EVALUATION OF
THE SPEED CAMERA PROGRAM
IN VICTORIA 1990-1993

PHASE 5: FURTHER INVESTIGATION OF
LOCALISED EFFECTS ON
CASUALTY CRASH FREQUENCY

by

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October 1995
Report No. 78

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Type of Report & Period Covered
GENERAL, 1990-1993

Sponsoring Organisation - This project was funded through the Centre's baseline research program for which grants have been received from:
Department of Justice
Royal Automobile Club of Victoria Ltd.
VicRoads
Transport Accident Commission

Abstract:

Phase 5 of the evaluation of the speed camera program in Victoria builds on the localised effects of the program studied in Phase 3, which found casualty crash reductions in areas within 1km of a speed camera site during high alcohol hours for up to 2 weeks after issue of a speed camera Traffic Infringement Notice (TIN). Phase 5 had 2 main aims; (1) To investigate the localised effects of the speed camera program on casualty crashes in rural towns and on rural highways in Victoria and (2) to calibrate the localised speed camera effects on casualty crashes in Metropolitan Melbourne established in Phase 3 of the evaluation. The Phase 5 analysis covered speed camera operations and casualty crashes occurring in the period July 1990 to December 1993.

Analysis in Victorian rural towns was unable to find a statistically significant localised speed camera effect on casualty crashes within 1km of a camera site when considering either influence due to camera site operations or receipt of a TIN. When considering casualty crashes within a 15km radius of a speed camera site on Victorian rural highways, a statistically significant reduction in crash frequency was observed on arterial roads in high alcohol hours in the week following the presence of a speed camera, whilst a weakly statistically significant crash reduction was observed in low alcohol hours on all roads in the 2 weeks following the issue of a speed camera TIN. However, these results should be treated with some caution because of firstly the weak statistical significance and secondly, the inability to find a corresponding effect when a 5km radius of influence was considered.

Analysis of localised speed camera effects in metropolitan Melbourne considered the effects on casualty crashes occurring within a 1km radius of a speed camera site. A statistically significant reduction in crash frequency was found in high alcohol hours on all roads for up to three weeks after the issue of a speed camera TIN, with the effect apparently diminishing across this period. A statistically significant crash reduction for 1 week after camera operations at a site was also found on arterial roads in both high and low alcohol hours. These results were much more reliable, statistically, than those reported for rural highways.

Key Words:
speed & evaluation (assessment), injury, collision, road trauma, traffic regulations, statistics, research report, speed camera*, speed enforcement*.

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ACKNOWLEDGMENTS

The authors wish to thank:

Chris Walker of Data Dimensions P/L for combining the location details of the speed camera sites with the casualty crash sites, and writing the SAS computer program to create the data file from which all the analysis in Phase 5 was based on.

Ron Cook, John Bodinnar and Paul Williamson from the Traffic Camera Office who provided data files containing details of all speed camera activity and output during the three and a half year period from July 1990 to December 1993.

Particular acknowledgment is made of the support provided by Pat Rogerson of VicRoads in assembling aspects of the data and providing many useful comments in the course of the project.
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EXECUTIVE SUMMARY

To date MUARC has completed four phases of the evaluation of the Speed Camera program (including the supporting publicity) in Victoria. Examined have been the general effects of the program, the effects of specific program mechanisms and the localised program effects on crash frequency and severity, as well as the general effects of the program on speeds.

Phase 5 of the evaluation of the speed camera program in Victoria builds on the localised effects of the program studied in Phase 3, which found casualty crash reductions in areas within 1km of a speed camera site during high alcohol hours for up to 2 weeks after issue of a speed camera Traffic Infringement Notice (TIN). Phase 5 had 2 main aims; (1) To investigate the localised effects of the speed camera program on casualty crashes in rural towns and on rural highways in Victoria and (2) to calibrate the localised speed camera effects on casualty crashes in Metropolitan Melbourne established in Phase 3 of the evaluation. The Phase 5 analysis covered speed camera operations and casualty crashes occurring in the period July 1990 to December 1993.

The Phase 5 analysis was unable to find a statistically significant localised speed camera effect on casualty crashes within 1km of a camera site in Victorian rural towns when considering either influence due to camera site operations or receipt of a TIN. When considering casualty crashes within a 15km radius of a speed camera site on Victorian rural highways, a statistically significant reduction in crash frequency was observed on arterial roads in high alcohol hours in the week following the presence of a speed camera, whilst a weakly statistically significant crash reduction was observed in low alcohol hours on all roads in the 2 weeks following the issue of a speed camera TIN. However, these results should be treated with some caution because of firstly the weak statistical significance and secondly, the inability to find a corresponding effect when a 5km radius of influence was considered.

The Phase 5 analysis of localised speed camera effects in metropolitan Melbourne considered the effects on casualty crashes occurring within a 1km radius of a speed camera site. A statistically significant reduction in crash frequency was found in high alcohol hours on all roads for up to three weeks after the issue of a speed camera TIN, with the effect apparently diminishing across this period. A statistically significant crash reduction for 1 week after camera operations at a site was also found on arterial roads in both high and low alcohol hours. These results were much more reliable, statistically, than those reported for rural highways.
1.0 INTRODUCTION

1.1 EVALUATION OF THE SPEED CAMERA PROGRAM IN VICTORIA

To date MUARC has completed four phases of the evaluation of the Speed Camera program (including the supporting publicity) in Victoria. Phase 1 and 2 (Cameron et al 1992) examined both the general effects and the effects of specific program mechanisms on crash frequency and severity. Phases 3 and 4 (Rogerson et al 1994) extended the investigation to examine respectively the localised effects of the Speed Camera program on casualty crash frequency and severity and the general effects of the program on speeds. An overview of the speed camera program in Victoria is given in Cameron et al (1992) along with a detailed review of relevant literature. An overview of Victorian speed camera operations in the first 18 months of the program is given in Sullivan et al (1992). A brief review of the results of Phases 1, 2 and 4 will be given here. A more extensive review of Phase 3, on which Phase 5 builds, is given in the following section.

Phases 1 and 2

The aim of Phase 1 of the speed camera program evaluation was to measure the generalised or dispersed effects beyond the immediate speed camera sites and times, given that speed cameras are:

- generally not obvious,
- used at many sites,
- used at sustained at high levels (relative to previous speed enforcement), and
- supported by pervasive and intensive publicity.

The effect was evaluated in terms of a reduction in casualty crash frequency and injury severity during the 'low alcohol hours'\(^1\) of the week. Comparisons were made with corresponding areas of New South Wales after correcting for differences in trends in unemployment rates. It was necessary to undertake the analysis in low alcohol hours because a major random breath testing campaign, also supported by massive publicity, was implemented at about the same time as the speed camera program. A consistent significant drop in the number of casualty crashes across all treated areas was observed for the periods corresponding to the publicity launch and the increase in speed camera enforcement, except for 100 km/h rural open roads where there was a significant drop in the speed camera enforcement period only.

The Phase 1 analysis showed a number of significant effects of the speed camera program on casualty crash frequency and severity. Reductions in casualty crash frequency in low alcohol hours, found in Phase 1 were

- around 30% reductions on 60 km/h arterial roads and all arterial roads in Melbourne
- around 20% reduction in Melbourne as a whole and in rest of Victoria 60 km/h zones
- 14% drop in one period only in rural 100 km/h zones.

\(^1\)The 'low alcohol hours' of the week, as defined by Harrison (1990), are Monday to Thursday 6am to 6pm, Friday 6am to 4pm, Saturday 8am to 2pm, Sunday 10am to 4pm, when less than 4% of drivers killed or admitted to hospital in 1988-89 had a Blood Alcohol Concentration (BAC) exceeding 0.05%.
This pattern of effects corresponds with the level of speed camera enforcement in these different areas.

Injury severity reductions of casualty crashes were observed in the Melbourne areas but not in the rest of Victoria. There was no substantial difference between the effects on Melbourne arterial roads only and all Melbourne roads, except that the decrease in severity appeared somewhat greater on the arterials.

Phase 2 extended the investigation of Phase 1 to identify the effect of specific speed camera program mechanisms (explanatory variables) on casualty crash frequency and severity in Melbourne as a whole and on arterial roads in Melbourne. The effects in the rest of Victoria were not included. Phase 2 estimated the impact of the speed camera program by modelling the various deterrence mechanisms of the program against the evaluation criteria.

The program mechanisms included were the monthly levels for:

- Speed camera operation hours
- Speed camera TINs (Traffic Infringement Notices) issued to drivers
- All TAC (Transport Accident Commission) road safety publicity
- TAC speed related publicity only.

The evaluation criteria used were the same as in Phase 1, being casualty crash incidence in low alcohol hours and injury severity in casualty crashes during low alcohol hours.

In terms of casualty crash frequency in low alcohol hours, the Phase 2 analysis showed there was a significant inverse relationship with

- the number of speed camera TINs issued to drivers
- all TAC road safety publicity

The relationship with the speed related TAC publicity was significant at the 0.07 level only. However there was no statistically significant relationship between the decrease in crash frequency and the increase in hours of speed camera operation. Further work by Cameron et al (1993) has confirmed these results.

In terms of injury severity of casualty crashes in low alcohol hours, there was a significant inverse relationship with:

- the number of speed camera TINs issued to drivers
- speed camera operation hours.

The apparent effects of speed camera TINs issued to drivers were related to both crash frequency and injury severity, with stronger effects observed on arterial roads for both evaluation criteria.
Phase 4

In response to the general effects and program mechanism effects of the speed camera program found in Phases 1 and 2, Phase 4 of the speed camera evaluation aimed to determine the overall effects on vehicle speed in Victoria.

To achieve the aims of Phase 4, data from speed monitoring programs established by VicRoads was examined to measure the change in vehicle speeds in Victoria after the introduction of speed cameras. Groups of sites where speed monitoring had taken place were chosen to represent vehicle speeds on roads with speed limits of 100 km/h, 75 km/h and 60 km/h. Some sites were in Melbourne and others in the rest of Victoria. The data examined covered the period starting from November 1989, prior to the commencement of the speed camera program. The major launch of the enforcement and associated publicity occurred in April 1990, although there was media coverage of the impending use of speed cameras by the police in Victoria before November 1989.

The results of the Phase 4 analysis inferred that the percentage of vehicles exceeding the speed limit by more than 15 km/h decreased from November 1989 to March 1990 and has remained below the previous levels in both 60 km/h and 75 km/h speed zones. The distribution of vehicle speeds recorded in 100 km/h speed zones did not change after the introduction of the speed camera program in Victoria. No significant change in the mean speed was detected.

Previous research in 1970 by the Research Triangle Institute (1970) suggested that the risk of casualty crash for vehicles exceeding the speed limit by at least 25 km/h is 6.9 times the risk for vehicles travelling around the speed limit. This predicts that the observed small decrease in the number of vehicles exceeding the speed limit by an excessive amount could have resulted in a large decrease (estimated 7%) in the number of casualty crashes.

1.2 DETAILED REVIEW OF PHASE 3: LOCALISED SPEED CAMERA EFFECTS

1.2.1 Background

Whilst Phases 1 and 2 of the speed camera evaluation estimated the generalised or dispersed effects on casualty crashes and investigated the effect of the various components of the program, the aim of Phase 3 was to tests for a reduction in casualty crash frequency and severity at those times and in those specific areas where speed cameras were used in Melbourne from 1 July 1990 to 31 December 1991. For the Phase 3 analysis, no comparisons with another jurisdiction nor corrections for unemployment and other factors were necessary because each day during the 18-month time period chosen has a hypothesised camera influence in some places and not in others. These places alternate from day to day and the crashes during the days with no camera influence provide the baseline with which to compare the crashes on days with a hypothesised camera influence. Separate links with the speed camera operations at the camera site, and with the subsequent issue of speed camera Traffic Infringement Notices (TINs) from the camera site, were investigated.

It was presumed that the disincentive to exceed the speed limit is strongest when passing a speed camera in operation (if seen) and that this influence diminishes with time and distance from the stimulus. Many drivers, however, may not be aware of passing a speed camera and only find out about the site location after receiving a TIN (which gives the time and place of the offence). Thus
it was presumed that there may be a disincentive to exceed the speed limit when driving near the known site of a previous speed camera operation after receiving a TIN.

Although the influence of the speed camera is thought to peak at the closest time and place to the camera operation and then reduce gradually, for the Phase 3 study an artificial cut-off point for the influence both in terms of time and distance had to be chosen. These cut-off points are somewhat arbitrary but fixed and were chosen as those most likely to encompass the speed camera influence.

Phase 3 aimed to investigate the direct link between speed camera operations and/or TIN receipts with a reduction in casualty crash frequency and/or crash severity. The methodology did not involve any measurements of speed or speed change, as did Phase 4, and did not rely on defining crashes in which speed may have been a major cause. All types of casualty crashes were included and therefore any reduction in frequency or severity found was less than that expected in the subset of speed related crashes.

1.2.2 Definition of speed camera influence and hypotheses tested

Based on a pilot study, the full Phase 3 study formulated the following hypotheses of localised speed camera influences, describing the extent and duration of the speed camera influence were adopted:

- camera site operation influence extends for 7 consecutive days
- TIN receipt influence extends for 14 consecutive days
- each influence extends for a distance of 1 km from each camera site
- the influence from 1 site operation is counted as the same as the influence (either site operation or TIN receipt) from many cameras at once.

The Phase 3 analysis centred on testing these hypotheses using appropriate data and statistical analysis methodology. The following variations of area, type and times of influence were investigated.

Area of influence

In order to ascertain on which road types speed cameras had the most effect, the hypothesised 1km area of influence was tested on each of the following road classifications separately:

- All places within 1 km radius of the camera site (All Roads and Streets)
- All arterial roads within 1 km radius of the camera site (Arterial Roads)
- Along the same arterial road, 1 km either side of the camera site (Matched Arterials)

Type of influence

Phase 2 of the project showed that the number of speed camera TINs issued to drivers was more closely related to the decrease in frequency and severity of crashes than the number of hours of speed camera operation. Consequently, Phase 3 tested three alternative types of speed camera influence:

- knowing about a speed camera in operation (Site operation influence)
• receiving a TIN (TIN receipt influence)
• both of the above (Both influences)

**Time of influence: Hours of the week**

Phases 1 and 2 of the evaluation excluded crashes in 'high alcohol hours' of the week to avoid contamination with the effects on crashes from the increase in Random Breath Testing activity by the police at this time. The exclusion of crashes in 'high alcohol hours', however, was not necessary in Phase 3. Therefore the localised effects of the speed camera program were measured in terms of:

• casualty crashes in low alcohol hours (low alcohol hours)
• casualty crashes in high alcohol hours (high alcohol hours)
• casualty crashes at all times of the day (all hours) (Crash severity only)

**Hypotheses tested**

For each investigation in Phase 3, the number of crashes on days with 'influence' and the number of crashes on days with 'no influence' were compared.

Phase 3 aimed to test the following hypotheses:

1. The crash frequency for days with an influence will be lower than the crash rate for days with no influence, for a particular type of influence, area of influence, and time of week.
2. The severity of crashes for days with an influence will be lower than the severity of crashes for days with no influence, for a particular type of influence, area of influence and time of week.

**1.2.3 Results and Conclusions of Phase 3**

**Crash frequency results**

• When including crashes on all roads, a significant reduction in crash frequency was found as a result of the TIN receipt influence in the high alcohol hours of the week.
• On arterial roads in high alcohol hours there was a significant reduction in crash frequency as a result of the TIN receipt influence.
• No statistically significant changes in casualty crash frequency was found when the influence of site operations was considered.

**Crash severity results**

There was no change found in crash injury severity due to the hypothesised presence of a speed camera influence in any of the situations analysed. This would suggest that the reduction in crash severity found in Phase 1 is a general effect and that there is no localised effect of the speed camera program on crash severity.
Summary

In summary, Phase 3 found a statistically significant reduction in casualty crashes within 1 km of a camera site as a result of the receipt of a TIN. This appeared to have affected drivers in the vicinity of the site for two weeks (and maybe longer) after receiving the penalty. The effect appears to have been confined to 'high alcohol hours' of the week (mainly night-time) on arterial roads. There was no statistically significant reduction in the number of crashes which occurred (within 1 km of the camera site) during the week immediately after the speed camera operation. There was also no evidence of a difference in crash severity between the crashes which happened on days when a speed camera influence was assumed to be present and crashes which happened on days when the speed camera influence was assumed to be absent.

1.2.4 Limitations of the Phase 3 analysis

Although Phase 3 of the speed camera evaluation was successful in finding evidence of localised effects of speed camera operation in reducing crash frequency, the study had a number of limitations. Firstly, the Phase 3 analysis was confined only to the Melbourne metropolitan area, with no consideration of possible speed camera effects in the rest of Victoria. This limitation was imposed by the crash location system used to relate speed camera operations with crash occurrence which, at the time, only covered the metropolitan area.

The second limitation of Phase three was the number of hypotheses of speed camera influence considered. Due to limitations on project resources, only the hypotheses described in Section 1.2.2 above were tested. Having found, in particular, a strong influence on crash frequency for a period of 2 weeks after TIN receipt, it is of interest to more accurately establish the duration for which this influence lasts.

1.3 AIMS OF PHASE 5

The limitations of the Phase 3 analysis discussed above reveal further areas of localised speed camera influence warranting investigation. These were discussed in the report of Phase 3 and endorsed by the Project Advisory Committee. The two most important of these tasks for further research constitute Phase 5 of the speed camera evaluation undertaken here. They are:

1.3.1 Localised speed camera influence in rural areas.

The first aim of Phase 5 of the speed camera program evaluation was to undertake an analysis of localised Speed Camera program effects in areas outside the MSD, similar to that carried out for the MSD in Phase 3. The effect of the speed camera program on roads in rural towns and on highways outside of towns were considered separately because of the obvious differences in speeding patterns and speed camera deployment. Appropriate hypotheses were developed for testing for each of the two road groupings being considered, particularly in respect to the hypothesised area of influence. Testing of the proposed hypotheses was carried out in the same way as for the phase 3 analysis.
1.3.2 Calibration of the established TIN receipt influence in Melbourne.

The results of the phase 3 analysis identified a significant reduction in casualty crashes in high alcohol hours on arterial roads for two weeks after the receipt of a TIN. The second aim of Phase 5 was to extend this analysis to consider a number of different durations of TIN receipt influence both longer and shorter than the two weeks hypothesised in phase 3. This aimed to pinpoint more precisely the actual duration of significant influence by TIN receipt on casualty crash frequency. Such research could be valuable in assisting Victoria Police in optimising speed camera use, particularly in regard to how often to revisit the same site.

2.0 DATA

The Traffic Camera Office provided the following data files:

1. A list of all speed camera site numbers, with Melway street directory reference for metropolitan sites and kilometre reference, VicRoads country directory reference, or written location description for country sites
2. A list of all unique film and photo combinations linked to site number and date
3. Date of TIN issue linked to film number and photo number

The first of these files was matched with the VicRoads database of Police accident reports using a location database in the Road Safety Division. For metropolitan locations, the location database codes the location of speed cameras either as the centre-point of the Melway street directory grid reference or onto the mid-point of a named arterial road running through the Melway grid reference. For the rest of Victoria, speed camera locations were coded using a similar method to metropolitan locations if a country directory reference or kilometre reference was available, or coded by hand if a description only was available. Police reported accidents for all of Victoria had already been coded onto the location system for other purposes. The calculation of the distance between two points - crash site and speed camera site - was made using Pythagoras' Theorem. If more than five camera sites were located less than 1 km from one crash site, only the five nearest camera sites were recorded.

The second and third files were combined and aggregated to produce a file containing a camera site number, a camera session day number and a TIN's issue day number for every film and photo number combination. Each day during the period was numbered from 1 to 1280 corresponding to each day in the 42 month period chosen for the evaluation period: 1 July 1990 - 31 December 1993.

The influence days due to the site operations were calculated by including the session day and the following 6 days. Similarly the influence days due to the TIN's receipt was calculated using the third day after the day of issue of the TIN (allowing for time in the mail) and including the specified number of following days, 6, 13 or 20 days. This resulted in a computer file which could be merged with the camera site enhanced road accident file.
3.0 DEFINITIONS AND HYPOTHESES

3.1 Definitions

As for the Phase 3 analysis, in further assessing the effect of speed camera operations on crash risk in Phase 5, boundaries on the effects in terms of:

- area of influence
- type of influence
- duration of influence.

were defined, in order to formulate hypotheses for testing. The combinations of these boundaries used for hypothesis formulation in Phase 5 are defined below whilst the statement of the generic hypothesis under which these specific boundaries of influence are tested is given in Section 3.2.

Area of influence

The following areas of influence in terms of the road network have been considered in Phase 5:

- All places within the defined radius of the camera site (All places)
- All arterial roads within the defined radius of the camera site (Arterial Roads)

The Phase 3 analysis also specifically considered crashes on the same arterial road as the speed camera was placed. This was, however, not possible for the Phase 5 analysis due to changes in the structure of the location database.

The radii of influence considered to complete the definition of area of influence in Phase 5 are

- Metropolitan area and Country towns: 1 km radius about the speed camera site
- Rural Highways: Two different radii of influence have been considered
  1. 5 km radius about the speed camera site
  2. 15 km radius about the speed camera site

For the metropolitan area, the radius of influence considered was chosen based on experience from the Phase 3 analysis. Given that urban centres in the rest of Victoria are likely to have road and travel environments similar to metropolitan Melbourne, the 1km radius of influence was also considered appropriate for towns in the rest of Victoria. Guidance in hypothesising a radius of influence on rural highways in Victoria was not readily available. Speed enforcement studies have generally found that drivers respond to highly visible Police vehicles by suppressing vehicle speeds for up to a maximum of 5km after the enforcement symbol (Portans 1988). In contrast, 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 crash reduction halo effect to 21km. It is not clear though how these results relate to Victorian speed camera operations which are not necessarily visible and operate at a finite number of locations. Using these studies only as a guide, the hypothesised radii of 5 and 15 Km have been tested in Phase 5. This covers a wide range of possible areas of influence.
**Type of influence**

As for Phase 3, two distinct types of speed camera operations influence, as well as their combined influence, were considered in the phase 5 analysis. These were:

- **Site operation influence**: having a speed camera recently in operation but not having TINs recently issued from that site of operation
- **TIN receipt influence**: having TINs recently issued from operations at a site but not having a speed camera recently in operation
- **Both Influences**: both having a speed camera recently in operation and having TINs recently issued from operations at that site

**Duration of influence**

The durations of the two types of influence considered in Phase 5 are summarised as follows:

For the metropolitan area:
- Site operation influence: the day of operation plus the following 6 days
- TIN receipt influence: The third day after the issuing of a TIN (to allow for postage time) plus:
  1. the following 6 days
  2. the following 13 days
  3. the following 20 days.

For both rural highways and towns in the rest of Victoria:
- Site operation influence: the day of operation plus the following 6 days
- TIN receipt influence: The third day after the issuing of a TIN (to allow for postage time) plus the following 13 days

The decision to consider only one duration of site operation influence stemmed from the fact that the Phase 3 analysis was not able to identify crash frequency reductions in times of site operation influence. Despite this, the effect was still tested for in Phase 5 because of the possibility that the greater quantities of data, compared with Phase 3, may enable a site operation effect to be found through greater statistical analysis power.

**Crash sub-sets**

Following the methods of Phase 3, it was decided to measure any localised effects of the speed camera program on the two time stratified sub-sets of casualty crashes in Melbourne.

- casualty crashes in low alcohol hours (*low alcohol hours*)
- casualty crashes in high alcohol hours (*high alcohol hours*).

Alcohol hours are as defined in Section 1.1 (see footnote 1). For completeness, it was also decided to examine the effects in all hours combined to assess whether an effect found in either one of the 2 time strata was large enough to provide a significant effect overall.
3.2 Hypotheses tested

Phase 5 of the speed camera program evaluation was based on specific comparisons of the observed number of casualty crashes in each of 3 influenced and one non-influenced categories against the number of crashes expected based on the relative time exposure to each influence type at each site.

The influenced and non-influenced categories for crashes are:

**Influenced Categories**: Crashes occurring on days when some drivers in that location were assumed to be influenced by:
- a recent nearby speed camera site operation
- recent receipt of TINs by drivers detected at a nearby speed camera site
- both of the above

**Non-Influenced Category**: Crashes occurring on days when no drivers in that location were assumed to be influenced by either a recent nearby speed camera site operation or a TIN receipt.

The crashes in each of the categories are drawn from the same areas of Melbourne (within the defined radius of every speed camera location) and over the same period of study. Each crash is labelled according to which one of the four influence types was present when the crash occurred. Also recorded for each crash is the number of days of the 1280 days of study each influence type was present at that crash site. The total number of crashes occurring under each influence type and the total days exposure of each influence are then calculated. Comparison of the observed proportion of crashes for a particular influence type with the proportion of exposure to that influence enables estimation of the magnitude and significance of reduction in casualty crashes due to that influence. Hence the following generic null and alternative hypotheses, under which each combination of type of speed camera influence, duration of influence and radius of influence considered, can be tested in the Phase 5 analysis is as follows.

**Null hypothesis**

It is assumed that, should there be no speed camera effect on crash incidence, then the total number of crashes at particular locations falling in each influence category would be proportionally distributed according to the number of days (of each influence and non-influence) when these crashes could occur.

**Alternative Hypothesis**

The crash rate for days with a particular influence will be lower than that expected under the null hypothesis, for each type of influence, area of influence, and time of week.

4.0 ANALYSIS METHODS

4.1 Matching of speed camera operations and crash data

The first step in the analysis process was to merge the speed camera location data with the Police reported crash data. The merging process, along with calculation of new variables, was carried out on the UNIX Workstation in VicRoads Road Safety Division using the statistical package SAS. The SAS code used in the merging process appears in Appendix A. The process of merging
produced a crash data file, containing each road casualty crash occurring in Victoria over the period 1 July 1990 to 31 December 1993 and within the hypothesised radius of influence of any speed camera, enhanced with a number of variables relating each crash to the operations of up to five of the closest speed cameras to the location of the crash. The variables created included the code names of each of the 5 closest camera sites to each crash location, flags to indicate which of the four possible types of speed camera influences were present at the time of the crash and variables indicating the total time each of the four hypothesised speed camera influences were present out of the 1280 total days of the study. The final composition of the data file is given in Appendix B. The date of each accident in the file was used to decide the type of influence on that day. The influence from one camera was assumed to be the same as the influence from up to five cameras.

A file of the kind described above was produced for each combination of radius of speed camera influence and duration of speed camera influence considered in each of metropolitan Melbourne, rural towns and rural highways.

4.2 Statistical analysis methods

The method of analysis separated crashes into three groups:

- accidents with a site influence (regardless of TIN influence)
- accidents with a TIN influence (regardless of site influence)
- accidents which occurred on days when both site and TIN influences were present

This allowed an examination of questions of the type: “Given the fact that a crash occurred in the 3.5 years, what is the probability of the crash happening in any of the four types of days.”

In the analysis, a method was chosen which makes use of all the crashes simultaneously to internally compare the crash rate for all subsets of data within the constraints of the fixed overall number of crashes for the study period.

Each enhanced crash data file, whose creation was described in Section 4.1 above, with the list of variables contained in Appendix B, was created to include for each crash the four possibilities in terms of:

- Influence on the day of the crash (Site only, TIN only, Both, Neither) and

- number of days at this site when each of the four influence possibilities were present out of a total 1280

For each combination of area of influence (all roads and arterial roads) and hours of the week (low or high alcohol hours or all hours) a table of crash data was extracted where each row of the table represents a single crash. The table format is given in Figure 1.
For convenience, in the following description of the analysis method, influence \( x \) will be general and stand for any one of none, site, TIN or both influences. The indicator functions \( I_{xi} \) are defined as 1 if influence \( x \) was present at the time of crash \( i \) and 0 if influence \( x \) was not present. For example, if crash \( i \) occurred at a time of TIN influence only that line would have \( I_{ti} = 1 \) and \( I_{ni} = I_{si} = I_{bi} = 0 \). \( I_x \) is the sum of the indicator functions \( I_{xi} \) over all crashes and is equal to the number of crashes occurring under influence \( x \). The second half of table 3 gives the exposure of each crash site to each influence. \( D_{xi} \) is the number of days out of the 1280 days of study that the site, at which crash \( i \) occurred, was exposed to influence \( x \). Hence for each crash

\[
D_x = \sum_{i} D_{xi}
\]

\( D_x \) is the sum of the exposure to influence \( x \) over all crashes and is a measure of exposure of all crashes under study to influence \( x \). Because equation 1 holds for all crashes, each crash has equal weighting in the total exposure to each influence, \( D_x \).

**Non-independence of influence types**

Equation 1 also implies that each influence type is not independent of the other three. For example if the time of TIN influence is decreased at a crash site then the time for none, site or both influences must increase. This means that the null hypotheses concerning site operation influence, TIN influence and both influences must be tested simultaneously in reference to the no-influence time using multivariate statistical techniques. The specific statistical technique for testing of the three hypotheses of influence will be described below. The test statistic is most conveniently formulated if the assumptions that the total number of crashes observed in Figure 3 is fixed and that each crash has a fixed probability of occurring at times with each type of influence are made.

Under the combined null hypothesis of no speed camera influence effects, the proportions of crashes occurring under each influence are expected to be equal to the proportions of exposure attributable to each influence type. For example, if there is a total of 1000 days exposure time with 400 days of no influence, 200 days of site operation influence, 300 days of TIN influence and 100 days of both influences then if 100 crashes are observed in total under the null hypothesis we would expect 40 to occur in times of no influence, 20 to occur in times of site operation influence, 30 to
occur in times of TIN influence and 10 to occur in times of both influences. Testing of the hypothesis then involves testing for a significant difference in the expected proportion of crashes occurring under each influence compared with the observed proportions of crashes, whilst specifying that the expected total number of crashes equals the observed total number of crashes. The multivariate statistical techniques for achieving this are described here along with the method by which percentage reductions in crash frequency due to each influence along with confidence limits can be calculated.

**Multinomial distribution**

In the following, let \( n \) denote no speed camera influence, \( s \) denote site operation influence, \( t \) denote TIN influence and \( b \) denote both site and TIN influence. Let \( x \) be a general term denoting any one of the four specific influence types. Let \( C \) be the number of crashes involved in testing the particular hypotheses set. From the data table, table 3 in the text, we have

\[
C = \sum_{i=1}^{C} I_{nx} + I_{sx} + I_{tx} + I_{bx}
\]

where \( I_{xi} \) is an indicator function which is 1 if influence \( x \) is present at the time of crash \( i \) and 0 otherwise. The total number of crashes observed occurring under influence \( x \) is then given by

\[
I_x = \sum_{i=1}^{C} I_{xi}
\]

Let \( D_{xi} \) be the number if days influence \( x \) was present at the site of crash \( i \). Since

\[
D_{nx} + D_{sx} + D_{tx} + D_{bx} = 1280
\]

for each \( i \), the total exposure days, \( E \), over all \( C \) crashes is

\[
E = \sum_{i=1}^{C} D_{nx} + D_{sx} + D_{tx} + D_{bx} = 1280C
\]

The total exposure to influence \( x \) over all \( C \) crashes is given by

\[
D_x = \sum_{i=1}^{C} D_{xi}
\]

Under the null hypothesis of no speed camera influence on crash frequency, the expected proportion of crashes occurring under influence \( x \), denoted \( p_x^e \), will be equal to the proportion of time for which that influence is operating. That is

\[
p_x^e = \frac{D_x}{1280C}
\]

Let the observed proportion of crashes occurring under influence \( x \) be \( p_x^o \) and be given by
The total number of crashes, \( C \), is considered to be fixed and the total number of days of study is fixed at 1280. This means that the hypotheses being tested, namely those of speed camera site, TIN and combined site and TIN influences, are dependent and must be tested simultaneously. The combined null hypothesis to be tested becomes

\[
H_0: P_O = P_E
\]

where \( P_E \) is the expected proportion vector, given by

\[
P_E = [p_n^E, p_s^E, p_t^E, p_h^E]^T
\]

and \( P_O \) is the observed proportion vector, given by

\[
P_O = [p_n^O, p_s^O, p_t^O, p_h^O]^T
\]

where \( T \) denotes the matrix transpose. Assuming \( C \) is fixed, under \( H_0 \) \( P_O \) has a multinomial distribution,

\[
P_O \sim \text{Multinomial}(C,P_E)
\]

with the expected value of \( P_O \) being \( P_E \). \( H_0 \) can be tested using a Hotelling's \( T^2 \) statistic. A large sample approximate distribution of \( T^2 \) can be used since \( C \) is large in all cases considered in this report.

Because we are dealing with proportions which must sum to one, Hotelling's \( T^2 \) cannot be calculated directly using \( P_O \) and \( P_E \). This is because the variance-covariance matrix of \( P_O \), denoted \( V \), is non-invertible, having rank 3 only. Under \( H_0 \), the elements of \( V \), \( V_{ij} \), are calculated by

\[
V_{ij} = \begin{cases} 
  p_i^E (1 - p_i^E), & i = j \\
  -p_i^E p_j^E, & i \neq j
\end{cases}
\]

Hotelling's \( T^2 \) is invariant under transformation so applying a suitable transformation set, \( R \), to \( P_O \) allows \( T^2 \) to be calculated indirectly for testing of the null hypothesis. \( R \) is chosen here as

\[
R = \begin{bmatrix} 
  1 & -1 & 0 & 0 \\
  1 & 0 & -1 & 0 \\
  1 & 0 & 0 & -1
\end{bmatrix}
\]
The form of R chosen here has intrinsic relevance to the hypothesis being tested here as it compares the proportion of crashes occurring under each influence to the proportion occurring under no influence.

The Hotelling's $T^2$ test statistic is given by

$$T^2 = C(R(P_o - P_x))(RV^{-1}R)(R(P_o - P_x))^T$$

where $T$ denotes matrix transpose and $^{-1}$ matrix inverse. Under $H_0$, $T^2$ is distributed as $\chi^2$ for large C. Hence if $T^2 > \chi^2_{3}(\alpha)$, $H_0$ is rejected at the $\alpha$ level of significance where $\chi^2_{3}(\alpha)$ is the upper $\alpha$ percentile of the $\chi^2$ distribution.

**Percentage reductions and confidence limits**

To establish which of the elements of $P_o$ differ from expected under $H_0$, simultaneous confidence limits for each element can be calculated. The Bonferroni method of calculating simultaneous confidence limits is the most appropriate for use here, giving shortest confidence interval length for large samples. The $(1-\alpha)\%$ simultaneous confidence intervals for the elements of $P_o$ are given by

$$P_x^o \pm t_{c-1,\alpha/3}\sqrt{P_x^o(1-P_x^o)/C}$$

If $P_x^e$ is outside this confidence limit then speed camera influence $x$ has a significant effect on crash frequency. The percentage reduction on crash frequency by influence $x$ is given by

$$(P_x^e - P_x^o)/P_x^o \times 100\%$$

with confidence limits

$$(P_x^e - (P_x^o + a))/P_x^o \times 100\%, (P_x^e - (P_x^o - a))/P_x^o \times 100\%$$

where

$$a = t_{c-1,\alpha/3}\sqrt{P_x^o(1-P_x^o)/C}$$

Full details including derivations of these methods can be found in Johnson and Wichern (1992), Chapter 5. The statistical package MINITAB was used to calculate the Hotelling's $T^2$ statistic and Bonferroni confidence limits.
5.0 RESULTS

5.1 LOCALISED SPEED CAMERA INFLUENCE IN RURAL AREAS

5.1.1 Speed camera influence in rural towns

For the purpose of this study, a rural town was defined as any population centre outside the Melbourne Statistical Division. In a practical sense, rural towns were identified in the location system by either centres appearing with a town map in the VicRoads country directory or alternatively, clusters of roads with speed zones less than 100 km/h. It should be noted that under this definition, Geelong and its surrounding urban area are considered as a rural town. This was considered appropriate for this study, rather than combining Geelong with metropolitan Melbourne, as this made the definition of metropolitan Melbourne comparable to that used in Phase 3, allowing direct comparison of the results.

There were 6946 Police-reported casualty crashes occurring within 1km of a speed camera site in rural towns in Victoria over the period 1 July 1990 to 31 December 1993. Of these, 4453 occurred in low alcohol hours whilst 2493 occurred in high alcohol hours. The subset of these crashes occurring on arterial roads in rural towns, as distinct from all roads, was 2643 or 38%. Appendix C gives a summary of the number of casualty crashes on all roads and on arterial roads by time of crash occurring in rural towns under no influence as well as each of the hypothesised speed camera influences (none, site, TIN and both).

Table 1 summarises, for rural towns in Victoria, the estimated percentage change in casualty crash numbers under each of the three hypothesised speed camera influences relative to that expected under no speed camera influence. Results are presented for each of the three time divisions of the week considered as well as for all roads and arterial roads. A negative sign on the estimate indicates a reduction in casualty crash numbers. Under each value of the estimated percentage change is a two sided 90% confidence limit. As the alternative hypothesis being tested here is one sided (ie. a reduction in crashes due to speed camera influence) these two sided 90% confidence limits are equivalent to a one sided 95% confidence limit.

Also presented in Table 1 are the significance probabilities of the Hotelling's $T^2$ tests used to test for significant influence of the hypothesised speed camera effects on casualty crash frequency. Small significance probabilities indicate the distribution of casualty crashes between each type of hypothesised speed camera influence (site, TIN or both) is different to that expected based on the relative exposure to each influence (null hypothesis). The one or more components of speed camera influence (site, TIN or both) contributing to any significant distributional shift can be seen by examining the confidence limits on the estimated change in casualty crash frequency. A confidence interval not overlapping zero indicates a significant reduction in crash frequency due to that effect.
Examination of Table 1 for rural towns in Victoria reveals no significant reduction in casualty crash frequency due to any of the hypothesised speed camera effects. This is reflected by large significance probabilities, of 0.40 or greater, for the Hotelling's $T^2$ hypothesis test and confidence limits on the casualty crash frequency reduction estimates which all overlap zero by a large amount. These results are further confirmed by examining the detailed analysis results for rural towns given in Appendix C. Here it can be seen that the observed proportion of casualty crashes occurring in each influence time is, in all instances, almost exactly that predicted from exposure to each influence.

Given the lack of identification of any significant localised speed camera effects, no additional analysis attempting to further calibrate any established effect was undertaken. The results obtained suggest that in rural towns in Victoria, neither of the two hypothesised mechanisms of localised speed camera influence has had an effect on casualty crash frequency within 1 km of camera sites at any time of the day. It should be stressed however, that the lack of any identified localised crash reduction due to speed camera operations does not imply the absence of general effects in rural towns which have been previously identified.

### 5.1.2 Speed camera influences on rural highways

The definition of rural highway used here is all areas outside the Melbourne Statistical Division not classified as rural towns by the definition given above. In practice, the definition of rural highways
used here will encompass all open roads with 100km/h speed zoning outside the Melbourne metropolitan statistical division.

Two radii of speed camera influence were hypothesised for the analysis of rural highway effects, being 5km and 15km. Appendix D shows the total number of crashes occurring within these two zones of influence, as well as broken down by influence type. There were 3638 casualty crashes occurring within a 5km of a speed camera site in rural towns in Victoria over the period 1 July 1990 to 31 December 1993. Of these 1964 occurred in low alcohol hours whilst 1674 occurred in high alcohol hours. When the zone of influence was increased to a radius of 15km, there were 6429 casualty crashes occurring within this distance of a speed camera site, with 3479 in low alcohol hours and 2950 in high alcohol hours. Appendix D summarises the number of casualty crashes under each influence on all roads and on arterial roads for both hypothesised zones of influence.

Table 2 summarises the estimated percentage change in casualty crash numbers under each of the three hypothesised speed camera influences relative to that expected under no speed camera influence. Results are presented for both radii of speed camera influence considered (5km and 15km) broken down by each of the three time divisions of the week considered, as well as for all roads and arterial roads. Interpretation of the sign of result, confidence limits and Hotellings $T^2$ significance probabilities are as for Table 1. Results shaded in darker grey in table 2 indicate statistically significant crash frequency reduction or Hotelling’s $T^2$ significance probability. Results shaded in lighter grey indicate marginal statistical significance.

The results presented in table 2 show a statistically significant localised speed camera effect on arterial roads during high alcohol hours when a 15km radius of influence is considered. This is shown by a Hotelling’s $T^2$ statistic significance probability of 0.04 (darker grey shading in Table 2). The observed significant localised speed camera effect at this time stems from a statistically significant reduction in serious casualty crashes of 23% in times up to 1 week after speed camera operation (site influence). It should be noted that the confidence limit for the estimated site influence just overlaps zero in this instance indicating only marginal statistical significance. This seems to contradict the statistically significant Hotelling’s $T^2$ statistic. It should be pointed out however, that the Hotelling’s $T^2$ test is an exact statistical test whilst the Bonferroni confidence limits calculated on the individual crash frequency changes are large sample approximations which tent to be slightly conservative in terms of confidence interval width. In the case of the statistically significant Hotelling’s $T^2$ statistic observed for the analysis of arterial roads in high alcohol hours with a 15km radius of influence, it is clearly the site influence, rather than TIN or both influences, leading to the observed significance.

The analysis results presented in Table 2 also indicate evidence of a reduction in casualty crash frequency for two weeks after TIN receipt in low alcohol hours on all rural highways. This is shown by a marginally statistically significant Hotelling’s $T^2$ statistic of 0.10, along with an estimated reduction in casualty crashes during times of TIN influence of 8.9% with a 95% confidence interval just overlapping zero. This is highlighted by the lighter grey shading in Table 2.

It may be noted that, whilst the two localised speed camera effects on rural highways have been established for an hypothesised radius of influence of 15km, the same results were not observed when considering the smaller 5km radius of influence. This is most likely a consequence of the smaller quantities of crash data included in the analysis when considering only a 5 km radius of influence not being sufficient to establish a statistically reliable estimates of effect. Lack of
statistical significance in this context does not exclude the possibility that there is a localised speed camera effect but rather that none could be found with the available data.

Appendix D gives detailed results of the analysis of localised speed camera influence on rural highways.

TABLE 2: Summary of percentage change in casualty crash numbers under each hypothesised speed camera influence.

<table>
<thead>
<tr>
<th>ROAD</th>
<th>TIME</th>
<th>RADIUS OF INFLUENCE CONSIDERED</th>
<th>Site Influence (1 week)</th>
<th>Tin Influence (2 weeks)</th>
<th>Both Site and Tin Influence</th>
<th>Significance Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Roads</td>
<td>All Hours</td>
<td>5km</td>
<td>2.79 (-16.13, 21.94)</td>
<td>-3.5 (-15.86, 8.96)</td>
<td>13.12 (-12.77, 39.01)</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>-0.32 (-16.98, 11.75)</td>
<td>-4.78 (-12.59, 3.03)</td>
<td>6.44 (-7.94, 21.03)</td>
<td>0.34</td>
</tr>
<tr>
<td>High Alcohol</td>
<td>Hours</td>
<td>5km</td>
<td>17.02 (-12.76, 46.59)</td>
<td>-13.2 (-30.6, 4.3)</td>
<td>-9.51 (-43.66, 24.65)</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>-9.05 (-25.9, 7.8)</td>
<td>-0.07 (-11.79, 11.64)</td>
<td>4.35 (-16.63, 23.16)</td>
<td>0.56</td>
</tr>
<tr>
<td>Low Alcohol</td>
<td>Hours</td>
<td>5km</td>
<td>-9.52 (-33.98, 14.72)</td>
<td>4.97 (-12.64, 22.59)</td>
<td>32.38 (-5.69, 70.11)</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>7.58 (-9.52, 24.68)</td>
<td>-8.92 (-19.46, 1.62)</td>
<td>8.61 (-11.69, 28.69)</td>
<td></td>
</tr>
<tr>
<td>Arterial Roads</td>
<td>All Hours</td>
<td>5km</td>
<td>-16.04 (-40.8, 8.49)</td>
<td>-1.71 (-19.68, 16.27)</td>
<td>5.88 (-32.58, 44.34)</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>-6.83 (-24.06, 10.41)</td>
<td>1.48 (-10.54, 13.51)</td>
<td>4.6 (-17.92, 27.12)</td>
<td>0.74</td>
</tr>
<tr>
<td>High Alcohol</td>
<td>Hours</td>
<td>5km</td>
<td>-16.89 (-53.01, 19.21)</td>
<td>-8.28 (-34.04, 17.47)</td>
<td>-29.59 (-76.23, 17.04)</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>-5.34 (-1.66, 0.42)</td>
<td>12.61 (-5.96, 31.19)</td>
<td>2.55 (-30.09, 35.18)</td>
<td></td>
</tr>
<tr>
<td>Low Alcohol</td>
<td>Hours</td>
<td>5km</td>
<td>-15.55 (-49.28, 17.94)</td>
<td>3.8 (-21.43, 28.92)</td>
<td>35 (-23.64, 94.09)</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15km</td>
<td>6.94 (-18.02, 31.8)</td>
<td>-7.86 (-23.49, 7.78)</td>
<td>6.55 (-24.68, 37.78)</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Statistically significant at the 5% level
Statistically significant at the 10% level
5.2 CALIBRATION OF THE ESTABLISHED TIN INFLUENCE IN MELBOURNE

The Phase three analysis found a significant reduction in casualty crashes during high alcohol hours for two weeks after TINs from a speed camera session were received by drivers detected speeding in metropolitan Melbourne. The analysis presented here for Phase 5 attempts to more closely establish the duration for which casualty crash frequency is significantly reduced due to the effects of speed camera TIN issue. To achieve this, three different durations of speed camera TIN effect durations have been hypothesised and tested here, being 1, 2 and 3 weeks. The same 1 week site influence and 1km radius of influence hypothesised in Phase 3 have again been used here.

There were 33113 casualty crashes occurring within a 1km of a speed camera site in Melbourne over the period 1 July 1990 to 31 December 1993. This compares with 14504 occurring over the period 1 July 1990 31 December 1991 as analysed in the Phase 3 study. Of the 33113 casualty crashes used in the Phase 5 analysis here, 20389 occurred in low alcohol hours whilst 12724 occurred in high alcohol hours. Casualty crashes on arterial roads made up 6480, or 19.6%, of the total. Appendix E summarises the number of casualty crashes under each influence on all roads and on arterial roads for each of the three hypothesised durations of TIN influence.

Table 3 summarises the estimated percentage change in casualty crash numbers under each of the three hypothesised speed camera influences relative to that expected under no speed camera influence. Results are presented for all three durations of speed camera TIN influence considered (1, 2 and 3 weeks) also broken down by each of the three time divisions of the week considered as well as for all roads and arterial roads. Interpretation of the sign of result, confidence limits and Hotellings $T^2$ significance probabilities is as for Tables 1 and 2. Statistically significant reductions in casualty crash frequency at the 5% level are shown in Table 3 with dark grey shading whilst results marginally statistically significant at the 5% level are indicated by lighter grey shading. Detailed results of the Metropolitan analysis appear in Appendix E.

As was found in the Phase 3 analysis, Table 3 shows a statistically significant localised reduction in casualty crash frequency on all roads in high alcohol hours due to the receipt of a speed camera TIN. The point estimates of crash reduction suggest this effect is strongest in the first week after issue of the TIN, with an estimated 8.9% localised reduction in casualty crash frequency, with a statistically significant crash reduction of 4.8% still being seen when 3 weeks of TIN effect are tested. It should be noted that, whilst the point estimates of crash reduction due to TIN influence suggest a diminishing effect over the hypothesised three week duration of influence, because the confidence limits on the estimates all overlap, no statistical confidence can be placed in this observation. The localised speed camera effect due to TIN influence observed in high alcohol hours is sufficiently strong to also be expressed when considering all hours of the week combined, as indicated by the grey shading in Table 3.

When examining the results of the analysis for arterial roads in Table 3, a different pattern of effects is evident. Whilst the Hotelling's $T^2$ test results indicate an effect of localised speed camera influence on casualty crashes in high alcohol hours, the effect on arterial roads is apparently due to the site influence for the duration of 1 week after the presence of a speed camera. This is in contrast to the result when considering all roads where the established effect was due to the influence of TIN receipt. A significant reduction in casualty crash frequency of around 17% in high alcohol...
hours is estimated due to the site influence on arterial roads. Again, this effect is strong enough to be distinguishable when considering all hours.

Table 3 also indicates a reduction in casualty crashes due to site influence in low alcohol hours when considering both all roads and just arterial roads. The effect appears to be somewhat stronger on arterial roads, with only marginal statistical significance being found when considering all road types. It might be expected that this result would be found when considering each hypothesised duration of TIN influence, rather than only the one week TIN influence as was the case. This is most likely due to the fact that the one week TIN influence, being the shortest hypothesised duration, allows the maximum duration of site only influence. This allows the analysis the maximum power to establish any site effect. This can be seen by examining the number of crashes occurring under each of the three hypothesised influence types (TIN, site and both) for each of the three hypothesised durations of TIN influence, shown in Appendix E.
### TABLE 3: Summary of percentage change in casualty crash numbers under each hypothesised speed camera influence.  
Melbourne metropolitan area

<table>
<thead>
<tr>
<th>ROAD TIME</th>
<th>TIME INFLUENCES CONSIDERED</th>
<th>Site Influence (1 week)</th>
<th>Tin Influence</th>
<th>Both Site and Tin Influence</th>
<th>Significance Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1wk</td>
<td></td>
<td>-2.45 (-7.36,2.34)</td>
<td>-0.53 (-6.68,5.80)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2wks</td>
<td></td>
<td>0.31 (-4.82,5.59)</td>
<td>-2.16 (-5.39,1.08)</td>
<td>-3.4 (-8.01,1.09)</td>
<td>0.06</td>
</tr>
<tr>
<td>3wks</td>
<td></td>
<td>0.2 (-5.65,6.25)</td>
<td>-2.78</td>
<td>(-6.91,1.44)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Roads</td>
<td>High Alcohol Hours</td>
<td>1.23 (-5.91,8.25)</td>
<td>-1.59 (-10.62,7.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1wk</td>
<td></td>
<td>-4.79 (-10.26,0.67)</td>
<td>-2.33 (-7.87,3.22)</td>
<td>0.17 (-6.99,7.17)</td>
<td>0.08</td>
</tr>
<tr>
<td>2wks</td>
<td></td>
<td>-1.09 (-7.79,5.45)</td>
<td>0.4 (-3.83,5.47)</td>
<td>4.57 (-3.83,5.47)</td>
<td>0.28</td>
</tr>
<tr>
<td>3wks</td>
<td></td>
<td>-1.01 (-9.48,7.46)</td>
<td>-1.4 (-4.99,2.13)</td>
<td>-3.9 (-9.14,1.33)</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Low Alcohol Hours</td>
<td>2.01 (-7.83,11.65)</td>
<td>-0.83</td>
<td>(-7.57,5.91)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arterial High Alcohol Roads</td>
<td>-1.49 (-17.02,16.89)</td>
<td>-3.53 (-23.03,23.03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1wk</td>
<td></td>
<td>-0.12 (-17.02,16.89)</td>
<td>0 (-23.03,23.03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2wks</td>
<td></td>
<td>-17.22 (-35.43,0.99)</td>
<td>2.22 (-10.64,15.08)</td>
<td>-5.86 (-24.32,12.46)</td>
<td>0.09</td>
</tr>
<tr>
<td>3wks</td>
<td></td>
<td>-5 (-9.74,12.17)</td>
<td>1.19 (-9.74,12.17)</td>
<td>-3.53 (-20.43,13.49)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low Alcohol Hours</td>
<td>-0.84 (-25.71,8.71)</td>
<td>-4.06 (-7.1,10.35)</td>
<td>-17.54 (-17.54,9.42)</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Statistically significant at the 5% level
Statistically significant at the 10% level
6.0 DISCUSSION

Given the localised effect of speed camera operations established in the Metropolitan area in both this study and the Phase 3 study, it is perhaps surprising that no influence was observed in the analysis of rural towns presented here. The table in Appendix C detailing the number of crashes occurring under times of each hypothesised speed camera influence shows that, within the hypothesised radius of speed camera influence, around 20% of casualty crashes occurred at times when a speed camera influence of some sort was operating. As an illustration, Figure 2 shows the number of casualty crashes occurring under and not under TIN influence in rural towns in Victoria.

FIGURE 2
Number of casualty crashes occurring under times of TIN and no TIN influence
All roads, all hours, Rural towns, Victoria

Figure 2 shows a mix of crashes occurring under times of TIN influence in rural towns in Victoria across the period of study. Whilst this is slightly less than the approximately 25% observed in the Metropolitan area (see Appendix E) the total proportion is still significantly large to provide acceptable power in the statistical analysis. Despite the lack of identified localised effects, Phase 1 of the speed camera program evaluation did identify general casualty crash reductions in 60km/h zones in rural Victoria (Cameron et al 1992) suggesting that the speed camera program is effective in rural towns, but due to a general effect rather than to localised influences.

In a similar way to Figure 2, Figure 3 shows the proportion of casualty crashes occurring under times with and without TIN influence on rural highways in Victoria, with around 25% of crashes on rural highways within 15km of a speed camera site having occurred in times of some speed camera influence. Significantly, both Figures 2 and 3, as well as Figure 4 for Melbourne shown below, show mix of both TIN and no TIN influence across the period of study. This is important as it eliminates possible bias in the study due to general improvements in road safety occurring across the study period coinciding with shifts in the speed camera influence mix distribution.
One possible reason for the apparently relatively weak localised speed camera effectiveness in areas outside Melbourne may lie in a difference between speed camera operations between the two areas. A study of relative speed camera operations patterns between metropolitan and rural areas would be necessary to further explore this possibility. Other differences, such as the actual number of TINs issued per camera session, the number of camera operating hours at a site as well as demographic, geographic and travel pattern differences, perhaps also in conjunction with speed camera operations differences, may also explain the lack of observed localised effects. Further study would also be needed to examine these possibilities.

The calibration of localised speed camera influences in the Metropolitan area has produced a number of noteworthy results. In comparison to the Phase 3 analysis, Phase 5 has identified the same strong influence of speed camera TIN receipt in high alcohol hours when considering all roads. The results indicate that this effect lasts for a duration of at least 3 weeks but shows signs of diminishing over this time, indicating that effectiveness may not last much longer than the 3 week period. The estimated magnitude of the TIN receipt effect is slightly less for the Phase 5 analysis (6.2% for 2 week duration) than in the Phase 3 analysis (8.4%). Whilst this difference is not statistically significant it may point to a possibility of diminishing effectiveness of speed camera TIN receipt over the three and a half years of study.

One area of discrepancy between the Phase 3 and Phase 5 results however is the effect of TIN receipt on arterial roads. Phase 3 found the TIN receipt effect to be strongest on arterial roads, whereas Phase 5 found no TIN effect on arterial roads. In addition Phase 5 found a strong effect of site influence on arterial roads during both high and low alcohol hours, effects which was not found in the Phase 3 analysis. The reason for these discrepancies may lie in the additional time span the Phase 5 analysis covers. Phase 5 adds an additional 2 years data over the 18 months used in Phase 3. It is possible that over this latter period, a learning process about speed camera operations has
gone on. The shift in results from Phase 3 to Phase 5 suggests that motorists may be becoming familiar with the operational patterns of speed cameras in the metropolitan Melbourne area. The established site effect on arterial roads suggests that, on these roads, motorists are developing the ability to spot the speed cameras in operation, resulting in the observed reduced crash risk in the area of operation.

FIGURE 4
Number of casualty crashes occurring under times of TIN and no TIN influence
All roads, all hours, Metropolitan Melbourne

The evidence of change in localised speed camera effectiveness over time, in both possible diminishing TIN effects and emerging site effect, warrants further study of changes in localised speed camera effects over time.

7.0 CONCLUSIONS

Phase 5 of the evaluation of the speed camera program in Victoria had 2 main aims; (1) To investigate the localised effects of the speed camera program on casualty crashes in rural towns and on rural highways in Victoria and (2) to calibrate the localised speed camera effects on casualty crashes in Metropolitan Melbourne established in Phase 3 of the evaluation. The Phase 5 analysis covered speed camera operations and casualty crashes occurring in the period July 1990 to December 1993.

The Phase 5 analysis was unable to find a statistically significant localised speed camera effect on casualty crashes within 1 km of a camera site in Victorian rural towns when considering either influence due to camera site operations or receipt of a TIN. When considering casualty crashes within a 15km radius of a speed camera site on Victorian rural highways, a statistically significant reduction in crash frequency was observed on arterial roads in high alcohol hours in the week following the presence of a speed camera, whilst a weakly statistically significant crash reduction
was observed in low alcohol hours on all roads in the 2 weeks following the issue of a speed camera TIN. However, these results should be treated with some caution because of firstly the weak statistical significance and secondly, the inability to find a corresponding effect when a 5km radius of influence was considered.

The Phase 5 analysis of localised speed camera effects in metropolitan Melbourne considered the effects on casualty crashes occurring within a 1km radius of a speed camera site. A statistically significant reduction in crash frequency was found in high alcohol hours on all roads for up to three weeks after the issue of a speed camera TIN, with the effect apparently diminishing across this period. A statistically significant crash reduction for 1 week after camera operations at a site was also found on arterial roads in both high and low alcohol hours. These results were much more reliable, statistically, than those reported for rural highways.

8.0 FURTHER RESEARCH RECOMMENDED

The results of analysis carried out in Phase 5 of the speed camera evaluation suggest the need for the following further research:

(1) Longitudinal analysis of localised speed camera effects

Observed changes between the results of the speed camera evaluation Phase 3 analysis, which covered the first 18 months of the program, and the Phase 5 analysis, which covers an additional 24 months, indicate a change in the localised effectiveness of the program with time. Specifically, crash reductions attributable to the effect of receiving a speed camera TIN appear to be diminishing, whilst knowledge of specific speed camera sites and times of operation appears to be increasing.

Further study examining the change in localised speed camera effectiveness over time is recommended to confirm and quantify these observations. This could be carried out relatively easily using the existing data sets up to December 1993, but would benefit from the inclusion of 1994 crash data.

(2) Analysis of speed camera operations data to relate the findings of the Phase 3 and 5 analyses to speed camera operations practice

The Phase 5 analysis found differences in the localised effectiveness of speed cameras in reducing crash frequency when considering rural towns, rural highways and the metropolitan area in Victoria. One possible reason suggested for these differences was speed camera operational differences between the three areas. Study of the operational difference in speed camera usage is recommended with respect to the localised effects on crash frequency found in Phase 5. Such research could be useful in understanding the difference in observed localised speed camera effectiveness, as well as being useful to the Police for optimising speed camera operational procedure.
9.0 REFERENCES


RESEARCH TRIANGLE INSTITUTE (1970) “Speed and accidents” National Highway Safety Bureau, USA.


APPENDIX A

SAS Code used for matching of speed camera operations with casualty crash data
filename camdat '/usr/sasdev/sas/camxy.dat';
filename camtime
'/users/chris/camera/9093tin.dat';
filename accam
'/users/chris/camera/metroacc.inf;

* this version runs metro accident day aspect only *;
* new version to check all accident sites for
days for influence *;
* modified mar 95 road safety for muarc
project extension *;
* written by : CHRIS WALKER (DATA
DIMENSIONS PTY LTD)*
* DATE : MAR 20-1995 *

* first section is concerned with filtering
location data only*;
* determine town/country for all declared road
segments *;

data town;
set new.linkname;
geode=fugcode;output;
gcode=tngcode;output;
keep gcode town;
run;

proc sort nodupkey;
by gcode;
run;

data rrpxy;
set new.vie_rrp;
keep rrp rrp_x rrp_y gcode lga1 ;
rename rrp_x=amge rrp_y=amgn;
run;

proc sort nodupkey;
by gcode;
run;

* merge town flag with rrp data*;

data rrptown;
merge rrpxy(in=a) town(in=b);
by gcode;
if a ;
run;

proc sort data=rrptown;
by rrp;

run;

data rxxy;
set new.vie_r;
gcode=fngcode;output;
gcode=tngcode;output;

* rs records are duplicated here - remove later *
* ;
* both ends of arc need to be checked for town
flag*

keep rs rs_x rs_y gcode lga1 ;
rename rs_x=amge rs_y=amgn;
run;

proc sort;
by gcode ;
run;

* add town flag in for midblock accidents here *
;

data rstown;
merge rxxy(in=a) town(in=b);
by gcode ;
if a ;
run;

proc sort ;
by rs;
run;

data accrrp accrs;
set all.newper;

* set date subset filter here *;

if ( year = 90 and month in
('Jul','Aug','Sep','Oct','Nov','Dec'))
or year in (91,92,93) ;

* convert character month to numeric (1-12)*;

if month = 'Jan' then mn=1;
else if month = 'Feb' then mn=2;
else if month = 'Mar' then mn=3;
else if month = 'Apr' then mn=4;
else if month = 'May' then mn=5;
else if month = 'Jun' then mn=6;
else if month = 'Jul' then mn=7;
else if month = 'Aug' then mn=8;
else if month = 'Sep' then mn=9;
else if month = 'Oct' then mn=10;
else if month = 'Nov' then mn=11;
else if month = 'Dec' then mn=12;

* convert day/month/year to julian day from start of tin days *

accday = mdy(mn,day,year)-mdy(06,30,90)-1;

if rrp > 0 then output accrrp;
else if rs > 0 then output accrs;

keep rrp rs accno accday speedlim;
run;

proc sort data=accrrp;
  by rrp;
run;

proc sort data=rrptown;
  by rrp;
run;

proc sort data=accrs;
  by rs;
run;

proc sort data=rstown;
  by rs;
run;

data accl;
  merge accrrp(in=a) rrptown(in=b);
  by rrp;
  if a and b;
  rename x=came y=camn site=cam;
run;

data camacc;
  set acc1 acc2;

* subset location aspects here by speed *
* subset location aspects here by speed *
* subset location aspects here by speed *

* new.camacc contains accident data with x-y positions for specified period *

run;

proc sort nodupkey out=new.camacc;
  by accno;

* end of location filtering here *

* tin data file here *

data camtim;
  infile camtime missover;
  input site $ 33-37 sesday 15-20 tinday 22-28;
run;

proc sort;
  by site;

data allcam;
  array camid(05) $ 5 cam1-cam5;
  array cflag(05) cflag1-cflag5;
  array tflag(05) tflag1-tflag5;
  array dist(05) cdist1-cdist5;
  array camcount(1000) _temporary_;
  do ii=1 to 5;
    camid(ii)='.
  end;
  set new.camacc;

* subset data here by time *

areainf=1000;
count=0;
do kk=1 to numobs;
set cam point=kk nobs=numobs;
* calculate distance between accident site and camera (metres) *
  if abs(came-amge) < areainf and abs(camm-amgn) < areainf then do;
    dist1 = sqrt((came-amge)**2 + (camm-amgn)**2);
  end;
else go to nexta;
* set area of influence here (metres) *
* i.e. 1000=km *
  if dist1 <= areainf then do;
    count=count+1;
* maximum of 5 cameras allowed per accident site *
  if count > 5 then go to out3;
    dist(count)= dist1;
    camid(count)=cam;
    output;
  end;
nexta:
end;
out3:
  keep cam;
proc sort data=allcam nodupkey;
  by cam;

data newcam;
merge camtim(in=a) allcam(in=b rename=( cam=site)) by site;
if a and b;
options linesize=180 missing=' ';
array camid(5) $ 5 cam1-cam5;
array cflag(5) cflag1-cflag5;
array tflag(5) tflag1-tflag5;
array dist(5) cdist1-cdist5;
array camcount(1000) _temporary_;
do j=1 to 5;
camera=camid(j);
if camera ne ' ' then do;
do kk=1 to numrec;
set newcam point=kk nobs=numrec;
if camera=site and sesday >=0 then do;
if ( sesday <= accday <= sesday+6) then do;
cflag(j)=1;
sflag=1;
end;
end;
if camera=site and tinday >= 0 then do;
if( tinday + 2 <= accday <= tinday + 15) then do;
tflag(j)=1;
tinflag=1;
end;
if tinflag=1 and sflag=1 then go to nextc;
end;
end;
end;
nextc:
if (cflag1=1 or cflag2=1 or cflag3=1 or
cflag4=1 or cflag5=1) then inf=1;
else inf=0;
if (tflag1=1 or tflag2=1 or tflag3=1 or
tflag4=1 or tflag5=1) then tinf=1;
else tinf=0;
if inf=0 and tinf=0 then countn=countn + 1 ;
else if inf=0 and tinf=1 then countt=countt + 1 ;
else if inf=1 and tinf=0 then counts=counts + 1 ;
else if inf=1 and tinf=1 then countb=countb + 1 ;
* end;
total=countt + counts + countb + countn ;
* error checking section -comment out for full run ;
* if total ne 1280 then do;
* put "* error wrong total ";
* stop;
* end;
put accno $ 1-10 countn 12-17 counts 19-24
countt 26-31 countb 33-37 ;
run;
* this version runs day 0-1279 aspect only *;
* metroacc.sas runs accident aspect *;
* new version to check all accident sites for
days for influence *
* modified mar 95 road safety for muarc
project extension written by : CHRIS
WALKER (DATA DIMENSIONS PTY LTD)
* DATE : MAR 20 -1995 *
* modified and rewritten : may 95 *
* technique changed to merge approach rather
than iterative * metro job takes approx 5 hrs to
run - submit overnight *
* first section is concerned with filtering
location data only *
* determine town/country for all declared road
segments *

* following is macro to submit 500 records at a
time to process *
* calculate distance between accident site and
camera (metres) *
if abs(came-amge) < areainf and abs(camm-
amgn) < areainf then do;
distl = sqrt((came-amge)**2 + (camn-
amgn)**2) ;
end;
else go to nexta;

* set area of influence here (metres) *
* i.e. 1000=km *
if distl <= areainf then do;
count=count+1;
nexta:
end;
out3:
if count > 5 then go to out3;
camid(count)=cam;
end;
end;
keep cam ;
data allsite;
array camid(05) $ 5 cam1-cam5 ;
set site;
do k=1 to 5 ;
camid(kk)=' ,
end;
set new.camacc( firstobs=&fobs
obs=&numobs ) ;
subset data here by time *
areainf=1000 ;
count=0;
do kk=1 to numobs;
set cam point=kk nobs=numobs;

data site ;
options linesize=180 missing=' ';array camid(05) $ 5 cam1-cam5 ;
do ii=1 to 5 ;
camid(ii)= ,
end;
set new.camacc( firstobs=&fobs
obs=&numobs ) ;
* subset data here by time *
areainf=1000 ;
count=0;
do kk=1 to numobs;
set cam point=kk nobs=numobs;

* calculate distance between accident site and
camera (metres) *
if abs(came-amge) < areainf and abs(camm-
amgn) < areainf then do;
distl = sqrt((came-amge)**2 + (camn-
amgn)**2) ;
end;
else go to nexta;

* set area of influence here (metres) *
* i.e. 1000=km *
if distl <= areainf then do;
count=count+1;
nexta:
end;
out3:
if count > 5 then go to out3;
camid(count)=cam;
end;
end;
keep cam ;
data allsite;
array camid(05) $ 5 cam1-cam5 ;
set site;
do k=1 to 5 ;
camid(kk)=' ,
end;
set new.camacc( firstobs=&fobs
obs=&numobs ) ;
subset data here by time *
areainf=1000 ;
count=0;
do kk=1 to numobs;
set cam point=kk nobs=numobs;

* calculate distance between accident site and
camera (metres) *
if abs(came-amge) < areainf and abs(camm-
amgn) < areainf then do;
distl = sqrt((came-amge)**2 + (camn-
amgn)**2) ;
end;
else go to nexta;

* set area of influence here (metres) *
* i.e. 1000=km *
if distl <= areainf then do;
count=count+1;
nexta:
end;
out3:
if count > 5 then go to out3;
camid(count)=cam;
end;
end;
keep cam ;
data allsite;
array camid(05) $ 5 cam1-cam5 ;
set site;
do k=1 to 5 ;
camid(kk)=' ,
end;
set new.camacc( firstobs=&fobs
obs=&numobs ) ;
subset data here by time *
areainf=1000 ;
count=0;
do kk=1 to numobs;
set cam point=kk nobs=numobs;
**proc sort;**
    by cam day;

**proc sql;**
    create table temp as
    select *
    from allcount a,newcam b
    where a.cam=newcam.site and
    ((tinday+2<=day<=tinday+15) or
    (sesday<=day<=sesday+6));

**data tinmer;**
    set temp;
    if tinday+2 <=day<= tinday + 15 then
tflag=1;
    if sesday <=day<= sesday + 6 then sflag=1;
    keep tflag sflag cam day;

**proc datasets;**
    delete temp;

**proc sort;**
    by cam day;

**data newtin;**
    set tinmer;
    by cam day;
    if first.day then do;
ttemp='O;
stemp=O;
end;
    if tflag=1 then ttemp= 1;
    if sflag=1 then stemp= 1;
    if last.day then output;
    rename ttemp=tflag stemp=sflag;
    retain ttemp stemp;
    keep cam day ttemp stemp;
    keep cam ttemp day;

**proc datasets;**
    delete tinmer;

**data tinmer2;**
    merge allcount(in=a) newtin(in=b);
    by cam day;
    if a;

**proc datasets;**
    delete newtin ;

**proc sort data=site;**
    by cam1 ;

**proc sql;**
    create table merg1 as
    select * from site
    a, tinmer2(rename=(cam=cam1 tflag=tflag1
    sflag=sflag1)) b
    where a.cam1=b.cam1;

**proc sort data=merg1;**
    by cam2 day ;

**data merg2;**
    merge merg1(in=a) tinmer2(in=b
    rename=(cam=cam2 tflag=tflag2
    sflag=sflag2));
    by cam2 day ;
    if a;
run;

**proc datasets;**
    delete merg1;

**proc sort data=merg2;**
    by cam3 day ;

**data merg3;**
    merge merg2(in=a) tinmer2(in=b
    rename=(cam=cam3 tflag=tflag3
    sflag=sflag3));
    by cam3 day ;
    if a;

**proc datasets;**
    delete merg2;
run;

**proc sort data=merg3;**
    by cam4 day ;

**data merg4;**
    merge merg3(in=a) tinmer2(in=b
    rename=(cam=cam4 tflag=tflag4
    sflag=sflag4));
    by cam4 day ;
    if a;

**proc datasets;**
    delete merg3;
run;

**proc sort data=merg4;**
    by cam5 day ;

**data merg5;**
    merge merg4(in=a) tinmer2(in=b
    rename=(cam=cam5 tflag=tflag5
    sflag=sflag5));
    by cam5 day ;
if (tflag1 = 1 or tflag2 = 1 or tflag3 = 1 or tflag4 = 1 or tflag5 = 1) then tinf = 1;
else tinf = 0;
if (sflag1 = 1 or sflag2 = 1 or sflag3 = 1 or sflag4 = 1 or sflag5 = 1) then inf = 1;
else inf = 0;
countn = 0; countt = 0; counts = 0; countb = 0;
if inf = 0 and tinf = 0 then countn = 1;
else if inf = 0 and tinf = 1 then countt = 1;
else if inf = 1 and tinf = 0 then counts = 1;
else if inf = 1 and tinf = 1 then countb = 1;
run;
proc datasets;
delete merg4;
proc sort;
by accno;
run;
proc summary data = merg5;
by accno;
var countn countt counts countb;
output out = totcount sum = ;
run;
proc datasets;
delete merg5;
data _null_
file accam mod;
set totcount;
put accno $ 1-10 countn 12-17 counts 19-24 countt 26-31 countb 33-37 ;
run;
%end;
%mend cammacro;
data town;
set new.linkname;
gcode = fngcode; output;
gcode = tngcode; output;
keep gcode town;
run;
proc sort nodupkey;
by gcode;
* merge town flag with rrp data *
data rrp town;
merge rrp (in = a) town (in = b);
by gcode;
if a;
run;
proc sort data = rrp town;
by rrp;
run;
data rxy;
set new.vic_rpp;
keep rrp rrp_x rrp_y gcode lga1;
rename rrp_x = amge rrp_y = amgn;
run;
proc sort nodupkey;
by gcode;
* rs records are duplicated here - remove later *
* both ends of arc need to be checked for town flag *
keep rs_x rs_y gcode lga1;
rename rs_x = amge rs_y = amgn;
run;
proc sort;
by gcode;
run;
* add town flag in for midblock accidents here *
data rstown;
merge rxy (in = a) town (in = b);
by gcode;
if a;
run;
proc sort;
by rs;
run;
data accrrp accrs;
set all.newper;

* set date subset filter here *;
if ( year = 90 and month in ('Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec')
or year in (91, 92, 93) ;

* convert character month to numeric (1-12) *
if month = 'Jan' then mn=1;
else if month = 'Feb' then mn=2;
else if month = 'Mar' then mn=3;
else if month = 'Apr' then mn=4;
else if month = 'May' then mn=5;
else if month = 'Jun' then mn=6;
else if month = 'Jul' then mn=7;
else if month = 'Aug' then mn=8;
else if month = 'Sep' then mn=9;
else if month = 'Oct' then mn=10;
else if month = 'Nov' then mn=11;
else if month = 'Dec' then mn=12;

* convert day/month/year to julian day from start of tin days *;
accday = mdy(mn, day, year) - mdy(06, 30, 90) - 1;
if rrp > 0 then output accrrp;
else if rs > 0 then output accrs;

keep rrp rs accno accday speedlim ;
run;

proc sort data=accrrp;
by rrp;
run;

proc sort data=rrptown;
by rrp;
run;

proc sort data=accrs;
by rs;
run;

proc sort data=rrstown;
by rs;
run;

data acc2;
merge accrs(in=a) rrstown(in=b);
by rs;
if a and b;
run;

* new.camall contains camera x-y locations *;
data cam;
set new.camall;
if x > 0 and y > 0;
rename x=came y=camn site=cam ;
run;

data camacc;
set acc1 acc2;

* subset location aspects here by speed *;
* subset location aspects here by speed *;
* subset location aspects here by speed *;
speed = 100 ;

* subset by lga here *;
if ( lga1 <= 56);
keep amge amgn accday accno;

* new.camacc contains accident data with x-y positions for specified period *;
run;

proc sort nodupkey out=new.camacc ;
by accno;

* end of location filtering here *;
* tin data file here *;
data camtim;
infile camtime missover;
input site $ 33-37 sesday 15-20 tinday 22-28;
run;

proc sort;
by site;
run;

data _null_
;
call symput('numacc',left(put(numobs, 12.));
stop;
set new.camacc nobs=numobs;
run;

%cammacro
APPENDIX B

List of variables in the speed camera operations enhanced casualty crash data file
1-5: The code-names of the 5 nearest speed camera sites within 1 km of the crash site

6-10: a distance in metres from each of the 5 speed camera sites

11: an on/off label to denote whether the day of the crash was on a day of no speed camera influence at any of the above 5 speed camera sites

12: an on/off label to denote whether the day of the crash was on a day of hypothesised site operation influence only at any of the above 5 speed camera sites

13: an on/off label to denote whether the day of the crash was on a day of hypothesised TIN receipt influence only from any of the above 5 speed camera sites

14: an on/off label to denote whether the day of the crash coincided with both a day of site operation influence and a day of TIN receipt influence.

The previous four labels describe the outcome of a comparison between all the days of influence of the five camera sites listed for this particular crash site to find whether the crash date coincided with

(a) no influence from any of the 5 speed camera sites
(b) the 7-day influence of at least one of the five camera sites but no TIN inf.
(c) the 14-day influence of TIN's from at least one of the five camera sites but no site inf.
(d) both of (b) and (c)

15: the number of days when variable 11 was positive out of 1280 possible days

16: the number of days when variable 12 was positive out of 1280 possible days

17: the number of days when variable 13 was positive out of 1280 possible days

18: the number of days when variable 14 was positive out of 1280 possible days

19: whether the crash site and camera site were on the same road

And including the following variables from the accident database:

20: the unique accident identifying number to enable any other variable recorded on the police reported accident database to be matched in any subsequent analysis

21-22: time of accident and day of accident to identify crashes in low alcohol hours,

23: place of accident (whether on an arterial road or not),

24: accident description (definition for classifying accidents in Victoria, DCA),

25: severity of the accident classified by the most severely injured person in the crash  
   (fatal, severe, minor).
APPENDIX C

Detailed analysis results of speed camera influence in rural towns in Victoria
INFLUENCE DURATION: Site - 1 week  Tin - 2 weeks  
RADIUS OF INFLUENCE : 1km  
Rural Towns

### Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Times of the Week</td>
<td>5429</td>
<td>648</td>
<td>596</td>
<td>273</td>
<td>6946</td>
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<tr>
<td>Low Alcohol Hours</td>
<td>3456</td>
<td>426</td>
<td>397</td>
<td>174</td>
<td>4453</td>
</tr>
<tr>
<td>High Alcohol Hours</td>
<td>1973</td>
<td>222</td>
<td>199</td>
<td>99</td>
<td>2493</td>
</tr>
<tr>
<td>Arterial Roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Times of the Week</td>
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<td>244</td>
<td>240</td>
<td>93</td>
<td>2643</td>
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<td>161</td>
<td>162</td>
<td>64</td>
<td>1749</td>
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<tr>
<td>High Alcohol Hours</td>
<td>704</td>
<td>83</td>
<td>78</td>
<td>29</td>
<td>894</td>
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</table>

### Detailed Analysis Results

<table>
<thead>
<tr>
<th>Road/Time</th>
<th>Significant Probabilities of Hypothesis Test</th>
<th>Crash Proportions with Bonferroni Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL ROADS</td>
<td>p*=0.83</td>
<td>EXP</td>
</tr>
<tr>
<td>ALL HOURS</td>
<td></td>
<td>No inf</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>p*=0.68</td>
<td>Site inf</td>
</tr>
<tr>
<td>HIGH ALCOHOL HOURS</td>
<td>p*=0.84</td>
<td>Tin inf</td>
</tr>
<tr>
<td>ARTERIAL ROADS</td>
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<td>Both inf</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>p*=0.55</td>
<td>EXP</td>
</tr>
<tr>
<td>ALL HOURS</td>
<td></td>
<td>No inf</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>p*=0.55</td>
<td>Site inf</td>
</tr>
<tr>
<td>HIGH ALCOHOL HOURS</td>
<td>p*=0.77</td>
<td>Tin inf</td>
</tr>
<tr>
<td>HIGH ALCOHOL HOURS</td>
<td>p*=0.77</td>
<td>Both inf</td>
</tr>
</tbody>
</table>

EXP = Expected Crash Proportion from Exposure  
OBS = Observed Crash Proportion
APPENDIX D

Detailed analysis results of speed camera influence on rural highways in Victoria
INFLUENCE DURATION: Site - 1 week  Tin - 2 weeks  
RADIUS OF INFLUENCE: 5 kms  

Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Times of the Week</td>
<td>3007</td>
<td>174</td>
<td>341</td>
<td>116</td>
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<td>Low Alcohol Hours</td>
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<td>82</td>
<td>199</td>
<td>73</td>
<td>1964</td>
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<td>High Alcohol Hours</td>
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<td>92</td>
<td>142</td>
<td>43</td>
<td>1674</td>
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<td>All Times of the Week</td>
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<td>170</td>
<td>46</td>
<td>1968</td>
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<tr>
<td>Low Alcohol Hours</td>
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<td>97</td>
<td>32</td>
<td>1077</td>
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<td>High Alcohol Hours</td>
<td>772</td>
<td>32</td>
<td>73</td>
<td>14</td>
<td>891</td>
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Detailed Analysis Results

<table>
<thead>
<tr>
<th>Road/Time</th>
<th>Significant Probabilities of Hypothesis Test</th>
<th>Crash Proportions with Bonferroni Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL HOURS</td>
<td>( p^* = 0.55 )</td>
<td>EXP</td>
</tr>
<tr>
<td></td>
<td>No inf</td>
<td>82.82%</td>
</tr>
<tr>
<td></td>
<td>Site inf</td>
<td>4.65%</td>
</tr>
<tr>
<td></td>
<td>Tin inf</td>
<td>9.71%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
<td>2.62%</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>( p^* = 0.11 )</td>
<td>EXP</td>
</tr>
<tr>
<td></td>
<td>No inf</td>
<td>82.92%</td>
</tr>
<tr>
<td></td>
<td>Site inf</td>
<td>4.62%</td>
</tr>
<tr>
<td></td>
<td>Tin inf</td>
<td>9.65%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
<td>2.61%</td>
</tr>
<tr>
<td>HIGH ALCOHOL HOURS</td>
<td>( p^* = 0.12 )</td>
<td>EXP</td>
</tr>
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<td></td>
<td>No inf</td>
<td>82.69%</td>
</tr>
<tr>
<td></td>
<td>Site inf</td>
<td>4.79%</td>
</tr>
<tr>
<td></td>
<td>Tin inf</td>
<td>9.77%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
<td>2.84%</td>
</tr>
<tr>
<td>ALL HOURS</td>
<td>( p^* = 0.41 )</td>
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<td></td>
<td>No inf</td>
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<tr>
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<td>Site inf</td>
<td>4.24%</td>
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<tr>
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<td>Tin inf</td>
<td>8.76%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
<td>2.21%</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>( p^* = 0.31 )</td>
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</tr>
<tr>
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<td>Site inf</td>
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<td>Tin inf</td>
<td>8.66%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
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<td>HIGH ALCOHOL HOURS</td>
<td>( p^* = 0.19 )</td>
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<td>4.52%</td>
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<tr>
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<td>Tin inf</td>
<td>8.83%</td>
</tr>
<tr>
<td></td>
<td>Both inf</td>
<td>2.23%</td>
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</table>

\( \text{EXP} = \) Expected Crash Proportion from Exposure  
\( \text{OBS} = \) Observed Crash Proportion
INFLUENCE DURATION: Site - 1 week  Tin - 2 weeks
RADIUS OF INFLUENCE: 15 kms

Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>All Times of the Week</td>
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<td>807</td>
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<td>6429</td>
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<td>2950</td>
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Detailed Analysis Results

<table>
<thead>
<tr>
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<th>Significant Probabilities of Hypothesis Test</th>
<th>Crash Proportions with Bonferroni Confidence Limits</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>EXP</td>
<td>OBS</td>
</tr>
<tr>
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<td>75.86%</td>
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<td>Site inf</td>
<td>6.30%</td>
<td>6.28%</td>
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<tr>
<td>Tin inf</td>
<td>13.18%</td>
<td>12.55%</td>
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<tr>
<td>Both inf</td>
<td>4.06%</td>
<td>4.96%</td>
</tr>
<tr>
<td>LOW ALCOHOL HOURS</td>
<td>p*=0.1</td>
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<tr>
<td>No inf</td>
<td>76.27%</td>
<td>76.57%</td>
</tr>
<tr>
<td>Site inf</td>
<td>6.20%</td>
<td>6.67%</td>
</tr>
<tr>
<td>Tin inf</td>
<td>13.00%</td>
<td>11.84%</td>
</tr>
<tr>
<td>Both inf</td>
<td>4.53%</td>
<td>4.92%</td>
</tr>
<tr>
<td>HIGH ALCOHOL HOURS</td>
<td>p*=0.56</td>
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<td>No inf</td>
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<td>Both inf</td>
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<td>4.92%</td>
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<td>ALL HOURS</td>
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<tr>
<td>No inf</td>
<td>76.91%</td>
<td>76.99%</td>
</tr>
<tr>
<td>Site inf</td>
<td>6.15%</td>
<td>5.73%</td>
</tr>
<tr>
<td>Tin inf</td>
<td>12.81%</td>
<td>13.00%</td>
</tr>
<tr>
<td>Both inf</td>
<td>4.13%</td>
<td>4.32%</td>
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<tr>
<td>No inf</td>
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<td>77.69%</td>
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<td>Site inf</td>
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<td>11.61%</td>
</tr>
<tr>
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<td>4.23%</td>
</tr>
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<td>76.03%</td>
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<td>Site inf</td>
<td>6.26%</td>
<td>4.81%</td>
</tr>
<tr>
<td>Tin inf</td>
<td>13.08%</td>
<td>14.73%</td>
</tr>
<tr>
<td>Both inf</td>
<td>4.32%</td>
<td>4.43%</td>
</tr>
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</table>

EXP = Expected Crash Proportion from Exposure
OBS = Observed Crash Proportion
APPENDIX E

Detailed analysis results of speed camera influence in metropolitan Melbourne
INFLUENCE DURATION: Site - 1 week  Tin - 1 week
RADIUS OF INFLUENCE: 1km

Metropolitan Melbourne

Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Times of the Week</td>
<td>25506</td>
<td>2896</td>
<td>2836</td>
<td>1875</td>
<td>33113</td>
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<td>15683</td>
<td>1741</td>
<td>1797</td>
<td>1168</td>
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<tr>
<td>High Alcohol Hours</td>
<td>9623</td>
<td>1155</td>
<td>1039</td>
<td>707</td>
<td>12724</td>
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<td>All Times of the Week</td>
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<td>440</td>
<td>502</td>
<td>301</td>
<td>6480</td>
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<td>Low Alcohol Hours</td>
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<td>303</td>
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<td>4024</td>
</tr>
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<td>High Alcohol Hours</td>
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<td>199</td>
<td>112</td>
<td>2456</td>
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</table>

Detailed Analysis Results

<table>
<thead>
<tr>
<th>Road/Time</th>
<th>Significant Probabilities</th>
<th>Crash Proportions with Bonferroni Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL ROADS</td>
<td>p* = 0.01</td>
<td>EXP</td>
</tr>
<tr>
<td>No inf</td>
<td>76.33%</td>
<td>77.03%</td>
</tr>
<tr>
<td>Site inf</td>
<td>8.97%</td>
<td>8.75%</td>
</tr>
<tr>
<td>Tin inf</td>
<td>8.99%</td>
<td>8.56%</td>
</tr>
<tr>
<td>Both inf</td>
<td>5.69%</td>
<td>5.66%</td>
</tr>
</tbody>
</table>

| LOW ALCOHOL HOURS | p* = 0.08 | EXP | OBS | Low CL | Upp CL |
| No inf   | 76.28% | 76.92% | 76.18% | 77.66% |
| Site inf | 8.97%  | 8.54%  | 8.05%  | 9.03%  |
| Tin inf  | 9.02%  | 8.81%  | 8.31%  | 9.31%  |
| Both inf | 5.72%  | 5.73%  | 5.32%  | 6.13%  |

| HIGH ALCOHOL HOURS | p* = 0.01 | EXP | OBS | Low CL | Upp CL |
| No inf   | 76.42% | 77.20% | 76.27% | 78.13% |
| Site inf | 8.97%  | 9.08%  | 8.44%  | 9.71%  |
| Tin inf  | 8.97%  | 8.17%  | 7.56%  | 8.77%  |
| Both inf | 5.65%  | 5.58%  | 5.06%  | 6.06%  |

| ARTERIAL ROADS | p* = 0.01 | EXP | OBS | Low CL | Upp CL |
| No inf   | 79.62% | 80.82% | 79.59% | 82.04% |
| Site inf | 7.93%  | 6.79%  | 6.01%  | 7.57%  |
| Tin inf  | 7.97%  | 7.75%  | 6.91%  | 8.57%  |
| Both inf | 4.48%  | 4.65%  | 3.99%  | 5.29%  |

| LOW ALCOHOL HOURS | p* = 0.05 | EXP | OBS | Low CL | Upp CL |
| No inf   | 79.89% | 80.93% | 79.39% | 82.49% |
| Site inf | 7.81%  | 6.83%  | 5.84%  | 7.83%  |
| Tin inf  | 7.56%  | 7.53%  | 6.49%  | 8.57%  |
| Both inf | 4.42%  | 4.70%  | 3.96%  | 5.53%  |

| HIGH ALCOHOL HOURS | p* = 0.05 | EXP | OBS | Low CL | Upp CL |
| No inf   | 79.18% | 80.62% | 78.62% | 82.61% |
| Site inf | 8.14%  | 6.72%  | 5.46%  | 7.98%  |
| Tin inf  | 8.11%  | 8.10%  | 6.73%  | 9.48%  |
| Both inf | 4.56%  | 4.56%  | 3.51%  | 5.61%  |

EXP = Expected Crash Proportion from Exposure
OBS = Observed Crash Proportion
INFLUENCE DURATION: Site - 1 week  Tin - 2 weeks
RADIUS OF INFLUENCE: 1km

Metropolitan Melbourne

Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Roads</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Times of the Week</td>
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<td>4809</td>
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<td>3044</td>
<td>1816</td>
<td>20392</td>
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<td>9102</td>
<td>844</td>
<td>1765</td>
<td>1019</td>
<td>12730</td>
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Detailed Analysis Results

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<tr>
<th>Road/Time</th>
<th>Significant Probabilities of Hypothesis Test</th>
<th>Crash Proportions with Bonferroni Confidence Limits</th>
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<tbody>
<tr>
<td>ALL HOURS</td>
<td>EXP = Expected Crash Proportion from Exposure</td>
<td>OBS = Observed Crash Proportion</td>
</tr>
<tr>
<td></td>
<td>EXP OBS Low CL Upp CL</td>
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<tr>
<td>ALL HOURS</td>
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<tr>
<td>Tin inf</td>
<td>14.84% 14.52% 14.04% 15.00%</td>
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<tr>
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<tr>
<td>Both inf</td>
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</tbody>
</table>

EXP = Expected Crash Proportion from Exposure
OBS = Observed Crash Proportion
INFLUENCE DURATION: Site - 1 week  Tin - 3 weeks
RADIUS OF INFLUENCE: 1 km

Metropolitan Melbourne

Sample Sizes

<table>
<thead>
<tr>
<th>Time / Influence</th>
<th>No Influence</th>
<th>Site Influence</th>
<th>Tin Influence</th>
<th>Both Influences</th>
<th>Total No. of Crashes</th>
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Detailed Analysis Results

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<td>ALL HOURS</td>
<td>$p^* = 0.01$</td>
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<td>No inf 68.13% 68.81% 68.26% 67.56%</td>
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<td>Site inf 4.96% 4.97% 4.68% 5.27%</td>
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<tr>
<td></td>
<td>Tin inf 19.20% 18.68% 18.15% 19.22%</td>
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<td>Both inf 9.70% 9.43% 9.03% 9.94%</td>
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<td>No inf 66.07% 66.78% 65.95% 67.60%</td>
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<tr>
<td></td>
<td>Site inf 4.96% 4.91% 5.63% 5.29%</td>
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