6	4 months
50 km/h or more	$360	6	6 months

Three sources of information are available which indicate the receipt of multiple TINs in the driving population.

Self-report data

An interview study (VIC ROADS, 1991, unpublished) was conducted in May 1991 and repeated in December 1991, in which a random sample of 1,050 licensed drivers were asked if they had received a TIN from a speed camera operation in the last 12 months, and if so how many. The responses indicated that 12 -14% of licensed drivers had been detected for speeding offences, and that the majority had had one offence only (particularly by December 1991). Furthermore, the number who had received three or more in the previous 12 month period appeared to have decreased in the second survey.

Table 1 Proportion of licensed drivers detected for a speeding offence by a speed camera

Number of speeding offences	May 1991 % drivers	December 1991 % drivers
One	6.2%	11.2%
Two	1.5%	1.8%
Three	4.0%	0.7%
Four	-	0.1%
Total one or more	11.7%	13.8%

(Source: VIC ROADS interview survey)

Traffic Camera Office TINs Issued Data

The TCO has undertaken an examination of the proportion of multiple offenders detected through the speed camera program in January and July 1992, using both driver licences and vehicle registrations as the basis for the calculations. This is summarised in table 2 below. The TCO data indicated that over 20% of drivers had been detected for speed camera offences since the beginning of the program (the interview survey referred to the percentage of drivers detected within a 12 month period only). The majority have only one offence although a significant proportion have had more than one TIN.

Table 2 Proportion of licensed drivers and registered vehicle owners issued a speeding TIN for an offence detected by a speed camera, Victoria

	January 1992		July 1992	
Number of TINs issued	% vehicle registrations	% driver licences	% vehicle registrations	% driver licences
One	13%	12%	12%	11%
Two	6%	4%	5%	3%
Three	2%	1%	2%	1%
Four	1%	1%	1%	-
Total one or more	22%	25%*	19%	22%*

*(Source: TCO) * 7% do not have a licence and/or omitted to provide their licence details*

Demerit points for licensed drivers

Table 3 shows six monthly figures since June 1990 of the proportion of licensed drivers with demerit points in Victoria (not exclusively for a speeding offence detected by a speed camera). Drivers with one or more demerit points have increased fourfold between June 1990 and December 1991. Increases have occurred across all levels of demerit points. The largest groups are those with one or with three demerit points.

Table 3 Proportion of licensed drivers with demerit points in Victoria (not exclusively for a speeding offence detected by a speed camera)

Number of demerit points	**June 1990** % drivers	**Dec 1990** % drivers	**June 1991** % drivers	**Dec 1991** % drivers
one	1.5	4.8	6.7	8.2
two	0.7	0.9	1.3	1.7
three	3.3	5.0	6.6	7.3
four	0.4	1.0	1.6	2.1
five	0.1	0.2	0.4	0.6
six	0.3	0.6	1.1	1.3
seven	0.07	0.2	0.4	0.5
eight	0.03	0.07	0.1	0.2
nine	0.04	0.1	0.2	0.3
ten	0.01	0.04	0.1	0.2
eleven	0.01	0.02	0.05	0.07
twelve	0.01	0.02	0.05	0.08
more than twelve	0.01	0.03	0.09	0.2
Total one or more	6.5	12.4	18.7	22.8

(Source: VIC ROADS)

4.2 GENERAL DETERRENCE MECHANISMS

General deterrence (in its classical sense) refers to the modification of behaviour by fear and avoidance of legal punishment. To be deterred by legal sanctions, drivers must perceive that they have a good chance of being detected and punished if they offend. Perceptions of being detected can be enhanced by indirect exposure to the program.

4.2.1 Knowledge of drivers caught

The VIC ROADS interview study (unpublished, 1991) indicated that 57% of licensed drivers knew someone who had been detected speeding by a speed camera, both in May 1990 and December 1991.

4.2.2 Knowledge of speed camera operations

In terms of actual speed camera operations, a high level of use of speed cameras was found Statewide (Sullivan, Cavallo, Rumbold & Drummond, 1992), increasing from around 250 hours per month in June 1990 to around 1500 hours or more per month throughout 1991. In total, in the period from July 1990 and December 1991, there has been 20,000 hours of total speed camera operation and 9,000 individual sessions. Over 11.5 million vehicles have passed a speed camera session. However, the number of drivers who saw these operations is not known. Sessions tend to last around 2-3 hours and are conducted on all days of the week (although weekdays have a greater number of sessions). Sessions are mainly conducted in the morning and afternoon with none before 6am in the morning and only around 4% after 8pm in the evening.

Whilst speed camera operations have been conducted in all areas of the State, the majority have been conducted in Melbourne (70% of total sessions on average have been conducted in Melbourne). Furthermore, 80-90% of camera sessions have been conducted in 60 km/h zones in both of the respective metropolitan and rural parts of the State. The differences between Melbourne and rural speed camera operations until the end of 1991 are outlined in Sullivan et al (1992) and are illustrated by the data below.

Melbourne:

- a total of around 6,300 speed camera sessions, with about 97% in 60 and 75 km/h speed zones
- 60,000 vehicles per month detected over set speed threshold
- non-speed camera speed offences declined from 10,000 - 12,000 per month to 6,000 - 7,000 per month

Rural Victoria:

- around 2,700 speed camera sessions in all, with 85% in 60 and 75 km/h speed zones
- 12,000 vehicles per month detected over set speed threshold
- non-speed camera speed offences dropped from 10,000 - 12,000 per month to 6,000 - 7,000 per month

The analysis of speed camera operations indicates that speed offences through enforcement measures other than speed cameras have reduced equally in Melbourne and rural Victoria, but speed camera enforcement is much greater in Melbourne than in rural Victoria. This suggests that there has been a much greater net increase in speed enforcement in Melbourne than in the rest of the State, which in fact appears to have experienced little change in actual net speed enforcement.

4.2.3 Mass media publicity

TAC mass media speed camera and speed related crash publicity with the theme "Don't fool yourself - speed kills" began in April 1990 and was maintained at intensive levels, particularly in 1990. TARPs (Target Audience Rating Points) is a measure relating to the estimated percentage of people (in the target group) who were likely to have seen the advertising, and thus provides a measure of the amount and intensity of television advertising. Monthly TARPs data revealed intensive periods of TAC speed publicity for most months in 1990 and around 4 months in 1991. A total of 5280 and 1772 TARPs relating to speed were achieved in 1990 and 1991, respectively on Melbourne television, which is a high level of publicity relative to previous levels of road safety publicity in Victoria.

5.0 EVALUATION PLAN FOR ASSESSING THE PROGRAM'S EFFECTS ON CRASHES

The paucity of relevant information about the effects of different types of speed enforcement on speed behaviour and speed-related crash risk is obvious from the review of existing research literature in the preceding sections of this report. The deterrence mechanisms underlying behavioural changes are also not well understood. Such information is important for guiding the structure of an evaluation of a program which is directed at behavioural change, such as the speed camera program. For example, information about where and for how long travel speeds (and therefore speed-related crash risk) are most likely to be affected by this type of enforcement allows identification of where and when the testing for crash effects of the program should be undertaken. Without this information, knowing where and when to look and test for effects is difficult to define.

Consequently, testing for effects in this evaluation has been conceived at a number of levels so that the evaluation is both as comprehensive and definitive as possible. The effects of the program on crashes was evaluated at three levels:

1. General effects Victoria-wide, in the Melbourne metropolitan and rest of State areas, and specifically on arterial roads in the respective areas

2. Effects through the specific and general deterrence mechanisms associated with the program (defined in section 4.0)

3. Localised effects in time and space related to the speed camera operations.

These are outlined below.

1. <u>General Effects: Victoria-wide, Melbourne metropolitan, and rest of State areas, and on arterial roads in the respective areas</u>

At this level, the evaluation attempted to determine the area-wide effects (if any) of the program on the evaluation criteria (casualty crash frequency and crash severity), as it operated during different periods during 1990 and 1991. This approach was taken because it was considered possible that the program could have generalised or dispersed effects beyond the immediate speed camera sites and times, given that speed cameras are generally not obvious, are used at many sites, use has been maintained at high levels (especially relative to previous speed enforcement) and related publicity has also been pervasive and intensive.

However, it is recognised that such an approach does not necessarily provide:

- the best test of the effects of the program (particularly if the effects are small and/or highly specific to camera locations), nor

- information about the how the program achieved its effects so that decisions can be made for future strategies for the program.

This phase of the evaluation was likely to provide equivocal conclusions regarding cause-and-effect. Two extra levels of analysis were undertaken to address these needs.

2. Effects through specific and general deterrence mechanisms

An attempt was made to develop a more detailed model with the various mechanisms generated by the program represented quantitatively. The measured mechanisms generated by the program were then be assessed for their relative impact on the evaluation criteria.

Time series data is available relating to:

1. number of TINs issued to offenders,
2. proportion of drivers with one or more TINs
3. proportion of drivers with a varying number of demerit points,
4. proportion of drivers who are aware of others who have been 'punished',
5. amount of paid television publicity, and
6. hours of speed camera operation.

Measures 1, 5, and 6 are available on a monthly basis, 3 is available on a quarterly basis, whilst 2 and 4 are available for particular dates only (shown and discussed in section 4.0). Thus, measures 2 and 4 cannot be used in the statistical analyses, but provide useful descriptive information about the program. Measure 3 was also problematic because it was available only Statewide and on a quarterly basis, and the appropriate quantitative representation of it in the model was not obvious.

Therefore an attempt was made to determine the relationship (if any) between deterrence mechanisms 1, 5, and 6 and the evaluation criteria.

Problems with this approach have been outlined previously in an evaluation of the Random Breath Testing (RBT) initiative in Victoria during 1989-91, where the feasibility of dissociating the effects of enforcement and publicity was discussed (Cameron, Cavallo & Sullivan, 1992). These include the statistical problems of collinearity between the measures and between the measures and other influences, the appropriate representation and quantification of the mechanisms within the model (eg. does a measure of enforcement, such as number of TINs issued, represent its effects on the public and therefore does this provide a fair test of its relationship with crashes?), and the possible non-linear relationships between the mechanisms and crash risk.

In addition, some of the mechanisms which may act to influence speed behaviour, would also at the same time be measures of behavioural change: eg. the level of TINs issued reflects both the mechanism influencing speed behaviour, and if the program is successful, an outcome indicator. The modelling of variables which could be **both** measures of treatment (independent variable) and of response to treatment (dependent variable) as independent variables, will diminish the power of this approach, particularly for later periods in the intervention when driver responses, if any, are most likely to be manifested in such measures.

The advantage of this approach is that it allows the form of the program to be directly represented in time by the changes and variations in intensity of the respective elements of the program, thus the variations in the program can be tested against changes and variations in crash risk. The difficulty is validly representing the form of the program, and the reliance on available quantified measures of the program for the model.

3. Localised effects in time and space related to speed camera operations

As noted earlier, the likely distribution of effects of the enforcement is not known. There are good reasons for testing, however, effects in varying times and areas related to the times and locations of operations. One of the most compelling reasons to do this is the transient nature of the target behaviour, that is, drivers can very quickly vary their travel speeds in response to a number of factors, including perceived enforcement presence (whether based on seeing operations, previous experience of enforcement at a location via receipt of a TIN, warnings from other drivers, or familiarity with and predictability in camera deployment).

The question is how long and how far are these effects maintained, because the greater the suppression of high risk travel speed, the greater the chance of decreasing speed related crashes and/or decreasing the severity of crashes which do occur. Operations which maximise the 'suppression' will achieve the greatest effects, and hence recommendations can be made for optimising enforcement strategies.

The advantage of this approach is that it provides the most definitive assessment of the cause-and-effect connection of the program if effects are found, compared with phases 1 and 2. This is because effects can be directly linked to the cause (operations) and by definition, generalised effects cannot occur if there are no local effects. The added advantage of this detailed analysis is that the effects of the program over time may be determined.

This approach, however, relies on knowledge of speed 'suppression' distributions across locations and times of driving, which is currently lacking, although some indications can be found from research into different speed enforcement techniques in different settings. Additionally, the selection of an appropriate research design could also pose problems (as has been the case for all phases of this evaluation), particularly the selection of appropriate comparison or untreated crash subsets.

This phase will be completed during 1993.

6.0 PHASE 1: EVALUATION OF GENERAL CRASH EFFECTS

6.1 TEMPORAL STRUCTURE OF CRASH DATA CORRESPONDING TO THE PROGRAM

As noted in Section 4.0, the program to date has been characterised by three distinct periods[1]:

T1a a period of low level camera trialing and localised low level publicity from December 1989 to March 1990,

T1b a period characterised by a high profile media launch of speed cameras and intensive publicity relating to speed-related crash risk, but little speed camera enforcement (ie. after an intense 9 day burst of camera use, negligible levels of speed camera use, offence detection and hence TINs issued) between April and late June 1990,

T2 the subsequent period in which enforcement increased dramatically, and thus also the detection and punishment of speed offenders, and was maintained at high levels, as was supporting publicity starting from July 1990 onwards.

Periods T1a and T1b essentially represent an introductory period prior to the large changes in speed enforcement practises, and as such is a "one-off" occurrence for the program. The T2 period had to be divided into the time between July 1990 and February 1991 (T2a) and March to December 1991 (T2b), to enable the most valid estimates of effect to be determined, for reasons outlined in section 6.5.2.

6.2 SPATIAL STRUCTURE OF CRASH DATA CORRESPONDING TO THE PROGRAM

Speed cameras have been used to a different extent in the Melbourne metropolitan area and rural areas in the State, and to differing extents on different zoned roads (section 4.0), which may or may not correspond to relative driver exposure (distance travelled) in these zones. Therefore, analyses were undertaken for each of the following treated areas:

↗ arterial roads (all zones)
Melbourne
↗ ↘ arterial roads (60 km/h zones)
Victoria
↘ ↗ arterial (open) roads (100km/h)
Rural Victoria
↘ roads in rural towns (60 km/h zones)

---

[1] The periods identified are based, more or less, on the presence or absence of parts of the package, ie publicity or enforcement. Further distinctions of qualitatively and quantitatively different program periods could be identified, however, the evidence for these in the data is not great and the assumptions would need to be made that differing amounts of enforcement and/or publicity (eg. 1,500 hours per month as opposed to 2,000 hours per month of camera operation) result in different outcomes or effects.

6.3 HYPOTHESES

Phase 1 of the evaluation study aimed to test and quantify the following hypotheses relating to the introduction of the speed camera program:

(a) a change in the evaluation criteria in Melbourne and the rest of Victoria (separately) and Victoria (as a whole) during T1a, T1b, T2a and T2b

(b) a change in the evaluation criteria on arterial roads (all speed zones) in Melbourne during T1a, T1b, T2a and T2b

(c) a change in the evaluation criteria on arterial roads zoned 60km/h in Melbourne during T1a, T1b, T2a and T2b

(d) a change in the evaluation criteria on rural open roads (zoned 100 km/h) during T1a, T1b, T2a and T2b

(e) a change in the evaluation criteria in country towns (60km/h zones) during T1a, T1b, T2a and T2b

(f) a relative change in the evaluation criteria on arterial roads in Melbourne relative to residential streets in Melbourne during T1a, T1b, T2a and T2b

The hypotheses are all bi-directional and hence two-tailed significance tests were applied throughout the study, as there is no precedent of such a program and therefore research establishing any directional effects of the program.

6.4 EVALUATION CRITERIA

The possible dual role of vehicle speed in crash occurrence and crash outcome (injury severity) indicated in previous studies required that both aspects be assessed as possible outcomes of the program.

Crashes reported to Police in Victoria were used in the study. Casualty crashes only were examined. Property-damage-only crashes were not included in the analysis since they have not been coded since January 1991, and prior to this only approximately 20% were actually reported to Police. Thus, property-damage-only crashes may not be representative of all such crashes in the population. Casualty crashes consist of fatal crashes (those in which one or more persons is killed), serious injury crashes (those in which one or more persons is seriously injured and probably admitted to hospital) and minor injury crashes (in which one or more persons requires medical treatment).

Casualty crash frequency

Changes in the frequency of casualty crashes (defined above) as a whole were assessed.

Although it would be more desirable to have a measure of the incidence of speed-related crashes over time, it was not possible to identify speed-related and non speed-related crash types (Appendix A). The consequence of using all casualty crashes for this criterion is the possible dilution of effects if speed-related crashes are only a small sub-set of all casualty crashes, making detection of an effect more difficult under this scenario. It is not clear, however, how large the target group of crashes might be and therefore whether this is a problem for the analysis. On the other hand, the arbitrary grouping of crashes into speed-related and non speed-related categories could result in incorrect categorisation and therefore an incorrect target group for assessment.

Casualty crash injury severity

The change in the injury severity of crashes was assessed by testing for changes in the relative proportion of crashes in each of the police reported crash severity levels of:

1. crashes which resulted in one or more fatalities or one or more persons admitted to hospital or seriously injured (serious casualty crashes)

2. crashes resulting in one or more persons with minor injury (minor injury crashes)

The ratio of fatal plus serious injury crashes to crashes involving minor injury only was used as the dependent variable representing crash injury severity.

Fatal and serious injury crashes were combined because of the lower numbers (statistically) of fatal crashes. If the program was successful, fewer crashes resulting in death or serious injury over time should have occurred.

6.5 RESEARCH DESIGN

The estimated percentage change in the evaluation criteria (casualty crash injury severity and casualty crash incidence) in each area described in section 6.2 during each of the post-intervention periods (T1a, T1b, T2a, and T2b) was adjusted by the parallel estimated percentage change in the comparable area in New South Wales (comparison areas) for the same periods. Taking into account parallel changes in comparison areas is a method for excluding the effects of extraneous influences on the evaluation criteria in the treatment areas, so that estimates reflect the impact solely of the program.

Multivariate time series models for each of the crash measures were developed for each of the treatment and comparison areas, so that the changes during each of the post-intervention periods of the initiative could be estimated for each series.

Percentage changes in each area could then be contrasted allowing the ***net percentage changes*** in each treatment area to be estimated. The net change provided an estimate of the percentage change in each of the crash measures that is attributable to the speed camera program.

6.5.1 Time series analysis

The time series method can control for long term trends, seasonal cycles and other regular patterns in the outcome variables. Road safety measures which have gradually decreased high risk factors related to the incidence and severity of crashes (eg. gradual decreases in drink driving, seat belt non-wearing, and excessive speeding; safer vehicles, improved road environments and traffic management) are represented as longer term, "smooth" trends in crash criteria over time. Such trends in a crash series were taken into account through a trend component in the time series models. This eliminated the need to include specific measures of such variables in the models to take them into account, and allowed a better assessment of the real effect of a new or abrupt change to the crash series in time.

The aim of the modelling process was to develop models that closely fit the number and severity of casualty crashes over the period January 1983 to December 1991, for each series (treatment and comparison areas), and to estimate the relationships between the variables in each model and the crash criteria.

6.5.2 Confounding factors

RBT in Victoria

The almost simultaneous introduction in Victoria of the RBT initiative late in 1989 meant that the effect on crashes of the two initiatives could confound estimations ascribed to the speed camera program only. RBT operates and targets crashes in high alcohol times (generally night-time) when 38.4% of serious casualty crashes (fatal and serious injury crashes) are alcohol related. Serious casualty crashes in low alcohol times (daylight hours) only include 4% where alcohol is a factor. Low alcohol times of the week are defined as Monday - Thursday 6am to 6pm, Friday 6am to 4pm, Saturday 8am to 2pm, and Sunday 10am to 4pm (Harrison, 1990).

The majority of speed camera sessions have been in daylight hours, although there was some overlap with high alcohol hours (17.6% averaged across the whole week) particularly on weekends when high alcohol times start earlier (around 50% in high alcohol hours). It is not known if driver responses to speed cameras (if any) are limited to their times of operation or whether speed behaviour has also been modified at night (which is encompassed by high alcohol times). Although there is yet no evidence for generalisation of behaviour beyond specific times and locations of speed enforcement, the current program is very different to previous enforcement programs.

Whilst it would have been desirable to estimate the effects (if any) of the program for crashes at night, it is only possible to do this for low alcohol hour crashes, when RBT effects are considered to be minimal. The proposed analyses are therefore limited to casualty crash severity and incidence in low alcohol hour times (42% of all times of the week).

Speed Cameras in NSW

Speed cameras were introduced in NSW in March 1991, although the use of cameras was different from their deployment in Victoria. This meant that the use of NSW as a comparison area for estimating the absolute effects in Victoria beyond this period was not possible. Therefore the proposed analyses are separated into comparisons of the T2 period between July 1990 and February 1991 (T2a) and March to December 1991 (T2b). T2b represents an estimation of the effects in Victoria over and above the effects of 'other factors' as well as the effects (if any) of the speed cameras in NSW.

6.5.3 The role of interstate comparisons

The interstate comparison areas provided a form of 'control' for the influence of other factors that may have also affected the crash measures in this period. The assumption made is that the changes in the comparison areas represent the effects of 'other factors' on the target crashes in the treatment areas, so that changes in comparison areas can be used to estimate the changes that would have occurred in treatment areas in the absence of the treatment (ie. the speed camera program).

Such interstate comparisons cannot provide perfect control since economic and other factors are not identical in both areas. However, it provided the best available comparison area for a post-hoc evaluation design of a pervasive Statewide intervention (whose effect has been conceptualised at the broadest area-wide level) for this phase of the evaluation.

New South Wales was considered the most appropriate comparison State for Victoria because it is the most comparable in terms of urbanisation, economic activity, population, size and other characteristics than other Australian States. If there are statistically significant reductions in NSW comparison areas for the periods being contrasted, however, it would be difficult to determine whether these in fact reflect the effect of other factors or whether they represent the effect of other (road safety) countermeasures in that State. Therefore, its adequacy as a comparison area is difficult to assess.

An examination of the availability of information on the major factor influencing crash levels, exposure to crash risk generally, prior to and during the intervention period was made for Victoria and NSW. This factor was considered to confound the role of NSW as a comparison area and so a proxy measure (unemployment rate) was introduced as a covariate in the multivariate time series models (see section 6.5.4).

6.5.4 Covariates-controlling for exposure using economic indicators

It was considered necessary to include a measure of driving exposure during low alcohol hours (essentially day time) in the models fitted for Victoria and NSW so that possible differences in the two States would be taken into account. It is well established that driving exposure is directly related to crash risk, and it was considered that although the interstate comparison provides some level of control for national changes in travel exposure, the different economic changes in the two States (eg. higher unemployment rate in Victoria compared to that in NSW since 1990) may have led to a greater reduction in vehicle travel in Victoria than in NSW.

Unfortunately, direct measures of total vehicle travel, or vehicle travel for different times of the day and days of the week (eg. through traffic counting programs) over time for the areas of interest were not available.

However, correlates with total vehicle travel such as fuel sales (Lambert, 1992) and unemployment figures (ABS, 1991,a) were available. Fuel sales data has been adjusted by fuel consumption rates and corrected to equate with the Australian Bureau of Statistics triennial Survey of Motor Vehicle Usage (ABS, 1991,b) to give an estimate of total travel in each State (Lambert, 1992). This estimate is only available on a Statewide basis whereas unemployment figures are available for metropolitan and rural areas separately. Both are gross measures and the extent to which they reflect vehicle travel for particular times of the day and week is not known. However, low alcohol times correspond to commuter travel times and would make up the bulk of total vehicle travel, making the use of gross proxy measures of total travel for low alcohol time exposure appropriate. In addition, previous research both in the United States (Partyka, 1984) and Victoria (Thoresen, Fry, Heiman & Cameron, 1992) has demonstrated significant correlational relationships between overall fatalities and unemployment measures over time.

An examination of the data for Victoria and NSW shows that the trends in estimated total vehicle kilometres travelled since 1983 for the two States were essentially parallel, increasing until 1990 when Victorian travel appears to decrease whilst travel in NSW remains steady (Figures 3 & 4). Similarly, unemployment rates for Melbourne and Sydney

(Figures 5 & 6), rural areas for both States (Figures 7 & 8), and the total State (Figures 9 & 10) showed decreasing parallel trends over time until late 1989/1990 when rates in both States increased and those for Melbourne and rural Victoria overtook those in Sydney and rural NSW, respectively.

These differences in trends in both estimated total travel and unemployment rate just prior to and during the intervention period suggest that there could be differences in changes in low alcohol hour travel between the two States. It was decided to include unemployment rate as a covariate for each time series developed to control for the differential effects of this factor in the treatment and comparison areas. This measure was preferred to estimated total vehicle travel, given its availability for the metropolitan and rural areas of each State, providing more specific control for the two different types of areas.

Figure 3
Estimated Total Vehicle Kilometres Travelled
(from Fuel Sales Data)
Victoria v. NSW

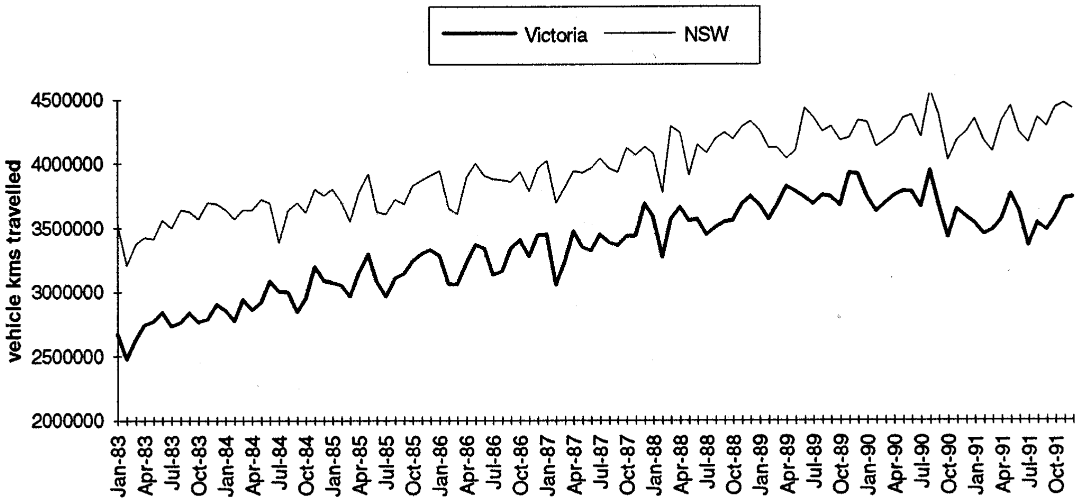


Figure 4
Estimated Total Vehicle Kilometres Travelled
(from Fuel Sales Data) 12 Month Moving Averages
Victoria v. NSW

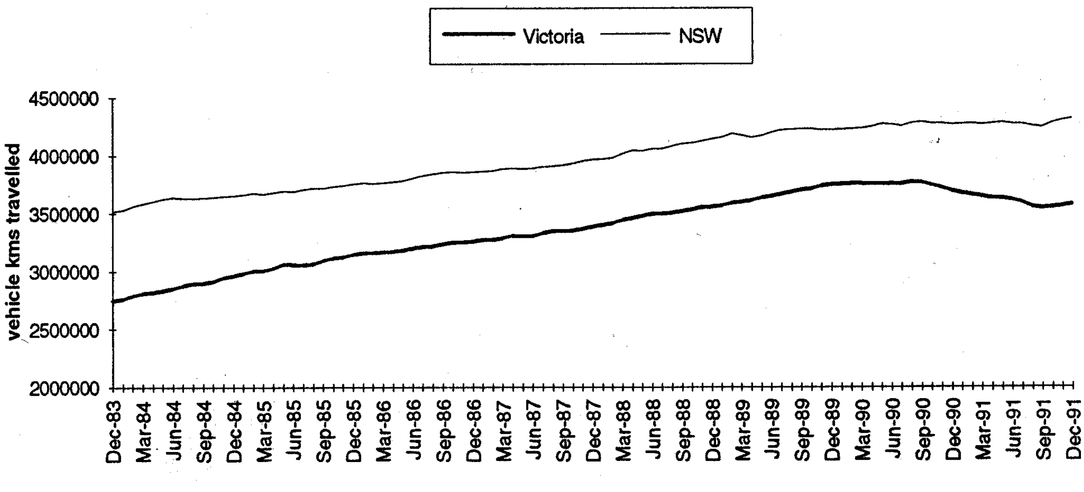


Figure 5
Unemployment Rates - Melbourne v. Sydney

Sydney — Melbourne

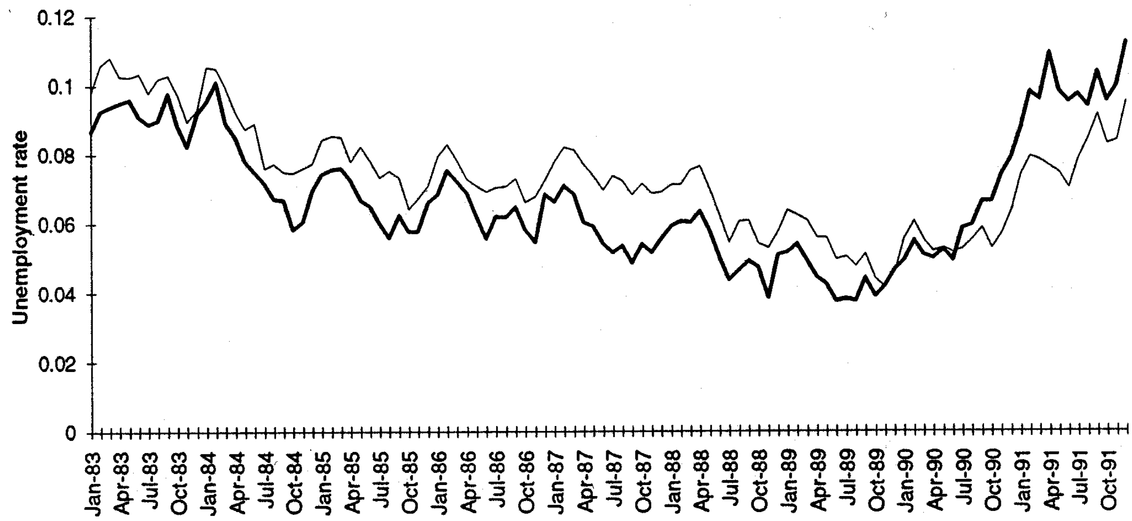


Figure 6
Unemployment Rate - Melbourne v. Sydney
12 Month Moving Averages

Sydney — Melbourne

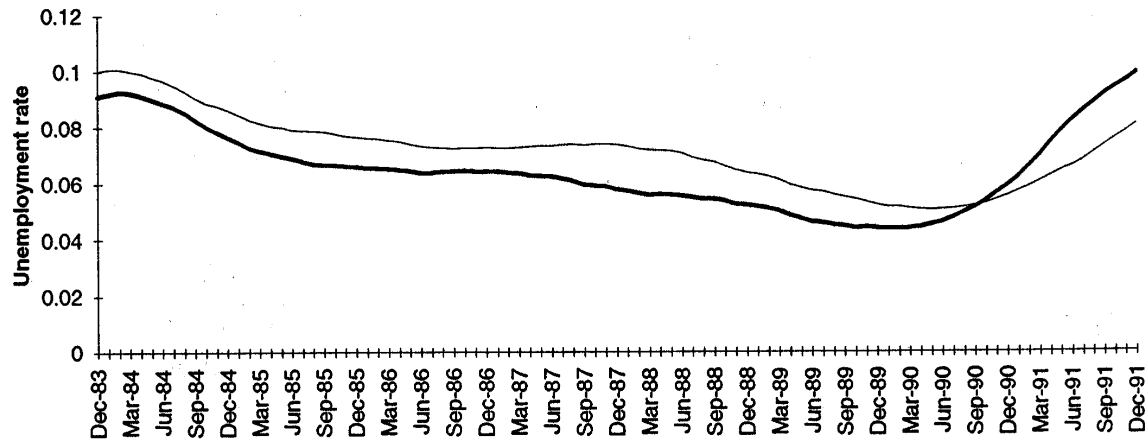


Figure 7
Unemployment Rates - Rural Victoria v. Rural NSW

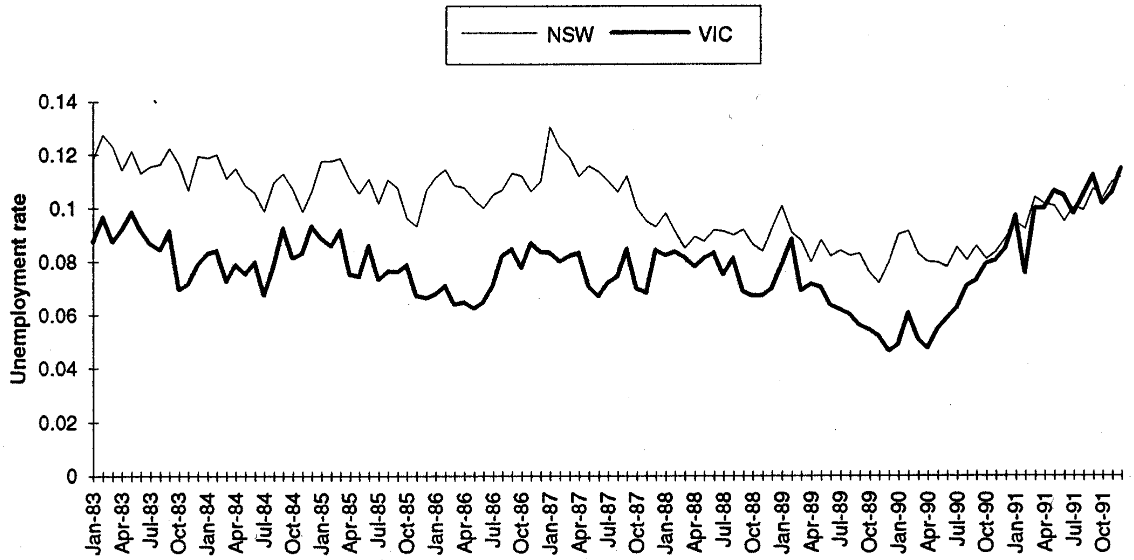


Figure 8
Unemployment Rates - Rural Victoria v. Rural NSW
12 Month Moving Averages

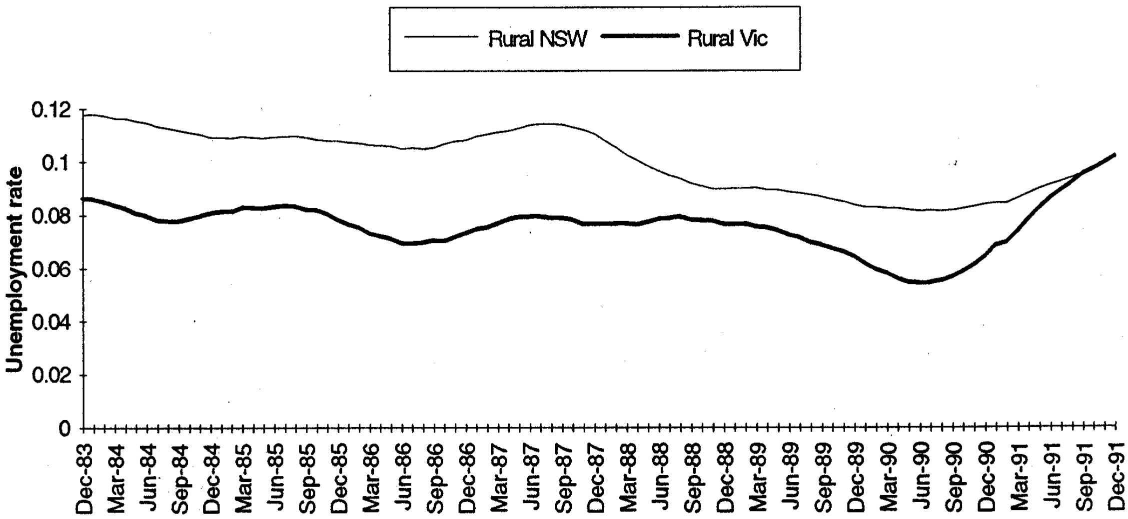


Figure 9
Unemployment Rates - Victoria v. NSW

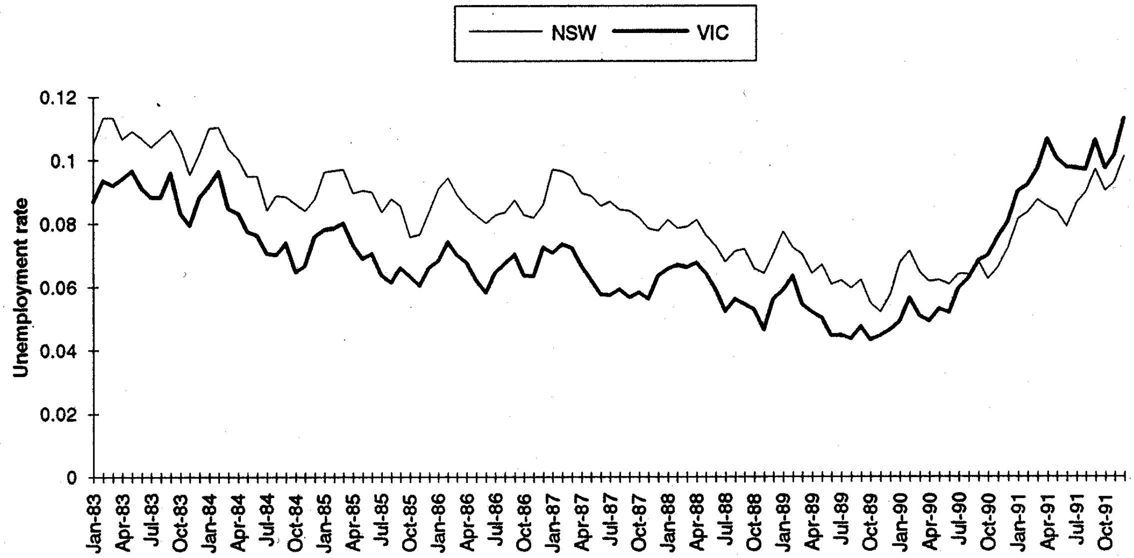
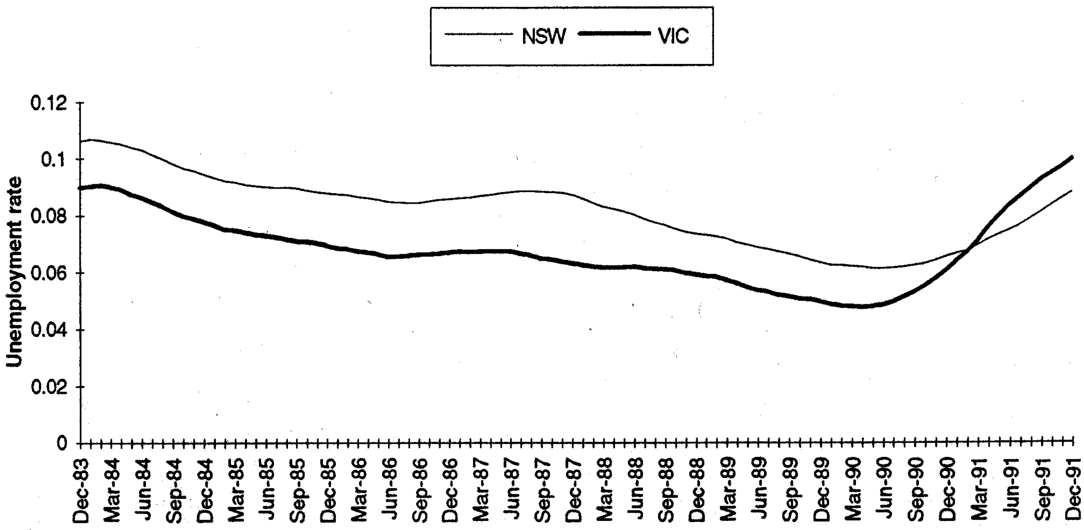


Figure 10
Unemployment Rates - Victoria v. NSW
12 Month Moving Averages



The correlation coefficient between estimated total travel and total unemployment rate in Victoria was -0.52 and in NSW was -0.69. Significant correlations (between -0.3 and -0.7) were also found between Statewide vehicle travel and unemployment rates for metropolitan and rural parts of each State over the time period to be used in the time series modelling, with higher correlations in NSW areas (Appendix B).

Unemployment rate provided the higher correlations than number of unemployed persons. It was decided that unemployment rate was the more appropriate measure, controlling for fluctuations in the numbers in the labour force at any one time. Unemployment numbers were highly correlated with rates which means that either measure could be used without changing analysis outcomes. A study of correlations between total estimated travel and unemployment rate with various lags incorporated, showed that zero lag provided the best correlation between the two measures.

The assumption made in introducing an exposure measure (such as unemployment rate) as a covariate is that the differences in patterns and levels of total vehicle travel and unemployment rate in the two States are large and important enough to have a different degree of impact on crash risk over the intervention period.

The second assumption made in using a global measure of exposure (unemployment rate in this study) is that this reflects the changes in exposure over time during the low alcohol hours of the week. The relationship between unemployment and travel patterns for different times of day and days of the week is uncertain. Previous research linking unemployment and fatalities does so globally, that is for all times and not for a subset of times.

6.6 TIME SERIES METHODOLOGY FOR MODELLING CRASHES

All models were undertaken using a monthly time series because monthly data only were available for unemployment to be included in the modelling.

6.6.1 Casualty crash frequency

The time series data were modelled using a form of ARIMA (Auto Regressive Integrated Moving Average) modelling known as *Intervention Analysis* (Box and Tiao, 1975) and multiple regression models.

ARIMA models

This method allows the use of covariates in models that make use of ARIMA techniques to represent trend and seasonality. The ARIMA methodology provides a general method for estimating a wide range of seasonal effects. A variety of trend and other recurring patterns can also be modelled by ARIMA. A sufficient number of data points were available for this type of modelling (a minimum of 5-6 seasons, or 60-72 observations, are required for multivariate ARIMA and multiple regression models [Makridakis, Wheelwright & McGee, 1983] and in the current study 108 observations are available for the years 1983-1991 inclusive).

The approach used was similar to that used by Wagenaar, Streff & Schultz (1990) in estimating the effects of raising the speed limit, from 55 to 65 mph, on Michigan's rural interstate highways. In order to estimate the effect of the intervention, a series of step functions, represented by dummy variables with values 0 (no intervention) and 1 (presence of the intervention) for appropriate months, were used in the model.

-Treatment of covariates

The data series to be modelled covered the period from January 1983 to December 1991 with the intervention beginning in December 1989. Since the intervention took different forms over the two year period (see section 6.1), it was decided that four dummy variables would be used to cover different parts of that period, so that the effects in each period could be estimated. The four dummy variables used for this purpose were for the periods:

- December 1989 to March 1990 (T1a)
- April to June 1990 (T1b)
- July 1990 to February 1991 (T2a)
- March to December 1991 (T2b)

Before developing the ARIMA models, the correlations between independent variables and between these and the dependent variable were examined (Appendix B). It was found that low alcohol hour casualty crashes correlated negatively with unemployment rates in Victoria (-0.73), Melbourne (-0.73), and rural Victoria (-0.44) but no significant correlation in the NSW areas.

Low to moderate significant correlations were found between unemployment rate and the four intervention variables, particularly for the T2b variable and unemployment rate in the Victorian areas (correlation 0.5). The reliability of the modelling procedure to provide valid estimates of effects of each variable (parameter estimates) relies on the condition that the variables are essentially uncorrelated; there is some indication that they are not. The modelling procedure also provides correlations between parameter estimates; these will be reviewed with the results in order to establish any intercorrelation problems.

-Model structure

It has been found in the past that, in part because of the nature of crash numbers being counts of events, that multiplicative models best model crash data (Hakim, Shefer, Hakkert & Hocherman, 1991; Thoresen et al, 1992). In order to fit multiplicative models, natural logarithms of the dependent variable, covariates and independent variables were taken.

The dummy variables were defined as "1" ($\log_e 1 = 0$) in the non-intervention period and the exponential constant "e" ($\log_e e = 1$) in the intervention period.

The modelling process began with the identification of univariate ARIMA models of the casualty crash data, for the **pre-intervention period** (January 1983 to November 1989), in each of the treatment and comparison areas. This was accomplished in two stages. The first stage involved the analysis of autocorrelation and partial autocorrelation functions to estimate possible models. The next stage required the over fitting of those models followed by model reduction to arrive at the best model for each set of crash data.

The models identified for each of the six areas all required seasonal components. Models with non-seasonal components were not selected. This is because a model structure with a non-seasonal component might be best for making predictions, but it was considered inappropriate for explanatory models covering the post-intervention period. The purpose of the covariates in the models was for them to describe the post-intervention changes.

It was also considered necessary for all models to be identical in structure so that the results would be consistent and comparable. The resultant model structure decided upon was the seasonal ARIMA (0,0,1) $(0,1,1)^{12}$ model. In all cases, this ARIMA structure was found to be the closest or the next closest fit.

The final models were ARIMA (0,0,1) $(0,1,1)^{12}$ with unemployment rate and intervention variables for T1a, T1b, T2a, and T2b included as covariates.

Multiple regression models

ARIMA models with Intervention Analysis are appropriate for estimating changes up to 12 months after the beginning of the intervention. Beyond this the model takes account of 1990 changes in the number of crashes. Thus the estimated impact of the program during T2b (and to some extent T2a), using this approach, could be under-estimated if the initiative was effective during 1990. Multiple regression provided an alternative technique to model the data in order to estimate the T2b change, and also to validate the estimates for the earlier intervention periods.

In keeping with the previous ARIMA modelling, a multiple regression model with a multiplicative structure was developed for each crash series. This was achieved, again, by taking natural logarithms of each variable in the model. The dependent variable in each model was again the number of casualty crashes in low alcohol hours while the independent variables in the regression equations were made up of:

- a linear trend component
- monthly dummy variables (to represent seasonality)
- the unemployment rate
- a dummy variable for December 1989 to March 1990 (T1a)
- a dummy variable for April to June 1990 (T1b)
- a dummy variable for July 1990 to February 1991 (T2a)
- a dummy variable for March to December 1991 (T2b)

6.6.2 Casualty crash injury severity

Logistic (multiple) regression models of casualty crash severity (in low alcohol times) were developed for each treatment and comparison area from January 1983 to December 1991.

Casualty crash severity was represented as the ratio:

$$\frac{\text{fatal \& serious injury crashes}}{\text{minor injury crashes}}$$

in order to determine whether crashes have become less severe, corresponding to the intervention periods. The same covariates were initially used in these analyses as those for casualty crash frequency. Intercorrelations between parameter estimates were examined and new models without some covariates developed. Some of the final models exclude the trend covariate.

6.6.3 Net effects in treated areas relative to respective comparison areas in NSW

Estimated percentage changes in the crash criteria associated with the periods of the initiative were calculated for each of the treated and comparison areas. The final step was to estimate the net effect for treated areas by calculating the differences between the respective treated and comparison areas. To do this the Victorian percentage changes in each intervention period were discounted by the corresponding NSW percentage changes for the same periods. (The NSW percentage change represents the effect of other factors not included in the models, and assumed to operate equally in Victoria). Confidence intervals for the net percentage change were also determined. The method for these calculations is illustrated in Appendix C.

6.6.4 State-wide analysis: unemployment rate vs. vehicle travel covariate

In both the ARIMA and regression modelling for casualty crash frequency (in low alcohol times), the State-wide Victorian and NSW models were used to validate the use of the unemployment rate as an indicator of vehicle travel. Two models were fitted for each State with one using estimated travel (based on fuel sales) and the other using the unemployment rate. The results obtained were virtually identical for models of casualty crash frequency regardless of whether estimated travel or unemployment rate was used. There were some differences for models of casualty crash injury severity depending on whether unemployment rate or travel was used. These are presented in Appendix D.

6.7 RESULTS

The results of each model and the net effects for each comparison are shown in Appendix E. The output from each model and corresponding diagnostic information is presented in Appendix F.

The following sections present the estimates of the effects of the speed camera program for the intervention periods on the frequency and injury severity casualty crashes (in low alcohol times) in the various treated areas.

Figures 11 and 12 below show the actual and fitted values of the two crash criteria in each month of 1983-91, for Victoria as a whole.

Figure 11
Number of Casualty Crashes in low alcohol times
Victoria

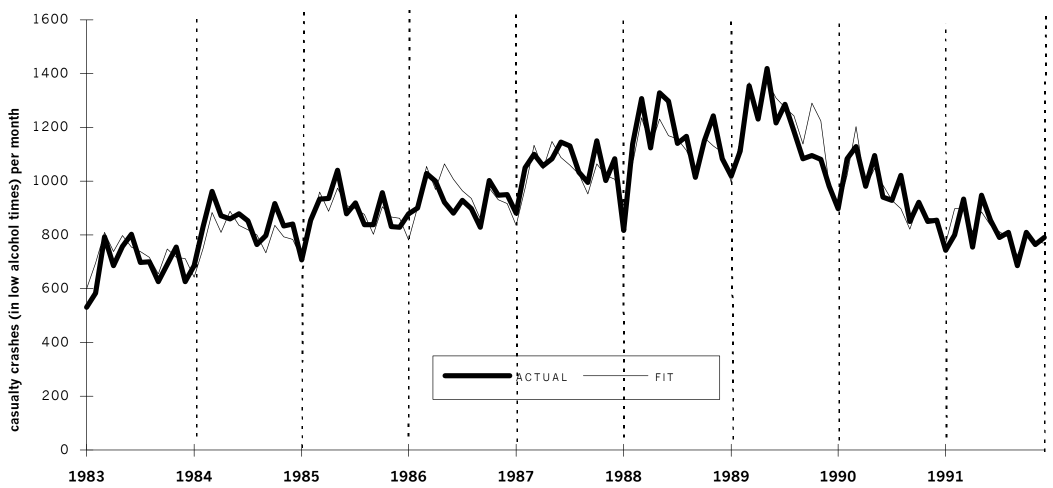
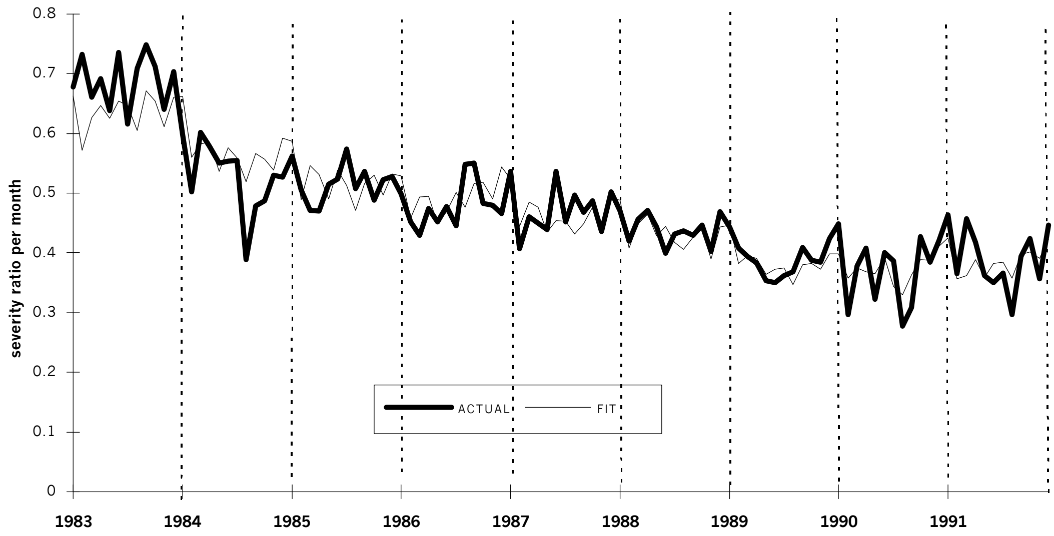


Figure 12
Casualty Crash Severity in low alcohol times, Victoria
(ratio of fatal & serious injury crashes to crashes involving minor injury only)



6.7.1 Effects on casualty crash frequency

Figure 13 shows the actual values of the frequency of casualty crashes (in low alcohol hours) in each month of 1983-1991, for Victoria as a whole. This Figure also shows the expected post-intervention trends (from the models) if the speed camera program had not been introduced. Two expected trends are displayed; one based on the model for Victoria, excluding the effect of other factors not implicit in the model, and the second trend including the effect of other factors, as measured by the experience in NSW. The difference between the expected trend (including other factors) and the actual represents the apparent effect of the program.

Figure 13
Number of Casualty Crashes per month in low alcohol times 1983-1991
Victoria

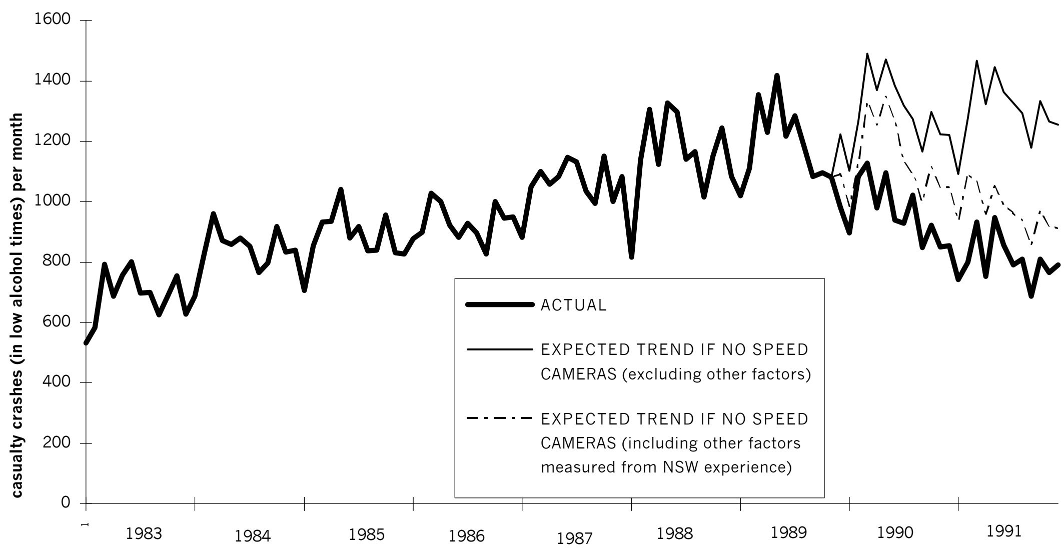


Table 4 shows the estimates of the net effects for each intervention period, after discounting changes in the Victorian areas by changes in the respective NSW areas, and after controlling for differential changes in unemployment rate. The changes in NSW were used to estimate the changes that would have occurred in Victoria had the intervention not taken place.

Area-wide effects

The pattern of results for the ARIMA and regression models are similar, particularly for estimates of T1a and T1b in Victoria and Melbourne. Confidence limits are also of similar magnitude for all estimates, except for T2b in Victoria and Melbourne which are larger (expectedly) for the regression models. Confidence intervals are of similar magnitude for all intervention estimates for ARIMA and regression models for rural Victoria. As noted in section 6.6.1, estimates for T2b would be larger for regression models than ARIMA models providing estimates which are not influenced by any earlier changes. For this reason, results for T2b are taken from the regression models. Results for T1a, T1b and T2a are taken from the ARIMA models, given the assessment of the efficacy of the models outlined below. Bolded figures in Table 4 refer to the results from the preferred models.

The netted percentage changes show that there were statistically significant reductions in low alcohol hour casualty crashes in T1b (April 1990) and T2a (July 1990) in Melbourne, rural Victoria and the whole of the Victoria coinciding with the major launch of the program and the increase in speed camera enforcement. The reductions were of the order of 20%. There was also a statistically significant reduction in T2b in rural Victoria only, although the wider confidence limits for T2b estimates in Melbourne and Victoria indicated that it was not possible to provide precise estimates in these areas. T2b represents the effects of the Victorian speed camera program over and above any effects of the program operating in NSW, and does not provide an estimate for the net effect of the Victorian program per se.

Effects on arterial roads and by speed zone

The pattern of results for the ARIMA and regression models were again similar. Confidence limits for all intervention estimates were generally larger for the regression models, particularly for T2b estimates, in spite of the fact that the regression models tended to fit the data series better.

The netted percentage changes show that there were statistically significant reductions in low alcohol hour casualty crashes in T1a, T1b, and T2a, but not in T2b, on all arterial roads and specifically on 60 km/h arterial roads in Melbourne compared with those in Sydney. In T1a the reduction was around 13%, whilst much higher reductions of around 30% were observed in T1b and T2a.

No statistically significant effect was observed on arterial roads compared to residential streets in Melbourne (although the estimate of a 9% reduction in T2a approached statistical significance). The individual models for the two road types indicate that there reductions on both arterials and residential streets. This relative comparison can be interpreted in two ways; either the program's effects extended to residential streets (although speed cameras did not operate in these streets) or the change in residential streets do not reflect the effects of the program but the changes in casualty crash risk in this period due to other influences. Without supporting evidence of speed behaviour monitored over time in residential streets, it is not possible to determine which interpretation is correct.

Open rural 100km/h roads in country Victoria experienced a 14% drop in low alcohol hour casualty crashes in the T2a period only, whilst in 60 km/h country zones (country towns) there were statistically significant reductions in the T1b (21%), T2a (23%) and T2b (37%) periods. This pattern of results appears to follow the amount of speed camera use in country areas where the vast majority (around 80-90%) of sessions were conducted in 60 km/h zones.

Table 4 Estimated net effects on the frequency of casualty crashes in treatment areas

TREATMENT AREA	ARIMA MODEL (with unemployment rate, no constant)		REGRESSION MODEL (with unemployment rate)	
	Net effects	95% C.I. [a]	**Net effects**	**95% C.I. [a]**
Victoria				
T1a	**- 8.0% ns**	-16.9% ~ + 2.0%	- 9.7% ns	-19.0% ~ + 0.8%
T1b	**-20.1% ***	-29.2% ~ - 9.8%	-22.2% *	-31.3% ~ -11.8%
T2a	**-20.9% ***	-27.9% ~ -13.3%	-17.9% *	-27.9% ~ - 6.6%
T2b	- 7.4% ns	-15.9% ~ +2.0%	**-15.6% ns**	-31.5% ~ +4.0%
Melbourne				
T1a	**- 7.0% ns**	-16.8% ~ + 4.3%	- 6.7% ns	-17.7% ~ + 5.9%
T1b	**-23.5% ***	-33.1% ~ -12.5%	-20.2% *	-31.1% ~ - 7.6%
T2a	**-21.1% ***	-28.9% ~ -12.4%	-12.7% ns	-25.4% ~ + 2.1%
T2b	- 4.5% ns	-14.3% ~ +6.6%	**- 3.3% ns**	-24.0% ~ +23.1%
Rural Victoria				
T1a	**- 3.7% ns**	-14.0% ~ + 7.8%	-12.8% ns	-24.3% ~ + 0.4%
T1b	**-16.4% ***	-27.4% ~ - 3.8%	-20.2% *	-31.6% ~ - 7.0%
T2a	**-19.5% ***	-27.5% ~ -10.7%	-20.4% *	-28.4% ~ -11.6%
T2b	-11.9% *	-21.1% ~ - 1.7%	**-27.7% ***	-37.3% ~ -16.6%
All arterials Melbourne vs all arterials Sydney				
T1a	**-14.6% ***	-23.6% ~ - 4.5%	-13.4% *	-23.8% ~ - 1.6%
T1b	**-33.8% ***	-42.2% ~ -24.1%	-27.4% *	-37.5% ~ -15.7%
T2a	**-32.4% ***	-38.8% ~ -25.3%	-23.2% *	-35.2% ~ - 9.1%
T2b	-10.6% *	-19.0% ~ - 1.3%	**-13.8% ns**	-33.8% ~ +12.3%
60km/h arterials Melbourne vs 60km/h arterials Sydney				
T1a	**-13.8% ***	-23.0% ~ - 3.4%	-12.7% *	-23.3% ~ - 0.6%
T1b	**-31.5% ***	-40.4% ~ -21.3%	-27.4% *	-37.7% ~ -15.4%
T2a	**-30.6% ***	-37.4% ~ -23.0%	-25.1% *	-37.0% ~ -11.0%
T2b	- 5.6% ns	-15.0% ~ + 4.7%	**-13.2% ns**	-33.8% ~ +13.8%
All arterials Melbourne vs residential streets Melb.				
T1a	**- 1.6% ns**	-14.6% ~ +13.3%	+13.4% ns	- 2.5% ~ +32.0%
T1b	**- 3.2% ns**	-18.5% ~ +14.9%	+ 2.1% ns	-14.9% ~ +22.5%
T2a	**- 9.1% ns**	-19.8% ~ + 2.9%	+ 1.7% ns	-19.6% ~ +28.8%
T2b	- 0.1% ns	-11.8% ~ +13.7%	**+16.2% ns**	-18.8% ~ +66.2%
100 km/h roads Rural Victoria				
T1a	**+ 0.2% ns**	-14.4% ~ +17.3%	-14.9% ns	-30.3% ~ + 3.0%
T1b	**- 8.1% ns**	-24.3% ~ +11.6%	-11.5% ns	-28.8% ~ + 9.9%
T2a	**-14.1% ***	-25.4% ~ - 1.1%	- 9.6% ns	-22.1% ~ + 4.9%
T2b	- 9.1% ns	-21.5% ~ + 5.2%	**-11.9% ns**	-28.0% ~ + 7.6%
60 km/h roads Rural Victoria				
T1a	**- 3.3% ns**	-15.0% ~ + 9.9%	- 2.6% ns	-17.9% ~ +15.5%
T1b	**-21.0% ***	-32.7% ~ - 7.3%	-23.0% *	-35.9% ~ - 7.4%
T2a	**-23.3% ***	-31.8% ~ -13.7%	-25.7% *	-34.6% ~ -15.7%
T2b	-17.8% *	-27.3% ~ - 7.0%	**-37.4% ***	-47.3% ~ -25.7%

[a] 95% C.I.- true reduction in casualty crash risk lies within the specified range with 95% confidence (ie. there is a 5% chance of the true reduction in casualty crash risk being outside this range)
** Statistically significant at $p< 0.05$ level ns not significant at the 0.05 level*
Bolded figures refer to the results derived from the preferred models for each intervention period

Efficacy of the models

An examination of the adjusted R^2 statistic for each of the final models (Appendix E) showed that in each case the regression models fitted better, as did all models for Victorian areas compared with the NSW areas for both ARIMA and regression models (higher adjusted R^2 values). Almost all models however, were of acceptable fit (adjusted R^2 values generally varied between 0.5 - 0.8). Examination of figure 11 shows a brief divergence between the model and the actual values in the third quarter of 1989. It has been suggested that 'Operation 100' Police activity and the high profile fatal bus crashes during that period could have been responsible for the lower number of crashes during this period than was expected by the model. These "one-off" events were not explicitly taken into account in the model because it is not possible to take into consideration every possible variable of interest, and their effect appear to be relatively brief as reflected by the convergence between the model and the actual data from late 1989.

The constant terms were removed for the final ARIMA models. This was because the correlations between the parameter estimates (see Appendix F) for the constant and unemployment rate was found to be extremely high (0.99) for metropolitan and rural models in both Victoria and NSW, and also for the Statewide models, which indicated that the two estimates were describing the same thing and that therefore the model had been overfitted.

An examination of the correlations between parameter estimates in the final ARIMA models (Appendix F) indicated that there were moderate but statistically significant correlations (between 0.35 and 0.5) between estimates for unemployment rate and intervention variables T1a, T1b, and T2a for Victorian and NSW models both Statewide and metropolitan and rural. It is assumed that the statistical technique was robust enough to cope with these intercorrelations and that therefore the estimates for the intervention variables are reliable.

A similar examination for the final regression models (Appendix F) revealed extremely high intercorrelations in all areas (Victoria, NSW, Melbourne, Sydney, rural Victoria and rural NSW) and between parameter estimates for unemployment rate, trend and the intercept, (generally 0.9). The estimates for unemployment rate, trend and the intercept were almost always highly correlated with estimates for intervention variables T2a and T2b, particularly T2b (generally around 0.8). These high intercorrelations suggest that the estimates given by these models for the intervention may be unreliable. Thus, although the regression models tended to fit the data series better, the higher intercorrelations between the estimates means that those provided by the regression models were more likely to be suspect compared with the ARIMA estimates.

It is interesting to note that, as reflected in the earlier correlations between variables, unemployment rate was not a statistically significant variable in models of NSW low alcohol hour casualty crashes, but was statistically significant in Victorian models of low alcohol hour casualty crashes. Statewide, total estimated vehicle travel in NSW appeared to be uncorrelated with low alcohol casualty crashes whilst in Victoria total vehicle travel was statistically related. This suggests that the relationship between exposure to risk and crash involvement is not always manifested, or that other factors are more important than this factor, or mediate its effect, in some places, or alternatively that the available measures are not adequate.

The primary purpose for including the unemployment rate covariate in the models was to improve the interstate comparisons to be made, by directly taking into account differences in changes in this measure in the two States. For the intra-Melbourne comparison between arterial roads and residential streets, the role of the unemployment covariate in this sense is redundant. However, given that unemployment rate was consistently found to be statistically significant in models of low alcohol hour casualty crashes in Victoria and its parts, it was included in the models for the intra-Melbourne comparison.

6.7.2 Effects on casualty crash injury severity

Figure 14 again illustrates the methodology for estimating the effects of the speed camera program. Shown are the actual values of the injury severity of casualty crashes (in low alcohol hours) in each month of 1983-1991, for Victoria as a whole. Two expected post-intervention trends (from the models) if the speed camera program had not been introduced are also shown; one based on the model for Victoria, excluding the effect of other factors not implicit in the model, and the second trend including the effect of other factors, as measured by the experience in NSW. The difference between the expected trend (including other factors) and the actual represents the apparent effect of the program on casualty crash injury severity (in low alcohol times).

Figure 14
Casualty Crash Severity per month in low alcohol times 1983-1991, Victoria
(ratio of fatal & serious injury crashes to crashes involving minor injury only)

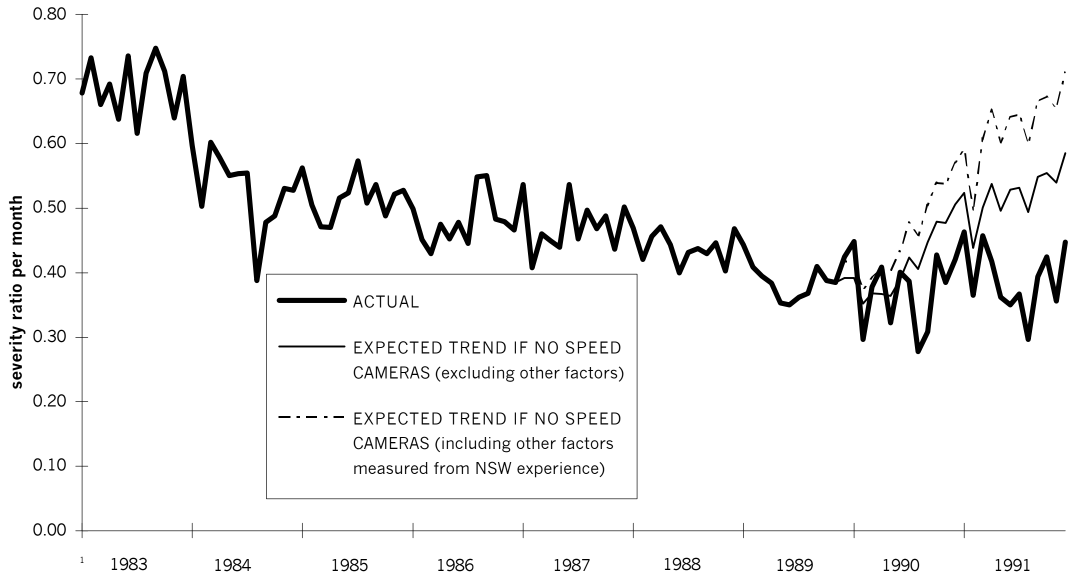


Table 5 shows the estimates of the net effects for each intervention period, after discounting changes in the Victorian areas by changes in the respective NSW areas, after controlling for differential changes in unemployment rate. The changes in NSW were used to estimate the changes that would have occurred in Victoria had the intervention not taken place.

Area-wide effects

There were statistically significant reductions in the severity of low alcohol hour casualty crashes in T2a (28%) and T2b (40%) in Victoria as a whole. Similarly, there were significant reductions in severity in Melbourne over each of the intervention periods, increasing in size over time (18% - 45%). In contrast no such reductions were observed in country Victoria, with a statistically significant increase in severity estimated in T1b (31%). The validity of these results are in question, however, given that the models fitted may be inadequate from a statistical perspective as outlined in the section below regarding the efficacy of the models.

Effects on arterial roads and by speed zone

Statistically significant reductions in the severity of low alcohol hour casualty crashes in all intervention periods (increasing from 22% to 48%) was observed for all Melbourne arterials, whilst reductions in T1b, T2a and T2b (increasing from 33% to 49%), but not in T1a, were observed on 60 km/h arterial roads in Melbourne.

A statistically significant effect was observed on arterial roads compared to residential streets in Melbourne in T2b only (19%), although the estimates for T1b and T2a appeared to approach statistical significance. The individual models for the two road types indicate that there were statistically significant reductions on both arterials and residential streets in T2a and T2b. The statistically significant reductions in residential streets in T2a and T2b can be interpreted in two ways; either the program's effects extended to residential streets (although speed cameras did not operate in these streets) or the change in residential streets do not reflect the effects of the program but the changes in casualty crash severity in this period due to other influences. Without supporting evidence of speed behaviour monitored over time in residential streets, it is not possible to determine which interpretation is correct.

Open rural 100km/h roads in country Victoria experienced no changes in the intervention periods, except for a significant 66% increase in low alcohol hour casualty crashes in T1b. In 60 km/h country zones (country towns) there were no statistically significant changes during the intervention periods.

Again, the validity of these results are in question given that the models fitted may be inadequate from a statistical perspective as outlined in the section below regarding the efficacy of the models.

Table 5 Estimated net effects on the injury severity of casualty crashes in treatment areas

TREATMENT AREA	LOGISTIC REGRESSION MODELS Net effects	95% C.I. ♠
Victoria *(including unemployment rate and trend)*		
T1a	**- 4.4% ns**	-17.7% ~ +11.1%
T1b	**- 9.5% ns**	-23.7% ~ + 7.5%
T2a	**-27.9% ***	-39.9% ~ -13.6%
T2b	**-40.3% ***	-55.4% ~ -20.1%
Melbourne *(including unemployment rate, no trend)*		
T1a	**-18.3% ***	-31.5% ~ - 2.6%
T1b	**-29.0% ***	-41.7% ~ -13.5%
T2a	**-35.2% ***	-42.6% ~ -26.9%
T2b	**-44.6% ***	-50.8% ~ -37.6%
Rural Victoria *(including unemployment rate and trend)*		
T1a	**+ 9.2% ns**	-13.2% ~ +37.4%
T1b	**+30.7% ***	+ 2.0% ~ +67.6%
T2a	**- 0.8% ns**	-16.3% ~ +17.6%
T2b	**+ 3.2% ns**	-18.1% ~ +30.1%
All arterials Melbourne vs all arterials Sydney *(including unemployment rate, no trend)*		
T1a	**-22.1% ***	-36.3% ~ - 4.7%
T1b	**-36.9% ***	-49.5% ~ -21.3%
T2a	**-37.1% ***	-45.0% ~ -28.0%
T2b	**-47.9% ***	-54.9% ~ -39.9%
60km/h arterials Melbourne vs 60km/h arterials Sydney *(including unemployment rate, no trend)*		
T1a	**-15.7% ns**	-32.5% ~ +5.3%
T1b	**-33.1% ***	-47.7% ~ -14.5%
T2a	**-38.4% ***	-46.9% ~ -28.5%
T2b	**-49.2% ***	-56.6% ~ -40.4%
All arterials vs residential streets in Melbourne *(including unemployment rate, no trend)*		
T1a	**-10.3% ns**	-31.5% ~ +17.4%
T1b	**-24.9% ns**	-44.5% ~ + 1.7%
T2a	**-16.0% ns**	-30.3% ~ + 1.3%
T2b	**-19.2% ***	-33.8% ~ - 1.5%
100 km/h roads Rural Victoria *(including unemployment rate and trend)*		
T1a	**+ 1.7% ns**	-27.7% ~ +43.0%
T1b	**+65.6% ***	+14.7% ~ +139.3%
T2a	**+ 8.4% ns**	-15.8% ~ +39.6%
T2b	**+15.3% ns**	-18.2% ~ +62.6%
60 km/h roads Rural Victoria *(including unemployment rate and trend)*		
T1a	**+14.4% ns**	-18.1% ~ +59.8%
T1b	**+15.4% ns**	-19.5% ~ +65.2%
T2a	**- 9.3% ns**	-29.1% ~ +16.1%
T2b	**- 7.3% ns**	-33.8% ~ +29.8%

♠ 95% C.I.- true reduction in casualty crash severity lies within the specified range with 95% confidence (ie. there is a 5% chance of the true reduction in casualty crash severity being outside this range)
**** Statistically significant at p< 0.05 level ns not significant at the 0.05 level***
Bolded figures refer to the results derived from the preferred models for each intervention period

Efficacy of the models

The confidence limits for net estimates in these models were wider than for those for casualty crash frequencies.

An examination of the adjusted R^2 statistic for each of the final models (Appendix E) showed that whilst the models developed for Victoria fitted well (R^2 values ranged between 0.45 - 0.78), the models for NSW areas were poor (adjusted R^2 values ranged between 0.01 - 0.48), particularly for Sydney models. The residential street model for Melbourne also fitted quite low (0.24).

An examination of the correlations between parameter estimates in all of the initial models fitted indicated that there were extremely high correlations (consistently around 0.9) between estimates for the unemployment rate, trend and intercept parameters for all the models. These 3 parameters were each also highly correlated with intervention variables T2a and T2b (0.8 - 0.9) for Victorian and Melbourne (area-wide, arterial and residential road) models and with T2b for all rural Victoria and NSW, Sydney and rural NSW models (area-wide and arterials) with correlations always between 0.7-0.9. These high intercorrelations suggest that the estimates given by such models for the intervention may be unreliable.

In order to improve these models, new models were fitted without the trend parameter. For the Melbourne and Sydney models the new models appeared to improve while State-wide and rural models did not. Therefore the final models adopted for Melbourne and Sydney excluded the trend parameter. The high intercorrelations between the intercept and unemployment parameters remained but these were no longer correlated with T2a and only moderately with T2b (0.55) for all Melbourne and Sydney models. The remaining high intercorrelations for these models and those for the other models may still affect estimates for the intervention estimates, and therefore these results are tentative.

The primary purpose for including the unemployment rate covariate in the models of casualty crash frequency was to improve the interstate comparisons to be made, by directly taking into account differences in changes in this measure (as a proxy for vehicle exposure) in the two States. However, there was no prior evidence for its importance in crash severity. Given that unemployment rate was found to be statistically significant in models of low alcohol hour casualty crash frequency in Victoria and its parts, it was included in all the models of casualty crash severity. It was found to be a statistically significant variable in Melbourne, Sydney and Victoria-wide models but not in rural or NSW-wide models of casualty crash severity, suggesting that increases in unemployment rate is associated with increases in the injury severity of crashes.

Its inclusion in models of casualty crash severity means that the estimated net effects are based on the premise that casualty crash severity (in low alcohol hours) would have increased in Melbourne and Victoria, given the increase in unemployment rate that occurred during the intervention period, had the speed camera program not been introduced. The estimated net effects therefore are not simply reflected in the actual trend in the casualty crash severity ratio over time.

The graphs of each data series (Appendix F), show that the recent trend in casualty crash severity in NSW is different to that in Victoria, with the severity of low alcohol hour casualty crashes increasing in the latter part of the series in NSW. This is reflected in the estimates of changes in NSW which indicate statistically significant increases in severity of rural NSW crashes in T2a (+12%) and T2b (+25%) and Sydney metropolitan crashes in T1b (+14%). In using NSW areas as comparison areas, it needs to be assumed that this would have been the trend in Victorian areas if the program had not operated. This needs to be kept in mind when judging these results.

6.8 DISCUSSION

The estimated effects for the various treated areas during the four intervention periods are summarised in Tables 6 and 7.

6.8.1 Frequency of casualty crashes (in low alcohol hours)

A consistent drop from what would have been expected in the **number of (low alcohol hour) casualty crashes** across all treated areas was observed for the periods corresponding to the publicity launch (T1b) and the increase in speed camera enforcement (T2a), except for 100 km/h rural open roads where there was a drop in T2a only. The largest of these reductions (around 30%) occurred on arterial roads in Melbourne. A smaller reduction (14%) during T1a was confined to Melbourne arterial roads only. Rural 60 km/h roads (and therefore rural Victoria as a whole) experienced a statistically significant drop relative to the respective rural NSW areas in T2b, when NSW also had a speed camera program operating.

6.8.2 Injury severity of casualty crashes (in low alcohol hours)

The Melbourne area (as a whole and on arterials roads specifically) experienced increasing reductions over time from what would have been expected in the **severity of (low alcohol hour) casualty crashes.** No changes were observed on 60 km/h rural roads, although 100 km/h rural roads and therefore the rural area as a whole experienced a substantial increase in casualty crash severity corresponding to the launch of the speed camera program (T1b). Given the different trends in the rural and metropolitan parts of the State, the averaged change for Victoria as a whole were significant reductions in the T2a (28%) and T2b (40%) periods.

It should be noted that the estimated percentage reductions in the injury severity of casualty crashes apply to the severity ratio defined earlier (page 19) and not to the more traditional measure of injury severity, namely the ratio of fatal plus hospitalisation crashes to all casualty crashes (ie. those involving death or any level of injury). The former ratio is likely to show larger changes than the latter; for example, the estimated 28% reduction in the Victoria-wide severity ratio during T2a is equivalent to a 21% reduction in the traditional measure.

These estimated net effects on casualty crash severity in Melbourne and Victoria-wide are influenced by the inclusion of unemployment rate in these models. Unemployment rate was included in the models of crash severity because a significant statistical relationship was found between unemployment rate and injury severity of casualty crashes in urban areas (Melbourne, Sydney and Victoria-wide, but not in rural areas of either State nor in

NSW overall) suggesting that increases in unemployment rate is associated with increases in the injury severity of crashes[2].

Thus, these estimated net effects on casualty crash severity are derived from models which take into account the effects of changes in unemployment rate. In practice this means that the estimated net effects are based on the expectation that casualty crash severity (in low alcohol hours) would have increased in Melbourne and Victoria, given the increase in unemployment rate that occurred during the intervention period, had the speed camera program not been introduced. Therefore estimated net percentage reductions are not simply reflected in the actual trend in the casualty crash severity ratio during the intervention period.

Table 6 Estimated net effects on the incidence and injury severity of casualty crashes (in low alcohol times) in treatment areas (relative to NSW comparison areas)

TREATMENT AREA	Low level enforcement & publicity Dec '89-Mar '90 (T1a)	Low level enforcement & intense publicity April-June 1990 (T1b)	High level enforcement & intense publicity July '90-Feb '91 (T2a)	High level enforcement & intense publicity Mar-Dec 1991 (T2b) ♠
Melbourne 60km/h arterials				
-casualty crashes	-13.8% *	-31.5% *	-30.6%*	
-severity		-33.1% *	-38.4% *	-49.2% *
Melbourne all arterials				
-casualty crashes	-14.6% *	-33.8% *	-32.4% *	
-severity	-22.1% *	-36.9% *	-37.1% *	-47.9% *
Melbourne				
-casualty crashes		-23.5% *	-21.1% *	
-severity	-18.3% *	-29.0% *	-35.2% *	-44.6% *
Rural Victoria 60 km/h roads				
-casualty crashes				
-severity		-21.0% *	-23.3% *	-37.4% *
Rural Victoria 100 km/h roads				
-casualty crashes				
-severity		+65.6% *	-14.1%*	
Rural Victoria				
-casualty crashes		-16.4% *	-19.5% *	
-severity		+30.7% *		-27.7% *
Victoria				
-casualty crashes			-20.9% *	
-severity		-20.1% *	-27.9% *	-40.3% *

**** Statistically significant at p< 0.05 level ♠ effects relative to NSW speed camera program (only statistically significant results are shown)***

[2] A possible explanation for this correlation is that decreased traffic volumes (related to economic recession) leads to higher travel speeds and hence greater crash severity. However, there was no prior evidence to suggest that vehicle exposure is related to the injury severity outcome of crashes.

6.8.3 Pattern of effects across areas and corresponding levels of speed camera operations

In terms of **casualty crash frequency in low alcohol times**, the pattern of results suggested that there were stronger reductions on 60km/h arterial roads and all arterial roads in Melbourne (around 30%) as compared with Melbourne as a whole and in rural 60km/h zones (around 20%) and also as compared with the weakest effect observed in rural 100km/h zones (14% drop in one period only). This pattern of effects appeared to correspond with the level of speed camera enforcement in these different areas:

- speed camera operations were conducted almost exclusively on arterial roads,
- a greater number speed camera operations were conducted in Melbourne than in rural areas (70% of total sessions on average have been conducted in Melbourne),
- most (80-90%) camera sessions have been conducted in 60 km/h zones in both the respective metropolitan and rural parts of the State.

The pattern of results therefore provided greater confidence that the observed reductions in the frequency of casualty crashes (in low alcohol hours) were related to the speed camera program.

In terms of the **injury severity of casualty crashes**, reductions were observed in the Melbourne areas but not in any of the rural areas, again corresponding to the greater level of speed camera enforcement in Melbourne compared with country Victoria. There was no substantial difference between the effects on Melbourne arterial roads only and all Melbourne roads, except that they appeared somewhat greater on the arterials (as could be expected).

6.8.4 Relative comparison

Table 7 shows the relative comparison of effects on arterial compared to local roads in Melbourne. A 19% reduction in the **severity of casualty crashes** during low alcohol times was observed on arterial roads compared to residential streets in Melbourne in T2b only.

Table 7 Relative effects on the incidence and severity of casualty crashes (in low alcohol times) on arterial roads compared to residential streets in Melbourne

TREATMENT AREA	Low level enforcement & publicity Dec '89-Mar '90 (T1a)	Low level enforcement & intense publicity April-June 1990 (T1b)	High level enforcement & intense publicity July '90-Feb '91 (T2a)	High level enforcement & intense publicity Mar-Dec 1991 (T2b) ♠
Melbourne all arterials vs residential streets -casualty crashes -severity				-19.2% *

**** Statistically significant at p< 0.05 level*** **♠ *effects relative to NSW speed camera program***
(only statistically significant results are shown)

6.8.5 Limitations of Phase 1

This research design involved a number of assumptions. These are considered in turn.

Interstate control

The conceptualisation of the effects of this program as being generalised across broad areas for this phase of the evaluation (partly because of the pervasiveness and intensity of the enforcement and publicity) led to the absence of an untreated area, time or other crash group in the respective Victorian metropolitan and rural areas to provide for a control group. This meant the use of an interstate comparison group was unavoidable. Although the most similar State to Victoria was chosen for this role, it is not known how well it provided control for other (exogenous) factors present over time in Victoria. The most obvious relevant differences between the two States, manifested in unemployment rates, were considered in the analysis. Changes in unemployment rates were explicitly taken into account in the analysis of each States' crash data.

However, even after unemployment rates were taken into account, the interstate comparison area experienced statistically significant reductions in low alcohol hour casualty crashes and in some instances increases in low alcohol hour casualty crash severity. It is not known the extent to which these reductions were related to safety measures particular to NSW or to "other" factors which were also applicable to Victoria.

The validity of the results therefore depends on whether the influences of extraneous factors (ie. factors not included in the models) on the evaluation criteria in NSW during the intervention were similar to those for Victoria.

It should also be noted that T2b represents the effects of the Victorian speed camera program over and above any effects of the program operating in NSW, and does not provide an estimate for the net effect of the Victorian program per se.

Relative control

The greater relative reduction in (low alcohol hour) casualty crash severity on Melbourne arterial roads compared with residential streets in T2b can be interpreted in one of two ways:

1. the program had a greater effect on arterial roads than residential streets, which were also affected by the program, or

2. that the changes in residential streets represents the base from which any additional effects can be ascribed to the program, ie. 19% drop in T2b

These interpretations are also subject to the assumption that the expected effect of the program and the effects of 'other factors' on the severity of casualty crashes on the two different types of roads would be expected to be the similar. That is, severity of crashes on both road types are equally susceptible to change.

Unemployment rate as a measure of low alcohol hour vehicle travel

Casualty crash frequency

The use of unemployment rate as a covariate to control for changes in low alcohol hour travel cannot be directly validated. There were substantial changes in the trends in total travel almost coinciding with the program and these changes differed between Victoria and NSW.

The assumption made in introducing an exposure measure (such as unemployment rate) as a covariate is that the differences in patterns and levels of total vehicle travel and unemployment rate in the two States are large and important enough to have a different degree of impact on crash risk over the intervention period.

The second assumption made in using a global measure of exposure (unemployment rate in this study) is that this reflects the changes in exposure over time during the low alcohol hours of the week. The relationship between unemployment and travel patterns for different times of day and days of the week is uncertain. Previous research linking unemployment and fatalities does so globally, that is for all times and not for a subset of times. Explicitly controlling for changes in exposure was considered to be important for estimating effects of the program on crash frequency.

Casualty crash injury severity

In the case of injury severity of crashes there was no theoretical reason or evidence to suggest that vehicle exposure is related to the injury severity outcome of crashes. Nevertheless, a significant statistical relationship was found between unemployment rate and injury severity of casualty crashes in Melbourne and in Sydney, Victoria-wide but not NSW-wide, and not in rural Victoria nor rural NSW. This suggested that increases in unemployment rate could be associated with increases in the injury severity of crashes, particularly in urban areas. One possible explanation for this is that when traffic congestion is reduced in times of economic recession, the opportunity to travel at higher speeds also increases (especially in urban areas) which leads to greater injury severity of those crashes which occur.

There is no evidence for this theory, but the strong negative correlation between unemployment rate and injury severity of low alcohol hour casualty crashes was considered to warrant the retention of unemployment rate in the models so it could be accounted for in estimating the effects of the program on crash severity. The estimates of the program in Melbourne and State-wide Victoria are therefore influenced by the presence of the unemployment variable in these models, because of its statistically significant role in these models of casualty crash severity.

Effects of the RBT Initiative

Although the majority of RBT sessions have been in high alcohol hours, there was a small proportion of RBT sessions occurring during low alcohol hours. It is not known if this overlap has resulted in some observed effects reflecting (in part) RBT effects.

Efficacy of the models

The validity of the results for casualty crash severity are tentative given that the models fitted may be inadequate from a statistical perspective as outlined in the results section regarding the efficacy of the models. These models were characterised by high intercorrelations between estimates for the predictors, in particular between those for unemployment rate, trend and T2b, which may have affected the estimates of the program variables. It was also assumed that the removal of the constant term and the correlations between some parameter estimates in the ARIMA modelling of casualty crash frequency did not affect the estimates for the intervention periods.

The approach used in the modelling was such that a specific test was made for a step change or reduction with the introduction of the program. This assumes that the nature of the effects of the program are immediate and maintained. If, for example, effects were initially small and increased incrementally over time, the current estimates will only be an average of these varying effects. Although this is a shortcoming, it is because of the unclear nature of the effects of the program over time that alternative frameworks were not used.

Low alcohol hour crashes

It is not known to what extent driver responses to speed cameras (if any) are limited to their times of operation or whether speed behaviour has also been modified at night (which is encompassed by high alcohol times). Although there is yet no evidence for generalisation of behaviour beyond specific times and locations of speed enforcement, the current program is very different to previous enforcement programs. Whilst it would have been desirable to test for night time effects of the program, this was not possible due to the concurrent operation of an intensive RBT initiative. The current results therefore only apply to low alcohol times, almost all of which are in daylight hours.

7.0 PHASE 2: EFFECTS OF PROGRAM MECHANISMS

Phase 2 of this evaluation attempts to further understand and estimate the impact of the program by modelling the various deterrence mechanisms of the program against the evaluation criteria (casualty crash incidence and severity during low alcohol times of the week). The measured mechanisms are represented quantitatively and are assessed for their relative impact on the evaluation criteria. The purpose of this is two-fold:

1. to attempt to link more directly the program mechanisms with observed reductions in crash criteria, and hence better establish the "cause-and-effect" of the program,

2. to attempt to indicate which of the program mechanisms appear to be most associated with changes in the speed-related crash criteria.

7.1 RATIONALE FOR ESTIMATING THE EFFECTS OF PROGRAM MECHANISMS ON CRASH CRITERIA

Models developed in Phase 2 test the changes and variations in intensity of the respective elements of the program against the changes and variations in the evaluation criteria. This provides a more rigorous test of whether the speed camera program has caused observed crash effects than the Phase 1 evaluation.

Phase 1 tested for simultaneous reductions in the evaluation criteria with the introduction of the various phases of the program (represented by intervention variables), after taking into account the effects of other influences; namely long-term trends in casualty crash risk and severity, seasonal trends and unemployment, and also changes in the evaluation criteria in NSW, which served as a comparison area. The effects observed in Phase 1 are strongly suggestive of a coincidental effect of the program on the evaluation criteria. However, it does not directly link the program to the observed effects, and hence it is possible that other influences, which are not accounted for, have caused these observed effects.

Phase 2 is more rigorous in testing the cause-and-effect link. Direct measures of the speed camera program operations are tested against changes in the evaluation criteria on a monthly time series basis, across the two year post-intervention period. Hence, a more specific and direct relationship is required in Phase 2 if it is to be concluded that the effects are attributable to the program, rather than on the basis of the presence or absence of the treatment in different time blocks, as in Phase 1.

An additional reason for modelling the various mechanisms of the program is to allow an understanding of how the program effects changes in the evaluation criteria, that is, which are the critical elements and ways in which the program could be improved to maximise road safety benefits.

One of the major practical difficulties with this approach, however, is validly representing the form of the program, and the reliance on available quantified measures of the program in a monthly time series.

7.2 DATA AVAILABLE RELATING TO PROGRAM MECHANISMS

Time series data relating to the program (see section 4.0) is available relating to:

1. number of speed camera TINs issued
   (monthly; Statewide only)

2. proportion of drivers issued with one or multiple speed camera TINs
   (two measurements from TCO in 1992 only)

3. proportion of drivers with a varying number of demerit points
   (quarterly only; Statewide only; demerit points from all types of traffic offences)

4. proportion of drivers who are aware of others who have been caught by a speed camera
   (two measurements in 1991 only)

5. amount of paid television publicity (in terms of TARPs[3])
   (monthly; metropolitan television only; both speed related TAC publicity and all TAC road safety publicity)

6. hours of speed camera operation
   (monthly; Statewide, metropolitan and rural areas).

7.3 SELECTION OF PROGRAM VARIABLES AND CRASH CRITERIA TO BE MODELLED

Program variables

Measures of TINs issued (1), publicity (5), and camera operations (6) are available on a monthly basis, demerit points (3) is available on a quarterly basis, whilst multiple TINs (2) and awareness of others caught (4) are available for two dates only (shown in section 4.0). Thus, measures 2 and 4 cannot be used in the statistical analyses.

Whilst it would be possible to interpolate the demerit points measure (3) to provide a monthly series from the quarterly data points available, the appropriate representation of this measure is not immediately obvious. For instance, the average number of demerit points over time may not be a sufficiently sensitive measure of change, given that the distribution of demerit points is highly skewed with relatively low proportions in the higher ranges. Selecting the proportion or number of drivers with demerit points above a particular level is also not satisfactory; that is, it raises the question which is the level of accumulated demerit points which most deters drivers from speeding and committing further offences, and hence reduces speed-related crash risk? For these reasons this measure was not included in the analysis for Phase 2.

Publicity data (5) is available monthly but for the metropolitan area only. Publicity, however, represents a major component of the program and was used at unprecedented levels, particularly in relation to speeding.

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[3] Target Audience Rating Points is a measure of the proportion of people in a nominated target group who have been exposed to the advertising and thus provides a measure of its amount and intensity

Therefore an attempt was made to determine the relationship (if any) between the evaluation criteria and deterrence mechanisms relating to TINs issued (1), publicity (both speed related and total road safety publicity [5]) and camera operations (6).

Evaluation criteria

Crash criteria chosen as evaluation outcomes were those selected in Phase 1, that is, casualty crash frequency and casualty crash injury severity (see section 6.4). These are police reported casualty crashes which include fatal crashes (those in which one or more persons is killed), serious injury crashes (those in which one or more persons is seriously injured and probably admitted to hospital) and minor injury crashes (in which one or more persons requires medical treatment).

Only casualty crashes in low alcohol hours of the week (mainly daytime) were examined given the parallel operation of a major Random Breath Testing (RBT) initiative primarily in high alcohol times. Thus the results pertain to the effects of the program mechanisms on crashes during low alcohol hours only (ie. Monday to Thursday 6am to 6pm, Friday 6am to 4pm, Saturday 8am to 2pm, Sunday 10am to 4pm).

Because of the availability of only Melbourne television publicity data, it was decided to undertake the analysis for crashes in the Melbourne area only. Data for speed camera operations in the Melbourne area only were used for comparability. Whilst it would have been desirable to use TINs issued data which related specifically to the Melbourne area only as well, this data was not available in disaggregated form for this Phase of the evaluation. Victoria-wide TINs issued were therefore used, on the assumption that it resembled the trends and changes for those related to the Melbourne area only. In addition, the greater usage of cameras in Melbourne would suggest that a large proportion of these TINs would emanate from the Melbourne area.

Crashes on Melbourne arterial roads specifically were also analysed given the larger reductions observed in the incidence and severity of crashes on these roads in Phase 1.

In summary, the following predictors and measures of speed-related crash risk were selected for the Phase 2 analyses:

Crash Variables:

1. casualty crash frequency in low alcohol times in Melbourne
2. casualty crash severity in low alcohol times in Melbourne
3. casualty crash frequency in low alcohol times on Melbourne arterial roads
4. casualty crash severity in low alcohol times on Melbourne arterial roads

Program Variables:

1. Number of speed camera TINs issued (Victoria)
2.a. Publicity (Melbourne television: speed-related TAC advertising only)
2.b. Publicity (Melbourne television: all TAC road safety advertising)
3. Hours of camera operations (Melbourne)

These data are displayed graphically in Figures 15 to 19.

Figure 15
Monthly number of casualty crashes in low alcohol hours
Melbourne, 1983-1991

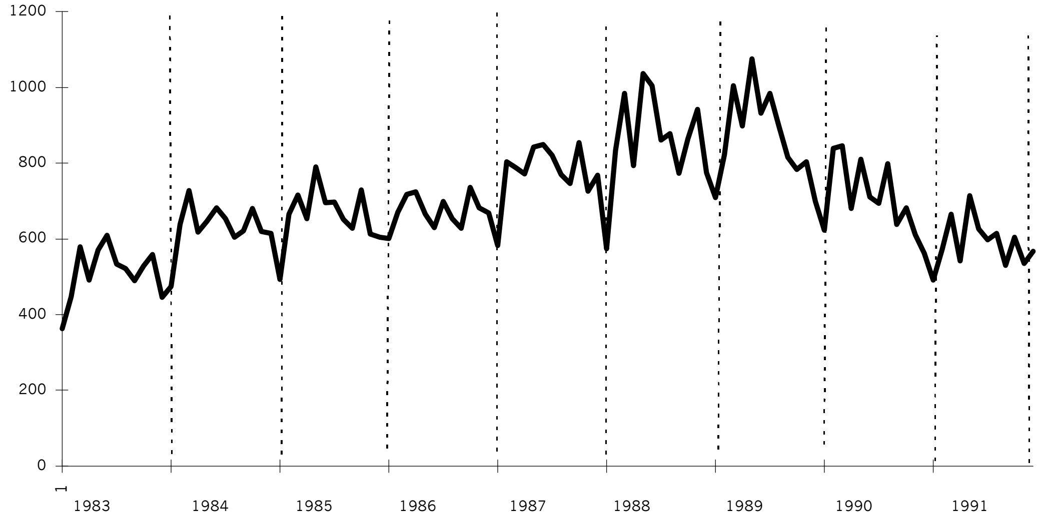


Figure 16
Casualty Crash Severity in low alcohol times during month
Melbourne 1983-1991
(ratio of fatal & serious injury crashes to crashes involving minor injury only)

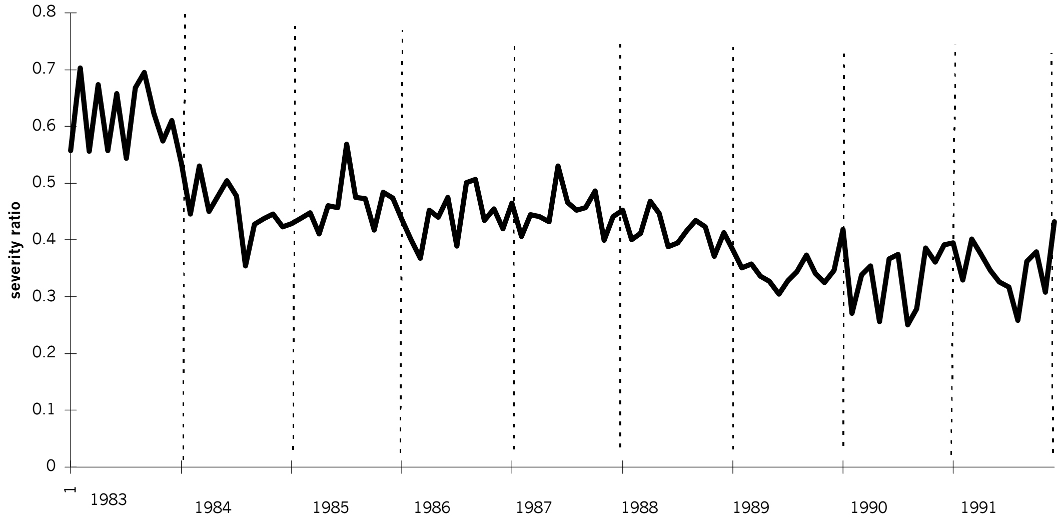


Figure 17
Monthly number of Traffic Infringement Notices Issued for Speeding Offences Detected by Speed Cameras Victoria 1989-1991

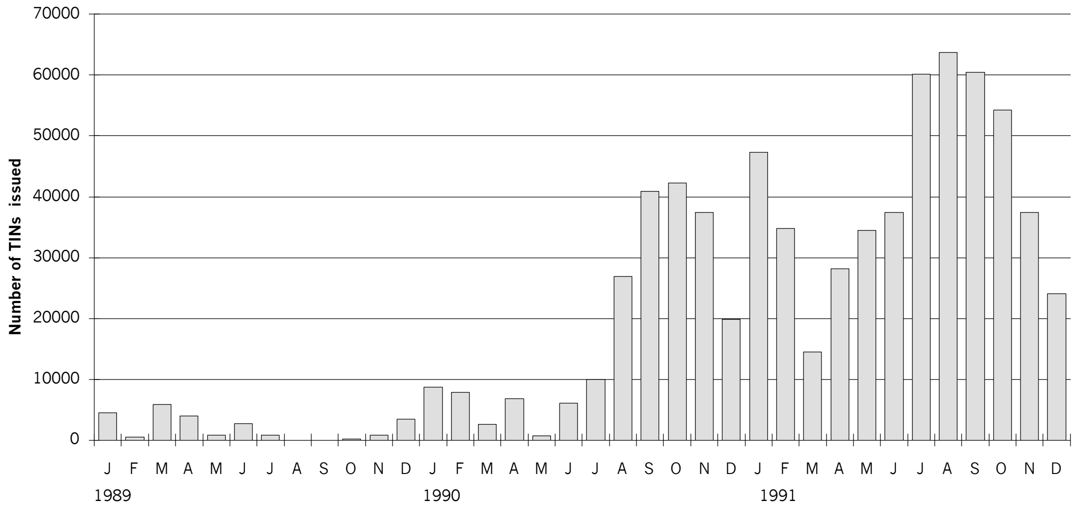


Figure 18
Melbourne television advertising: monthly number of TARPs Speed related publicity and other TAC road safety publicity

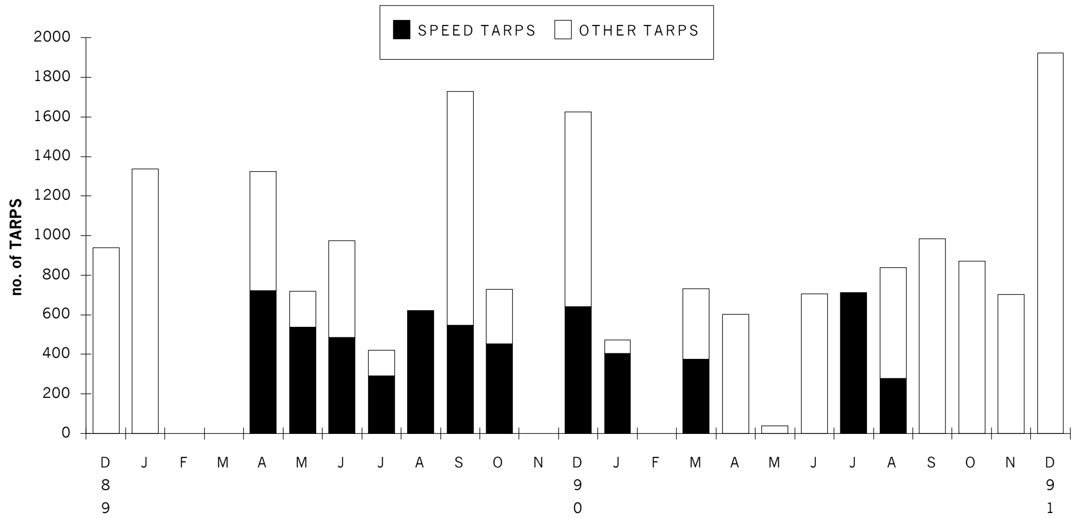
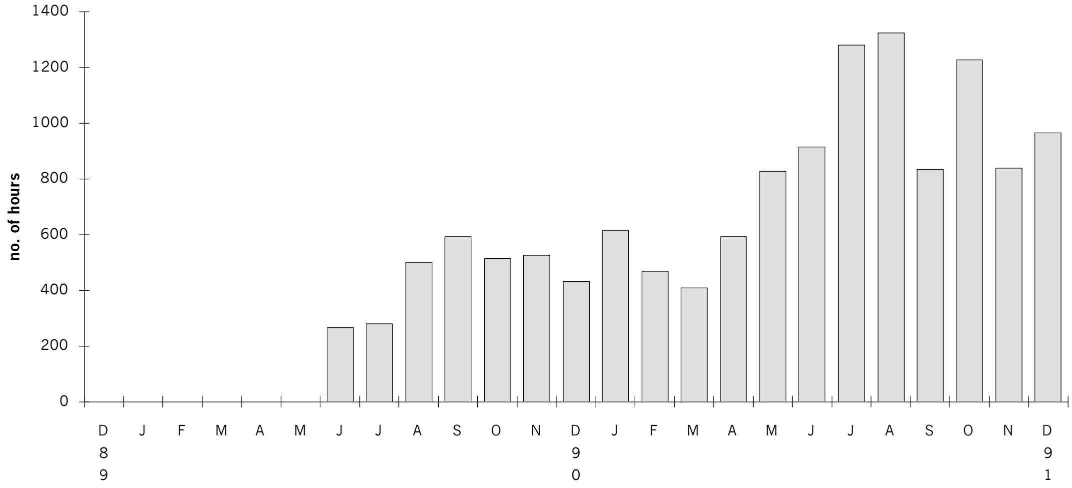


Figure 19
Monthly number of hours of camera operations
Melbourne, June 1990-December 1991



7.4 HYPOTHESES

Phase 2 aimed to test the following hypotheses relating to the program.

A reduction in the frequency and injury severity of low alcohol hour casualty crashes **in Melbourne** related to:

(a) the number of speed camera TINs issued to drivers Victoria-wide

(b) the level of the TAC Melbourne television speed publicity campaign (Don't fool yourself, speed kills)

(c) the level of all TAC Melbourne television road safety publicity

(d) the number of hours of speed camera operations in the metropolitan area

A reduction in the frequency and injury severity of low alcohol hour casualty crashes on **Melbourne arterial roads** related to:

(e) the number of speed camera TINs issued to drivers Victoria-wide

(f) the level of the TAC Melbourne television speed publicity campaign

(g) the level of all TAC Melbourne television road safety publicity

(h) the number of hours of speed camera operations in the metropolitan area

The hypotheses are all uni-directional and hence one-tailed significance tests were applied throughout this part of the study, as the results in Phase 1 indicate a directional effect (reduction) of the program in Melbourne.

7.5 METHODOLOGY

The relationships between the evaluation criteria (the frequency and injury severity of casualty crashes which occurred in low alcohol times) in Melbourne and the different program measures were determined using multivariate time series analysis models.

7.5.1 Time series analysis

Time series analysis can control for long term trends, seasonal cycles and other regular patterns in the crash variables. Longer term, "smooth" trends (due to a variety of factors including road safety programs) in the crash criteria were taken into account through a trend component in the time series models if necessary. This eliminated the need to include specific measures of such variables in the models, and allowed a better assessment of the real effect of a new or abrupt change to the crash series in time.

The aim of the modelling process was to develop models that closely fit the number and severity of casualty crashes over the period January 1983 to December 1991, for each series, and to estimate the relationships between the program variables in each model and the crash criteria. All models were undertaken using monthly data.

Frequency of casualty crashes

The time series data were modelled using multiple regression methods. The dependent variable in each model was again the monthly number of casualty crashes in low alcohol hours while the independent variables in the regression equations were made up of:

- a linear trend
- monthly dummy variables (to represent seasonal variations)
- unemployment rate in Melbourne
- number of TINs issued in Victoria
- number of TAC speed publicity TARPs or number of all TAC road safety publicity TARPs on Melbourne television
- number of speed camera hours of operation in Melbourne

Unemployment rate was included in the models because it was found to play a significant role in those fitted for Melbourne in Phase 1. It was also considered important for the models in Phase 2 to be compatible with those developed in Phase 1. Similarly, for compatibility with Phase 1, multiplicative models were fitted; natural logarithms of the dependent variable, covariates and independent variables were taken.

Before developing the multiple regression models, the correlations between independent variables were examined because the reliability of the modelling procedure to provide valid estimates of effects of each variable (parameter estimates) relies on the condition that the variables are not highly correlated (Appendix G). An examination of correlations between independent variables showed that the unemployment rate was significantly correlated with hours of camera operation (0.5) and all TAC road safety publicity (0.3), but not with TINs issued nor speed related TAC publicity. Both hours of camera operation and number of speed camera TINs issued correlated significantly with speed related TAC publicity (both 0.6) and all TAC road safety publicity (both 0.8). Number of speed camera TINs issued and hours of camera operation were also significantly correlated (0.8) with each other. These latter correlations suggest that the program variables are highly correlated with one another. The modelling procedure also provides correlations between parameter estimates; these will be reviewed with the results in order to establish any intercorrelation problems.

Correlations between dependent and independent variables also revealed that low alcohol hour casualty crashes in Melbourne were significantly correlated with the unemployment rate (-0.75), with hours of camera operations (-0.26) and with all TAC road safety publicity (-0.20).

Casualty crash injury severity

Logistic (multiple) regression models of casualty crash severity (in low alcohol times) were developed for crashes in Melbourne from January 1983 to December 1991. Casualty crash injury severity was represented as the ratio:

$$\frac{\text{fatal \& serious injury crashes}}{\text{minor injury crashes}}$$

to provide a sensitive measure of changes in the injury severity of crashes. The same covariates were used in these analyses as those for casualty crash frequency, except for the trend variable which was omitted from the models (as in Phase 1) to reduce problems of intercorrelations between parameter estimates. Thus, the severity models are also compatible with those developed in Phase 1.

7.6 RESULTS

The output from each model and corresponding diagnostic information is presented in Appendix H. The following tables present the estimated relationships between the modelled speed camera program mechanisms and changes in the frequency and injury severity of casualty crashes (in low alcohol hours), specifically on Melbourne arterials and also on all roads in Melbourne.

7.6.1 Models assessing monthly TINs issued, camera operations and speed related TAC publicity only

Table 8 below shows the estimated relationship between TINs issued from speed camera offences, speed publicity and hours of camera operations, and casualty crash frequency and injury severity in low alcohol times of the week, after accounting for the variance related to unemployment rate, seasonal trends and trend over time (for casualty crash frequency only in the case of trend).

The estimated effect of each variable is given by the coefficient for that variable, its T distribution value and its level of statistical significance (the two-tailed significance levels given in Appendix H have been halved because one-tailed directional tests of the hypotheses were made; see section 7.4). The coefficient can be interpreted as the percentage change per month in crash frequency or severity, respectively, given a one percent change in the predictor variable.

Table 8 Estimated effect of monthly speed camera TINs issued, speed related publicity and hours of camera operations on the incidence and severity of casualty crashes (in low alcohol times) on arterial roads in Melbourne and all roads in Melbourne

TREATMENT AREA	Estimated coefficient of logged variable	T value (>90 d.f.)	Significance level (one-tailed)
Melbourne arterial roads			
-casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0132****	-3.096	0.0013
· ***hours of speed camera operations during month***	**-0.0079**	-0.636	0.2632
· ***speed related TAC publicity during month***	**-0.0091**	-1.538	0.0638
-severity of casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0233*****	-3.990	0.0001
· ***hours of speed camera operations during month***	**-0.0339****	-2.694	0.0042
· ***speed related TAC publicity during month***	**-0.0050**	-0.602	0.2744
Melbourne all roads			
-casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0078*****	-3.692	0.0002
· ***hours of speed camera operations during month***	**-0.0033**	-0.628	0.2660
· ***speed related TAC publicity during month***	**-0.0040**	-1.504	0.0681
-severity of casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0188*****	-3.297	0.0007
· ***hours of speed camera operations during month***	**-0.0380****	-3.099	0.0013
· ***speed related TAC publicity during month***	**0.0004**	0.055	0.4783

**** Statistically significant at p<0.05 level; ** Statistically significant at p<0.01 level; *** Statistically significant at p< 0.001 level***

The results in Table 8 indicate that there is a significant relationship between **casualty crash frequency (in low alcohol times)** and speed camera TINs issued to drivers, for crashes on arterial roads specifically and on all roads in Melbourne, with a stronger effect observed on arterial roads. The estimated effect of speed related publicity on the frequency of casualty crashes approached statistical significance at the 0.05 level. Hours of camera operation did not appear to be associated with reductions in the frequency of casualty crashes.

Casualty crash injury severity (in low alcohol times) was also significantly related to speed camera TINs issued to drivers, for crashes on arterial roads specifically and on all roads in Melbourne, with a stronger effect observed on arterial roads. In addition, hours of camera operation was related to casualty crash injury severity for all Melbourne roads and for arterial roads only. There was no statistically significant relationship between speed related publicity and casualty crash severity.

Efficacy of the models

Examination of all the models indicated that they fit the crash data well with around 84% and 66% of the variance in casualty crash frequency and casualty crash severity, respectively, accounted for by these models.

Inspection of intercorrelations between coefficient estimates for **casualty crash frequency models** indicated however, that there were high correlations (around 0.8) between estimates for the intercept term, unemployment rate, and trend; between the estimate for hours of camera operation and estimates for the intercept, unemployment rate and trend (around -0.7). Moderate correlations (around 0.4) were also observed between the estimate for speed publicity and those for the intercept, trend and unemployment rate. As indicated by the correlations between variables in section 7.5.1, hours of camera operations was significantly correlated with unemployment rate, speed publicity and TINs issued; TINs issued was also significantly correlated with speed publicity. Such intercorrelations may mean that the estimated relationships reported in Table 8 are unreliable, particularly that indicated for camera operations (and to a lesser extent that for speed publicity) given its high correlations with the estimates for other significant variables (ie. TINs issued, unemployment rate and trend).

Inspection of intercorrelations between coefficient estimates for **casualty crash injury severity models** also indicated high (0.6 - 0.9) but fewer correlations than for the casualty crash models mainly because the trend variable was omitted from these models for comparability with Phase 1 models. The estimated coefficient for unemployment rate was correlated with those for the intercept term, hours of camera operation and TINs issued; the estimate for TINs issued was also correlated with the estimate for hours of camera operations. These intercorrelations may also have affected the estimated relationships derived from the models of casualty crash injury severity.

7.6.2 Models assessing monthly TINs issued, camera operations and all TAC road safety publicity

Table 9 shows the estimated relationships when all TAC road safety publicity is included in the models rather than only speed related publicity.

These results confirm the relationships observed in Table 8, but also indicate that there is a statistically significant relationship between casualty crash frequency and total TAC road safety publicity. The estimated size of the effects of the other program variables (TINs issued and camera operation hours) varied only slightly when the models are fitted with total publicity data, except for the estimate of the effect of TINs issued on casualty crash frequency on arterial roads which halved in size (but remained statistically significant).

Table 9 Estimated effect of monthly camera TINs issued, all TAC road safety publicity and hours of camera operations on the incidence and severity of casualty crashes (in low alcohol times) on arterial roads in Melbourne and all roads in Melbourne

TREATMENT AREA	Estimated coefficient of logged variable	T value (>90 d.f.)	Significance level (one-tailed)
Melbourne arterial roads			
-casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0065****	-2.754	0.0036
· ***hours of speed camera operations during month***	**-0.0069**	-1.367	0.0876
· ***all TAC road safety publicity during month***	**-0.0056***	-1.669	0.0493
-severity of casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0228*****	-3.620	0.0003
· ***hours of speed camera operations during month***	**-0.0354****	-2.814	0.0030
· ***all TAC road safety publicity during month***	**-0.00270**	-0.258	0.3983
Melbourne all roads			
-casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0065****	-3.000	0.0018
· ***hours of speed camera operations during month***	**-0.0043**	-0.921	0.1797
· ***all TAC road safety publicity during month***	**-0.0077****	-2.499	0.0071
-severity of casualty crashes in low alcohol times			
· ***no. of speed camera TINs issued during month***	**-0.0183****	-2.981	0.0019
· ***hours of speed camera operations during month***	**-0.0371****	-3.029	0.0016
· ***all TAC road safety publicity during month***	**-0.0019**	-0.188	0.4256

Statistically significant at p<0.05 level; ** Statistically significant at p<0.01 level; *** Statistically significant at p< 0.001 level

The intercorrelations between estimated coefficients present in the models of casualty crash frequency and injury severity using only speed publicity are again present in these models. However, whilst there had been moderate correlations between the speed publicity estimate and the intercept, trend and unemployment rate estimates in casualty crash frequency models, this was not the case when all TAC road safety publicity was used. This may explain why all TAC publicity appears to have a statistically significant relationship with casualty crash frequency, whilst speed publicity does not achieve statistical significance.

7.7 DISCUSSION

Significant relationships were found between some of the measures of the program and the frequency and injury severity of casualty crashes which occurred in low alcohol times, in 1990 and 1991. These were:

Frequency of casualty crashes (low alcohol times)	**Injury severity of casualty crashes (low alcohol times)**
• Speed camera TINs issued to drivers • All TAC road safety publicity • Speed related TAC publicity (sig. at 0.07 level only)	• Speed camera TINs issued to drivers • Speed camera operation hours

The effects of speed camera TINs issued to drivers was consistently related to both crash frequency and injury severity, with stronger effects observed on arterial roads for both criteria. The direct effects of speed camera operations themselves (basically the immediate effects of the cameras operating) appeared to be confined to casualty crash injury severity only. This may indicate that:

- drivers are not aware of cameras operating because they are generally not obvious and hence cannot react to operations directly, or
- exposure to camera operations is not sufficient to modify speed behaviour to the degree required to reduce the risk of a casualty crash occurring but receipt of a TIN and punishment for speeding is effective in reducing crash risk.

Alternatively, the high intercorrelations between variables and estimates for the variables, especially for camera operations and other significant variables, may have masked its relationship with casualty crash frequency. In addition, the casualty injury severity measure may be a more specific and more sensitive criterion related to speed than casualty crash frequency.

In relation to the findings for publicity, similar comments apply for the relationship between speed related publicity and casualty crash frequency. The estimate for this variable was correlated with the estimates for other significant variables. On the other hand, the stronger significant effect of all TAC road safety publicity rather than speed related publicity on casualty crash frequency may reflect that casualty crash frequency is a general measure of the risk of all types of (low alcohol hour) crashes and it is not confined to "speed-related" crashes (which could reasonably be expected to be affected by the speed-related publicity).

It appears that TAC publicity (speed related only or all publicity) was not related to casualty crash injury severity.

As noted in relation to the results of Phase 1, the results of Phase 2 are also based on the inclusion of unemployment rate in the models of casualty crash frequency as well as for the models of casualty crash injury severity. Explicitly controlling for changes in exposure was considered to be important for estimating the effects of the program on crash frequency[4]. Although there was no prior evidence of the importance of exposure/unemployment rate on crash severity, a significant statistical relationship was found between unemployment rate and the injury severity of casualty crashes (in urban areas in particular) which led to its inclusion in models of crash severity as well.

Thus, estimated effects of program variables on casualty crash severity in Melbourne are based on models which take into account the effects of changes in unemployment rate. This means that these estimated effects are based on the premise that casualty crash severity (in low alcohol hours) would have increased in Melbourne (given the increase in unemployment rate which occurred during the intervention period) had the speed camera program not been introduced.

[4] It was considered that unemployment was an adequate proxy measure of vehicle travel over time given some prior evidence of a correlational relationship between unemployment rate and fatalities and relatively high correlations between State-wide estimated total vehicle travel (based on fuel sales) and unemployment rate measures.

7.8 LIMITATIONS OF PHASE 2

Difficulties inherent in this approach

One of the major practical difficulties with attempting to model the specific aspects of the program is the reliance on available quantified measures of the program and representing it validly. The lack of monthly time series data for other program mechanisms (eg. knowledge of other drivers who have been caught, number of drivers issued with multiple TINs, number of drivers with increasing demerit points) meant that a full model of the program mechanisms and therefore its effects was not developed. On the other hand, while this was theoretically desirable, in practice it may have been impossible to develop a full model and disaggregate each mechanism's sole contribution to observed reductions in the crash criteria, given that the mechanisms are unavoidably interrelated.

Problems with the feasibility of this aim have been outlined previously in an evaluation of the Random Breath Testing (RBT) initiative in Victoria during 1989-1991, where the feasibility of dissociating the effects of enforcement and publicity was discussed (Cameron, Cavallo & Sullivan, 1992). These include the statistical problems of collinearity between the measures, and between the measures and other influences, the appropriate representation and quantification of the mechanisms within the model (eg. does a measure of enforcement, such as number of TINs issued, represent its effects on the public and therefore does this provide a fair test of its relationship with crashes?), the possible non-linear relationships between the mechanisms and crash risk, and the fact that correlational relationships between the program and crashes does not prove causality absolutely. To properly dissociate the effects of the parallel elements of the program a longer post-intervention period (3-4 years) is required. For these reasons, statistically significant effects which seem related to a particular program mechanism cannot definitively be attributed to that particular part of the program only, given that it operated in the presence of the other mechanisms (quantified and unquantified) and other unknown factors. Indeed, the relative importance of the various mechanisms in driver perceptions, speed choice and speed behaviour and the extent to which these have altered cannot be understood through this quantitative approach.

Additionally, some of the mechanisms which may act to influence speed behaviour, would also at the same time be measures of behavioural changes; eg. the level of TINs issued reflects both the mechanism influencing speed behaviour, and if the program is successful, an outcome indicator. The modelling of variables which could be **both** measures of treatment (independent variable) and of response to treatment (dependent variable) as independent variables, will diminish the power of this approach, particularly for later periods in the intervention when driver responses, if any, are most likely to be manifested in such measures.

Efficacy of the models

The models were found to fit the crash data well (around 84% and 66% of the variance in the casualty crash frequency and casualty crash severity criteria, respectively, was accounted for by these models). However, intercorrelations between coefficient estimates for **casualty crash frequency models** (in particular) and **casualty crash injury severity models** indicated that there were high correlations between many estimates. Such intercorrelations may mean that the estimated relationships reported are unreliable, particularly that indicated for the relationship between camera operations (and to a lesser extent that for speed publicity) and casualty crash frequency, given its high correlations with the estimates for other significant variables (ie. TINs issued, unemployment rate and trend).

Unemployment rate as a measure of low alcohol hour vehicle travel

The same assumptions that applied to Phase 1 apply to this part of the study (see section 6.8.1).

8.0 FURTHER RESEARCH

It is now planned to undertake Phase 3 of this evaluation, as outlined in section 5.0. This should provide more definitive evidence of a cause-and-effect link between the speed camera operations and the general effects observed in Phase 1 of the evaluation. This phase should also provide further understanding of the key factor affecting the deterrent effect of the program, so that future camera operations of the program can be optimised.

An additional Phase which attempts to examine existing traffic speed data over time to provide additional supporting evidence linking the observed effects to the speed camera program will also be attempted. It may not, however, replace the evidence that should be provided by the proposed Phases 3 of the evaluation, given the paucity of traffic speed data over the relevant time period.

Additional research areas and data requirements emerged from the study to date.

These relate to:

- an urgent need for better vehicle exposure/traffic volume information over time, given the importance of taking into account changes in exposure when assessing the effects of road safety programs, particularly for post-hoc, quasi-experimental evaluations where the availability of adequate comparison areas is questionable and given that statistical forms of control using surrogate measures also poses problems;

- an investigation of the risk of varying levels of injury outcomes in crashes under different levels of vehicle exposure/traffic volumes, given the finding that unemployment rate in urban areas was found to correlate with the severity of casualty crashes in low alcohol hours;

- a research program which investigates the process of changes in driver perceptions, speed choice and speed behaviour and the factors involved, given that the process by which such changes may have occurred are poorly understood and would be useful for improving behavioural change programs; in particular, the extent and consistency of modifications in speed behaviour amongst drivers in relation to a number of contingencies (given that speed behaviour is transient and is influenced by a variety of factors), the nature of speed deterrence and the critical elements which enact and maintain desired behavioural changes.

9.0 CONCLUSIONS

The introduction of the speed camera program and supporting publicity in Victoria has been associated with decreases in the frequency of reported casualty crashes which occur in low alcohol times of the week and also decreases in their injury severity. These decreases have been calculated as departures from expected values based on past trends and seasonal patterns, changes in unemployment rate, and using the comparable areas of NSW as a control. The magnitudes of these decreases have varied with the region of the State and nature of the program operated during different periods. The program appears to have had its greatest effects (in terms of the frequency of casualty crashes) on arterial roads in Melbourne and on 60 km/h roads in rural Victoria, where the majority of the speed camera operations have taken place within the respective Melbourne and country areas. This pattern of results provides further evidence that the observed effects relate to the speed camera program.

The results of Phase 2 suggest that the reductions in the frequency of casualty crashes (in low alcohol hours) appeared to be linked with speed camera TINs issued to detected drivers, TAC road safety publicity in general and TAC speed related publicity (lower level of significance). Reductions in the injury severity of casualty crashes (in low alcohol hours) appeared to be associated with speed camera TINs issued and hours of camera operation.

On the basis of the analyses in this report, it is clear that the speed camera program (enforcement and supporting publicity) has been effective.

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APPENDIX A

EVALUATION CRITERIA: SPEED-RELATED CRASHES

A sound impact evaluation uses an evaluation criterion (or criteria) which is directly related to the program to ensure that it is as valid and as statistically powerful (within the constraints of the sample size available) as possible. In most road safety program evaluations the target group is clearly defined (eg. young drivers) and/or there are direct measures of the target crash type available in mass data (eg. intersection crashes, alcohol-involved crashes) or very good surrogate measures exist (serious casualty crashes in high alcohol hours).

In contrast, "speeding" is a pervasive and transient behaviour making it difficult to identify its presence in crash types or characteristics. Given the difficulties in studying the relationship between travel speed and crashes, its role as a factor in contributing to or causing crash risk is not well understood. There is therefore no empirical evidence pointing to a target group. Notwithstanding this, an attempt has been made to identify target group(s) (available in the mass crash data) which might be related to speed-related crashes. A review of **available** information and literature on "speeding" was undertaken to do this, with emphasis placed upon Australian studies/data. The balance between the need to identify a target group and maintaining the validity of the evaluation was discussed in the main part of the report. It was decided that the available evidence was insufficient to identify speed-related crashes.

Selected studies pointing to potential target group(s)

Solomon (1964)- Elevated crash risk found for significant departures from average traffic speeds for night-time crashes (U shaped relationship), whilst the trend for daytime crashes was much weaker. Crash types that showed this trend were (mainly) night-time single vehicle ran off road collisions (only for higher speeds) and head-on collisions. Solomon found no evidence of an interaction between driver age or sex and travel speed for accident involvement rates at lower speed ranges. For the highest speeds there appeared to be a difference between younger and older drivers, with younger drivers over represented in higher speeds.

Accident data, speed profiles and vehicle volumes (used to estimate vehicle-miles of travel) were collected on selected 2-lane and 4-lane US main **rural** highways (freeways were not included) during the day and night. Six thousand crashes and 10,000 vehicle-involvements were used in the study. However, most of the speed estimates of crash-involved vehicles were made by police or third parties, and averaged estimates of vehicle-miles travelled across speed distributions were used. The data relate to the late 1950's.

Research Triangle Institute Study (1970) & West & Dunn (1971)- Flat U shaped relationship found between crash risk and departure from average traffic speeds. Small sample sizes did not allow disaggregation by crash types or other characteristics. There was a tendency, however, for younger drivers (<= 24 years) to be involved in crashes involving higher speeds and older drivers (>= 40 years) in crashes involving lower speeds.

These studies are considered to better estimate the speeds of crash involved vehicles prior to crashing, and provide matched speed distributions of the traffic flow for the times and locations of the individual crashes investigated. Sample sizes are much smaller than for Solomon's study. The four State highways in Indiana were used in the study. Both these and Solomon's study use the concept of comparing speed distribution of vehicles involved in crashes, for comparison with the speeds of vehicles in the traffic stream, to estimate those parts of the speed distribution which are associated with high crash rates.

Cowley (1983) Characteristics of the speeding driver- review and analysis of ARRB rural journey speed data (1979) suggested that young, male drivers, and younger vehicles were associated with higher travel speeds. However, these type of data provide characteristics related to travel speeds and these may have little bearing on "speeding" in crashes. Comparisons between "speeders" and "non-speeders", and "speeding" and "non-speeding" factors only are possible using such data.

Casualty crash data were also analysed for 1979 and although speed estimation of crash involved vehicles is fraught with problems, the data are directly related to casualty crash frequency. Cowley found that "serious speeding" (defined as travelling at 25 km/h over the posted speed limit) was more likely to be associated with: young (< 25 years) drivers; male drivers; drivers with less than two years driving experience; drink driving; night-time; weekend driving; high crash severity. The advantages of this study are that the results are based on Victorian data and use casualty crash involvement to determine factors related to speeding in crashes.

Cowley also undertook a review of available Australian and overseas literature. He concluded that:

- there appears to be some association between speeding and alcohol in crashes
- young drivers and possibly male drivers are more likely to speed or travel at high speeds
- newer, high-powered cars are probably associated with speeding or high speeds
- longer trips are possibly associated with high speeds or speeding.

Fildes, Rumbold & Leening (1991) Speed behaviour and driver attitudes to speeding- Younger drivers (< 34 years) were likely to be "excessive fast travellers" whilst drivers aged 45 years or more were more likely to be "excessively slow" travellers. Sex of the driver was unrelated to travel speed. The number of vehicle occupants was also significantly related to travel speeds.

This study provides information relevant to the recent Victorian context for both rural and urban locations, during daylight hours. It focuses on the characteristics of and differences between drivers who travel at differing speeds. There is no information relating to the characteristics of those who are involved in "speed-related" crashes. Therefore, the assumption has to be made that age group involvement in varying travel speeds is mirrored in crash travel speeds, assuming a direct exposure-crash involvement relationship exists.

APPENDIX B

CORRELATIONS BETWEEN VARIABLES

1. Correlations between estimated total vehicle travel and unemployment measures for Melbourne, Sydney, rural Victoria and rural NSW for the period January 1983-December 1991 are presented. Correlations between estimated total vehicle travel and unemployment rates, incorporating monthly lags, are also shown.

2. Correlations between the variables used in each model are presented. The variables are unemployment rate, the intervention variables (T1a to T2b) and the dependent variables number of low alcohol hour casualty crashes and severity of low alcohol hour casualty crashes.

Correlations were conducted on log transformed data as this was the form of the data to be used in the modelling (to achieve a multiplicative structure).

Glossary of variable codes

LOGUNEMP	Natural Logarithm of number of unemployed persons
LOGURATE	Natural Logarithm of unemployment rate
LOGTRAV	Natural Logarithm of estimated total vehicle travel
LOGCNT	Natural Logarithm of number of low alcohol hour casualty crashes
LOG_T1A	Natural Logarithm of December 1989-March 1990 (T1a) Intervention (Dummy) Variable = e in Dec. 1989-March 1990 and 1 elsewhere
LOG_T1B	Natural Logarithm of April 1990-June 1990 (T1b) Intervention (Dummy) Variable = e in April 1990-June 1990 and 1 elsewhere
LOG_T2A	Natural Logarithm of July 1990-February 1991 (T2a) Intervention (Dummy) Variable = e in July 1990-February 1991 and 1 elsewhere
LOG_T2B	Natural Logarithm of March 1991-December 1991 (T2b) Intervention (Dummy) Variable = e in March-December 1991 and 1 elsewhere

Covariate Correlations - Melbourne - Jan 1983 to Dec 1991

Correlation Coefficients

	LOGUNEMP	LOGURATE	LOGTRAV
LOGUNEMP	1	0.9738	-0.3552
LOGURATE	0.9738	1	-0.5427
LOGTRAV	-0.3552	-0.5427	1

Covariate Correlations - Rural Victoria - Jan 1983 to Dec 1991

Correlation Coefficients

	LOGUNEMP	LOGURATE	LOGTRAV
LOGUNEMP	1	0.9125	0.0253
LOGURATE	0.9125	1	-0.335
LOGTRAV	0.0253	-0.335	1

Covariate Correlations - Sydney - Jan 1983 to Dec 1991

Correlation Coefficients

	LOGUNEMP	LOGURATE	LOGTRAV
LOGUNEMP	1	0.9734	-0.5119
LOGURATE	0.9734	1	-0.6658
LOGTRAV	-0.5119	-0.6658	1

Covariate Correlations - Rural NSW - Jan 1983 to Dec 1991

Correlation Coefficients

	LOGUNEMP	LOGURATE	LOGTRAV
LOGUNEMP	1	0.9095	-0.4031
LOGURATE	0.9095	1	-0.6946
LOGTRAV	-0.4031	-0.6946	1

Travel v. Unemployment Rate Correlations - Melbourne - Jan 1983 to Dec 1990 1

CORR	KMTRAVEL	LAG_0	LAG_1	LAG_2	LAG_3	LAG_4	LAG_5	LAG_6
KMTRAVEL	1	-0.8336	-0.7808	-0.7196	-0.6552	-0.5811	-0.5316	-0.4886
LAG_0	-0.8336	1	0.9445	0.8805	0.8098	0.7394	0.6845	0.6137
LAG_1	-0.7808	0.9445	1	0.9435	0.8806	0.8068	0.74	0.6857
LAG_2	-0.7196	0.8805	0.9435	1	0.944	0.882	0.809	0.7428
LAG_3	-0.6552	0.8098	0.8806	0.944	1	0.9422	0.8826	0.8105
LAG_4	-0.5811	0.7394	0.8068	0.882	0.9422	1	0.941	0.8818
LAG_5	-0.5316	0.6845	0.74	0.809	0.8826	0.941	1	0.9417
LAG_6	-0.4886	0.6137	0.6857	0.7428	0.8105	0.8818	0.9417	1

Travel v. Unemployment Rate Correlations - Rural Victoria - Jan 1983 to Dec 1990 2

CORR	KMTRAVEL	LAG_0	LAG_1	LAG_2	LAG_3	LAG_4	LAG_5	LAG_6
KMTRAVEL	1	-0.6077	-0.5467	-0.5073	-0.4791	-0.4317	-0.3766	-0.3497
LAG_0	-0.6077	1	0.7885	0.6745	0.6433	0.5286	0.4202	0.3053
LAG_1	-0.5467	0.7885	1	0.7738	0.6846	0.6532	0.544	0.4393
LAG_2	-0.5073	0.6745	0.7738	1	0.7546	0.6614	0.6184	0.5167
LAG_3	-0.4791	0.6433	0.6846	0.7546	1	0.7632	0.6763	0.6339
LAG_4	-0.4317	0.5286	0.6532	0.6614	0.7632	1	0.77	0.6868
LAG_5	-0.3766	0.4202	0.544	0.6184	0.6763	0.77	1	0.78
LAG_6	-0.3497	0.3053	0.4393	0.5167	0.6339	0.6868	0.78	1

Travel v. Unemployment Rate Correlations - Sydney - Jan 1983 to Dec 1990 3

CORR	KMTRAVEL	LAG_0	LAG_1	LAG_2	LAG_3	LAG_4	LAG_5	LAG_6
KMTRAVEL	1	-0.8479	-0.8174	-0.8015	-0.7877	-0.7701	-0.7509	-0.7457
LAG_0	-0.8479	1	0.9557	0.8949	0.849	0.8211	0.7936	0.7632
LAG_1	-0.8174	0.9557	1	0.9551	0.8929	0.8447	0.8159	0.7875
LAG_2	-0.8015	0.8949	0.9551	1	0.953	0.8879	0.8374	0.8054
LAG_3	-0.7877	0.849	0.8929	0.953	1	0.9508	0.8823	0.827
LAG_4	-0.7701	0.8211	0.8447	0.8879	0.9508	1	0.9485	0.8759
LAG_5	-0.7509	0.7936	0.8159	0.8374	0.8823	0.9485	1	0.9456
LAG_6	-0.7457	0.7632	0.7875	0.8054	0.827	0.8759	0.9456	1

Travel v. Unemployment Rate Correlations - Rural NSW - Jan 1983 to Dec 1990 4

CORR	KMTRAVEL	LAG_0	LAG_1	LAG_2	LAG_3	LAG_4	LAG_5	LAG_6
KMTRAVEL	1	-0.8007	-0.7563	-0.7635	-0.7452	-0.7289	-0.7495	-0.7525
LAG_0	-0.8007	1	0.8938	0.8167	0.7743	0.7845	0.7534	0.7205
LAG_1	-0.7563	0.8938	1	0.8941	0.8117	0.7703	0.7799	0.7511
LAG_2	-0.7635	0.8167	0.8941	1	0.8871	0.8092	0.7619	0.7799
LAG_3	-0.7452	0.7743	0.8117	0.8871	1	0.8871	0.8041	0.758
LAG_4	-0.7289	0.7845	0.7703	0.8092	0.8871	1	0.8866	0.8011
LAG_5	-0.7495	0.7534	0.7799	0.7619	0.8041	0.8866	1	0.8855
LAG_6	-0.7525	0.7205	0.7511	0.7799	0.758	0.8011	0.8855	1

Correlations between Intervention Variables & Unemployment Rate
Correlations between number of low alcohol hour casualty crashes & Unemployment Rate

Correlation Coefficients

AREA	LOG_T1A	LOG_T1B	LOG_T2A	LOG_T2B	LOGCNT
Melbourne				0.5	-0.75
Sydney	-0.26	-0.25	-0.21	0.19	
Rural Victoria	-0.42	-0.33		0.54	-0.44
Rural NSW	-0.23	-0.3	-0.31		
Victoria	-0.25	-0.21		0.54	-0.73
NSW	-0.26	-0.28	-0.26		

APPENDIX C

METHOD FOR CALCULATING CONFIDENCE INTERVALS FOR NET PERCENTAGE CHANGES

Parameter estimates and related standard errors are used to calculate net percentage changes and confidence intervals. All calculations are undertaken in log space, then the final figures are converted.

Parameter estimates for a treated area and its respective comparison area are subtracted to provide the net parameter estimate, which is then converted from log space and expressed as a percentage. Its confidence interval is calculated by simply adding the variances of the two areas and taking their square root*[*], to provide a variance for the net difference, from which a confidence interval can be calculated in the standard way.

An illustration is presented showing net percentage changes and their confidence intervals derived from individual models.

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Victoria (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1 (0,1,1)'							
MA1	-0.1932	0.1019	-1.8960	0.06			
SMA1	0.7170	0.1281	5.5963	0.00			
LOGURATE	-0.0308	0.0020	-15.6100	0.00			
LOGD_T1A	-0.1709	0.0396	-4.3118	0.00	-15.7%	-22.0%	-8.9%
LOGD_T1B	-0.3416	0.0474	-7.2027	0.00	-28.9%	-35.2%	-22.0%
LOG_T2A	-0.3361	0.0342	-9.8252	0.00	-28.5%	-33.2%	-23.6%
LOG_T2B	-0.2454	0.0346	-7.0993	0.00	-21.8%	-26.9%	-16.3%
R SQUARE ADJ		0.7014					
N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1 (0,1,1)'							
MA1	-0.5150	0.0828	-6.2187	0.00			
SMA1	0.9991	30.0155	0.0333	0.97			
LOGURATE	-0.0007	0.0019	-0.3443	0.73			
LOGD_T1A	-0.0881	0.0339	-2.5994	0.01	-8.4%	-14.3%	-2.1%
LOGD_T1B	-0.1173	0.0400	-2.9361	0.00	-11.1%	-17.8%	-3.8%
LOG_T2A	-0.1013	0.0325	-3.1159	0.00	-9.6%	-15.2%	-3.7%
LOG_T2B	-0.1689	0.0347	-4.8706	0.00	-15.5%	-21.1%	-9.6%
R SQUARE ADJ		0.4986					
Net Percentage Changes							
LOGD_T1A					-8.0%	-16.9%	2.0%
LOGD_T1B					-20.1%	-29.2%	-9.8%
LOGD_T2A					-20.9%	-27.9%	-13.3%
LOGD_T2B					-7.4%	-15.9%	2.0%

[*] Theorem 5.8(b) Mendenhall, Scheaffer & Wackerly "Mathematical Statistics with Applications"

APPENDIX D

STATEWIDE RESULTS

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Victoria (Travel) - Crashes 1, 2, 3							
ARIMA(0,0,1) (0,1,1)							
MA1	-0.1603	0.1011	-1.5736	0.12			
SMA1	0.7465	0.1347	5.5418	0.00			
LOGTRAV	0.0057	0.0003	17.1169	0.00			
LOGD_T1A	-0.1747	0.0373	-4.6846	0.00	-16.0%	-21.9%	-9.7%
LOGD_T1B	-0.3371	0.0447	-7.5272	0.00	-28.6%	-34.6%	-22.1%
LOGD_T2A	-0.3366	0.0324	-10.3815	0.00	-28.6%	-33.0%	-23.9%
LOGD_T2B	-0.2593	0.0331	-7.8215	0.00	-22.8%	-27.7%	-17.7%
R SQUARE ADJ		0.7168					
Victoria (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1) (0,1,1)'							
MA1	-0.1932	0.1019	-1.8960	0.06			
SMA1	0.7170	0.1281	5.5963	0.00			
LOGURATE	-0.0308	0.0020	-15.6100	0.00			
LOGD_T1A	-0.1709	0.0396	-4.3118	0.00	-15.7%	-22.0%	-8.9%
LOGD_T1B	-0.3416	0.0474	-7.2027	0.00	-28.9%	-35.2%	-22.0%
LOGD_T2A	-0.3361	0.0342	-9.8252	0.00	-28.5%	-33.2%	-23.6%
LOGD_T2B	-0.2454	0.0346	-7.0993	0.00	-21.8%	-26.9%	-16.3%
R SQUARE ADJ		0.7014					

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
N.S.W (Travel) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1) (0,1,1)							
MA1	-0.5144	0.0833	-6.1762	0.00			
SMA1	0.9904	2.9786	0.3325	0.74			
LOGTRAV	0.0002	0.0003	0.4913	0.62			
LOGD_T1A	-0.0899	0.0339	-2.6517	0.01	-8.6%	-14.5%	-2.3%
LOGD_T1B	-0.1193	0.0397	-3.0059	0.00	-11.2%	-17.9%	-4.1%
LOGD_T2A	-0.1032	0.0322	-3.2075	0.00	-9.8%	-15.3%	-3.9%
LOGD_T2B	-0.1701	0.0346	-4.9135	0.00	-15.6%	-21.2%	-9.7%
R SQUARE ADJ		0.5001					
N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1) (0,1,1)'							
MA1	-0.5150	0.0828	-6.2187	0.00			
SMA1	0.9991	30.0155	0.0333	0.97			
LOGURATE	-0.0007	0.0019	-0.3443	0.73			
LOGD_T1A	-0.0881	0.0339	-2.5994	0.01	-8.4%	-14.3%	-2.1%
LOGD_T1B	-0.1173	0.0400	-2.9361	0.00	-11.1%	-17.8%	-3.8%
LOGD_T2A	-0.1013	0.0325	-3.1159	0.00	-9.6%	-15.2%	-3.7%
LOGD_T2B	-0.1689	0.0347	-4.8706	0.00	-15.5%	-21.1%	-9.6%
R SQUARE ADJ		0.4986					

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Victoria (Travel) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	-5.9610	3.6422	-1.6370	0.11			
IDNUM	0.0039	0.0010	3.7000	0.00			
LOGTRAV	0.8324	0.2457	3.3870	0.00			
LOGD_T1A	-0.1897	0.0381	-4.9860	0.00	-17.3%	-23.2%	-10.9%
LOGD_T1B	-0.3035	0.0450	-6.7460	0.00	-26.2%	-32.4%	-19.4%
LOGD_T2A	-0.3372	0.0380	-8.8690	0.00	-28.6%	-33.7%	-23.1%
LOGD_T2B	-0.4875	0.0472	-10.3270	0.00	-38.6%	-44.0%	-32.6%
R SQUARE ADJ		0.8813					
Victoria (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	6.0465	0.2330	25.9550	0.00			
IDNUM	0.0063	0.0008	8.0670	0.00			
LOGURATE	-0.1416	0.0993	-1.4260	0.16			
LOGD_T1A	-0.2148	0.0397	-5.4030	0.00	-19.3%	-25.4%	-12.8%
LOGD_T1B	-0.3388	0.0457	-7.4200	0.00	-28.7%	-34.8%	-22.1%
LOGD_T2A	-0.3504	0.0572	-6.1280	0.00	-29.6%	-37.0%	-21.2%
LOGD_T2B	-0.4896	0.0924	-5.2990	0.00	-38.7%	-48.9%	-26.5%
R SQUARE ADJ		0.8691					

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
N.S.W (Travel) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	1.8504	4.0278	0.4590	0.65			
IDNUM	-0.0007	0.0008	-0.9290	0.36			
LOGTRAV	0.3446	0.2671	1.2900	0.20			
LOGD_T1A	-0.1130	0.0388	-2.9150	0.00	-10.7%	-17.2%	-3.6%
LOGD_T1B	-0.0857	0.0442	-1.9400	0.06	-8.2%	-15.8%	0.1%
LOGD_T2A	-0.1318	0.0316	-4.1750	0.00	-12.4%	-17.6%	-6.8%
LOGD_T2B	-0.2747	0.0320	-8.5940	0.00	-24.0%	-28.6%	-19.1%
R SQUARE ADJ		0.6670					
N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	7.1911	0.2124	33.8490	0.00			
IDNUM	0.0006	0.0007	0.8830	0.38			
LOGURATE	0.0679	0.0987	0.6880	0.49			
LOGD_T1A	-0.1132	0.0393	-2.8800	0.01	-10.7%	-17.3%	-3.6%
LOGD_T1B	-0.0881	0.0444	-1.9830	0.05	-8.4%	-16.1%	-0.1%
LOG_T2A	-0.1529	0.0330	-4.6390	0.00	-14.2%	-19.5%	-8.4%
LOG_T2B	-0.3203	0.0530	-6.0460	0.00	-27.4%	-34.6%	-19.5%
R SQUARE ADJ		0.6626					

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95%Conf. Interval Lower	Upper
Victoria(Travel)							
LOGISTIC REGRESSION							
INTERCEP	16.1405	5.5898	2.887	0.00			
IDNUM	-0.0019	0.0016	-1.167	0.25			
LOGTRAV	-1.1125	0.3771	-2.95	0.00			
LOGD_T1A	-0.0296	0.0584	-0.507	0.61	-2.9%	-13.4%	8.9%
LOGD_T1B	-0.0176	0.0691	-0.254	0.80	-1.7%	-14.2%	12.5%
LOGD_T2A	-0.0605	0.0583	-1.037	0.30	-5.9%	-16.0%	5.5%
LOGD_T2B	-0.0272	0.0725	-0.376	0.71	-2.7%	-15.6%	12.2%
R SQUARE ADJ	0.7628						
Victoria (Unemployment)							
LOGISTIC REGRESSION							
INTERCEP	0.8845	0.3317	2.667	0.01			
IDNUM	-0.0026	0.0011	-2.388	0.02			
LOGURATE	0.5296	0.1413	3.747	0.00			
LOGD_T1A	0.0183	0.0566	0.324	0.75	1.9%	-8.8%	13.8%
LOGD_T1B	0.0045	0.0650	0.069	0.95	0.4%	-11.6%	14.1%
LOGD_T2A	-0.2080	0.0814	-2.555	0.01	-18.8%	-30.8%	-4.7%
LOGD_T2B	-0.3236	0.1315	-2.461	0.02	-27.6%	-44.1%	-6.4%
R SQUARE ADJ	0.7750						

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95%Conf. Interval Lower	Upper
N.S.W.(Travel)							
LOGISTIC REGRESSION							
INTERCEP	-7.8977	5.2959	-1.491	0.14			
IDNUM	-0.0041	0.0010	-4.148	0.00			
LOGTRAV	0.4628	0.3512	1.317	0.19			
LOGD_T1A	0.0710	0.0510	1.392	0.17	7.4%	-2.9%	18.6%
LOGD_T1B	0.1105	0.0581	1.902	0.06	11.7%	-0.3%	25.2%
LOGD_T2A	0.1295	0.0415	3.119	0.00	13.8%	4.9%	23.5%
LOGD_T2B	0.1923	0.0420	4.574	0.00	21.2%	11.6%	31.6%
R SQUARE ADJ	0.3223						
N.S.W.(Unemployment)							
LOGISTIC REGRESSION							
INTERCEP	-1.0236	0.2800	-3.656	0.0004			
IDNUM	-0.0032	0.0009	-3.622	0.0005			
LOGURATE	-0.0483	0.1301	-0.371	0.7114			
LOGD_T1A	0.0630	0.0518	1.217	0.2268	6.5%	-3.8%	17.9%
LOGD_T1B	0.1041	0.0585	1.778	0.0788	11.0%	-1.1%	24.5%
LOGD_T2A	0.1195	0.0434	2.751	0.0072	12.7%	3.5%	22.7%
LOGD_T2B	0.1929	0.0698	2.763	0.0069	21.3%	5.8%	39.1%
R SQUARE ADJ	0.3103						

APPENDIX E

MODELS OF CASUALTY CRASH FREQUENCY AND THEIR INJURY SEVERITY FOR REGIONS ACROSS VICTORIA & NSW AND NET EFFECTS FOR EACH COMPARISON

Modelling Output Glossary

- ARIMA (0,0,1) (0,1,1)

MA1	Non-seasonal moving average component
SMA1	Seasonal moving average component
LOGURATE	Natural Logarithm of the Unemployment Rate
LOGTRAV	Natural Logarithm of the Total Vehicle Kilometers Travelled
LOGD_T1a	Natural Logarithm of December 1989 to March 1990 Dummy Variable = e in time period and 1 elsewhere
LOGD_T1b	Natural Logarithm of April 1990 to June 1990 Dummy Variable = e in time period and 1 elsewhere
LOGD_T2a	Natural Logarithm of July 1990 to February 1991 Dummy Variable = e in time period and 1 elsewhere
LOGD_T2b	Natural Logarithm of March 1991 to Dec 1991 Dummy Variable = e in time period and 1

- Regression Equation

INTERCEP Regression Equation Intercept
IDNUM Linear Trend Component of Regression Equation
= 1 in January '83, 2 in February '83 etc.

LOGURATE }
LOGTRAV }
LOGD_T1a } Same as with ARIMA modelling
LOGD_T1b }
LOGD_T2a }
LOGD_T2b }

LOGFEB Natural Logarithm of February Dummy Variable
= e in February and 1 in other months

LOGMAR Natural Logarithm of March Dummy Variable
= e in March and 1 in other months

LOGAPR Natural Logarithm of April Dummy Variable
= e in April and 1 in other months

LOGMAY Natural Logarithm of May Dummy Variable
= e in May and 1 in other months

LOGJUN Natural Logarithm of June Dummy Variable

= e in June and 1 in other months

LOGJUL	Natural Logarithm of July Dummy Variable = e in July and 1 in other months
LOGAUG	Natural Logarithm of August Dummy Variable = e in August and 1 in other months
LOGSEP	Natural Logarithm of September Dummy Variable = e in September and 1 in other months
LOGOCT	Natural Logarithm of October Dummy Variable = e in October and 1 in other months
LOGNOV	Natural Logarithm of November Dummy Variable = e in November and 1 in other months
LOGDEC	Natural Logarithm of December Dummy Variable = e in December and 1 in other months

e is the exponential constant and $LOG_e(e)=1$, $LOG_e(1)=0$

MODELS FOR PHASE 1: GENERAL EFFECTS OF THE PROGRAM

Models for Casualty Crashes

1. ARIMA time series model with covariates

CASUALTY CRASHES = a	*x*	MA^b	(non-seasonal moving average)
	x	SMA^c	(seasonal moving average)
	x	$URATE^d$	(unemployment rate)
	x	$T1A^e$	(dummy for Dec 1989 to March 1990)
	x	$T1B^f$	(dummy for April 1990 to June 1990)
	x	$T2A^g$	(dummy for July 1990 to Feb 1991)
	x	$T2B^h$	(dummy for March 1991 to Dec 1991)

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Victoria (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1 (0,1,1)'							
MA1	-0.1932	0.1019	-1.8960	0.06			
SMA1	0.7170	0.1281	5.5963	0.00			
LOGURATE	-0.0308	0.0020	-15.6100	0.00			
LOGD_T1A	-0.1709	0.0396	-4.3118	0.00	-15.7%	-22.0%	-8.9%
LOGD_T1B	-0.3416	0.0474	-7.2027	0.00	-28.9%	-35.2%	-22.0%
LOG_T2A	-0.3361	0.0342	-9.8252	0.00	-28.5%	-33.2%	-23.6%
LOG_T2B	-0.2454	0.0346	-7.0993	0.00	-21.8%	-26.9%	-16.3%
R SQUARE ADJ		0.7014					
N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1 (0,1,1)'							
MA1	-0.5150	0.0828	-6.2187	0.00			
SMA1	0.9991	30.0155	0.0333	0.97			
LOGURATE	-0.0007	0.0019	-0.3443	0.73			
LOGD_T1A	-0.0881	0.0339	-2.5994	0.01	-8.4%	-14.3%	-2.1%
LOGD_T1B	-0.1173	0.0400	-2.9361	0.00	-11.1%	-17.8%	-3.8%
LOG_T2A	-0.1013	0.0325	-3.1159	0.00	-9.6%	-15.2%	-3.7%
LOG_T2B	-0.1689	0.0347	-4.8706	0.00	-15.5%	-21.1%	-9.6%
R SQUARE ADJ		0.4986					
Net Percentage Changes							
LOGD_T1A					-8.0%	-16.9%	2.0%
LOGD_T1B					-20.1%	-29.2%	-9.8%
LOGD_T2A					-20.9%	-27.9%	-13.3%
LOGD_T2B					-7.4%	-15.9%	2.0%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Melbourne (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.2166	0.1024	-2.1146	0.04			
SMA1	0.7692	0.1466	5.2469	0.00			
LOGURATE	-0.0294	0.0020	-14.5627	0.00			
LOGD_T1A	-0.1677	0.0423	-3.9651	0.00	-15.4%	-22.2%	-8.1%
LOGD_T1B	-0.3555	0.0512	-6.9469	0.00	-29.9%	-36.6%	-22.5%
LOGD_T2A	-0.3507	0.0375	-9.3563	0.00	-29.6%	-34.6%	-24.2%
LOGD_T2B	-0.2363	0.0384	-6.1537	0.00	-21.0%	-26.8%	-14.9%
R SQUARE ADJ		0.6932					
Sydney (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.5429	0.0815	-6.6643	0.00			
SMA1	0.9611	0.7124	1.3489	0.18			
LOGURATE	0.0013	0.0021	0.6331	0.53			
LOGD_T1A	-0.0966	0.0394	-2.4514	0.02	-9.2%	-16.0%	-1.9%
LOGD_T1B	-0.0878	0.0458	-1.9161	0.06	-8.4%	-16.3%	0.2%
LOGD_T2A	-0.1136	0.0378	-3.0032	0.00	-10.7%	-17.1%	-3.9%
LOGD_T2B	-0.1907	0.0403	-4.7297	0.00	-17.4%	-23.6%	-10.6%
R SQUARE ADJ		0.4794					
Net Percentage Changes							
LOGD_T1A					-7.0%	-16.8%	4.3%
LOGD_T1B					-23.5%	-33.1%	-12.5%
LOGD_T2A					-21.1%	-28.9%	-12.4%
LOGD_T2B					-4.5%	-14.3%	6.6%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Rural Victoria (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.0779	0.0944	-0.8253				
SMA1	0.9403	0.4154	2.2636	0.41			
LOGURATE	-0.0342	0.0021	-16.0867	0.02			
LOGD_T1A	-0.1532	0.0438	-3.4920	0.00	-14.2%	-21.3%	-6.5%
LOG_T1B	-0.2991	0.0547	-5.4622	0.00	-25.9%	-33.4%	-17.5%
LOGD_T2A	-0.3091	0.0402	-7.6728	0.00	-26.6%	-32.2%	-20.6%
LOGD_T2B	-0.2772	0.0423	-6.5479	0.00	-24.2%	-30.2%	-17.7%
R SQUARE ADJ		0.5670					
Rural N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.2087	0.0938	-2.2249	0.03			
SMA1	0.9928	3.6364	0.2730	0.79			
LOGURATE	-0.0041	0.0021	-1.9423	0.06			
LOGD_T1A	-0.1157	0.0372	-3.1130	0.00	-10.9%	-17.2%	-4.2%
LOG_T1B	-0.1202	0.0464	-2.5942	0.01	-11.3%	-19.0%	-2.9%
LOGD_T2A	-0.0920	0.0349	-2.6334	0.01	-8.8%	-14.8%	-2.3%
LOGD_T2B	-0.1501	0.0368	-4.0788	0.00	-13.9%	-19.9%	-7.5%
R SQUARE ADJ		0.4617					
Net Percentage Changes							
LOGD_T1A					-3.7%	-14.0%	7.8%
LOGD_T1B					-16.4%	-27.4%	-3.8%
LOGD_T2A					-19.5%	-27.5%	-10.7%
LOGD_T2B					-11.9%	-21.1%	-1.7%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Melbourne Arterials (Unemployment) - Crashes, 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.2059	0.1020	-2.0187	0.05			
SMA1	0.7663	0.1478	5.1835	0.00			
LOGURATE	-0.0323	0.0022	-14.9136	0.00			
LOGD_T1A	-0.1782	0.0454	-3.9274	0.00	-16.3%	-23.4%	-8.5%
LOGD_T1B	-0.3627	0.0549	-6.6073	0.00	-30.4%	-37.5%	-22.5%
LOGD_T2A	-0.3791	0.0401	-9.4488	0.00	-31.6%	-36.7%	-26.0%
LOGD_T2B	-0.2545	0.0411	-6.1988	0.00	-22.5%	-28.5%	-16.0%
R SQUARE ADJ		0.6355					
Sydney Arterials (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1)(0,1,1)							
MA1	0.0710	0.1174	0.6050	0.55			
SMA1	0.8789	0.5832	1.5069	0.14			
LOGURATE	0.0218	0.0030	7.1404	0.00			
LOGD_T1A	-0.0209	0.0343	-0.6079	0.55	-2.1%	-8.4%	4.7%
LOGD_T1B	0.0494	0.0424	1.1646	0.25	5.1%	-3.3%	14.2%
LOGD_T2A	0.0125	0.0310	0.4025	0.69	1.3%	-4.7%	7.6%
LOGD_T2B	-0.1428	0.0292	-4.8839	0.00	-13.3%	-18.1%	-8.2%
R SQUARE ADJ		0.4242					
Net Percentage Changes							
LOGD_T1A					-14.6%	-23.6%	-4.5%
LOGD_T1B					-33.8%	-42.2%	-24.1%
LOGD_T2A					-32.4%	-38.8%	-25.3%
LOGD_T2B					-10.6%	-19.0%	-1.3%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Melbourne Arterials 60 Kmh Speed Zone (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1 (0,1,1)							
MA1	-0.2269	0.0970	-2.3381	0.02			
SMA1	0.8448	0.1953	4.3250	0.00			
LOGURATE	-0.0283	0.0021	-13.3958	0.00			
LOGD_T1A	-0.1709	0.0450	-3.7972	0.00	-15.7%	-22.8%	-7.9%
LOGD_T1B	-0.3491	0.0553	-6.3175	0.00	-29.5%	-36.7%	-21.4%
LOGD_T2A	-0.3650	0.0411	-8.8745	0.00	-30.6%	-36.0%	-24.8%
LOGD_T2B	-0.2425	0.0428	-5.6620	0.00	-21.5%	-27.8%	-14.7%
R SQUARE ADJ		0.5961					
Sydney Arterials 60 Kmh Speed Zone (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1)(0,1,1)	ok						
MA1	-0.0037	0.1167	-0.0314	0.98			
SMA1	0.9128	0.7801	1.1701	0.25			
LOGURATE	0.0232	0.0033	7.0595	0.00			
LOGD_T1A	-0.0230	0.0363	-0.6336	0.53	-2.3%	-9.0%	4.9%
LOG_T1B	0.0295	0.0448	0.6587	0.51	3.0%	-5.7%	12.5%
LOGD_T2A	0.0003	0.0333	0.0087	0.99	0.0%	-6.3%	6.8%
LOGD_T2B	-0.1846	0.0315	-5.8673	0.00	-16.9%	-21.8%	-11.6%
R SQUARE ADJ		0.5128					
Net Percentage Changes							
LOGD_T1A					-13.8%	-23.0%	-3.4%
LOGD_T1B					-31.5%	-40.4%	-21.3%
LOGD_T2A					-30.6%	-37.4%	-23.0%
LOGD_T2B					-5.6%	-15.0%	4.7%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Melbourne Arterials (Unemployment) - Crashes, 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.2059	0.1020	-2.0187	0.05			
SMA1	0.7663	0.1478	5.1835	0.00			
LOGURATE	-0.0323	0.0022	-14.9136	0.00			
LOGD_T1A	-0.1782	0.0454	-3.9274	0.00	-16.3%	-23.4%	-8.5%
LOGD_T1B	-0.3627	0.0549	-6.6073	0.00	-30.4%	-37.5%	-22.5%
LOGD_T2A	-0.3791	0.0401	-9.4488	0.00	-31.6%	-36.7%	-26.0%
LOGD_T2B	-0.2545	0.0411	-6.1988	0.00	-22.5%	-28.5%	-16.0%
R SQUARE ADJ		0.6355					
Melbourne Residential (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.1200	0.1038	-1.1558	0.25			
SMA1	0.7626	0.1430	5.3338	0.00			
LOGURATE	-0.0221	0.0026	-8.4297	0.00			
LOGD_T1A	-0.1616	0.0563	-2.8732	0.01	-14.9%	-23.8%	-5.0%
LOGD_T1B	-0.3301	0.0683	-4.8312	0.00	-28.1%	-37.1%	-17.8%
LOGD_T2A	-0.2832	0.0493	-5.7429	0.00	-24.7%	-31.6%	-17.0%
LOGD_T2B	-0.2559	0.0503	-5.0913	0.00	-22.6%	-29.8%	-14.6%
R SQUARE ADJ		0.4940					
Net Percentage Changes							
LOGD_T1A					-1.6%	-14.6%	13.3%
LOGD_T1B					-3.2%	-18.5%	14.9%
LOGD_T2A					-9.1%	-19.8%	2.9%
LOGD_T2B					-0.1%	-11.8%	13.7%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Rural Victoria 100 Kmh Speed Zones (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.0435	0.0935	-0.4650	0.64			
SMA1	0.9583	0.6401	1.4970	0.14			
LOGURATE	-0.0275	0.0028	-9.8816	0.00			
LOGD_T1A	-0.0839	0.0580	-1.4464	0.15	-8.0%	-17.9%	3.0%
LOGD_T1B	-0.1944	0.0725	-2.6811	0.01	-17.7%	-28.6%	-5.1%
LOG_T2A	-0.2548	0.0531	-4.7942	0.00	-22.5%	-30.2%	-14.0%
LOG_T2B	-0.1835	0.0559	-3.2843	0.00	-16.8%	-25.4%	-7.1%
R SQUARE ADJ		0.3749					
Rural N.S.W. 100 Kmh Speed Zones (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1 (0,1,1)							
MA1	-0.1090	0.1009	-1.0803	0.28			
SMA1	0.7661	0.1228	6.2399	0.00			
LOGURATE	0.0024	0.0032	0.7384	0.46			
LOGD_T1A	-0.0859	0.0556	-1.5458	0.13	-8.2%	-17.7%	2.3%
LOGD_T1B	-0.1098	0.0675	-1.6262	0.11	-10.4%	-21.5%	2.3%
LOGD_T2A	-0.1027	0.0488	-2.1043	0.04	-9.8%	-18.0%	-0.7%
LOGD_T2B	-0.0876	0.0497	-1.7624	0.08	-8.4%	-16.9%	1.0%
R SQUARE ADJ	0.2321						
Net Percentage Changes							
LOGD_T1A					0.2%	-14.4%	17.3%
LOGD_T1B					-8.1%	-24.3%	11.6%
LOGD_T2A					-14.1%	-25.4%	-1.1%
LOGD_T2B					-9.1%	-21.5%	5.2%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Rural Victoria 60 Kmh Speed Zones (Unemployment) - Crashes 1, 2, 3							
ARIMA(0,0,1)(0,1,1)							
MA1	-0.0135	0.0946	-0.1430	0.89			
SMA1	0.9328	0.4384	2.1279	0.04			
LOGURATE	-0.0367	0.0025	-14.4234	0.00			
LOGD_T1A	-0.1905	0.0532	-3.5784	0.00	-17.3%	-25.5%	-8.3%
LOGD_T1B	-0.3259	0.0665	-4.8985	0.00	-27.8%	-36.6%	-17.8%
LOG_T2A	-0.3445	0.0485	-7.1038	0.00	-29.1%	-35.6%	-22.1%
LOG_T2B	-0.3818	0.0509	-7.5063	0.00	-31.7%	-38.2%	-24.6%
R SQUARE ADJ		0.5374					
Rural N.S.W. 60 Kmh Speed Zones (Unemployment) - Crashes 1, 2, 3, 4							
ARIMA(0,0,1(0,1,1)							
MA1	-0.0462	0.0951	-0.4860	0.63			
SMA1	0.9793	1.3665	0.7166	0.48			
LOGURATE	-0.0024	0.0021	-1.1400	0.26			
LOGD_T1A	-0.1565	0.0379	-4.1282	0.00	-14.5%	-20.6%	-7.9%
LOGD_T1B	-0.0896	0.0475	-1.8847	0.06	-8.6%	-16.7%	0.4%
LOGD_T2A	-0.0795	0.0351	-2.2678	0.03	-7.6%	-13.8%	-1.1%
LOGD_T2B	-0.1863	0.0368	-5.0679	0.00	-17.0%	-22.8%	-10.8%
R SQUARE ADJ	0.4372						
Net Percentage Changes							
LOGD_T1A					-3.3%	-15.0%	9.9%
LOGD_T1B					-21.0%	-32.7%	-7.3%
LOGD_T2A					-23.3%	-31.8%	-13.7%
LOGD_T2B					-17.8%	-27.3%	-7.0%

MODELS FOR PHASE 1: GENERAL EFFECTS OF THE PROGRAM

Models for Casualty Crashes (cont.)

2. Multiple regression model

$$
\begin{aligned}
\text{CASUALTY CRASHES} = a \;\; & x\ (e^{\text{TREND}})^{b} && \text{(1 in Jan 1983, 2 in Feb 1983, ..)}\\
& x\ \text{URATE}^{c} \\
& x\ \text{T1A}^{d} \\
& x\ \text{T1B}^{e} \\
& x\ \text{T2A}^{f} \\
& x\ \text{T2B}^{g} \\
& x\ \text{FEB}^{h} && \text{(dummy for February months)}\\
& \vdots \\
& x\ \text{DEC}^{r} && \text{(dummy for December months)}
\end{aligned}
$$

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Victoria (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	6.0465	0.2330	25.9550	0.00			
IDNUM	0.0063	0.0008	8.0670	0.00			
LOGURATE	-0.1416	0.0993	-1.4260	0.16			
LOGD_T1A	-0.2148	0.0397	-5.4030	0.00	-19.3%	-25.4%	-12.8%
LOGD_T1B	-0.3388	0.0457	-7.4200	0.00	-28.7%	-34.8%	-22.1%
LOGD_T2A	-0.3504	0.0572	-6.1280	0.00	-29.6%	-37.0%	-21.2%
LOGD_T2B	-0.4896	0.0924	-5.2990	0.00	-38.7%	-48.9%	-26.5%
R SQUARE ADJ		0.8691					
N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	7.1911	0.2124	33.8490	0.00			
IDNUM	0.0006	0.0007	0.8830	0.38			
LOGURATE	0.0679	0.0987	0.6880	0.49			
LOGD_T1A	-0.1132	0.0393	-2.8800	0.01	-10.7%	-17.3%	-3.6%
LOGD_T1B	-0.0881	0.0444	-1.9830	0.05	-8.4%	-16.1%	-0.1%
LOGD_T2A	-0.1529	0.0330	-4.6390	0.00	-14.2%	-19.5%	-8.4%
LOGD_T2B	-0.3203	0.0530	-6.0460	0.00	-27.4%	-34.6%	-19.5%
R SQUARE ADJ		0.6626					
Net Percentage Changes							
LOGD_T1A					-9.7%	-19.0%	0.8%
LOGD_T1B					-22.2%	-31.3%	-11.8%
LOGD_T2A					-17.9%	-27.9%	-6.6%
LOGD_T2B					-15.6%	-31.5%	4.0%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Melbourne (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	5.4319	0.2157	25.1880	0.00			
IDNUM	0.0048	0.0009	5.2530	0.00			
LOGURATE	-0.2500	0.0929	-2.6910	0.01			
LOGD_T1A	-0.1661	0.0436	-3.8080	0.00	-15.3%	-22.2%	-7.7%
LOGD_T1B	-0.3088	0.0526	-5.8690	0.00	-26.6%	-33.8%	-18.6%
LOGD_T2A	-0.2774	0.0679	-4.0870	0.00	-24.2%	-33.7%	-13.4%
LOGD_T2B	-0.3519	0.1031	-3.4130	0.00	-29.7%	-42.5%	-13.9%
R SQUARE ADJ		0.8610					
Sydney (Unemployment) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	6.4336	0.2173	29.6040	0.00			
IDNUM	-0.0002	0.0008	-0.2460	0.81			
LOGURATE	0.0193	0.0974	0.1980	0.84			
LOGD_T1A	-0.0973	0.0471	-2.0670	0.04	-9.3%	-17.3%	-0.5%
LOGD_T1B	-0.0826	0.0534	-1.5480	0.13	-7.9%	-17.1%	2.2%
LOGD_T2A	-0.1413	0.0420	-3.3680	0.00	-13.2%	-20.0%	-5.7%
LOGD_T2B	-0.3183	0.0671	-4.7450	0.00	-27.3%	-36.2%	-17.0%
R SQUARE ADJ		0.6828					
Net Percentage Changes							
LOGD_T1A					-6.7%	-17.7%	5.9%
LOGD_T1B					-20.2%	-31.1%	-7.6%
LOGD_T2A					-12.7%	-25.4%	2.1%
LOGD_T2B					-3.3%	-24.0%	23.1%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Rural Victoria (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	5.1627	0.2081	24.8080	0.00			
IDNUM	0.0077	0.0005	16.6190	0.00			
LOGURATE	-0.0133	0.0858	-0.1560	0.88			
LOGD_T1A	-0.2739	0.0570	-4.8050	0.00	-24.0%	-32.0%	-15.0%
LOGD_T1B	-0.3213	0.0599	-5.3630	0.00	-27.5%	-35.5%	-18.4%
LOGD_T2A	-0.3800	0.0413	-9.2080	0.00	-31.6%	-36.9%	-25.9%
LOGD_T2B	-0.6071	0.0575	-10.5620	0.00	-45.5%	-51.3%	-39.0%
R SQUARE ADJ		0.8198					
Rural N.S.W (Unemployment) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	6.3954	0.2264	28.2530	0.00			
IDNUM	0.0010	0.0006	1.8100	0.07			
LOGURATE	0.0439	0.1109	0.3950	0.69			
LOGD_T1A	-0.1365	0.0442	-3.0890	0.00	-12.8%	-20.0%	-4.9%
LOG_T1B	-0.0952	0.0504	-1.8890	0.06	-9.1%	-17.6%	0.4%
LOGD_T2A	-0.1514	0.0343	-4.4100	0.00	-14.1%	-19.6%	-8.1%
LOGD_T2B	-0.2829	0.0444	-6.3670	0.00	-24.6%	-30.9%	-17.8%
R SQUARE ADJ		0.5315					
Net Percentage Changes							
LOGD_T1A					-12.8%	-24.3%	0.4%
LOGD_T1B					-20.2%	-31.6%	-7.0%
LOGD_T2A					-20.4%	-28.4%	-11.6%
LOGD_T2B					-27.7%	-37.3%	-16.6%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Melbourne Arterials (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	5.0273	0.2347	21.4210	0.00			
IDNUM	0.0050	0.0010	5.0480	0.00			
LOGURATE	-0.2905	0.1011	-2.8730	0.01			
LOGD_T1A	-0.1425	0.0475	-3.0020	0.00	-13.3%	-21.0%	-4.8%
LOGD_T1B	-0.3010	0.0572	-5.2570	0.00	-26.0%	-33.8%	-17.2%
LOGD_T2A	-0.2824	0.0739	-3.8230	0.00	-24.6%	-34.8%	-12.9%
LOGD_T2B	-0.3433	0.1121	-3.0600	0.00	-29.1%	-43.1%	-11.6%
R SQUARE ADJ		0.8570					
Sydney Arterials (Unemployment) - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	6.5265	0.2173	30.0360	0.00			
IDNUM	-0.0041	0.0012	-3.5290	0.00			
LOGURATE	0.1170	0.0999	1.1720	0.25			
LOGD_T1A	0.0013	0.0443	0.0290	0.98	0.1%	-8.2%	9.2%
LOGD_T1B	0.0192	0.0506	0.3800	0.71	1.9%	-7.7%	12.6%
LOGD_T2A	-0.0179	0.0444	-0.4040	0.69	-1.8%	-10.0%	7.1%
LOGD_T2B	-0.1948	0.0747	-2.6070	0.01	-17.7%	-28.9%	-4.7%
R SQUARE ADJ		0.8177					
Net Percentage Changes							
LOGD_T1A					-13.4%	-23.8%	-1.6%
LOGD_T1B					-27.4%	-37.5%	-15.7%
LOGD_T2A					-23.2%	-35.2%	-9.1%
LOGD_T2B					-13.8%	-33.8%	12.3%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
Melbourne 60 Kmh Arterials (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	5.0129	0.2421	20.7060	0.00			
IDNUM	0.0048	0.0010	4.6500	0.00			
LOGURATE	-0.2227	0.1043	-2.1360	0.04			
LOGD_T1A	-0.1448	0.0490	-2.9560	0.00	-13.5%	-21.4%	-4.8%
LOGD_T1B	-0.3270	0.0591	-5.5380	0.00	-27.9%	-35.8%	-19.0%
LOGD_T2A	-0.3143	0.0762	-4.1250	0.00	-27.0%	-37.1%	-15.2%
LOGD_T2B	-0.3904	0.1157	-3.3730	0.00	-32.3%	-46.1%	-15.1%
R SQUARE ADJ		0.8340					
Sydney Arterials 60 Kmh Speed Zone (Unemployment) - Crashes, 1, 2, 3, 4							
REGRESSION							
INTERCEP	6.4178	0.2188	29.3290	0.00			
IDNUM	-0.0044	0.0012	-3.8010	0.00			
LOGURATE	0.1146	0.1006	1.1390	0.26			
LOGD_T1A	-0.0091	0.0447	-0.2030	0.84	-0.9%	-9.2%	8.2%
LOG_T1B	-0.0065	0.0510	-0.1270	0.90	-0.6%	-10.1%	9.8%
LOGD_T2A	-0.0248	0.0447	-0.5560	0.58	-2.5%	-10.6%	6.5%
LOGD_T2B	-0.2488	0.0752	-3.3080	0.00	-22.0%	-32.7%	-9.6%
R SQUARE ADJ		0.8532					
Net Percentage Changes							
LOGD_T1A					-12.7%	-23.3%	-0.6%
LOGD_T1B					-27.4%	-37.7%	-15.4%
LOGD_T2A					-25.1%	-37.0%	-11.0%
LOGD_T2B					-13.2%	-33.8%	13.8%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Melbourne Arterials (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	5.0273	0.2347	21.4210	0.00			
IDNUM	0.0050	0.0010	5.0480	0.00			
LOGURATE	-0.2905	0.1011	-2.8730	0.01			
LOGD_T1A	-0.1425	0.0475	-3.0020	0.00	-13.3%	-21.0%	-4.8%
LOGD_T1B	-0.3010	0.0572	-5.2570	0.00	-26.0%	-33.8%	-17.2%
LOGD_T2A	-0.2824	0.0739	-3.8230	0.00	-24.6%	-34.8%	-12.9%
LOGD_T2B	-0.3433	0.1121	-3.0600	0.00	-29.1%	-43.1%	-11.6%
R SQUARE ADJ		0.8570					
Melbourne Residential (Unemployment) - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	4.2080	0.3012	13.9690	0.00			
IDNUM	0.0047	0.0013	3.6620	0.00			
LOGURATE	-0.0975	0.1298	-0.7510	0.45			
LOGD_T1A	-0.2686	0.0609	-4.4090	0.00	-23.6%	-32.2%	-13.9%
LOGD_T1B	-0.3217	0.0735	-4.3780	0.00	-27.5%	-37.2%	-16.3%
LOGD_T2A	-0.2995	0.0948	-3.1590	0.00	-25.9%	-38.4%	-10.7%
LOGD_T2B	-0.4934	0.1440	-3.4270	0.00	-38.9%	-54.0%	-19.0%
R SQUARE ADJ		0.7350					
Net Percentage Changes							
LOGD_T1A					13.4%	-2.5%	32.0%
LOGD_T1B					2.1%	-14.9%	22.5%
LOGD_T2A					1.7%	-19.6%	28.8%
LOGD_T2B					16.2%	-18.8%	66.2%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Rural Victoria 100 Kmh Speed Zones - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	4.0661	0.2923	13.91	0.00			
IDNUM	0.0057	0.0007	8.75	0.00			
LOGURATE	-0.2117	0.1205	-1.757	0.08			
LOGD_T1A	-0.2965	0.0801	-3.704	0.00	-25.7%	-36.5%	-13.0%
LOGD_T1B	-0.3043	0.0842	-3.616	0.00	-26.2%	-37.5%	-13.0%
LOGD_T2A	-0.2378	0.0580	-4.102	0.00	-21.2%	-29.6%	-11.7%
LOGD_T2B	-0.3343	0.0807	-4.14	0.00	-28.4%	-38.9%	-16.1%
R SQUARE ADJ	0.7456						
Rural N.S.W 100 Kmh Speed Zones - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	5.3097	0.3218	16.499	0.00			
IDNUM	-0.0005	0.0008	-0.587	0.56			
LOGURATE	-0.0480	0.1577	-0.304	0.76			
LOGD_T1A	-0.1353	0.0628	-2.154	0.03	-12.7%	-22.8%	-1.2%
LOGD_T1B	-0.1816	0.0717	-2.535	0.01	-16.6%	-27.5%	-4.0%
LOGD_T2A	-0.1367	0.0488	-2.8	0.01	-12.8%	-20.7%	-4.0%
LOGD_T2B	-0.2070	0.0632	-3.276	0.00	-18.7%	-28.2%	-8.0%
R SQUARE ADJ	0.6409						
Net Percentage Changes							
LOGD_T1A					-14.9%	-30.3%	3.0%
LOGD_T1B					-11.5%	-28.8%	9.9%
LOGD_T2A					-9.6%	-22.1%	4.9%
LOGD_T2B					-11.9%	-28.0%	7.6%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Rural Victoria 60 Kmh Speed Zones - Crashes 1, 2, 3							
REGRESSION							
INTERCEP	4.6148	0.2662	17.337	0.00			
IDNUM	0.0086	0.0006	14.355	0.00			
LOGURATE	0.1285	0.1097	1.171	0.24			
LOGD_T1A	-0.1916	0.0729	-2.629	0.01	-17.4%	-28.4%	-4.8%
LOGD_T1B	-0.3031	0.0766	-3.955	0.00	-26.1%	-36.4%	-14.2%
LOGD_T2A	-0.4653	0.0528	-8.813	0.00	-37.2%	-43.4%	-30.4%
LOGD_T2B	-0.8133	0.0735	-11.063	0.00	-55.7%	-61.6%	-48.8%
R SQUARE ADJ	0.7709						
Rural N.S.W 60 Kmh Speed Zones - Crashes 1, 2, 3, 4							
REGRESSION							
INTERCEP	5.9908	0.2448	24.469	0.00			
IDNUM	0.0012	0.0006	1.984	0.05			
LOGURATE	0.1695	0.1200	1.413	0.16			
LOGD_T1A	-0.1651	0.0478	-3.454	0.00	-15.2%	-22.8%	-6.9%
LOGD_T1B	-0.0419	0.0545	-0.769	0.44	-4.1%	-13.8%	6.7%
LOGD_T2A	-0.1677	0.0371	-4.515	0.00	-15.4%	-21.4%	-9.1%
LOGD_T2B	-0.3446	0.0481	-7.169	0.00	-29.2%	-35.5%	-22.2%
R SQUARE ADJ	0.5853						
Net Percentage Changes							
LOGD_T1A					-2.6%	-17.9%	15.5%
LOGD_T1B					-23.0%	-35.9%	-7.4%
LOGD_T2A					-25.7%	-34.6%	-15.7%
LOGD_T2B					-37.4%	-47.3%	-25.7%

MODELS FOR PHASE 1: GENERAL EFFECTS OF THE PROGRAM

Model for Injury Severity of Casualty Crashes

(Logistic multiple regression model)

$$\text{Severity Ratio} = \frac{\text{Fatal plus Serious Injury Crashes}}{\text{Minor Injury Crashes}}$$

$$
\begin{aligned}
\text{SEVERITY RATIO} = a \; & x\ (e^{\text{TREND}})^{b} \\
& x\ \text{URATE}^{c} \\
& x\ \text{T1A}^{d} \\
& x\ \text{T1B}^{e} \\
& x\ \text{T2A}^{f} \\
& x\ \text{T2B}^{g} \\
& x\ \text{FEB}^{h} \\
& \vdots \\
& x\ \text{DEC}^{r}
\end{aligned}
$$

Note: $\text{Injury Severity} = \dfrac{\text{Fatal plus Serious Injury Crashes}}{\text{All Injury Crashes}} = \dfrac{\text{SEVERITY RATIO}}{1 + \text{SEVERITY RATIO}}$

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
'pvic.reg							
Victoria Total (Unemployment & Trend)							
REGRESSION							
INTERCEP	0.8845	0.3317	2.667	0.01			
IDNUM	-0.0026	0.0011	-2.388	0.02			
LOGURATE	0.5296	0.1413	3.747	0.00			
LOGD_T1A	0.0183	0.0566	0.324	0.75	1.9%	-8.8%	13.8%
LOGD_T1B	0.0045	0.0650	0.069	0.95	0.4%	-11.6%	14.1%
LOGD_T2A	-0.2080	0.0814	-2.555	0.01	-18.8%	-30.8%	-4.7%
LOGD_T2B	-0.3236	0.1315	-2.461	0.02	-27.6%	-44.1%	-6.4%
'R SQUARE ADJ	0.7750						
'PNSW.REG							
N.S.W. Total (Unemployment & Trend)							
REGRESSION							
INTERCEP	-1.0236	0.2800	-3.656	0.00			
IDNUM	-0.0032	0.0009	-3.622	0.00			
LOGURATE	-0.0483	0.1301	-0.371	0.71			
LOGD_T1A	0.0630	0.0518	1.217	0.23	6.5%	-3.8%	17.9%
LOGD_T1B	0.1041	0.0585	1.778	0.08	11.0%	-1.1%	24.5%
LOGD_T2A	0.1195	0.0434	2.751	0.01	12.7%	3.5%	22.7%
LOGD_T2B	0.1929	0.0698	2.763	0.01	21.3%	5.8%	39.1%
'R SQUARE ADJ	0.3103						
Net Percentage Changes							
LOGD_T1A					-4.4%	-17.7%	11.1%
LOGD_T1B					-9.5%	-23.7%	7.5%
LOGD_T2A					-27.9%	-39.9%	-13.6%
LOGD_T2B					-40.3%	-55.4%	-20.1%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Melbourne Total (Unemployment) - Crash Severity							
REGRESSION	ok						
INTERCEP	0.9019	0.1541	5.8510	0.00			
LOGURATE	0.6185	0.0561	11.0330	0.00			
LOGD_T1A	-0.0919	0.0667	-1.3790	0.17	-8.8%	-20.0%	3.9%
LOGD_T1B	-0.1984	0.0749	-2.6480	0.01	-18.0%	-29.2%	-5.0%
LOGD_T2A	-0.3744	0.0463	-8.0930	0.00	-31.2%	-37.2%	-24.7%
LOGD_T2B	-0.5640	0.0492	-11.4680	0.00	-43.1%	-48.3%	-37.3%
R SQUARE ADJ		0.6733					
Sydney Total (Unemployment) - Crash Severity							
REGRESSION	ok						
INTERCEP	-0.9749	0.1466	-6.6500	0.00			
LOGURATE	0.1616	0.0570	2.8340	0.01			
LOGD_T1A	0.1106	0.0600	1.8440	0.07	11.7%	-0.7%	25.6%
LOGD_T1B	0.1442	0.0671	2.1490	0.03	15.5%	1.3%	31.8%
LOGD_T2A	0.0592	0.0406	1.4580	0.15	6.1%	-2.0%	14.9%
LOGD_T2B	0.0267	0.0360	0.7420	0.46	2.7%	-4.3%	10.2%
R SQUARE ADJ		0.0370					
Net Percentage Changes							
LOGD_T1A					-18.3%	-31.5%	-2.6%
LOGD_T1B					-29.0%	-41.7%	-13.5%
LOGD_T2A					-35.2%	-42.6%	-26.9%
LOGD_T2B					-44.6%	-50.8%	-37.6%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
Rural Victoria (Unemployment & Trend) - Crash Severity							
REGRESSION							
INTERCEP	0.0613	0.3557	0.1720	0.86			
IDNUM	-0.0086	0.0008	-10.7630	0.00			
LOGURATE	0.0151	0.1466	0.1030	0.92			
LOGD_T1A	0.1134	0.0974	1.1640	0.25	12.0%	-7.5%	35.6%
LOGD_T1B	0.3058	0.1024	2.9860	0.00	35.8%	11.1%	65.9%
LOGD_T2A	0.1160	0.0705	1.6450	0.10	12.3%	-2.2%	29.0%
LOGD_T2B	0.2775	0.0982	2.8260	0.01	32.0%	8.9%	60.0%
R SQUARE ADJ		0.6735					
Rural N.S.W (Unemployment & Trend)							
REGRESSION							
INTERCEP	-0.9080	0.3345	-2.7150	0.01			
IDNUM	-0.0053	0.0008	-6.3140	0.00			
LOGURATE	-0.1786	0.1639	-1.0900	0.28			
LOGD_T1A	0.0254	0.0653	0.3890	0.70	2.6%	-9.8%	16.6%
LOGD_T1B	0.0378	0.0745	0.5070	0.61	3.8%	-10.3%	20.2%
LOGD_T2A	0.1242	0.0507	2.4480	0.02	13.2%	2.5%	25.1%
LOGD_T2B	0.2459	0.0657	3.7450	0.00	27.9%	12.4%	45.4%
R SQUARE ADJ		0.4834					
Net Percentage Changes							
LOGD_T1A					9.2%	-13.2%	37.4%
LOGD_T1B					30.7%	2.0%	67.6%
LOGD_T2A					-0.8%	-16.3%	17.6%
LOGD_T2B					3.2%	-18.1%	30.1%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
'pmlba_io.reg							
Melbourne Arterials (Unemployment)							
REGRESSION							
INTERCEP	0.8561	0.1628	5.258	0.00			
LOGURATE	0.6171	0.0592	10.422	0.00			
LOGD_T1A	-0.1239	0.0704	-1.759	0.08	-11.7%	-23.0%	1.4%
LOGD_T1B	-0.2625	0.0792	-3.316	0.00	-23.1%	-34.1%	-10.2%
LOGD_T2A	-0.4268	0.0489	-8.735	0.00	-34.7%	-40.7%	-28.2%
LOGD_T2B	-0.5920	0.0519	-11.396	0.00	-44.7%	-50.0%	-38.7%
'R SQUARE ADJ	0.6823						
'psyda_io.reg							
Sydney Arterials (Unemployment)							
REGRESSION							
INTERCEP	-1.3937	0.3017	-4.619	0.00			
LOGURATE	0.0140	0.1142	0.123	0.90			
LOGD_T1A	0.1253	0.0745	1.68	0.10	13.3%	-2.1%	31.2%
LOGD_T1B	0.1983	0.0808	2.453	0.02	21.9%	4.1%	42.9%
LOGD_T2A	0.0368	0.0483	0.763	0.45	3.8%	-5.6%	14.0%
LOGD_T2B	0.0599	0.0515	1.162	0.25	6.2%	-4.0%	17.4%
'R SQUARE ADJ	0.0652						
Net Percentage Changes							
LOGD_T1A					-22.1%	-36.3%	-4.7%
LOGD_T1B					-36.9%	-49.5%	-21.3%
LOGD_T2A					-37.1%	-45.0%	-28.0%
LOGD_T2B					-47.9%	-54.9%	-39.9%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
'pmlb60io.reg							
MELBOURNE ARTERIALS 60KMH SPEED ZONES (UNEMPLOYMENT)							
REGRESSION							
INTERCEP	0.9138	0.1796	5.089	0.00			
LOGURATE	0.6472	0.0653	9.911	0.00			
LOGD_T1A	-0.1310	0.0777	-1.687	0.10	-12.3%	-24.7%	2.1%
LOGD_T1B	-0.2127	0.0873	-2.436	0.02	-19.2%	-31.9%	-4.1%
LOGD_T2A	-0.4466	0.0539	-8.287	0.00	-36.0%	-42.4%	-28.9%
LOGD_T2B	-0.6180	0.0573	-10.788	0.00	-46.1%	-51.8%	-39.7%
'R SQUARE ADJ	0.6524						
'psyd60_io.reg							
SYDNEY ARTERIALS 60KMH SPEED ZONES (UNEMPLOYMENT)							
REGRESSION							
INTERCEP	-1.4251	0.3352	-4.252	0.00			
LOGURATE	0.0277	0.1268	0.219	0.83			
LOGD_T1A	0.0395	0.0828	0.477	0.64	4.0%	-11.6%	22.4%
LOGD_T1B	0.1894	0.0898	2.109	0.04	20.8%	1.3%	44.1%
LOGD_T2A	0.0373	0.0536	0.695	0.49	3.8%	-6.6%	15.3%
LOGD_T2B	0.0590	0.0572	1.03	0.31	6.1%	-5.2%	18.7%
'R SQUARE ADJ	0.0051						
Net Percentage Changes							
LOGD_T1A					-15.7%	-32.5%	5.3%
LOGD_T1B					-33.1%	-47.7%	-14.5%
LOGD_T2A					-38.4%	-46.9%	-28.5%
LOGD_T2B					-49.2%	-56.6%	-40.4%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
'pmlba_io.reg							
Melbourne Arterials (Unemployment)							
REGRESSION							
INTERCEP	0.8561	0.1628	5.258	0.00			
LOGURATE	0.6171	0.0592	10.422	0.00			
LOGD_T1A	-0.1239	0.0704	-1.759	0.08	-11.7%	-23.0%	1.4%
LOGD_T1B	-0.2625	0.0792	-3.316	0.00	-23.1%	-34.1%	-10.2%
LOGD_T2A	-0.4268	0.0489	-8.735	0.00	-34.7%	-40.7%	-28.2%
LOGD_T2B	-0.5920	0.0519	-11.396	0.00	-44.7%	-50.0%	-38.7%
'R SQUARE ADJ	0.6823						
'pmlbr_io.reg							
Melbourne Residential Streets (Unemployment							
REGRESSION							
INTERCEP	0.8907	0.2729	3.264	0.00			
LOGURATE	0.5808	0.0992	5.852	0.00			
LOGD_T1A	-0.0149	0.1180	-0.126	0.90	-1.5%	-21.8%	24.2%
LOGD_T1B	0.0233	0.1327	0.175	0.86	2.4%	-21.1%	32.8%
LOGD_T2A	-0.2528	0.0819	-3.087	0.00	-22.3%	-33.9%	-8.8%
LOGD_T2B	-0.3784	0.0871	-4.347	0.00	-31.5%	-42.2%	-18.8%
'R SQUARE ADJ	0.2423						
Net Percentage Changes							
LOGD_T1A					-10.3%	-31.5%	17.4%
LOGD_T1B					-24.9%	-44.5%	1.7%
LOGD_T2A					-16.0%	-30.3%	1.3%
LOGD_T2B					-19.2%	-33.8%	-1.5%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	Upper
'prov100.log							
Rural Vic 100Kmh Speed Zones (Unemployment & Trend)							
REGRESSION							
INTERCEP	0.6669	0.5356	1.245	0.22			
IDNUM	-0.0096	0.0012	-8.029	0.00			
LOGURATE	0.1056	0.2208	0.478	0.63			
LOGD_T1A	0.0925	0.1467	0.63	0.53	9.7%	-17.7%	46.2%
LOGD_T1B	0.4221	0.1542	2.737	0.01	52.5%	12.7%	106.3%
LOGD_T2A	0.1331	0.1062	1.253	0.21	14.2%	-7.2%	40.7%
LOGD_T2B	0.2541	0.1479	1.718	0.09	28.9%	-3.5%	72.3%
'R SQUARE ADJ	0.5255						
Rural N.S.W. 100Kmh Speed Zones (Unemployment)							
REGRESSION							
INTERCEP	-0.2993	0.4802	-0.623	0.53			
IDNUM	-0.0038	0.0012	-3.163	0.00			
LOGURATE	-0.0878	0.2353	-0.373	0.71			
LOGD_T1A	0.0757	0.0938	0.807	0.42	7.9%	-10.2%	29.6%
LOGD_T1B	-0.0825	0.1069	-0.772	0.44	-7.9%	-25.3%	13.5%
LOGD_T2A	0.0522	0.0728	0.717	0.48	5.4%	-8.7%	21.5%
LOGD_T2B	0.1116	0.0943	1.184	0.24	11.8%	-7.1%	34.5%
'R SQUARE ADJ	0.2260						
Net Percentage Changes							
LOGD_T1A					14.4%	-18.1%	59.8%
LOGD_T1B					15.4%	-19.5%	65.2%
LOGD_T2A					-9.3%	-29.1%	16.1%
LOGD_T2B					-7.3%	-33.8%	29.8%

	Coefficient	Standard Error	T-Ratio	Approx. Probability	Percent Change	95% Conf. Interval Lower	95% Conf. Interval Upper
'prov60.log							
Rural Vic 60 Kmh Speed Zones (Unemployment & Trend)							
REGRESSION							
INTERCEP	-0.4466	0.5353	-0.834	0.41			
IDNUM	-0.0081	0.0012	-6.733	0.00			
LOGURATE	-0.0222	0.2207	-0.101	0.92			
LOGD_T1A	0.0928	0.1466	0.633	0.53	9.7%	-17.7%	46.2%
LOGD_T1B	0.2435	0.1541	1.58	0.12	27.6%	-5.7%	72.6%
LOGD_T2A	0.0419	0.1062	0.394	0.69	4.3%	-15.3%	28.4%
LOGD_T2B	0.2395	0.1478	1.62	0.11	27.1%	-4.9%	69.8%
'R SQUARE ADJ	0.4475						
'pron60.log							
Rural N.S.W. 60 Kmh Speed Zones (Unemployment & Trend)							
REGRESSION							
INTERCEP	-1.3703	0.4455	-3.076	0.00			
IDNUM	-0.0063	0.0011	-5.597	0.00			
LOGURATE	-0.2324	0.2183	-1.065	0.29			
LOGD_T1A	-0.0421	0.0870	-0.484	0.63	-4.1%	-19.1%	13.7%
LOGD_T1B	0.1007	0.0992	1.016	0.31	10.6%	-8.9%	34.3%
LOGD_T2A	0.1391	0.0676	2.059	0.04	14.9%	0.7%	31.2%
LOGD_T2B	0.3156	0.0875	3.608	0.00	37.1%	15.5%	62.7%
'R SQUARE ADJ	0.3985						
Net Percentage Changes							
LOGD_T1A					14.4%	-18.1%	59.8%
LOGD_T1B					15.4%	-19.5%	65.2%
LOGD_T2A					-9.3%	-29.1%	16.1%
LOGD_T2B					-7.3%	-33.8%	29.8%