Greenland, Karen

From: Greenland, Karen
Sent: Monday, 23 June 2014 5:30 PM
To: Boogs, Monika; Hosking, Kim
Cc: Ng, Daniel; Crowhurst, Moira; Playford, Alison; Phillips, Brett; Snowden, David; Swale, Brett; Davidson, Geoffrey; McIntosh, Andrew
Subject: FW: Road Safety Camera Evaluation - draft report

Hi Monika and Kim -

FYI - the draft report: Evaluation of the ACT Road Safety Camera Program from UNSW was received late last week. For information, here are some key findings and issues.

- The report includes a **statistical analysis of the impact of mobile cameras on speed and crashes**
  Key findings include:
  - Mobile camera operations progressively increased from introduction in 1999 to a peak in 2006, after which they declined approx 30% due to resource limitations (following up with TCO to clarify further)
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  - Mean and 85th percentile speeds reduced by 7% and 9%,respectively, on streets with mobile cameras from mid-2006 – 2012
  - Fatal crashes on streets with cameras generally decreased over the study period
  - There was a large decrease in serious injury crashes in mid-2002 on streets with mobile cameras when mobile camera operations increased from around 400 per month to over 600 per month. This was sustained until around late 2004.
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- **The report does not include a statistical analysis of crash impacts of fixed mid-block cameras as crash data available does not sufficiently accurately identify the crash location on the mid-block.** (However, note outcome of literature review on these cameras referenced below.)

- **The report does not include a statistical analysis of crash impacts for point to point cameras as these are recent installations and insufficient data is available for a meaningful analysis.** (UNSW has been asked to address future evaluation requirements for these cameras in the report.)

- The report includes a **literature review for all camera types used in the ACT**. The literature confirms that evaluations of mobile, fixed intersection, fixed mid-block and point to point cameras have identified benefits such as reduced speeds and crash reductions.

  - In relation to fixed mid-block cameras evaluations have identified these benefit in the vicinity of the camera. (This confirms the concern raised in the Auditor General's report about fixed cameras having a limited localised effect, rather than a capacity to influence driver behaviour across the road network.)
  - In relation to point to point cameras there is very limited evaluation of these systems. The report cites one study which involved a sufficiently rigourous evaluation of P2P. The evaluation showed significant crash reductions, although there was an effectiveness decrease over time.

- In relation to fixed red light cameras at intersections, there are mixed effects: benefits include reduced red-light running and right-angle crashes ; detriments include increased rear-end crashes (a less severe type of crash) in the initial phase following introduction.

- The report includes a **review of community attitudes to speeding**
  - Since the introduction of the cameras the number of residents that agree that "safe speeding is OK" has decreased. However around one half agree with the view that speeding fines are for revenue raising.
  - The report recommends that the ACT government re-engage with the community regarding the benefits of reducing speed for road safety and the role of cameras in reducing speeds.

  JACS is requesting some further work on the draft report to address the agreed evaluation scope, in particular assessment of the governance arrangements for the current program.

JACS considers that the report also needs, more directly and explicitly, to draw out findings, conclusions and recommendations which address the following that were to be identified by the evaluation:

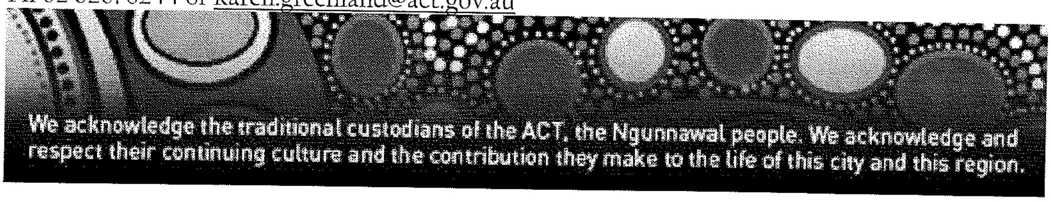
(a) Potential opportunities to gain improved road safety effectiveness from existing resources of the program;
(b) Future opportunities to maximise the road safety effectiveness of the program (in terms of both resources and governance);
(c) An appropriate ongoing evaluation framework to support an effective program.

Under the contract the final report is due on 28 June. UNSW lost a week recently due to illness of one of the consultants and may request some additional time to address the comments requesting further material in the final report. As it will be important to ensure these aspects of the evaluation are addressed, we are likely to need to agree to a short extension past the end of June deadline. UNSW is getting back to us about what additional time they believe is required to complete the report.

Karen

Karen Greenland
Deputy Executive Director, Legislation, Policy and Programs
ACT Justice and Community Safety Directorate

Ph 02 62076244 or karen.greenland@act.gov.au



Karen

Davidson, Geoffrey
Monday, 23 June 2014 5:53 PM
Raphael Grzebieta; Ann Williamson
Greenland, Karen
ubject: RE: Comments on Camera Report

Hi Raphael

Comments below – as discussed on the phone this afternoon.

The analysis and literature review address the first part of the scope (ie impact on crashes and speed), accepting limitations of data for midblocks and point to point.

However, I don't see any assessment of the governance arrangements for the current program. As discussed, we are seeking expert advice on the existing governance arrangements and whether these are adequate and effective or alternatively how they could be improved. To assist with this, I sent a table of agency roles to responsibilities and :he terms of reference for the Road Safety Camera Program Management Group to Ann. Please let me know if you would like me to resend this information. I thought that Soames may be able to assist with this component of the evaluation and review – based on his experiences at the NSW Centre for Road Safety.

The report also needs, more directly and explicitly, to draw out findings, conclusions and recommendations which address the following that were to be identified by the evaluation:

(a) Potential opportunities to gain improved road safety effectiveness from existing resources of the program;
(b) Future opportunities to maximise the road safety effectiveness of the program (in terms of both resources and governance);
(c) An appropriate ongoing evaluation framework to support an effective program.

In relation to (b), for example, it would be useful to pull together findings, conclusions or recommendations that could inform decision making about the mix, density and manner of deployment of various camera types as well a supporting measures to improve effectiveness (eg community engagement);
In relation to (c) as well as drawing together relevant findings, conclusions or recommendations already in the draft report (eg re improved speed surveys), it would be valuable to have some commentary around any other changes to data collection that would assist in future evaluation of the program (including to address gaps identified by the report such as lack of data on location of mid-block crashes). For the point to point cameras, given the report finds that it is too early to undertake an analysis of crash and speed outcomes, it would be useful for the report to suggest an appropriate timeline and methodology (at least at a high level) for a meaningful evaluation of those cameras. Restructuring the report to include additional headings (perhaps each of the dot points above could be specific headings) may be one way of achieving this, however additional content would still be required in some cases.

As a way forward, if you could please provide a response on how the above comments could be addressed in the final report. We will also need quick advice on any impact on the timing of the final report.

I will be in Adelaide for the next two days. You can get me on my mobile on or Karen on 02 6207 6244.

Looking forward to your response.

Thanks

Geoff

Geoffrey Davidson | Manager, Road Safety

Legislation, Policy & Programs | Justice and Community Safety Directorate | **ACT Government**

Level 2, 12 Moore Street, CANBERRA CITY ACT 2601 | GPO Box 158, CANBERRA ACT 2608

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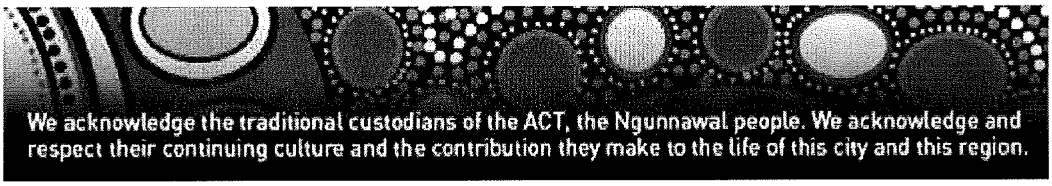

From: Raphael Grzebieta [mailto:
Sent: Thursday, 19 June 2014 3:18 PM
To: Davidson, Geoffrey
Cc: Ann Williamson; ___________@unsw.edu.au; Jake Olivier;
Subject: Report

Dear Geoff,

Attached is the draft report.

I have provided both the Word version and a PDF version for you perusal and for tracking comments or changes.

I will have to send them in two emails.

Kind Regards

Raphael

Raphael Grzebieta PhD
(Professor, Road Safety)

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DECADE OF ACTION FOR ROAD SAFETY 2011-2020

Greenland, Karen

From: Greenland, Karen
Sent: Wednesday, 25 June 2014 3:49 PM
To: Boogs, Monika; Hosking, Kim
Cc: Ng, Daniel; Crowhurst, Moira; Playford, Alison; Phillips, Brett; Snowden, David; Swale, Brett; Davidson, Geoffrey; McIntosh, Andrew
Subject: RE: Road Safety Camera Evaluation - draft report

Hi Monika and Kim – have just spoken to UNSW consultants who confirm they will need an extra two weeks to address some issues we have raised re the draft camera program evaluation report. They propose to get the final to us by 11 July 2014. (two weeks later than the 28 June deadline in the original contract).

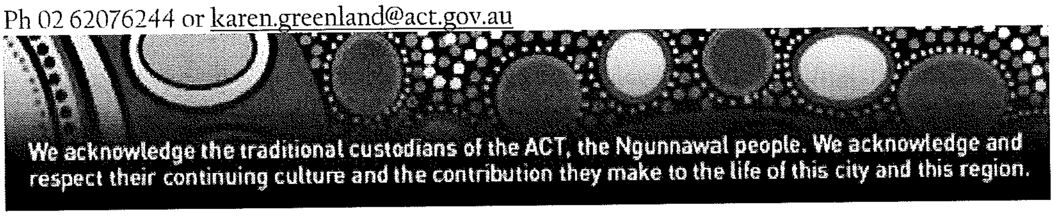
As addressing the issues identified in the draft is necessary to get the most out of the evaluation, we propose to agree to the extension. Let me know if you need more info on this.

Thanks

Karen

Karen Greenland
Deputy Executive Director, Legislation, Policy and Programs
ACT Justice and Community Safety Directorate

Ph 02 62076244 or karen.greenland@act.gov.au



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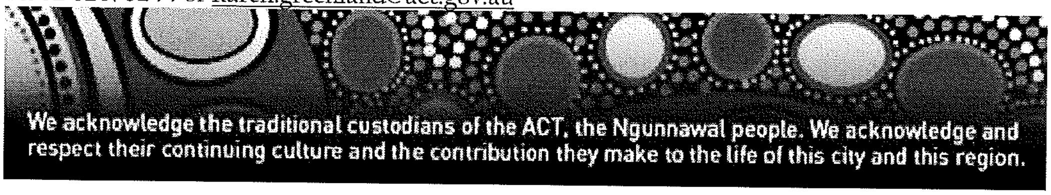

Greenland, Karen

From: Raphael Grzebieta
Sent: Wednesday, 25 June 2014 12:39 PM
To: Greenland, Karen
Subject: RE: Draft Report - ACT Camera Program Evaluation

Thanks Karen.

Cheers

Raph

Raphael Grzebieta PhD
(Professor, Road Safety)

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iversity of New South Wales (UNSW)
ydney, NSW 2052

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DECADE OF ACTION FOR ROAD SAFETY 2011-2020

From: Greenland, Karen [mailto:Karen.Greenland@act.gov.au]
Sent: Wednesday, 25 June 2014 11:01 AM
To: Raphael Grzebieta
Cc: Swale, Brett; Davidson, Geoffrey; Snowden, David
Subject: Draft Report - ACT Camera Program Evaluation

Hi Raphael,

Another issue that it would be useful to explore, arising from the draft report, is the apparent reduction in mobile camera operations from around 2006. Brett Swale, Manager Road User Services (which includes the Traffic Camera Office), will get in touch to see if we can get a better understanding of this.

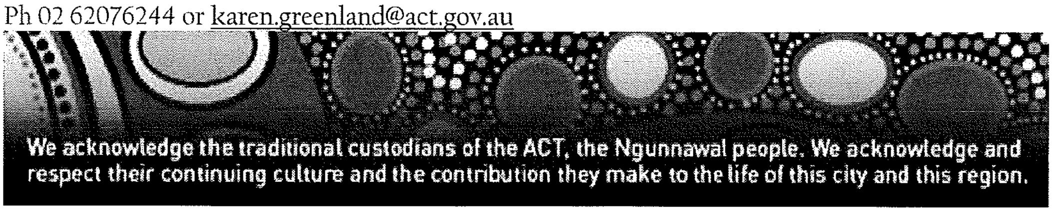
Brett – Prof Grzebieta's phone contact is (02)

Regards

Karen

Karen Greenland
Deputy Executive Director, Legislation, Policy and Programs
ACT Justice and Community Safety Directorate

Ph 02 62076244 or karen.greenland@act.gov.au



Issues requiring clear info in the Evaluation report

What could not be evaluated in relation to data available and why (some info in the report but needs to be explicit and easily located)?

For those aspects that could not be evaluated now – what advice for the future, noting a significant component of the task was advice to assist with setting up an evaluation framework.

Fixed midblocks – insufficient data showing crash locations. Notes better data from 2011 onwards. Would help to explain why post 2011 data insufficient.

In relation to future evaluation of these or other similar cameras – need clarity as to appropriate methodology and/or principles (data needed to support this including any commentary on what this would mean in terms of crash database).

P2P – explains too soon. Again – what guidance re future evaluation? Timing, methodology/data requirements?

Intersection redlight/speed – clarity re why evaluated as "job lot" rather than camera by camera. Given some expectation that evaluation might support understanding of whether these are at highest priority sites, commentary around basis of appropriate methodology for determining use/location of these cameras would be useful.

Crash database – any enhancements in terms of what is collected and accessibility/functionality required or desirable to support improved management/evaluation of program?

Mobile cameras – clarify issue re apparent drop in activity in 2006.

Any commentary around site selection and deployment methodology?

Governance – needs to be addressed

Were bicycle counted/excluded? crashes

Never Stand Still | Science | Transport and Road Safety (TARS) Research | School of Aviation

Draft Report:

Evaluation of the ACT Road Safety Camera Program

A TARS Research report for the ACT Government Justice and Community Safety Directorate

June 2014

TRANSPORT AND ROAD SAFETY
(TARS) RESEARCH

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Project Team

Prof. Ann Williamson (Project Leader, TARS)
Prof. Soames Job (TARS Adjunct)
Dr. Mike Bambach (TARS)
Dr. Joanna Wang (TARS/UNSW Maths)
Prof. Raphael Grzebieta (TARS)
A/Prof. Jake Olivier (UNSW Maths)
Ms. Amy Chung (UNSW Aviation)
Mr. David Hicks (TARS)

Acknowledgements

The authors wish to thank the Justice and Community Safety Directorate, particularly Geoff Davidson, Gordon Stone and Brett Swale, and the Territory and Municipal Services Directorate, particularly Pawel Potapowicz and Leonie Keal, for providing data and assistance for this study as well as the commitment to objective assessment of the ACT Road Safety Camera Program.

This research was funded by the ACT Government, Justice and Community Safety Directorate. The analyses, conclusions and/or opinions presented in this report are based on information available to the authors at the time of its writing. Further review and analyses may be required should additional information become available, which may affect the analyses, conclusions and/or opinions expressed in this report. The research conclusions are those of the authors and any views expressed are not necessarily those of the funding agency. This work is not endorsed or guaranteed by the Justice and Community Safety Directorate.

Definitions

Road crash – police-reported road crash that occurred on a public ACT roadway, resulting in property damage, injury or fatality
Serious road crash – police-reported road crash that occurred on a public ACT roadway, resulting in injury or fatality
Casualty crash – fatal and serious injury crashes
Case streets – ACT streets on which road safety cameras were installed/operated
Control streets – ACT streets on which road safety cameras were not installed/operated
Driver – Vehicle driver including light and heavy drivers and motorcycle riders
Intervention 1 – Introduction of the ACT Road Safety Camera Program, on the 6th October 1999
Intervention 2 – Reduction of mobile camera operations on ACT streets, around October 2006
Begin-date – Date of the introduction of cameras on a particular street/intersection
CL_L – Lower 95% confidence limit
CL_U – Upper 95% confidence limit
Statistically significant – a statistical result with a p value less than 0.05
Mean speed – the mean of all vehicle speeds measured during a speed survey
85th percentile speed – the speed below which 85% of vehicles were travelling during a speed survey (conversely, the speed 15% of vehicles were exceeding)
RTM – Regression to the mean
Spillover effect – when the effects of a fixed camera extend further along a roadway from the camera location

Executive Summary

Background

The ACT Government is ~~interested in road safety and~~ committed to improving ~~the~~ safety ~~of~~ the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, in order to guide improvement of the Program. This report delivers that independent evaluation.

Aim

The aim of this study was to investigate the performance of the ACT Road Safety Camera Program as a whole, including its impact on speeding and road crashes, and identify opportunities for improvement.

Whilst the above aim has been addressed in this report, emphasis in terms of evaluation of the camera program's effectiveness has been placed on whether the program has reduced serious and fatal injury crashes. This emphasis was implemented based on the National Road Safety Strategy (ATC, 2011) vision that no person should be killed or seriously injured on Australia's roads, where the strategy presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. In this context the following statements from that strategy document are particularly relevant: '*Crashes will continue to occur on our roads because humans will always make mistakes no matter how informed and compliant they are. But we do not have to accept a transport system that allows people to be killed or severely injured as a consequence..... This means we must manage the combined effects of the speeds at which we travel, the safety of the vehicles we use, and the level of protection provided by our roads — not only to minimise the number of crashes, but to ensure that when crashes do occur they do not result in death or serious injury.*'

Thus a key question in this evaluation the Authors decided to further consider is whether casualty crashes in the ACT have reduced as a result of the introduction of the ACT Road Safety Camera Program.

Methods

Speed surveys and road crash data were assessed for the period from 1994 to 2012 (inclusive). A sample of 95 ACT streets and 26 ACT intersections were assessed, including 48 case streets (with mobile cameras), 47 control streets (without mobile cameras), 13 case intersections (with fixed cameras) and 13 control intersections (without fixed cameras). It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

Data were collected for a total of 57,809 road crashes, 3,325 serious road crashes, 100 fatal road crashes, 4,261 intersection crashes, 1,758 speed surveys and 87,687 mobile camera operations. The sample represents 40% of the total number of ACT road crashes that occurred in the period.

Statistical models were developed to assess speed and crash trends, effects of interventions (introduction of cameras) and perform case-control analyses. Additionally, 66 assessments of road safety camera programs in the scientific literature were summarised, as were surveys of community attitudes to speeding collected from 1995 to 2011 (inclusive).

Results

- The number of mobile camera operations undertaken in the ACT increased following their introduction until late 2006, after which they decreased (around 30%) due to resource limitations;
- Mobile camera infringement rates decreased from approximately 6% to 0.6% of vehicles passing cameras during the first three years of operations, and remained thereafter steady at this low rate;
- Mean percentile speeds reduced by 6% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- mean 85th percentile speeds reduced by 8% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- Over the next two years, speeds on streets with mobile camera operations returned to levels similar to those before their introduction (mid-2004 to mid-2006);
- Mean and 85th percentile speeds then reduced by 7% and 9%, respectively, on streets with mobile cameras (mid-2006 to 2012);
- Mean and 85th percentile speeds on streets without mobile cameras were generally constant in the long term, and were lower in magnitude than speeds on streets with cameras reflecting the original reasons for the selection of some streets for camera enforcement;
- 85th percentile speeds were higher in magnitude than mean speeds, and although reduced by the cameras remained above the speed limit during the study period;
- Fatal crashes on streets with cameras generally decreased over the study period;
- Serious injury crashes at intersections were generally lower following the introduction of fixed cameras;
- Crashes at intersections with fixed cameras increased after their installation due to an increase in rear-end crashes which was then followed by a decline to levels slightly below baseline levels;
- Crashes at intersections without fixed cameras remained relatively constant although trending slightly upwards, and were lower in magnitude than crashes at intersections with fixed cameras reflecting the original reasons for the selection of some intersections for camera enforcement;
- There was a decreasing trend in serious crashes around the time of the introduction of mobile cameras, on both streets in which mobile cameras were operating and not;
- There was a large decrease in serious injury crashes in mid-2002 on streets with mobile cameras when mobile camera operations increased from around 400 per month to over 600 per month;

- The large decrease (around 40%) in serious injury crashes commencing in mid-2002 was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend steadily increasing up to 2013 to the same levels when cameras were first introduced;
- The rising trend in serious injury crashes starting from around 2004 through to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period;
- The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006;
- The large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras occurred in the year immediately following the period when more than two-thirds of survey participants reported that enforcement had increased in 2001;
- In the surveys conducted between 1999 and 2001 and in 2001 the percentage of people reporting no change in enforcement clearly fell to its lowest level in the survey period. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years up to 2006, perception of increased speed enforcement remained high. This increased awareness of speed enforcement coincides with the large 40% decrease in serious injury crashes commencing in mid-2002 until the end of 2004;
- More ACT residents reported decreasing their own driving speed in 2000 up until around 2005, being the period following the introduction of mobile and red light cameras and the period when there was a large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras. However, since 2008 around three quarters of drivers reported no change to their speed coinciding with the period of steady increase in serious injury crashes;
- More ACT residents reported supporting lowering residential speed limits following the introduction of mobile and red light cameras;
- Since the introduction of cameras in the proportion of residents that agree that safe speeding is 'OK' has decreased, however around one half agree with the view that speeding fines are for revenue raising;
- Evaluations of red light cameras in the literature have identified mixed effects: benefits include reduced red light running and right-angle crashes; detriments include increased rear-end crashes (a less severe crash type) during the initial phase when introduced however, right angle crashes are on average more severe than the rear end crashes;
- Evaluations of fixed speed cameras in the literature have identified benefits such as reduced speeds in the vicinity of the camera and reductions in injury and fatal crashes;
- Evaluations of mobile speed cameras in the literature have identified benefits such as reductions in speeds and speeding, and reductions in crashes;
- Evaluations of point-to-point cameras in the literature have identified benefits such as reductions in crashes

Conclusions

Beginning at the start of 2000, mobile cameras reduced speeds by around 6%-8% in the short-term (late-1999 to mid-2002), and remained at the lower speed until 2004 (a total period of four to five years). Speeds then began to rise back to pre-camera levels over a period of approximately four years (mid-2004 to mid-2007). The 6%-8% fall in speed reached by mid-2002 coincided with a 25% to 30% reduction in serious injury crashes on streets where cameras were present. This reduction in serious injury crashes was sustained until mid-2005. If this fall in serious injury crashes is attributed to the average speed reduction it would be consistent with the Nilsson power model where a 6% to 8% reduction in speed is estimated to result in around 20% serious and fatal (casualty) crashes. This short-term effect of speed cameras is consistent with camera evaluations in other jurisdictions and countries.

It is noted that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. This increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Coinciding with this 25% to 30% fall in serious injury crashes from mid-2002 to the end of 2004 period, the survey of community attitudes to speeding indicated a marked increase in survey participants' awareness from 2001 to 2004 that speed enforcement had increased. This indicates that drivers (includes motorcycle riders) likely adjusted their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. When they found that they were not being caught as often as they thought they would be, their speed started to return to customary levels. Associated with this rise in average speed was a rise in serious injury crashes to the same rates as those when cameras operations started in 1999. Alternatively, it could be other factors like initial bursts of enforcement, which slowed drivers (and riders) down.

The introduction of cameras had a short-term effect on vehicle mean and 85th percentile speeds. This short term effect coincided with driver's awareness that enforcement of speeds had increased. As a result serious crashes fell around mid-2002. However, serious crashes and speeds started to trend upwards since around 2005-2006, finally reaching the same levels of serious injury crashes as when cameras were first introduced. Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. Further speculating, the loss of this benefit may be reflecting an unrelated background trend such as an increase in traffic activity. It could also be due to drivers realising the low risk of detection and possibly weak penalties. When a driver receives an infringement and little changes with respect to penalty fees and to loss of their license, then the impact of detection is weakened. For example, in NSW when the law was introduced that any speeding by a P1 driver would cause them to lose their licence, the speed related fatalities dropped by over on third (Job, 2013). However, it appears that the main cause may have been the drop in mobile camera hours from a peak of 700 operations per month to an average of around 500 per month (around 30% reduction) in 2007. This pattern of data over time, with the decreases in severe crashes and decreases in speeding and then increases in both serious crashes and speed, reinforce the key role of speed in road trauma. Regardless, this increase in serious crashes over the last five to six years presents a substantial road safety challenge to the ACT.

Intersection cameras produced reductions in right angle crashes and small decrease in serious crashes offset by increases in rear end crashes. Concurrently rear-end crashes were on an upward slope at control intersections. Thus, the initial increase in rear-end crashes followed by a steady return to baseline rates at case intersections resulted in a net reduction in serious crashes. On average, whilst the number of injuries resulting from rear end crashes can be substantial in terms of number of lower severity injury claims, and can have long term chronic effects related to whiplash injuries, they are often significantly less severe than side impact crashes, mainly as a result of the crashworthiness crush and occupant protection characteristics of the struck vehicle.

Recommendations

The results strongly suggest that the cameras had a positive effect on reducing speeds and thus serious injury crashes when first introduced, but that this effect began to dissipate starting around the mid-2000's. The reasons for the increases in speeding and in crashing are not clear, but factors that may have played a role were a distinct reduction in the number and consistency of mobile camera operations in approximately late 2006, and avoidance mechanisms by drivers. Simply the threat or even presence of cameras is unlikely to have an effect of reducing speeds unless there is a clear consequence of doing so. A review is recommended of the information sources available for avoidance and improved management of camera operations to create true unpredictability (along with strong publicity warning that these changes are occurring)

Other factors that may have played a role could include less media and community awareness raising of the presence of cameras and the importance of speed as a factor in road safety around 2006 to 2007. The survey data indicates an increase of survey participants reporting no change in enforcement around then. It is therefore recommended that the ACT government re-engages with the community regarding the benefits of reducing speeds for road safety and the role of cameras in reducing speeds.

Alternative accounts of the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Evaluation of these possible accounts through further research is recommended.

Serious crashes have been increasing in the ACT since around mid-2005. It is also worth noting that the total ACT vehicle fleet has increased 25% over the period 2004–2013, and transport modelling of car trips during the morning peak period suggests the total number increase by 7% from 2006 to 2011 and by 13.5 % from 2001 over a ten year period. Given the infrastructure remains relatively constant (approximately the same road area and intersections) this increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes. It is therefore recommended that further research on injury crashes during this period is performed, in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

1. Introduction

1.2 Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, as well as the governance of the program. The key reason for conducting this evaluation is to identify opportunities for improvement. This report delivers that independent evaluation.

1.2 General

Camera technology has been adopted widely as a means of encouraging drivers to reduce their driving speed. Lack of control of speed is a major challenge to road safety, and is a large contributor to road crashes, especially more severe crashes. The use of photographic or camera enforcement automates and extends the reach of enforcement in an effort to encourage drivers to comply with speed limits.

Red light cameras are used to encourage compliance with traffic signals and by doing so promote lower driving speeds around signalised intersections. Fixed speed cameras being located at specific points in the road network are used to encourage lower speeds usually in areas of higher traffic risk, often regarded as traffic 'black spots'. As fixed cameras become a standard fixture they can be expected to have local effects on driving speeds. On the other hand, mobile speed cameras can be placed at any position in the road network and this position can be varied so drivers will not expect their presence. Mobile cameras therefore would be expected to have a more general effect on driving speeds as drivers cannot predict their presence around the road network. Some jurisdictions, including the ACT, operate mobile cameras overtly and provide information to drivers about the presence of mobile cameras. Others operate mobile cameras covertly, providing only general information to drivers that cameras may be operating 'anywhere, anytime'. Different outcomes might therefore be expected from overt and covert operation of mobile cameras. Overt operations that make the need to reduce speeds clear to drivers might be expected to have effects in their immediate vicinity. The general deterrence effect might be expected to be stronger in situations where mobile cameras are used covertly although this effect is likely to be much weaker as the effect will require drivers to reduce speeds 'just in case' there are cameras in their vicinity, and many other factors are likely to influence this effect including driver attitudes towards road safety and enforcement.

Evaluation of the effectiveness of safety camera programmes requires well-designed studies. Evaluation studies that only include measurement before and after cameras are implemented only provide weak evidence. At the least, study design needs to include appropriately chosen controls where measures are taken at the same time as the camera measures in order to be able to show that any changes seen after the cameras are in place are not simply due to changes in driver behaviour over time. An ideal study design would also include randomisation of locations for cameras and controls to ensure that choice of location does not bias measures of effectiveness of the cameras. In road safety, however, interventions like safety cameras are almost never randomly assigned; rather they are implemented in locations where they are likely to achieve the best improvements in road safety. Nevertheless, evaluation studies should still involve the best design possible and at least a before-after design with control groups.

In evaluating the effectiveness of safety cameras in particular, two other factors commonly cited as potential threats to the validity of safety camera evaluations are Regression to the Mean (RTM) and spillover effects. Non-random assignment of cameras to locations makes these types of evaluations vulnerable to RTM effects. Cameras are almost always implemented at sites that have high demonstrated crash risk and crash risk will be significantly lower after cameras are implemented if they operate as expected. It is possible, however, that the high initial crash risk is due to natural variation in crashing that occurs potentially in any location in the road network, in which case crash risk will decrease for the same reason, rather than due to the presence of cameras. RTM effects can lead to overestimation of the effects of safety cameras and so should be avoided if we want to reveal the effect of the presence of safety cameras. Best study designs for avoiding RTM effects include using long periods for before and after measurement so natural variation can be captured in the study and using statistical means such as empirical Bayes methodology (Hallmark et al, 2010).

It is argued that spillover effects, sometimes also referred to as halo effects, threaten the validity of the evaluation of safety cameras in studies where the chosen control sites may be influenced by the presence of the safety camera such as a similar location in the next section of road. In such locations, it is argued that driver speed may still be low due to a lasting effect of the camera. Spillover effects will underestimate the effectiveness of safety cameras and again invalidate the evaluation of the effect of the camera. It should be recognised, however, that spillover effects are also likely to occur due to general community awareness of speeding and speed-related enforcement that usually occurs around the introduction of safety cameras. Where this is the case, the finding of improvements in road safety outcomes at comparison locations with no camera should be viewed as another outcome of the road safety intervention rather than a nuisance factor in the evaluation. The comparison between camera and no camera sites will then be showing the additional effect of cameras to a road safety program rather than necessarily the whole program itself. Spillover effects of cameras may be less likely for some types of safety cameras. In particular, where camera locations are known and expected, such as fixed location cameras (red light and fixed speed), people come to anticipate their presence and so would be expected to produce less spillover effect as drivers respond to the particular sites that they know are enforced. Overall, to evaluate the effect of a safety camera program in its entirety would ideally ensure that control sites are in areas that will not be influenced by any facets of the program, not just the presence of cameras.

Finally, good evaluation designs should include measures relevant to the outcome expected to change as a result of the intervention. The objective of introducing safety cameras is to reduce driving speeds and as a result to reduce crashes and casualties. As shown in Figure 1, it is expected that the presence of safety cameras and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication is a key part of any enforcement program. The relationship between speed and casualty crashes is well known and has been modelled by many researchers. For example, Figure 2 shows the often cited Nilsson (2004) power model showing the relationship between the change in mean speed and fatal and serious injury crashes. It shows that a 7% reduction in mean speed will result in around 20% fall in Fatal and Serious injury crashes.

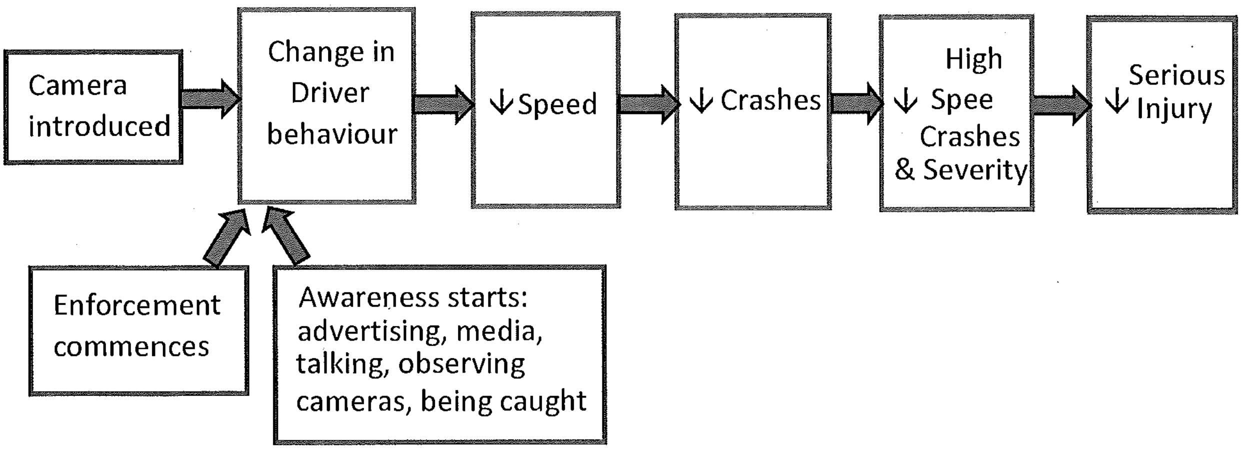

Figure 1: Schematic of the expected effects of safety cameras on road safety outcomes.

Figure 2: Nilsson (2004) power model showing relationship between casualty crashes and mean speed.

It must not be overlooked that the effect of safety cameras is also through punishment or enforcement of speed limits which also encourages changes in driver behaviour to produce lower speeds, crashes and injury. In this way, simply the presence of safety cameras can have a general deterrence effect on driver behaviour due to the fear of being caught, whereas the use of enforcement together with communication tends to have a specific effect on individual driver behaviour, mainly influencing speeding drivers who are caught.

These three effects of cameras, communication and enforcement are also likely to produce different changes in behaviour in parts of the road network in which cameras are introduced or not. The strongest effects naturally should occur in the safety camera locations where the presence of cameras combined with enforcement and communication provides the greatest encouragement for drivers to comply. It would be expected, that cameras will also influence driver behaviour in areas where some drivers might suspect that cameras are operating and so modify their behaviour accordingly. In most settings, the introduction of safety cameras is publicised and justified through media and other means of dissemination. This will also raise awareness amongst the community of the general presence of safety cameras which would be expected to add incentives for some drivers to change their behaviour and reduce speed because they want to avoid penalties and because they believe that compliance is safer.

The presence of enforcement and consequent speeding infringements for drivers who violate the speed limit, is likely to create further incentive for drivers to reduce their speed in locations where the enforcement occurs. Following the introduction of safety cameras it would be expected that infringements may be initially high, but will reduce as drivers learn about the presence of cameras and enforcement either through their own experience or the publicised experiences of others. With time, infringement rates would be expected to reduce as driver speed is reduced because of the cameras having an effect.

Safety camera evaluations should therefore include measures of changes in driver behaviour, especially speed around speed cameras and speed and red light running around red light cameras. As the ultimate outcome of camera programmes is to reduce injury crashes, these measures should also be included. Measures of enforcement should also be included in camera evaluations because enforcement is an integral aspect of the road safety intervention. Numbers of infringements are not a direct outcome of camera programmes. However, they would be expected to influence driver behaviour both independently and in combination with the presence of cameras. In the present study, efforts have been made to include all the relevant measures (infringement rates, speed, injury and crash data), while minimising the potential confounders (RTM and spillover effect).

2. Method

2.1 Literature review

The review of existing scientific literature on the impact and effectiveness of road safety cameras looked at published studies in the international peer-reviewed literature and unpublished reports from English-speaking countries including all Australian jurisdictions, Canada, UK, NZ and USA and from the top road safety performing countries in the OECD where their websites are translated into English (e.g., Sweden, Netherlands, France). The objective of these literature searches was to identify evidence of best practice in implementation of road safety cameras in order to evaluate the impact of different types of cameras, identify any issues that need to be taken into account in implementing safety camera programs and to determine whether there are new opportunities to improve the effectiveness of the current program in the ACT.

A search of the available published scientific literature was conducted using four major search engines including Web of Science, PsycINFO, Scopus and PAIS International. The key words used included speed, camera, red light camera, evaluation and enforcement in different combinations. A search of reports of evaluations of safety camera effectiveness was also conducted. This involved a website search of the main websites of road authorities in the different jurisdictions of Australia, Canada, UK, NZ and USA as well as Sweden, Netherlands, France (where their website is in English). The purpose of this search was to identify any grey literature that was not located from the conventional literature search.

2.2 Review of community attitudes to speeding

This review used existing literature to understand changes in community attitudes to speeding in the ACT following the introduction of different types of speed cameras, including the results of the series of community attitude surveys conducted for the Department of Infrastructure and Development and related entities over nearly 25 years. Changes in respondent's views of speeding were linked to the introduction of the different types of cameras in the ACT (i.e., mobile cameras from 1999, fixed red light/speed cameras from 2000, fixed speed cameras from 2007). As community attitudes are an important component of compliance with speed limits, this analysis may provide some other insights into the comparative effectiveness of the road safety camera program.

A series of community attitude surveys have been conducted for the Australian government's transport portfolio, currently the Department of Infrastructure and Regional Development. A total of 22 surveys have been conducted on a regular basis since the late 1980's. Questions about speeding were included in all surveys but since 1995 there has been a standard series of questions about speeding included in each survey. Answers to many of these questions are also available by jurisdiction so that it is possible to track changes in the perceptions and attitudes of ACT residents about speeding over the 15 years between 1995 and 2011. This data also allows investigation of the influence of the introduction of safety camera's on community attitudes towards speed and speeding over the period. With the staggered introduction of different types of cameras in the ACT, it was possible to look at the relative impact of each type of camera on community attitudes. This will allow examination of the general deterrence effect of mobile cameras which were introduced from 1999, the effects of fixed red light cameras operating in specific locations which were introduced from 2000 and fixed speed cameras from 2007.

Each of the 22 Community Attitude surveys conducted by the federal transport authority between 1995 and 2011 were reviewed to establish the series of questions on speeding that had remained the same across each survey.

The questions included were:

- "In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"
- "Have you personally been booked for speeding in the last two years?" And, if so "Have you personally been booked for speeding in the last six months?"
- "Thinking about 60km/h speed zones in urban areas:
  1. How fast should people be allowed to drive without being booked for speeding? (i.e. the 'acceptable' speed tolerance)
  2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"
- "Thinking about 100km/h speed zones in rural areas,
  1. How fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance)
  2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

- Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:
  1. Fines for speeding are mainly intended to raise revenue
  2. I think it is okay to exceed the speed limit if you are driving safely
  3. Speed limits are generally set at reasonable levels
  4. If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
  5. An accident at 70km/h will be a lot more severe than an accident at 60km/h
- "Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?"
- "Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"
- "Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways", they were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"
- "In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

Each survey looked at a national sample of residents 15 years and over. Survey was by telephone with a letter in advance advising the household about the survey. Sampling of all states and territories was stratified by regional probability sampling, but from 1999 the sampling strategy was modified to ensure at least 150 interviews in each jurisdiction. Sample size for the 1995 to 1998 surveys was around 100 interviews in each survey.

2.3 Speed survey and road crash data study

2.3.1 Data collections

The data collections that were accessed for the data study are summarised in Table 1.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 1: Data collections used for the study

Speed survey data was available from 1997 to 2012 (inclusive), and consisted of the annual summaries indicating the site location, speed limit, survey date, 24 hours traffic volume, mean and 85^{th} percentile speeds of the survey. The road crash data consisted of all police-reported crashes that occurred on public ACT roadways, resulting in either property damage, injury or fatality. In order to have five years of crash data prior to the start of the camera program, crash data was extracted from 1994 to 2012 (inclusive). Enforcement data for both fixed and mobile cameras consisted of the number of vehicles checked by the camera, and the number of infringements issued, and was available from the implementation of each camera.

2.3.2 Selection of case and control mobile camera locations

The present study considered two types of roadway locations; streets in which mobile cameras were implemented anytime during the period 1999 to 2012, and streets in which they were not. Streets with mobile camera operations are hereafter termed 'case' streets, while those without cameras are termed 'control' streets. It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

During the implementation of the mobile camera program since 1999, a total of 177 ACT streets were approved for mobile camera operations. Road crash data was available for all public ACT streets on a continuous basis. Speed survey data was available for selected ACT streets on a discontinuous basis, since surveys have been performed in a non-systematic way since 1997. In order to select locations for the present study of mobile camera operations, the speed survey data was deemed to be the limiting data collection and was therefore used.

Initially, streets on which mobile camera operations were introduced were identified in the speed surveys undertaken in 1997. This allowed for as much pre-camera data as possible. These streets were then tracked temporally and the number of years in which at least one survey was undertaken up to 2012 (inclusive) was established. Streets were then ranked according to the total number of years available, resulting in a total of 48 streets with five or more survey years. Streets on which mobile camera operations were not introduced were then selected in the same manner, resulting in a total of 47 streets with five or more survey years available. These analyses were performed manually using the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

This resulted in a total of 95 streets for the mobile camera analysis. The full list of case and control streets is provided in Appendix A. Crash data located anywhere along these streets was then provided by the ACT Territory and Municipal Services Directorate. Each street was then treated as a single location, a location number was assigned to it, and any crash or speed survey located at any position along the full length of that street, was assigned to that location number.

2.3.3 Selection of case and control fixed camera locations

There are three different types of fixed cameras operating in the ACT; combined red light and speed cameras located at intersections, speed cameras located along mid-block sections and point-to-point cameras. Point-to-point cameras were recently installed in 2012, thus insufficient data was available to assess these two cameras in this study. Road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. However, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis.

Intersection crashes are identified specifically in the road crash data collection, thus particular intersections were easily identified, and an assessment of the association of the introduction of fixed intersection cameras with crash outcomes could be assessed. Case and control intersections were identified in a similar manner to the mobile cameras, where case intersections were those on which fixed red light and speed cameras were installed. Since there was a relatively small number of these (thirteen), all fixed camera intersection locations were selected. Thirteen control intersections were then identified by randomly selecting other intersections located on the same street as each of the case intersections. This resulted in a total of 26 intersections for the fixed intersection camera analysis. The full list of case and control intersections is provided in Appendix A.

2.3.4 Time periods

The ACT road safety camera program began on the 6^{th} October 1999 with the introduction of mobile camera operations on 22 streets. Fixed cameras began to be introduced shortly thereafter in 2000. There was a reduction in mobile operations in 2006, where due to various resource limitations mobile camera vans performed fewer operations. In order to assess associations with the overall camera program, the two key dates of the introduction (October 1999) and the change (October 2006) were identified, and are hereafter termed Intervention 1 and Intervention 2, respectively.

For each case street, the date on which mobile camera operations began in that street was established, and is hereafter termed the 'begin-date'. Begin-dates for the selected streets ranged between October 1999 and March 2011. In order to perform the case-control analyses, each control street was matched to a case street, based upon traffic volume and speed zone. Since every case and control street had a speed survey performed in 1997, the traffic volume in 1997 was used to establish matched street pairs. Each control street was matched to a unique case street, and the begin-date of the case street was then allocated to the matched control street.

For each case intersection, the date of the installation of the fixed red light and speed camera was established as the begin-date for that street, and ranged between June 2000 and August 2007. Begin-dates were then assigned to control intersections, as the date corresponding to the begin-date of the matched case intersection.

2.3.5 Statistical analysis

The statistical analyses were divided into two categories, assessing the association of the camera program with changes in; vehicle speeds and road crashes. Vehicle speeds were assessed using speed survey mean and 85^{th} percentile values. Road crashes were aggregated into intersection and non-intersection crashes. Intersection crashes were aggregated into serious (injury or fatality), rear-end, non-rear-end and right angle/right turn into oncoming vehicle crashes. Non-intersection crashes were aggregated into fatal, serious and all crashes. Within these categories the analyses were divided into two further categories, assessing associations with regards to; the implementation of the overall camera program and the implementation of cameras at particular streets/intersections. A total of 32 models were developed, as outlined in Table 2. All outcomes of vehicle speeds and crash counts were aggregated into monthly counts.

The aim of assessing the implementation of the overall camera program was to identify the effect of the camera program on the network generally. For this purpose the case and control streets were aggregated and assessed individually, in order to assess the effect of the camera program on streets that had, or did not have, camera operations. These analyses were relative to the start date of the camera program (Intervention 1) and the change date of mobile operations (Intervention 2).

Model #	Outcome	Type	Intervention	Intervention dates
1	Speed surveys – mean	cases	Overall program	Interventions 1 and 2
2	Speed surveys – mean	controls	Overall program	Interventions 1 and 2
3	Speed surveys – mean	cases	Individual mobile cameras	Begin-date of cameras on each street
4	Speed surveys – mean	controls	Individual mobile cameras	Begin-date of cameras on each street
5	Speed surveys – mean	case-control	Individual mobile cameras	Begin-date of cameras on each street
6	Speed surveys – 85th percentile	cases	Overall program	Interventions 1 and 2
7	Speed surveys – 85th percentile	controls	Overall program	Interventions 1 and 2
8	Speed surveys – 85th percentile	cases	Individual mobile cameras	Begin-date of cameras on each street
9	Speed surveys – 85th percentile	controls	Individual mobile cameras	Begin-date of cameras on each street
10	Speed surveys – 85th percentile	case-control	Individual mobile cameras	Begin-date of cameras on each street
11	Serious road crashes	cases	Overall program	Interventions 1 and 2
12	Serious road crashes	controls	Overall program	Interventions 1 and 2
13	Serious road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
14	Serious road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
15	Serious road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
16	Road crashes	cases	Overall program	Interventions 1 and 2
17	Road crashes	controls	Overall program	Interventions 1 and 2
18	Road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
19	Road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
20	Road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
21	Serious intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
22	Serious intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
23	Serious intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
24	Intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
25	Intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
26	Intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
27	Intersection crashes-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
28	Intersection crashes-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
29	Intersection crashes-non-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
30	Intersection crashes-non-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
31	Intersection crashes-right A/T	cases	Individual fixed cameras	Begin-date of cameras on each street
32	Intersection crashes-right A/T	controls	Individual fixed cameras	Begin-date of cameras on each street

Table 2: Statistical models

The aim of assessing the implementation of cameras on particular streets/intersections was to identify the local effect of introducing individual cameras or camera operations. These analyses were relative to the begin-date for case streets/intersections, or the assigned begin-date for control streets/intersections (i.e. the begin-date of the matched case street/intersection). Case and control streets/intersections were first aggregated and assessed individually, then aggregated and assessed in a case-control study. The latter analysis provides statistical measures of the difference between the implementation of cameras on case and control streets/intersections. However, this comes with the caveat concerning the limitations outlined earlier regarding the selection of the control streets and the spillover effects that may be occurring.

Poisson regression was used for all models, and Pearson deviance was used to correct for over-dispersion. Poisson regression fits a log-linear model to the data, and is therefore most appropriate when the data approximates a log-linear trend. Before-and-after studies typically use the same temporal length both before and after, however are not bound by this. For the assessment of the implementation of camera operations on each individual street/intersection, this seemed a rational approach and the temporal period was set by the minimum amount of pre-data available (60 months for the crash data and 33 months for the speed survey data). For the assessment of the implementation of the overall camera program, the raw data was first assessed. For the crash data a relatively linear trend was observed between Intervention 1 and Intervention

2, therefore a single model was fit for this period. For the speed survey data a bilinear trend was observed during this period, therefore two models were fit. The first model used the same temporal length as the pre-camera speed survey data (33 months), while the second model used the remaining period up to Intervention 2. Accordingly, the crash data model was continuous between Intervention 1 and Intervention 2, while the speed survey model was not.

The outcome (COUNT) for the models was either monthly speed survey results (Models 1 – 10) or monthly crash counts (Models 11 – 32). The former were expressed as the measured speed divided by the speed limit (speed rate). Since speed surveys were not continuous over time, for each month all the speed rates for case streets were averaged, as were all the rates for control streets. Monthly crash counts were normalised to monthly vehicle registrations in the ACT (where monthly values were linear interpolations of annual values), for models considering the overall camera program (1994 to 2012). For all statistical models the following two covariates were assessed; TIME and CAMERA. The variable TIME represents monthly intervals and was a continuous covariate centred on the intervention date being considered. CAMERA was a binary variable which had the value zero prior to the intervention, and one following the intervention. For all models of crash counts, the locations (i.e. individual streets) were treated as subjects, where responses from different subjects were assumed to be statistically independent, while responses within subjects were assumed to be correlated. These models took the form of Equation 1. For the case-control models (Models 5, 10, 15, 20, 23, and 26), the identification of the location as a case or control street was included as an additional binary variable CASE. These models took the form of Equation 2. Interactions between variables were also considered. It should be noted that in all 32 statistical models the outcome considered was based on a period of one month, however in many results figures plotted in the following sections the raw crash counts are plotted with respect to three months, purely for clarity in the figures. SAS version 9.3 was used for all statistical analyses. Statistical significance was measured at the 0.05 level.

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,(\text{TIME} \times \text{CAMERA}) \tag{1}$$

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,\text{CASE} + \beta_4\,(\text{TIME} \times \text{CAMERA}) + \beta_5\,(\text{TIME} \times \text{CASE}) + \beta_6\,(\text{CAMERA} \times \text{CASE}) + \beta_7\,(\text{TIME x CAMERA} \times \text{CASE}) \tag{2}$$

3. Results

3.1 Literature review

3.1.1 Evaluations of red light cameras

Appendix B provides a summary of the papers and reports identified in the literature search. Four existing reviews of literature on the effectiveness of red light cameras were identified (Table 3a). The first was a critical review of international literature (Retting, Ferguson and Hakkert, 2003) looking at outcomes of violations and crashes, however no information was provided about how studies were chosen for inclusion in the review, except that they were all controlled evaluations of before and after effects. Only some of the studies included in this review accounted for RTM and spillover effects. The second was a Cochrane Collaboration meta-analysis review (Aeron-Thomas et al, 2005) of violations and different crash types from studies selected based on searches of electronic databases that fulfilled established criteria for inclusion. This review included only studies with controlled before-after designs and controls for regression to the mean (RTM) and spillover effects. The third was a meta-analysis of studies investigating intersection crashes that were identified from searches of electronic databases (Erke, 2009). This review included all designs including uncontrolled before-after studies and only some of the studies included controls for RTM and spillover effects. The fourth was an update and extension of the third review and again involving studies of intersection crashes that were identified from electronic searches, but with no restrictions on design or whether or not RTM and spillover was accounted for (Hoyos 2013). As might be expected there was a significant degree of overlap between the four reviews. Of the 10 papers included in the Cochrane review, 60 percent were shared with the Retting et al (2003) review and all were included in the two most recent reviews which included 14 and 11 new studies respectively. The Retting et al (2003) review included seven studies that were not included in any of the recent reviews.

In addition, the search in the current review of literature found four more recent evaluation studies of red light cameras (Table 3b). Two of these studies were well-designed before-after evaluations of the installation of red cameras (Ko, Geedipally and Walton, 2013; McCartt and Hu, 2014) and the other two involved studies comparing before and after the removal of red light cameras (Porter, Johnson and Bland, 2014; and Pulugurtha and Otturu, 2014). All studies involved controls of some type and all took steps to control for RTM and spillover effects.

The review also identified four evaluation studies of safety cameras that incorporated red light and speed cameras (Table 4). These were included in this review as they were the only evaluations found specifically of safety cameras which combine the two types. Three of these studies involved before and after with control designs (Vanlaar, Robertson and Marcoux, 2014; Kloeden, Edwards and McClean, 2009; Budd, Scully and Newstead, 2011) and one involved description of the change after cameras were introduced and did not include before measures or controls (McKenzie, Kloeden and Hutchinson, 2012). Only two of these studies accounted for RTM effects (Vanlaar et al, 2014; Budd et al, 2011) and only one accounted for spillover effects (Vanlaar et al., 2014)

Overall, each of the reviews concluded that the presence of red light cameras decreased injury crashes especially right angle crashes, however, the extent of the decrease varied between reviews and the extent to which the reviewers took into account RTM and spillover effects. Both

Retting et al (2003) and the Cochrane review concluded that injury crashes were reduced by 25-30%. It is notable however that the conclusion from the Cochrane review was based on a single well-designed study with appropriate controls. In contrast, the most recent reviews concluded either that there was no statistically significant change in casualty crashes (Hoyos, 2013) or a 13 percent increase in such crashes (Erke, 2009). While these reviews were the most comprehensive, including the largest number of studies, unlike the Cochrane review approach, they included all studies regardless of design flaws. Lund et al (2009) criticised the Erke (2009) review and cautioned against accepting its conclusions on the basis that it included a number of poorly designed studies. In response, Hoyos (2013) conducted a revised review that included extensive analysis of the role of potential moderator variables. Hoyos (2013) concluded that when RTM is controlled there is no evidence of significant effects of red light cameras on overall injury crashes, but the presence of red light cameras reduced right angle casualty crashes by 33 percent. The earlier review by Erke (2009) also found a significant, but smaller reduction of 10 percent in right angle crashes once RTM and spillover effects were accounted for. Two recent evaluation studies of the presence of red light cameras (Ko et al, 2013; Pulugurtha and Othuru, 2014) also showed a 24 and 69 percent decrease respectively in right angle crashes. Similarly the three recent A-B/control evaluation studies of red light and speed camera combinations (Vanlaar, et al, 2014; Kloeden et al, 2009; Budd, et al, 2011) all found significant decreases in right angle crashes of over 40 percent. The Cochrane review found no significant effect on right angle crashes but this was based on only two studies with partial control of moderator variables and the Retting et al (2003) review did not look at specific types of crashes. The evidence therefore leads to the conclusion that the presence of red light cameras have a significant benefit of reducing right angle crashes. This conclusion is supported by the nature of the crash that shows the most benefit. We would expect that red light cameras should reduce right angle crashes the most, and the evidence suggests that they do.

On the other hand, almost all of the reviews and studies that included measures of rear-end crashes made the opposite conclusion: rear-end crashes increased by around 40 percent after the introduction of red light cameras (Erke, 2009; Hoyos, 2013; Vanlaar et al, 2014; Pulugurtha and Otturu, 2014) and by around 19 percent for injury crashes (Hoyos, 2013). The exceptions were the Cochrane study which found no significant change across three studies, and two of the red light/speed camera combination evaluations (Kloeden et al, 2009; Budd et al, 2011), none of which accounted for the effects of all moderator variables.

In combination, the above studies indicate that red-light cameras reduce right angle crashes and increase rear-end crashes. While both crash types can be severe, on average right angle crashes are significantly more severe than rear-end crashes mainly as a result of the vehicle's structure and hence occupant protection crashworthiness. For example, in a side impact, the crush distance is small and hence there is little opportunity for ride-down to reduce the severity of the impact. On the other hand, in rear-end impacts, the crush distances are much larger (both the front end of the impacting vehicle and the rear end of the struck vehicle), and with current improved seat back and head rest anti-whiplash design, the severity of the crash would be substantially reduce compared to a side impact.

Red light cameras would also be expected to influence violations in the form of reductions in red light running. The Retting et al (2003) review concluded that these cameras reduced violations by 40 to 50 percent and two recent studies (Ko et al, 2013; McCartt and Hu, 2014) made similar conclusions, with McCartt and Hu (2014) finding that violations involving making very late decisions to run the red light (up to 1.5 seconds after red) were almost eliminated. Again, the

Study	Study design	RTM	Spill over	Outcome	Conclusions
a) Reviews of evaluations: Red light cameras					
Retting, Ferguson & Hakkert (2003)	Review but no detail on study selection	N	Y	Violations (7 studies)	↓ camera sites (22-78%), but ↓ noncamera sites (27-69%) (4 studies) = for control sites (3 studies)
	A-B + controls (15 studies)	some (4)	some (1)	Crashes/injury (8 studies)	↓ camera sites: noncamera (10-39%) (7 studies)
Aeron-Thomas (2005)	Cochrane review A-B+controls (10 studies)	Y	Y	Injury crashes, (5 studies)	↓ camera sites: noncamera/controls (29%)* 1 study ↓ camera sites: noncamera (13%)* (3 studies)
				right-angle (2 studies)	not significant
				rear-end (3 studies)	not significant
				Violations (1 study)	not significant
Erke (2009)	Meta-analysis varied designs (21 studies)	Y	Y	All crashes	↑ camera sites (if control RTM & Spillover effects) (+15%) ↓ camera sites (if no/some controls) (-16-19%)
				Injury crashes	↑ camera sites (if control RTM & Spillover effects) (+13%) ↓ camera sites (if no/some controls) (- 17-25%)
				Right angle	↓ camera sites (if control RTM & Spillover effects) (-10%) ↓ camera sites (if no/some controls) (- 14-49%)
				Rear end	↑ camera sites (if control RTM & Spillover effects) (+43%) ↓ camera sites (if no/some controls) (- 4- +17%)
Hoyos (2013)	Meta-analysis (28 studies)	Y	Y	All crashes	not significant (+6%)
				Injury crashes	not significant (+13%)
				Right angle	↓ camera sites (non-injury: -13%; injury: - 33%)
				Rear end	↑ camera sites (non-injury: +39%; injury: +19%)

Table 3: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
b) Recent evaluations: Red light cameras					
Ko, Geedipally, Walden (2013)	A-B +empirical Bayes (245 cameras, 66 no cameras)	Y	Y	Red light running Right angle Rear end	↓ camera sites (-20%) ↓ camera sites (-24%) ↑ camera sites (+37%)
Porter, Johnson, Bland (2014)	A-B + controls: Cameras removed (4 cameras, 2 local no cameras, 2 outside no cameras)	Y	Y	Red light running	Change 3.1% with cameras to 11.3% after removal Non-treated - 14%
McCartt, Hu (2014)	A-B +controls (4 camera, 4 local no camera, 4 outside no cameras	Y	Y	Violations 1 yr after ticketing commenced	↓ camera sites (-39% for 0.5secs after red) ↓ camera sites (-86% for 1.5secs after red)
Pulugurtha, Otturu (2014)	A-B -C: Cameras removed, empirical Bayes (32 cameras)	Y	Y	intersections with reduced crashes intersections with reduced rear end/ sideswipe crashes	↓ camera sites (-50% for before - after cameras) ↓ camera sites (-16% for before - termination of cameras) ↑ camera sites (+>50%)

Table 3 cont'd: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
Vanlaar, Robertson, Marcoux (2014)	A-B +controls Time series (4 cameras, 4 local no cameras), no cameras comparison)	Y	Y	Right angle Rear end Speed	↓ camera sites (-46%) ↑ camera sites (+42%) No change
McKenzie , Kloeden, Hutchinson, 2012)	Change after cameras introduced (21 cameras)	N	N	Red light Violations Speed violations	↓ over 12 months (slow change) ↓ over 12 months (rapid change, especially higher range speeding)
Kloeden, Edwards, McClean (2009)	A-B +controls (1988: 8 cameras, all no camera sites in Adelaide) (2001: 24 cameras, all no camera sites)	?	N	Casualty crashes Right angle Rear end	1988 study: ↓ camera sites (-21%) 2001 study: no change 1988 study: ↓ camera sites (-491%) 2001 study: no change No change
Budd, Scully, Newstead (2011)	A-B+controls (76 camera sites: Camera activated, camera not activated)	Y	N	Casualty crashes Right angle/right turn Rear end	↓ camera sites (-47% direction of travel monitored by camera; -26% for all) ↓ camera sites (-44%) No change

Table 4: Summary of literature on red light and speed camera evaluations

Cochrane review failed to find evidence of changes in violations due to red light cameras, but only one study included this measure. One study (Porter et al, 2014) studied the effect of removing red light cameras and found an increase in violations of around 8 percent after they were removed.

3.1.2 Evaluations of speed cameras

The literature search identified three reviews of speed cameras generally (fixed and mobile). This included a meta-analysis by Pilkington and Kinra (2005), which reviewed 14 controlled trials and observational studies and a systematic, narrative review by Thomas, Srinivasan, Decina and Stapin (2008) containing 13 studies chosen because of their methodological strengths. The most recent review was a Cochrane Collaboration review by Wilson, Willis, Hendrika, Brocque and Bellamy (2010), which examined the use of speed cameras for the prevention of road injuries and fatalities. The three reviews overlapped considerably. The Pilkington and Kinra (2005) and Thomas et al. (2008) reviews shared seven studies and the Cochrane review contained all of the studies in the Thomas review and 64.3 percent of those in the Pilkington and Kinra review as well as 20 additional studies, most of which were more recent. The Cochrane review was therefore the most comprehensive and became the basis of the current review.

Overall, the Cochrane review concluded that in the presence of speed cameras, average speed reduced by between 1 and 15 percent and the proportion of vehicles speeding by 14 to 65 percent compared to controls. They also concluded that in the vicinity of cameras, all crashes reduced by 8 to 49 percent and fatal and serious injury crashes by 11 to 44 percent, leading to an overall improvement of between 8 to 50 percent compared to control sites. This provides a good appraisal of the existing well-designed evaluations of speed cameras, however the review did not distinguish fixed and mobile cameras. As the action of these two types of cameras is quite different, the current review included the studies in the Wilson et al review but separated them into those looking at each type of camera in order to determine the separate effects of each type. Additional studies published since the Cochrane review were also included in this analysis.

3.1.3 Evaluation of fixed speed cameras

The Cochrane review (Wilson et al., 2010) included 17 studies of the effectiveness of fixed speeding cameras which were judged to have adequate study designs. In addition to those included in the Cochrane review, the electronic searches for this review identified two additional more recent studies so the review for this report included 19 studies of fixed speed cameras (Table 5).

The studies included in the review involved study designs with pre/post camera implementation measures and control or comparison sites (78.9%) or interrupted time series analysis (21.1%). Using the Cochrane collaboration criteria which require random assignment of treatment and controls, these studies designs would be classified as only of moderate methodological quality. Around half addressed the problem of potential bias due to RTM (52.6%). None of the studies formally addressed spillover effects, although it could be argued that the inclusion of appropriate control or comparison groups provided an opportunity to assess these effects by showing the extent of additional change due to the presence of the camera itself. Around half of the studies looked at the effect of cameras on both speeding and crashes (52.6%), with half of the remainder looking at effects only on speed (21.1%) or crashes (26.3%). The studies were conducted in a

broad range of countries including Australia, Canada, Germany, Spain, Finland, UK, Hong Kong, Netherlands, New Zealand and USA.

All studies showed benefits of fixed speed cameras for reducing speed in the location of the cameras. Overall, the studies showed reductions in mean speed in the vicinity of cameras of 3 to 10 percent or 2 to 8kph reductions in mean speed. Studies that included control of RTM effects showed similar reductions in speed. Of the five studies that looked at the proportion of speeding vehicles in the vicinity of fixed cameras, all showed reductions but there was a very large variation between studies, ranging from 10 to 70%, although the two studies that controlled for RTM showed similar reductions of around 30 percent. Twelve studies measured injury crashes and all found reductions following implementation of fixed cameras ranging from 7 to 32 percent. In studies that controlled for RTM effects, the reductions tended to be greater (20-56%). Only five studies measured fatal crashes specifically, and again all showed reductions after implementation of fixed cameras ranging from 11 to 89 percent.

The greatest effects of fixed cameras are likely to be in their immediate vicinity. In some studies, the effects of cameras may have been underestimated as the effects were measured 2km from the treatment area (Chen et al, 2002; Makinen, 2001) although studies that directly measured distance halo effects showed decreases in road safety benefit with increased distance from the fixed camera site (Mountain, et al., 2004; Hess and Polack, 2003; De Pauw et al, 2013). Figure 3 shows the 85th percentile speeds around a speed camera in NSW and shows that speeding drivers slow for the cameras and speed up again after the camera, i.e. deliberate slowing for the camera (Job 2014).

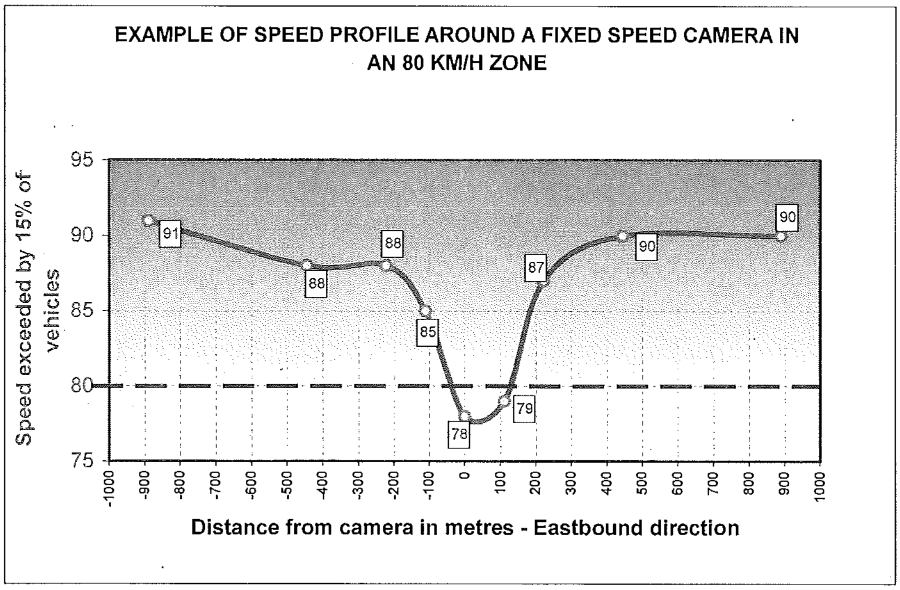

Figure 3: 85th percentile speeds recorded on approach and departure around a sign-posted speed camera in in an 80km/h speed limit in New South Wales

The duration of the benefit of fixed cameras over time was examined in some studies, with findings of fatal crash reductions for up to two years (ARRB, 2005; Perez et al, 2007; Makinen, 2001), but Retting, Kyrychenko and McCartt (2008) showed that positive speed reductions diminished when the enforcement period ended.

Study	Design	RTM	Spillover	Outcome	Conclusions
ARRB Group Project Team (2005)	A-B+Control	N	N	Speed fatal crashes injury crashes	↓ 6.3 km/h mean speeds, 5.8kh/h at 2 years ↓ 70% exceeding speed limit, maintained at 2 years ↓ 86% exceeding speed limits by at least 10 km/h, 88% at 2 yrs. ↓ 22.8% all fatal and injury crashes ↓ 89.8% fatal crashes ↓ 20.1% injury crashes at 1 yr
Diamantopoulou, Corben (2002) (2 reports)	A-B+Control.	N	N	Speed reduction	↓ 3.4% speed reduction ↓66% drivers exceeding the 80km/h posted speed limit ↓ 79% drivers speeding over 90km/h ↓ 76% drivers speeding over 110km/h ↓ 13% fatal crashes ↓ 10% serious injury ↓ 7% overall injuries
Chen, Meckle, Wilson (2002)	A-B+Control	Y	N	crashes Mean speed	↓2.8km/h mean speed at monitoring site 2km from treatment area ↓14% expected crashes at photo-radar locations ↓ 19% at non-Photo-Radar locations ↓ 16% along the study corridor as a whole
Lamm, Kloeckne (1984)	A-B+Control	N	N	Median speed crashes (injury and fatal)	↓ 30kph median speed ↓ 42kph 85th percentile speed ↓ 18 times in injury crash frequency ↓ fatal crashes
Perez, Mari-Dell'Olmo, Borrell (2007)	Interrupted time series	N.	N	crashes injured	RR= 0.69 (95% CI = 0.54 - 0.89) crash 2 years post implementation RR= 0.70 (95% CI = 0.53-0.92) injury = comparison sites.
Makinen (2001)	A-B+Control	N	N	speeding crashes	↓ 8% speeding at 80kph limit in year one, further ↓2% in year two. ↓ 5% speeding at 100km/h in year one, further ↓2% in year two. Distance halo of 3km upstream and 2km downstream. no change in crashes compared to controls

Mountain, Hirst, Maher (2004)	A-B+Control	Empirical Bayes	N	speeds	↓4.4mph mean speeds ↓5.9 mph 85th percentile speeds ↓35% percentage exceeding the speed limit. ↓ 25% personal injury crashes, 11% fatal and serious at 500m post camera ↓ 24% personal injury crashes, 13% fatal and serious at 1km post camera
Hess (2003) (2 reports)	Interrupted time series	Y	N	Injury crashes	↓ 45.74% weighted injury crashes in 250m from camera sites ↓ 20.86% injury crashes in 2000m from the camera.
Gains, Heydecker, Shrewsbury, Robertson (2004) (3 reports)	A-B+Control	empirical Bayes	N	speed Fatal/serious injury injury crashes	↓ 6% mean speed ↓7% 85th percentile speed ↓ 30% exceeding speed limit ↓43% exceeding speed limit > 15 mph ↓42% fatal/serious injury ↓ 24% injury crashes
Highways Agency's London Network and Customer Services (LNCS) (1997)	A-B+Control	N	N	crashes (fatal, serious, and injury)	↓ 12.4% all crashes. ↓69.4% fatal crashes pre/post and 55.7% relative to controls. ↓ 25% serious injuries ↓ 31% fatal/serious crashes combined.
Hung-Leung (2000)	A-B+Control	N	N	speeding cars injury, fatal crashes	↓ 65% speed > 15 km/h over limit. ↓ 23% injury crashes pre/post; ↑32% in the control group. ↓66% fatal crashes.
Oei (1996) (2 reports)	A-B+Control	N	N	speed crashes	↓3 - 5kph mean speed ↓3-8kph 85 percentile speed ↓ 10% to 27% drivers speeding over limit ↓ 35% crashes pre/post and control
Elvik (1997)	A-B+Control	Y	N	injury crashes	↓20% injury crashes
Tay (2000)	A-B+Control	N	N	crashes speed	↓ 9.17% all crashes ↓ 32.4% serious injury = speed, pre/post
Shin, Washington, van Schalkwyk (2009)	A-B+Control	Y	N	crashes	↓44 to 55% crashes ↓ 46-56% injury crashes = rear-end crashes

Retting, Kyrychenko, McCartt (2008)	A-B+Control	N	N	speed	↓ 5mph mean speeds pre/post no change control site ↓ 13% exceeding speed limit after speed camera enforcement suspended both increased.
Retting, Farmer, McCartt (2008)	A-B+Control	N	N	speed	↓10% mean speed ↓ 70% > 10 mph above the speed limits (with warnings and camera enforcement), ↓ 39% > 10 mph above the speed limits (with warning signs only) ↓ 16% on 40 mph residential streets (no warnings or speed cameras).
De Pauw, Daniels, Brijs, Hermans, Wets (2013)	A-B	N	N	injury crashes	↓ 29% serious/fatal injuries in 500m of camera
Novoa, Perez, Santamarina-Rubio, Mari-Dell'Olmo, Tobias	Time series analyses	N	N	Crashes injuries	↓ 30% and 26% on enforced and non-enforced arterial road respectively.

Table 5: Summary of literature on fixed speed camera evaluations

Only eight of the studies mentioned the speed limit at the fixed camera sites. In five studies the cameras were on high speed roads (80+ kph) and the remainder were in the 50-80 kph regions. There were no obvious patterns of effects on speeding or crashes on different speed limit areas. Novoa et al (2010) found benefits of fixed speed cameras on a high speed beltway, but not on lower speed arterial roads, suggesting that there may be influences of speed limit on the effectiveness of fixed cameras.

3.1.4 Evaluation of mobile cameras

A total of 19 of the studies included in the Cochrane review (Willis, et al., 2010) involved an evaluation of mobile cameras. The electronic searches found one further evaluation study (Moon and Hummer, 2010) so the current review involved 20 studies in total (Table 6).

As for the fixed camera evaluations, the majority of studies included involve a pre/post implementation with control design (80%) with the remainder an interrupted time series design. Few studies (25%) included control for RTM effects although this may not be as great a concern for mobile cameras which by definition are moved around so they may not necessarily be located only in locations of high concern for road safety. Spillover effects were also managed indirectly by inclusion of control locations in all studies. Most of the evaluations looked at either speed (40%) or crash (35%) outcomes and only 25% looked at both. Evaluations were from a broad range of countries including Australia, Canada, Denmark, UK, Norway, New Zealand and the USA.

Across evaluation studies, consistent benefits were found for mobile speed cameras. Seven studies cited reductions of mean speeds in the location of mobile cameras with effects ranging from around 1 to 6kph. There was a very large range in the proportion of vehicles exceeding the speed limit, from 10 to 70 percent across five studies. Similarly, the reductions in injury crashes also varied considerably between the six studies that included this measure, from 21 to 71.3 percent although reductions in fatal crashes were more consistent (31-44% across three studies).

As might be expected, there is evidence that the effect of mobile cameras extend well-beyond the immediate vicinity of the camera. Cairney (1988) found effects of reduced speed for up to 14 km downstream of mobile cameras. The study by Newstead and Cameron (2003) measured crashes within 2 kms, 2-4kms and 4-6kms of camera sites and found a decreasing effect on crashes with increasing distance away from cameras, although even at the greatest distance, there were still 10.7 percent reductions in all severity crashes.

A number of studies looked at the time halo or duration of the effect of mobile cameras. Time halo effects ranged from at least two days of continued lower proportion of speeding vehicles (Armour, 1984), three days of lower mean speeds after a single day of enforcement (Hauer and Ahlin 1982) to up to eight weeks of lower mean speeds (Vaa, 1997). On the other hand, Legget (1988) found no time halo effect on mean speed.

The effects of speed cameras may vary with the speed limit of roads, however most studies (55%) failed to mention the speed limit on which the cameras were placed. In seven studies (35%) mobile cameras were sited on higher speed roads of 80kph or greater. Only two studies involved mobile cameras on roads of 60kph or lower.

In the majority of studies, mobile cameras were marked with warning signs to alert drivers to their presence. Two studies looked at the effect of covert or overt placement of mobile cameras. Diamantopoulou and Cameron (2002) compared the two strategies of camera use and concluded that the best effect on injury crashes occurred when a mix of overt and covert cameras were in

Study	Design	RTM	Spillover	Outcome	Conclusions
Amour (1984)	A-B +Control	N	N	speeders	↓ 70% proportion vehicles exceeding the speed limit with camera Time halo effect ≥ two days
Cairney (1988)	A-B +Control	N	N	Mean speed	↓ 2-3kph mean speed at camera and control sites. Distance halo up to 14km downstream with aerial surveillance
Kearns & Webster (1988)	A-B +Control	N	N	crashes	↓ 23% crashes at camera sites during the day, ↓ 21% at other times, compared to controls
Newstead, Cameron, Leggett (2001)	A-B with comparison group	N	N	fatal crashes	↓ 31% fatal crashes. ↓ 11% total crashes outside of metropolitan Brisbane.
Newstead, Cameron (2003) (2 reports)	A-B +Control	N	N	No. of crashes (fatal and injury)	↓ 45% fatal crashes in 2km of camera sites ↓ 31% hospitalisation crashes in 2km of camera sites ↓ 39% medically-treated crashes in 2km of camera sites ↓ 19% other injury crashes in 2km of camera sites ↓ 21% non-injury crashes in 2km of camera sites All crashes: ↓ 17.5% all severity crashes in 2km of camera sites ↓ 11.4% all severity crashes in 2 - 4km of camera sites ↓ 10.7% all severity crashes in 4 - 6km of camera sites
Cairney, Fackrell (1993) (2 reports)	A-B +Control	N	N	Median traffic speed	↓ 5kph median speeds reduced sharply by 5 km/h on camera roads but then little change despite intensified enforcement, control sites no change
Leggett (1988)	A-B +Control	N	N	Mean speed No. of crashes (injury or fatal)	↓ 3-6kph mean speeds compared to pre, only during enforcement no time halo effect. ↓ 58% serious injury crashes. ↑ 33% serious injury during non-enforced times of day
Cameron, Cavallo, Gilbert (1992) (2 reports)	Interrupted time series	N	N	No. of injury crashes	↓ 30% injury crash on 60km/h city roads with camera over12mths ↓ 20% injury crash on rural 60km/h zones with camera over 12 mths ↓ 14% injury crash on rural 100km/h zones with camera over 12 mths
Diamantopoulou, Cameron (2002) (3 reports)	A-B +Control	N	N	No. of injury crashes	↓ 71.3% injury crashes within 4 days of presence of enforcement ↓73.9% injury crashes with mix of overt/covert enforcement in use.
Chen, Wilson, Meckle, Cooper (2000)	A-B +Control	Y	N	No. of speeding vehicles No. of crashes	↓ 31% speeding vehicles pre/post cameras ↓ 12% speeding at control sites ↓ 17% reduction in daytime crash fatalities

Hauer, Ahlin (1982)	A-B +Control	N	N	Average speed	time halo for three days with1 day enforcement, for six days after five days enforcement
Agustsson (2001)	A-B +Control.	N	N	Mean speed % drivers exceeding spee limit by 10km/hr No. of injury crashes	↓ 2.4 km/ h mean speed ↓ 10.4% exceeding speed limit ↓ 4.5% exceeding the speed limit by 10km. ↓ 22% injury crashes in first year, ↓ 20% in second year post intervention compared to pre
Jones, Sauerzapf, Haynes (2008)	A-B +Control	Y	N	No. of crashes	↓ 19% all crashes at camera sites ↓ 44% for fatal and serious crashes at camera sites .
Christie, Lyons, Dunstan, Jones (2003)	A-B +Control	N	N	No. of injury crashes	↓ 50% injury crashes sustained for two years at camera sites
Goldenbeld, van Schagen (2005)	A-B +Control	Y	N	speeds speeders over the targeted speed limit	↓ 12% speeders at camera sites, ↓ 5% speeders at controls ↓ 21% injury crashes for enforcement period compared to pre
Vaa (1997)	A-B +Control	N	N	Average speed No. Speeding drivers	↓ 0.9 to 4.8kph mean speeds time halo effect of up to eight weeks ↓ 10% speeding drivers
Keall, Povey, Frith (2002) (2 reports)	Interrupted time series	N	N	Mean speed 85th percentile speed No. of injury crashes	↓1.3kph mean speed over 2 years ↓ 4.3kph 85th percentile speeds on open roads ↓ 11% all crashes compared to control areas ↓ 19% injury crashes additional effect for covert cameras period compared to overt cameras ↓ 17% for crashes at camera sites compared to controls ↓ 31% for injury crashes
Cunningham, Hummer, Moon (2005)	A-B +Control	Y	N	crashes, speeds	↓ 12% total crashes in camera corridors compared to expected ↓0.91 miles/hr mean speeds at camera sites, control sites no change ↓ 0.99mph in 85th percentile speeds, controls no change.
Retting, Farmer (2003)	A-B +Control	N	N	Mean speed Proportion of vehicles exceeding the speed limit by more than 10mph	↓ 14% mean speeds at camera sites compared to control sites. ↓ 82% exceeding the speed limit by more than 10mph
Moon, Hummer (2010)	A-B with comparison sites.	Y	N	No. of crashes	↓ crashes in camera sites pre/post.

Table 6: Summary of literature on mobile speed camera evaluations

place, although the additional reductions in injury crashes were not pronounced. A study by Keall, Povey and Frith (2002) compared the effect on injury crashes of a period of overt camera use with a period where camera use was covert and found an additional 19 percent reduction in injury crashes with covert use of cameras. It should be noted however that covert camera use occurred following overt use so some of the effect may be due to the fact that drivers were aware the cameras were in operation.

3.1.5 Point-to-point cameras

The literature for this camera system type is sparse. There are three articles discussing the benefits of point-to-point in terms of reduced speeds and crash reduction. However, only one study by Montella et al (2012) was adequate in its design in terms of providing a rigorous statistical evaluation of a system installed in Italy (Table 7). The system is composed of steel gantries at the section entrance and exit, with one camera and inductive loop detectors for each lane. Data were collected and processed by police at a central monitoring station.

The study analysis period was over 9 years, with a before period of 6.5 years and an after period of 2.5 years. The number of crashes per kilometre in the before period was 4.2, which decreased to 2.2 during the after period. A reduction in crashes per kilometre was observed for all crash types.

The authors used an empirical Bayes methodology evaluation which accounted for regression to the mean, changes over time not due to the treatment being evaluated and overcoming exposure crash rates in normalising volume differences.

The evaluation of the point-to-point cameras revealed a total crash reduction of 31.2%. The greatest crash reductions were observed for 55.6% severe crashes and 43.3% crashes at curves. However they noted an effectiveness decrease over time, i.e. 39.4% total crashes for the first semester and 18.7% in the fifth semester after activation. The authors suggest that the decrease system effectiveness over time may have been due to a reduction in speed enforcement and driver adaptation. They suggest that higher compliance to the speed limits might be achieved by a better strategy of communication and information to the road users and a speed limit management strategy synergic between the highway agency and the Police who actually manage the commitments of fines.

Study	Design	RTM	Spillover	Outcome	Conclusions
Montella, Persaud, D'Apuzzo, Imbriani (2012)	Empirical Bayes observational before-and-after study. Crash data disability lasting at least 15 days.	Y	N	No. of crashes	↓ 31.2% total crash The greatest crash reductions were observed for ↓ 55.6% severe crashes and 43.3% crashes at curves, effectiveness decreased over time ↓ 39.4% total crashes - first semester ; ↓ 18.7% - fifth semester after activation.

Table 7: Summary of literature on point-to-point speed camera evaluations

3.2 Review of community attitudes to speeding

This section summarises the results of the Community Attitude surveys for ACT residents over 1995 to 2011. The detailed collated results are shown in Appendix C.

3.2.1 Perceptions of changes in enforcement

The year following the introduction of mobile speed cameras was associated with an increase in the percentage of ACT residents who perceived that the amount of speed enforcement had changed over the past two years (Figure 4). In the surveys conducted between 1999 and 2001 more than two-thirds of survey participants reported that enforcement had increased and in 2001 there was a clear fall in the percentage reporting no change in enforcement. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years, perception of increased speed enforcement remained high. Interestingly, the introduction of fixed speed cameras in 2007 was not associated with increased perception of more enforcement activity. However, this question only has a few broad options to choose from and may likely have been too coarse to determine accurate perceptions of change in enforcement.

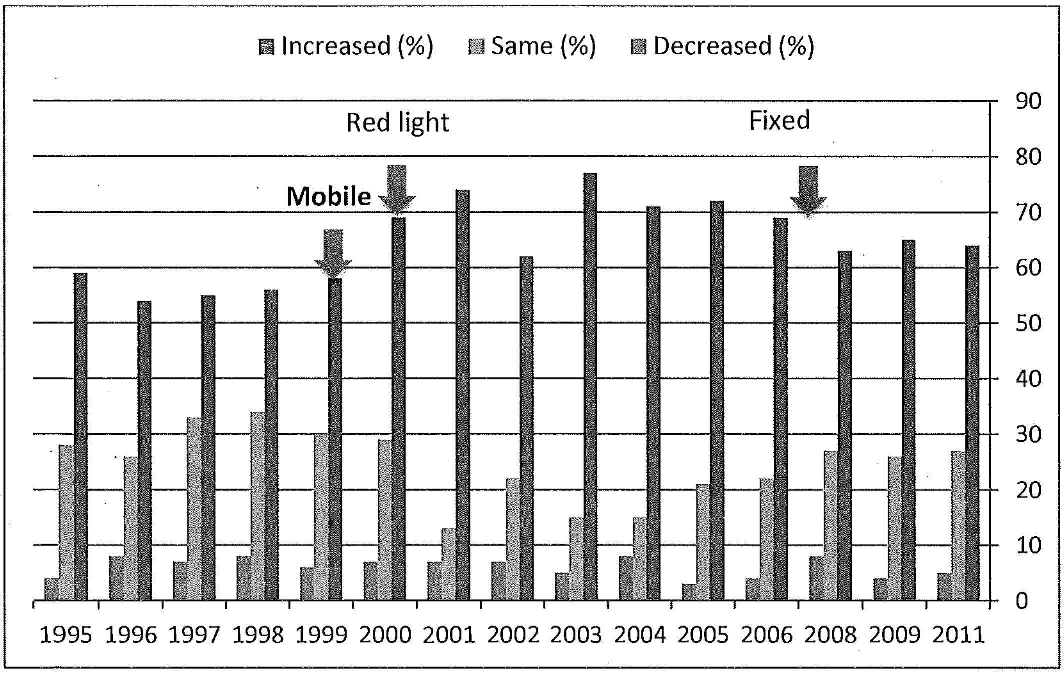

Figure 4: Perceptions of whether the amount of speed limit enforcement has changed over the last two years

The reported likelihood of being booked for speeding varied considerably across the survey years (Figure 5). Reports of being booked in the last two years were lowest in 1999 when mobile cameras were introduced, but between 1999 and 2003 the percentage of survey participants reporting being booked for speeding increased more than two-fold to more than one in four participants. Reports of speeding infringements decreased again to 2008, but following the introduction of fixed speed cameras, there was some increase in reported infringements to 2011. Reports for the last 6 months showed similar patterns. Notably, reports of being booked in the last 6 months were lowest in 2004 compared to all other years, and were lowest compared to other jurisdictions as well.

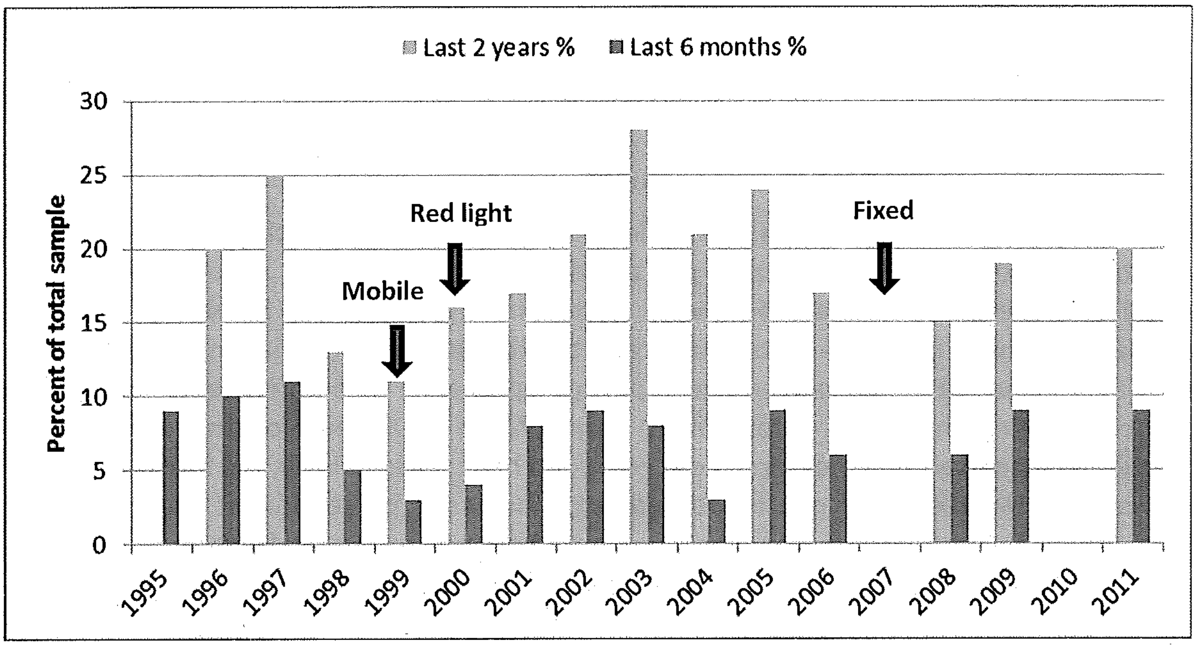

Figure 5: Incidence of being booked for speeding in the last 2 years and the last 6 months

3.2.2 Perceptions of acceptable and actual speed tolerances

ACT residents believe that the median acceptable speed in 60kph urban zones should be around 65 km/h (Table 8). Interestingly, this is almost identical to the median of their reported actual speed. Neither of these judgements showed much variation across the seven surveys in which these questions were asked. Around one-third of Survey participants across all surveys between 2003 and 2011 agreed that there should be no tolerance of speeding in 60kph zones. However in surveys before 2003 nearly half of respondents felt that there should be no tolerance for speeding in 60kph zones. This was coincident with the introduction of the first mobile and red light cameras. It is possible that the strong community response for no tolerance for speeding in 60kph zones that preceded the introduction of cameras may have played a role in their introduction. However, community acceptance of no tolerance for speeding clearly decreased a few years after the first wave of the introduction of cameras so by 2003 and subsequent years, there has been considerably lower support for no tolerance of speeding in these zones.

For 100kph zones, acceptable speeds for respondents were between 105 and 110kph and actual reported speeds were very similar, or higher (Table 9). There were no consistent patterns for judgements of acceptance of no tolerance for speeding with between one in four and one in three respondents supporting no tolerance. In contrast, between 2002 and 2011 there has been notable change in ACT residents perceptions of no tolerance of actual speeding. Where in 2006 almost no ACT respondent perceived no tolerance for speeding over 100kph and this was lower than all other jurisdictions, by 2011 the situation had reversed. Over one in five respondents felt that there was no tolerance for speeding in 100kph zones in the ACT which was significantly higher than other jurisdictions.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1995		34		
1996		42		
1997		49		
1998		49		
1999 Mobile		49		
2000 Red light		38		
2001		44		
2002		51	64.9	15
2003	64.2	33	65.4	10
2004	65	28	65	13
2005	64	33	64	12
2006	64	32	64	15
2008 Fixed	64	36	65	21
2009	65	34	64	22
2011	64	31	64	20

Table 8: Perceived acceptable and actual speed in 60kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1996		27		
1997		23		
1998		36		
1999 Mobile		28		
2000 Red light		25		
2001		26		
2002		35	109.2	10
2003	106.8	22	108.7	6
2004	110	23	109	8
2005	109	20	109	7
2006	107	18	107	5
2008 Fixed	105.5	28	108	14
2009	110	23	107.9	15
2011	106	25	106	21

Table 9: Perceived acceptable and actual speed in 100kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

3.2.3 Attitudes to speeding, speed enforcement and penalties

ACT survey respondents attitudes to speed-related issues did not change greatly across the 1999 to 2011 period for most questions. The majority of respondents (>85% in all years) viewed speed limits as generally reasonable. Similarly, almost all respondents (>89% in all years) agreed that an accident at 70kph would be more severe than one at 60kph. Notably, fewer felt that they would be more likely to be in an accident if they increased their speed by 10kph, but there was no pattern of change across the survey years on this question.

Two questions showed some evidence of attitudinal changes between 1999 and 2011 that may be associated with safety camera use in the ACT. Associated with the introduction of the mobile and red light cameras in 1999 and 2000 there has been a decrease in respondents agreeing that exceeding the speed limit is okay if you are driving safely. The percentage increased again for the 2008 survey following the introduction of fixed cameras, but decreased to the lowest level in 2009 and remained fairly low in 2011. In contrast, there was no change in the percentage of respondents viewing speeding fines as revenue raising associated with mobile or red light cameras, but 2008 and 2009 following the introduction of fixed cameras saw the highest percentage of respondents viewing speed fines as revenue raising (Figure 6).

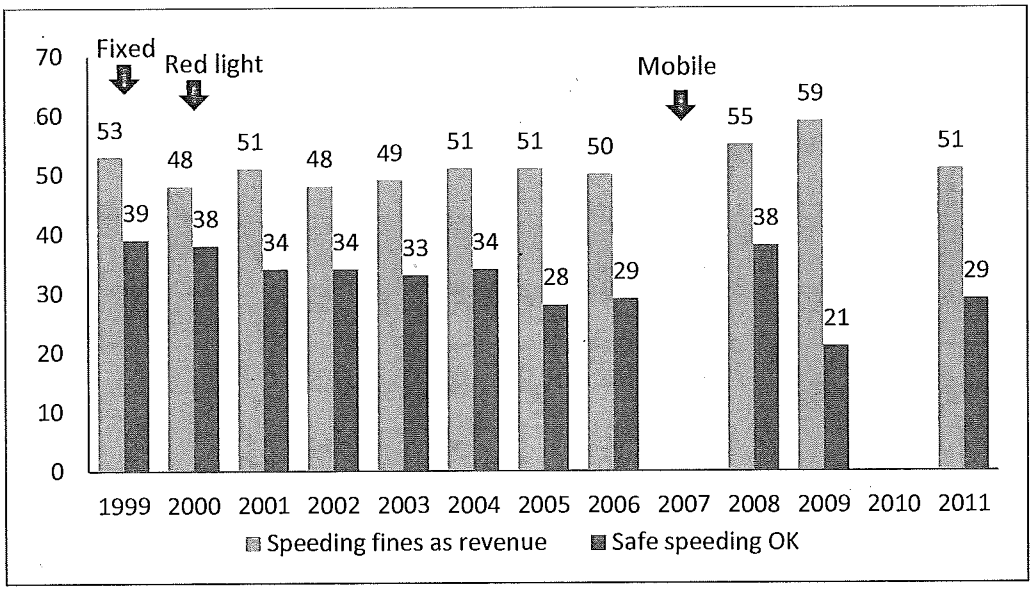

Figure 6: Percentage of ACT resident agreeing with the statements 'Fines for speeding are mainly intended to raise revenue' and 'I think it is okay to exceed the speed limit if you are driving safely'

Questions were asked about their views of the level of enforcement and severity of penalties from the 2003 survey (Figures 7 and 8). Increasing percentages of ACT residents believed the level of enforcement and severity of penalties should increase for 2003 and 2004, but this decreased in the next two years. In the survey following the introduction of fixed speed cameras the percentage of respondents who felt enforcement should increase grew to nearly half and this remained high to the most recent survey in 2011. For severity of penalties, there was not much change before and after the introduction of fixed cameras, although the most recent survey had the highest percentage of respondents reporting that they should be increased.

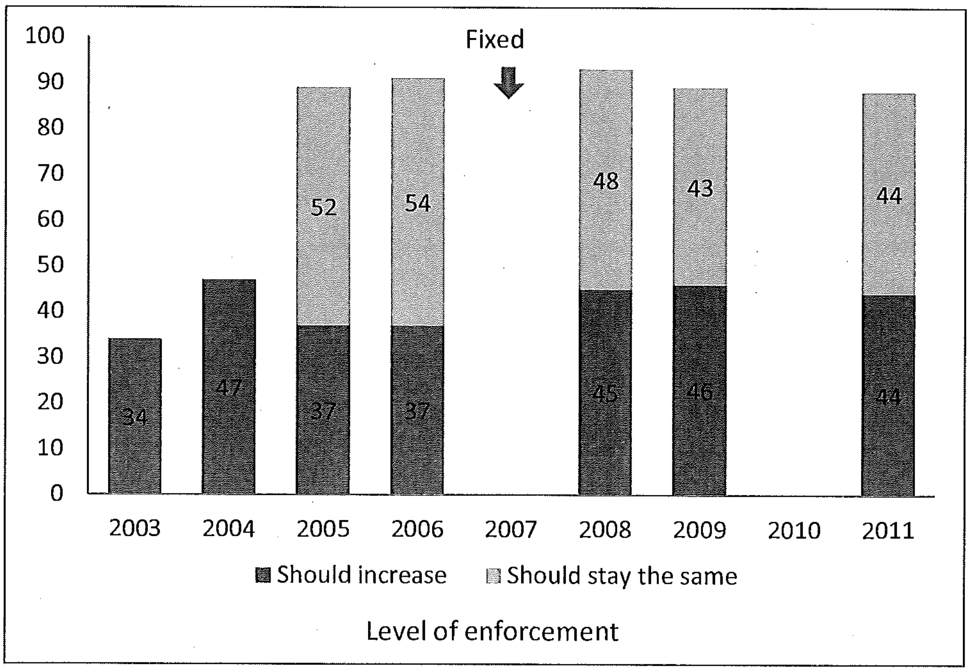

Figure 7: Percentage of ACT residents responding that the level of enforcement should increase or stay the same

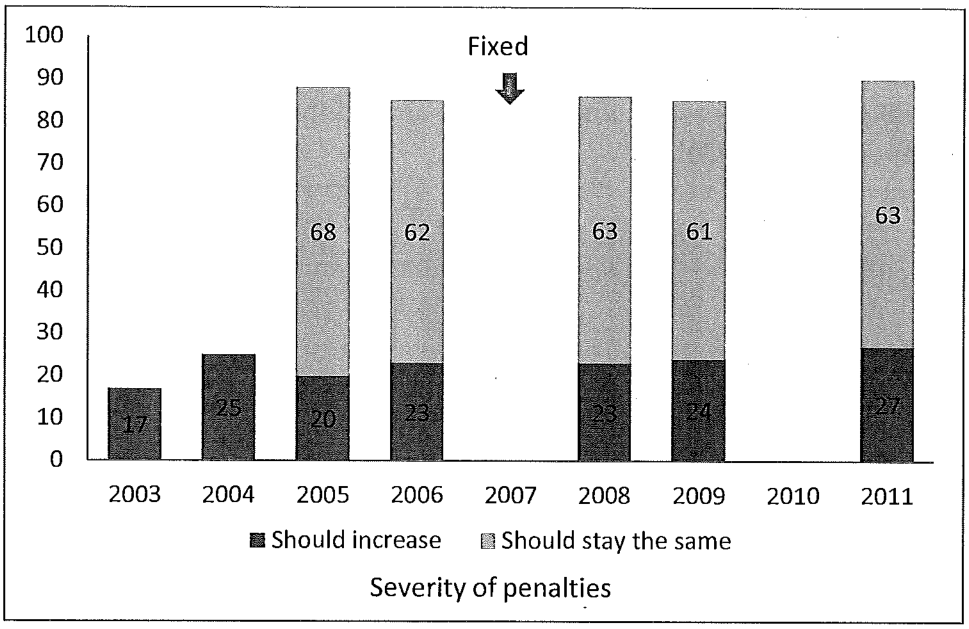

Figure 8: Percentage of ACT residents responding that the severity of penalties should increase or stay the same

The patterns of approval for lowering residential speed limits from 60 to 50 kph show an association with the introduction of mobile and red light cameras (Figure 9). Since 2000 when both types of cameras were in operation, there has been a clear increase in the percentage of survey respondents who showed approval for such a change so that by 2003 the greater majority of respondents were in agreement.

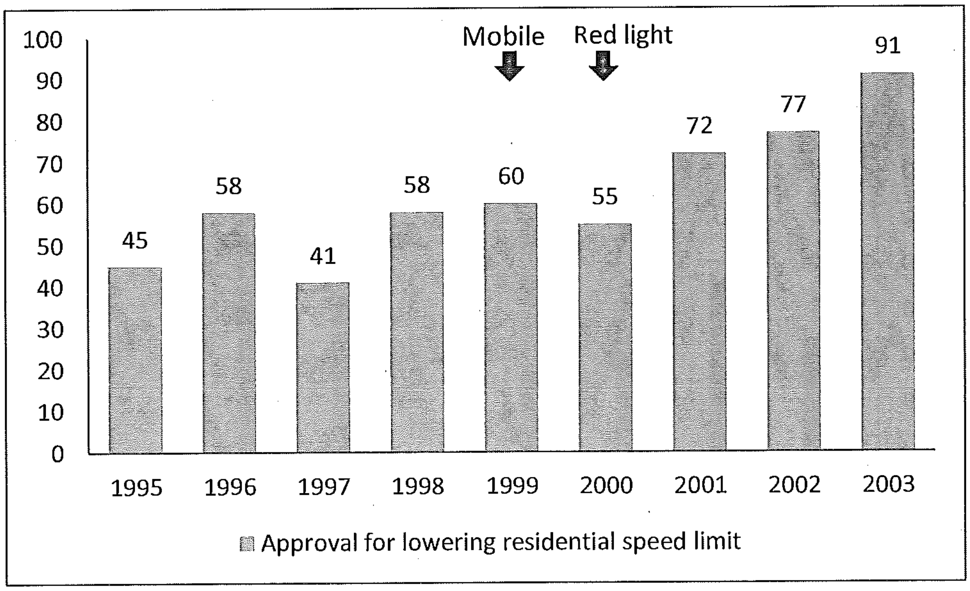

Figure 9: Percentage of ACT residents approving (somewhat and strongly) a potential decision to lower the speed limit in residential areas to 50kph

3.2.4 Changes in self-reported driving speed

Following the introduction of mobile and red light cameras a larger percentage of ACT respondents reported that their driving speed had decreased over the past two years, however since 2008 this effect has decreased somewhat with around three-quarters of drivers reporting no change to their speed (Figure 10).

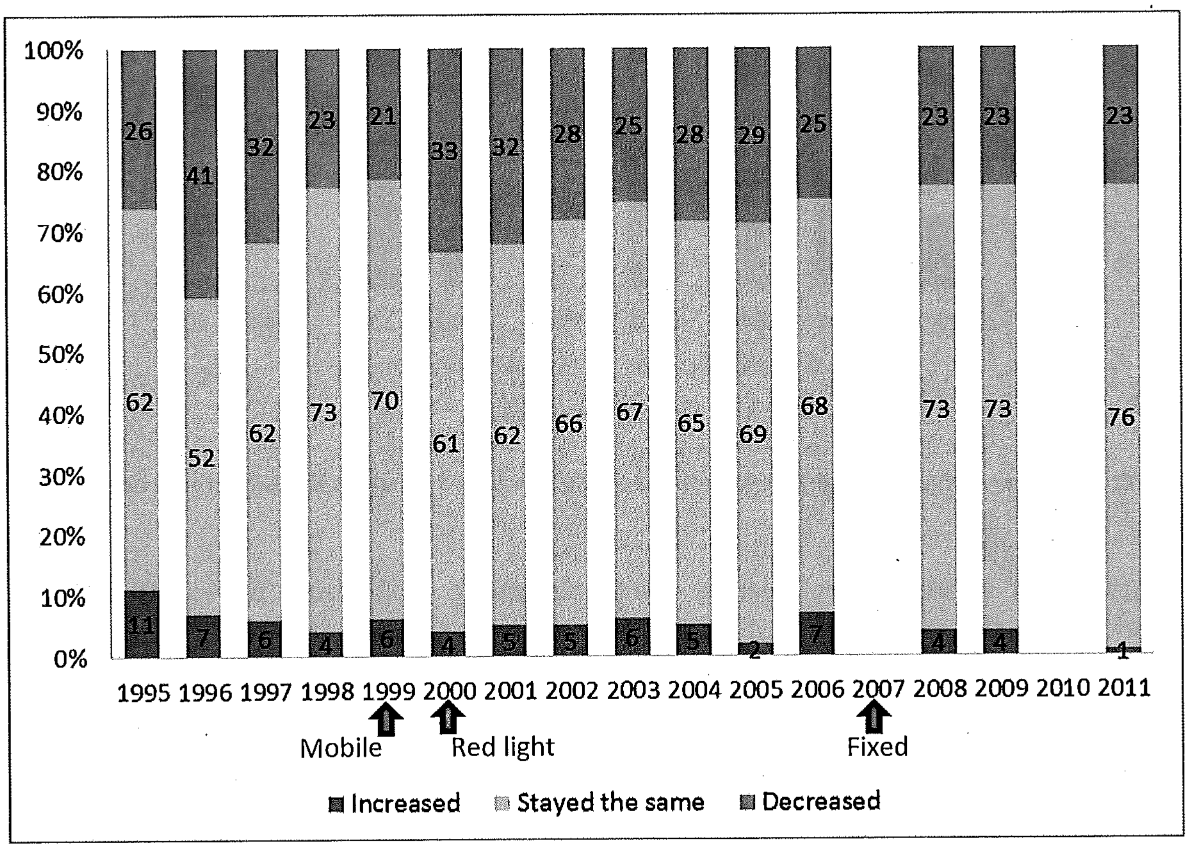

Figure 10: Reported changes in driving speed over the last two years

3.3 Infringements data

The infringements data are expressed as the proportion of infringements issued to vehicles checked, and data were available for the 14 year period from 1999 to 2012 (inclusive). It is noted that all fixed and mobile camera operations data were included, not only those related to the case and control streets/intersections selected for this study. Infringement rates for fixed and mobile cameras over the period are plotted in Figure 11. For the mobile cameras, mean infringement rates were up to 10% initially, however dropped to an average long-term value of approximately 0.6% during a period extending to approximately late 2002. For the fixed intersection cameras, mean infringement rates reduced rapidly to less than 0.2%. It is noted that due to data issues, the fixed camera infringement rates are not plotted beyond 2008 in Figure 11.

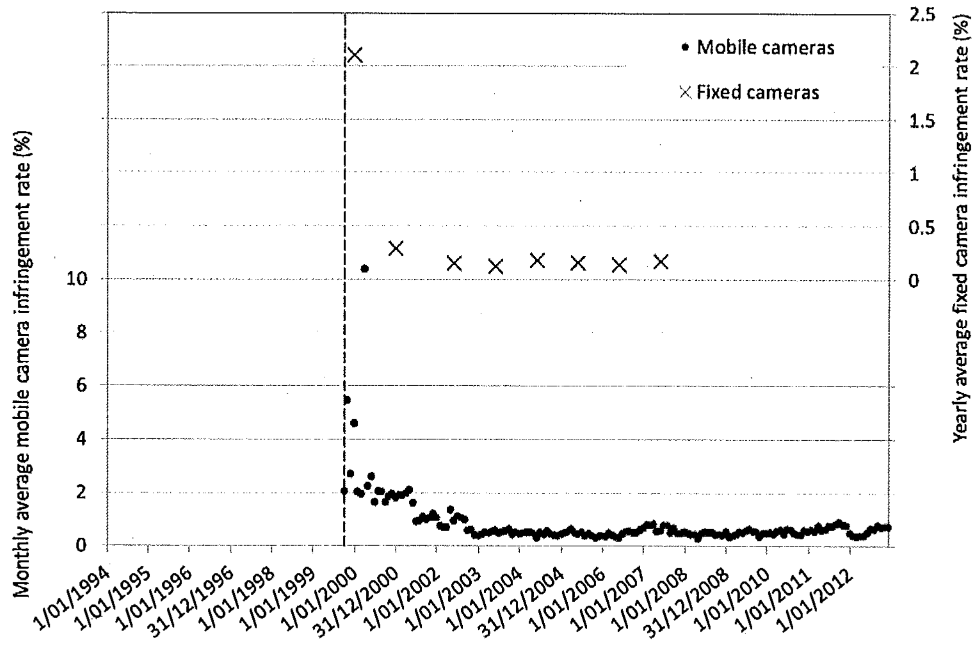

Figure 11: Infringement rates for fixed and mobile cameras

3.4 Speed survey analyses – effects of mobile cameras on mean vehicle speeds (Models 1 to 5)

Speed surveys were assessed for the 95 street locations for the 16 year period from 1997 to 2012 (inclusive). A total of 1,758 speed surveys were identified in the period, including 1,032 that were undertaken on case streets and 726 on control streets. The speed survey results are plotted for case and control streets, and compared with mobile camera operations on each individual street, in Appendix D. Considering an outcome of monthly averaged values of the mean survey speed divided by the speed limit, the statistical models are tabulated in Tables 10 to 12. Models 1 to 4 are plotted in Figures 12 to 14. In Models 1 and 3, trends in mean speeds for case streets showed increases in the pre-intervention period (however in Model 3 the value was very small), and decreases in the post-intervention periods, where the intervention was Intervention 1 (Model 1) or the camera begin-date (Model 3). Trends in mean speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 1). Mean speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 2 and 4). CAMERA

estimates were generally not statistically significant, indicating changes that occurred in mean speeds at the intervention times were not generally significant (Tables 10 and 11).

Annual trend magnitudes for case streets were an increase of 0.7% and decrease of 3.2% prior to and following Intervention 1, and an increase of 1.7% and decrease of 0.9% prior to and following Intervention 2. An increase of 0.1% and decrease of 1.8% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 2.4% and decrease of 0.8% prior to and following Intervention 1, and an increase of 0.1% and decrease of 0.2% prior to and following Intervention 2. A decrease of 3.9% and decrease of 3.8% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 12. The estimate for the CASE variable was highly significant, likely a result of the fact that mean speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The speed survey results for case streets are compared with the mobile camera infringement rates in Figure 15, where the change from a decreasing trend in speeds to an increasing trend approximately corresponds to the beginning of the long-term infringement rate of 0.6%. The regression models for case and control streets (Models 1 and 2) are compared in Figure 16. Mean speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The mean speeds on all streets were predominantly below the speed limit for the full time period.

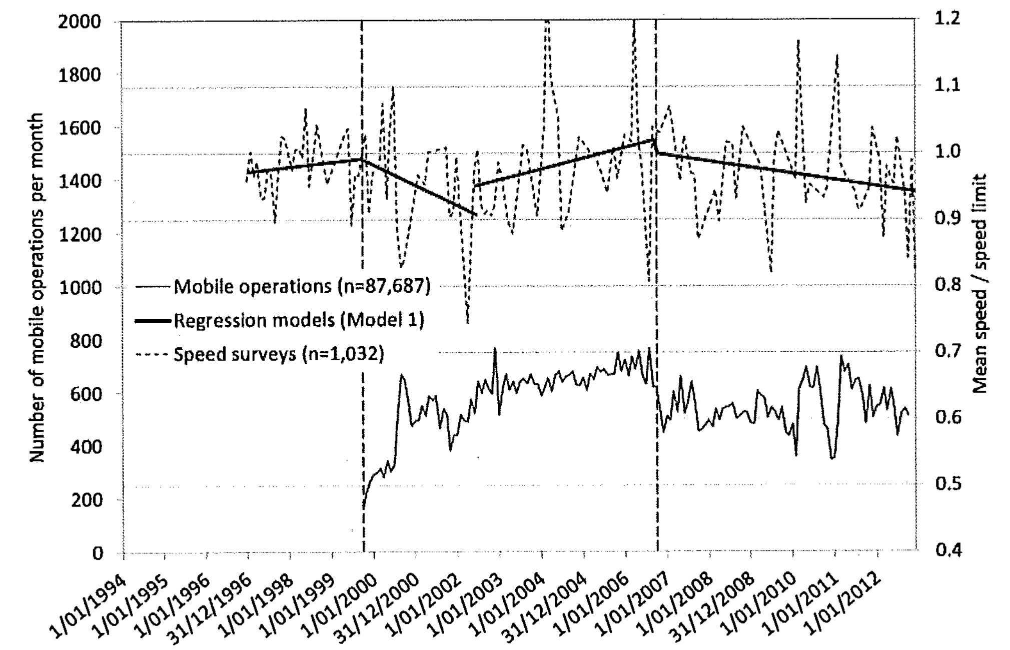

Figure 12: Mean speed survey data relative to the overall camera program – case streets

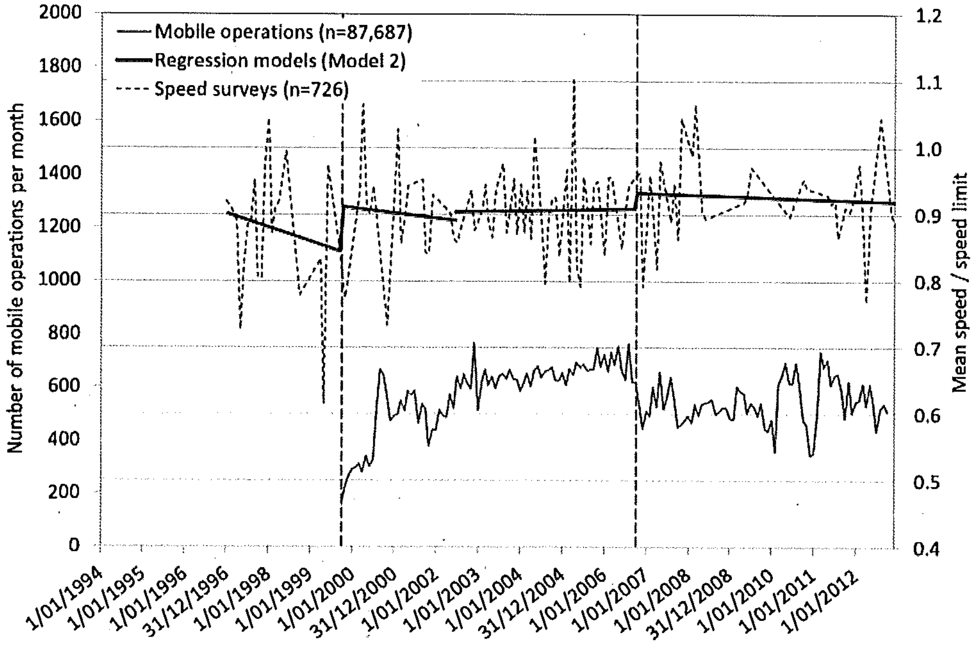

Figure 13: Mean speed survey data relative to the overall camera program – control streets

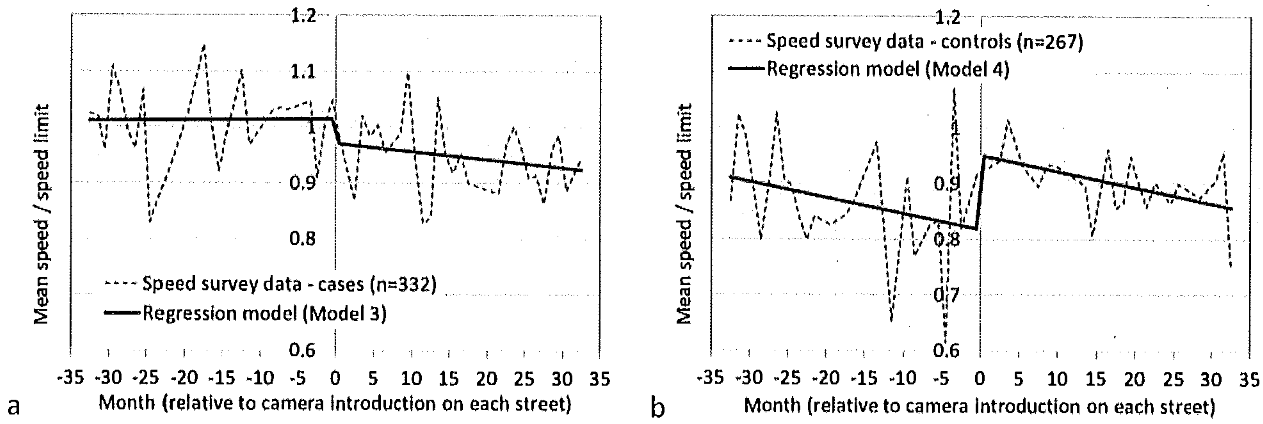

Figure 14: Mean speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

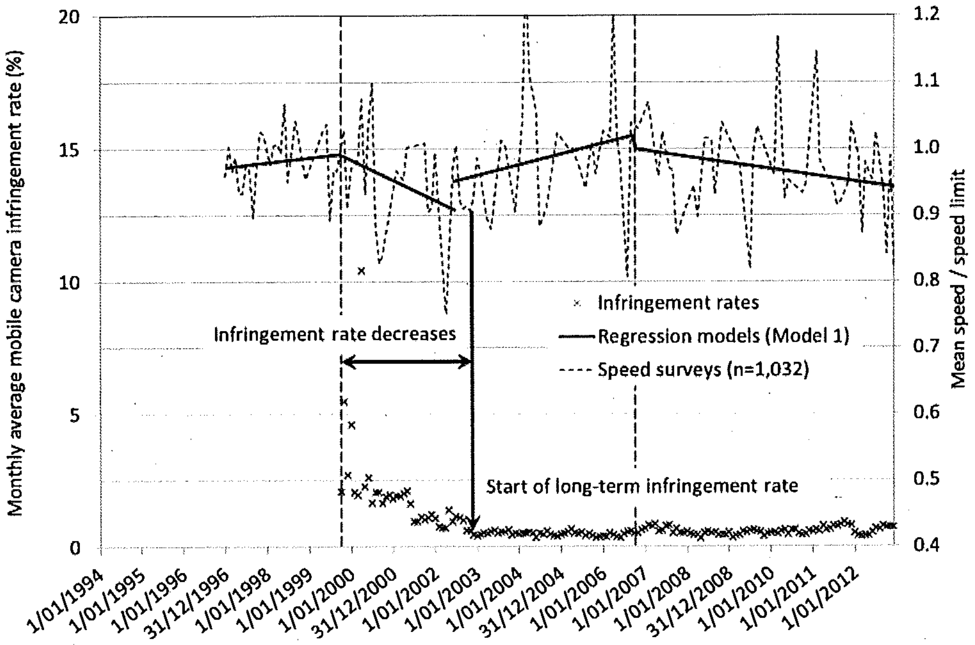

Figure 15: Mean speed survey data relative to the overall camera program – case streets

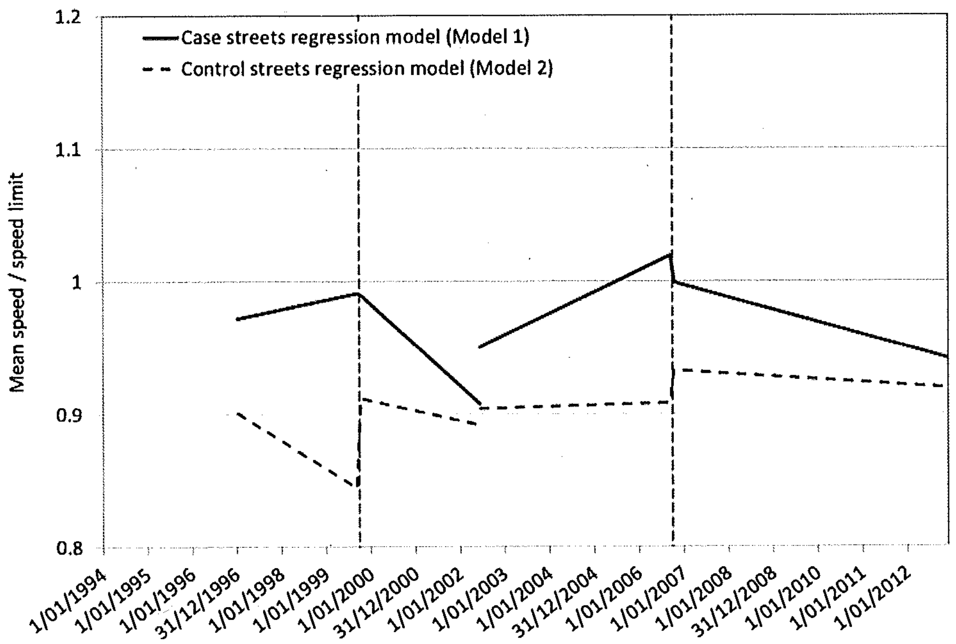

Figure 16: Comparison of the regression models of mean speeds for case and control streets

	MODEL 1 Cases (streets with cameras)								MODEL 2 Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.009	-0.065	0.047	0.754	0.020	-0.031	0.070	0.442	-0.170	-0.268	-0.073	0.001	-0.096	-0.142	-0.050	<.0001
Time (T)	0.001	-0.002	0.003	0.666	0.001	0.000	0.003	0.087	-0.002	-0.007	0.003	0.386	0.000	-0.002	0.002	0.901
Camera (C)	0.000	-0.079	0.078	0.992	-0.021	-0.090	0.049	0.560	0.078	-0.064	0.220	0.282	0.027	-0.037	0.090	0.408
T x C	-0.003	-0.007	0.001	0.116	-0.002	-0.004	0.000	0.027	0.001	-0.006	0.008	0.711	0.000	-0.002	0.002	0.743

Table 10: Mean speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 3 Cases (streets with cameras)				MODEL 4 Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.015	-0.037	0.067	0.577	-0.201	-0.280	-0.122	<.0001
Time (T)	0.000	-0.003	0.003	0.977	-0.003	-0.007	0.001	0.087
Camera (C)	-0.044	-0.118	0.029	0.236	0.151	0.031	0.271	0.014
T x C	-0.002	-0.005	0.002	0.409	0.000	-0.006	0.006	0.963

Table 11: Mean speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 5			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.201	-0.270	-0.133	<.0001
Time (T)	-0.003	-0.007	0.000	0.049
Camera (C1)	0.151	0.047	0.256	0.004
Case (C2)	0.216	0.124	0.308	<.0001
T x C1	0.000	-0.005	0.005	0.958
T x C2	0.003	-0.001	0.008	0.145
C1 x C2	-0.196	-0.331	-0.060	0.005
T x C1 x C2	-0.002	-0.009	0.005	0.619

Table 12: Mean speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.5 Speed survey analyses – effects of mobile cameras on 85th percentile vehicle speeds (Models 6 to 10)

Considering an outcome of monthly averaged values of the 85th percentile speed divided by the speed limit, the statistical models are tabulated in Tables 13 to 15. Models 6 to 9 are plotted in Figures 17 to 19. In Models 6 and 8, trends in 85th percentile speeds for case streets were relatively constant in the pre-intervention periods, and decreased in the post-intervention periods, where the intervention was Intervention 1 (Model 6) or the camera begin-date (Model 8). Trends in 85th percentile speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 6). 85th percentile speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 7 and 9). CAMERA estimates were generally not statistically significant, indicating changes that occurred in 85th percentile speeds at the intervention times were not generally significant (Tables 13 and 14).

Annual trend magnitudes for case streets were an increase of 0.1% and decrease of 1.8% prior to and following Intervention 1, and an increase of 1.4% and decrease of 1.1% prior to and following Intervention 2. A decrease of 0.8% and decrease of 1.7% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 3.6% and decrease of 0.7% prior to and following Intervention 1, and an increase of 0.2% and decrease of 0.4% prior to and following Intervention 2. A decrease of 4.6% and decrease of 5.2% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 15. The estimate for the CASE variable was highly significant, likely a result of the fact that 85th percentile speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The regression models for case and control streets (Models 6 and 7) are compared in Figure 20. 85th percentile speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The 85th percentile speeds on all streets were predominantly above the speed limit for the full time period.

Comparison of the mean and 85th percentile speeds indicates that trends were very similar between the two, however the magnitudes of the 85th percentile speeds were higher than the mean speeds. This is also evident in the speed survey results plotted in Appendix D, where mean and 85th percentile speeds are plotted on the same graphs.

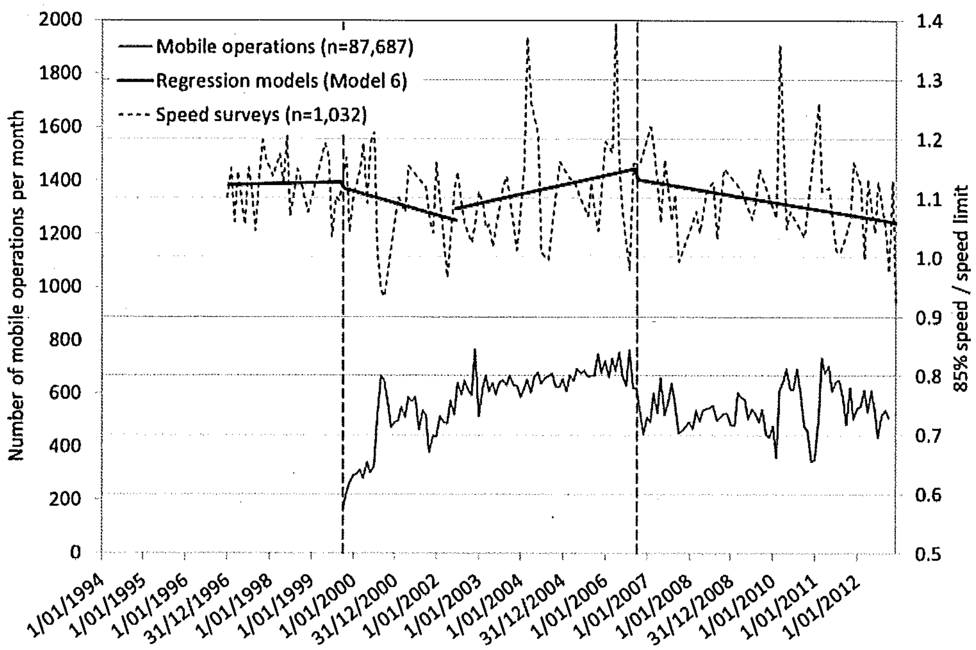

Figure 17: 85th percentile speed survey data relative to the overall camera program – case streets

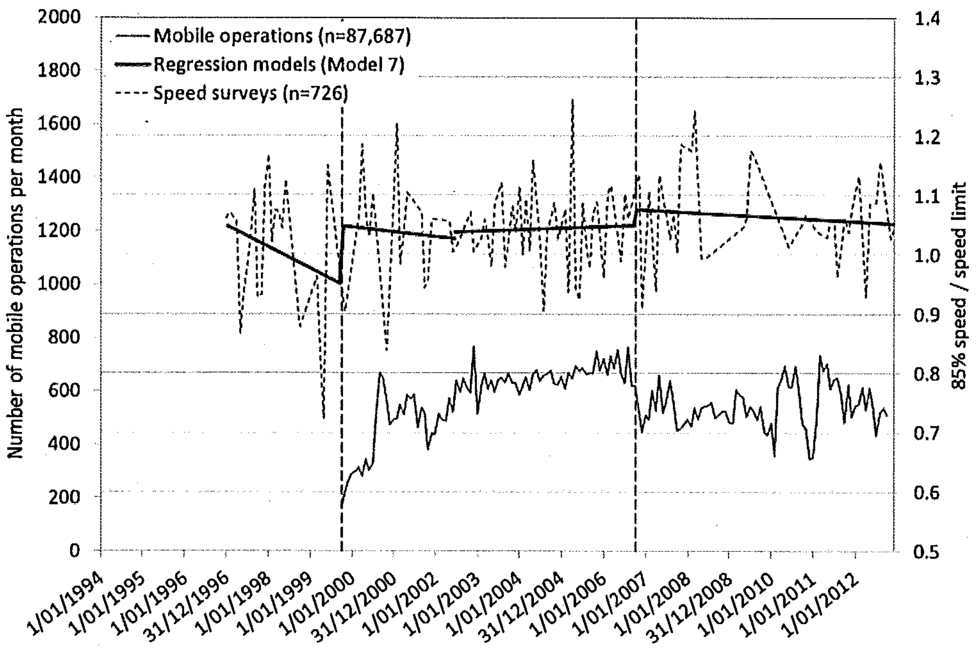

Figure 18: 85th percentile speed survey data relative to the overall camera program – control streets

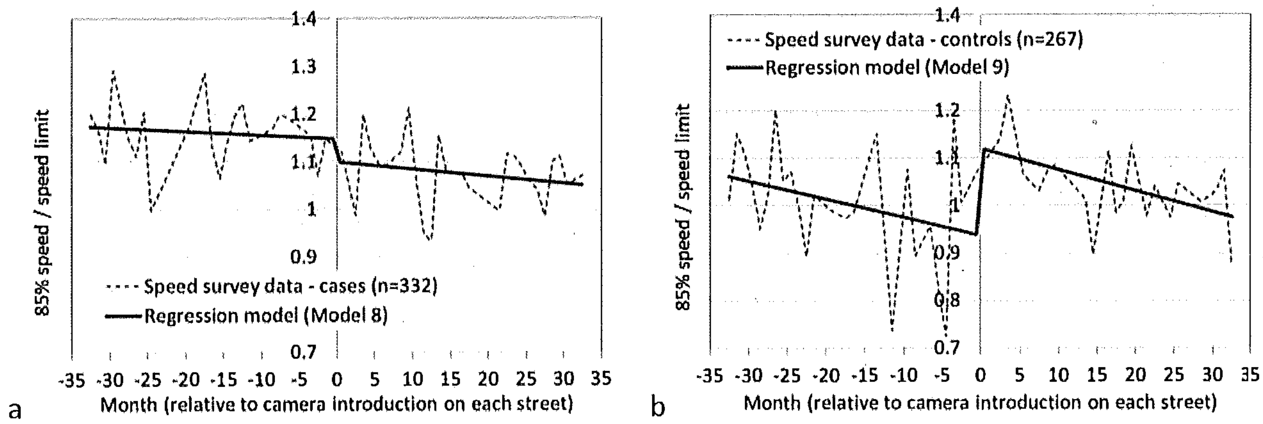

Figure 19: 85th percentile speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

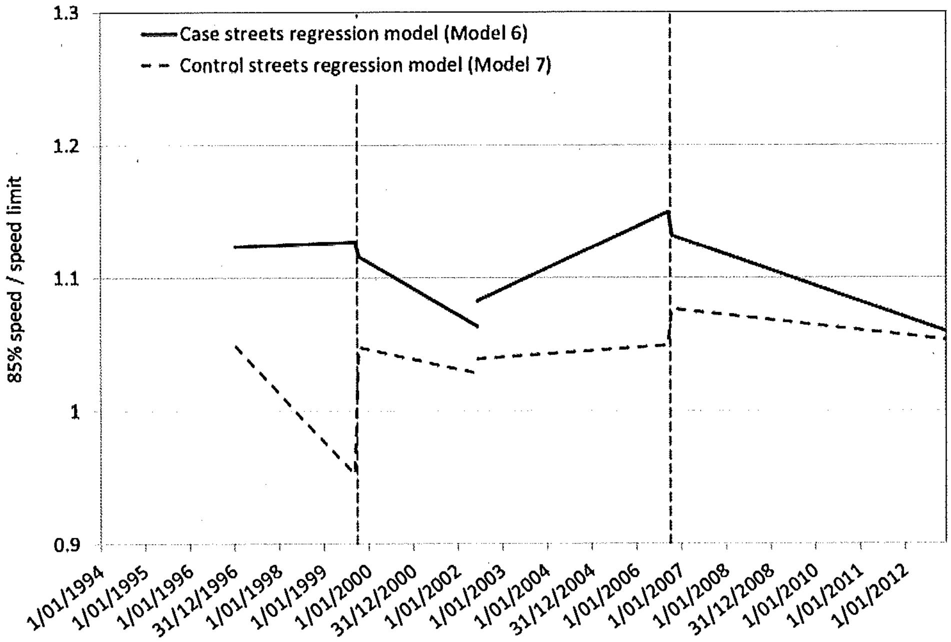

Figure 20: Comparison of the regression models of 85th percentile speeds for case and control streets

	MODEL 6 Cases (streets with cameras)								MODEL 7 Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.120	0.070	0.169	<.0001	0.140	0.093	0.187	<.0001	-0.051	-0.150	0.048	0.315	0.048	0.002	0.094	0.040
Time (T)	0.000	-0.002	0.003	0.908	0.001	0.000	0.003	0.120	-0.003	-0.008	0.002	0.208	0.000	-0.001	0.002	0.820
Camera (C)	-0.009	-0.079	0.061	0.797	-0.016	-0.081	0.049	0.636	0.098	-0.046	0.241	0.182	0.026	-0.037	0.089	0.426
T x C	-0.002	-0.005	0.002	0.390	-0.002	-0.004	0.000	0.026	0.002	-0.005	0.010	0.508	-0.001	-0.002	0.001	0.618

Table 13: 85th percentile speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 8 Cases (streets with cameras)				MODEL 9 Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.138	0.092	0.184	<.0001	-0.065	-0.146	0.017	0.120
Time (T)	-0.001	-0.003	0.002	0.578	-0.004	-0.008	0.000	0.060
Camera (C)	-0.043	-0.108	0.022	0.197	0.179	0.055	0.302	0.005
T x C	-0.001	-0.004	0.003	0.697	-0.001	-0.007	0.006	0.867

Table 14: 85th percentile speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 10			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.065	-0.132	0.002	0.059
Time (T)	-0.004	-0.007	-0.001	0.022
Camera (C1)	0.179	0.077	0.280	0.001
Case (C2)	0.202	0.112	0.293	<.0001
T x C1	-0.001	-0.006	0.005	0.839
T x C2	0.003	-0.001	0.008	0.167
C1 x C2	-0.222	-0.354	-0.089	0.001
T x C1 x C2	0.000	-0.007	0.007	0.967

Table 15: 85th percentile speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.6 Road crash analyses – effects of mobile cameras on fatal crashes

Fatal crashes for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 100 fatal crashes were identified in the period, including 91 that occurred on case streets and 9 that occurred on control streets. Fatal crash counts are plotted in Figures 21 to 22. Due to small crash counts statistical models were not fitted to these data, however it is clear from visual inspection of Figure 21 that fatal crashes on case streets generally decreased over the study period.

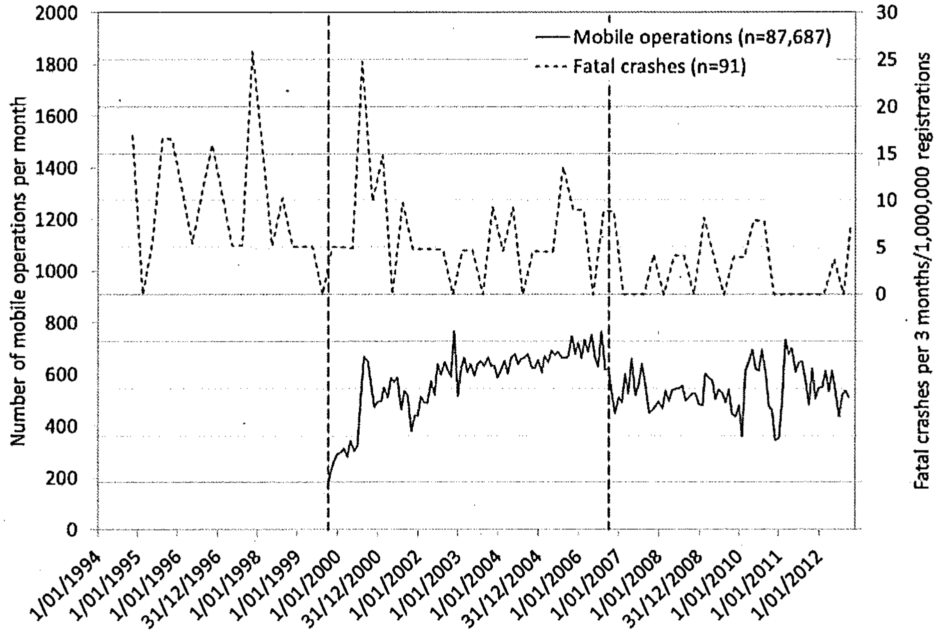

Figure 21: Fatal crash data relative to the overall camera program – case streets

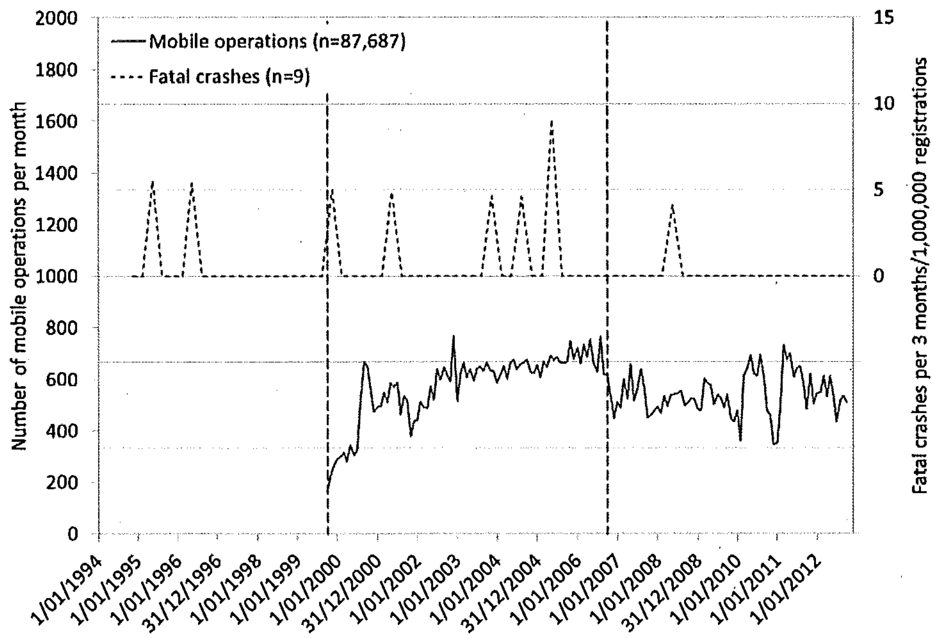

Figure 22: Fatal crash data relative to the overall camera program – control streets

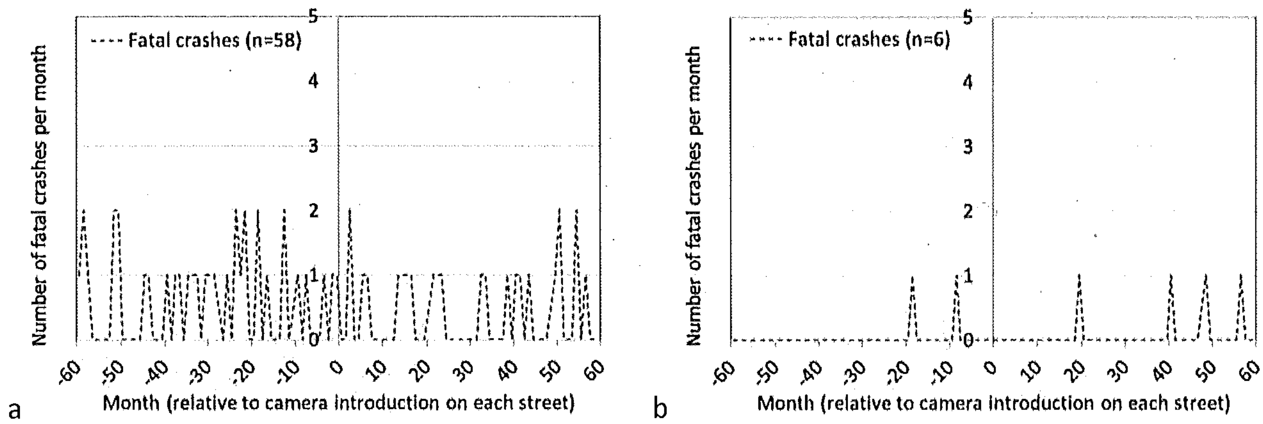

Figure 23: Fatal crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

3.7 Road crash analyses – effects of mobile cameras on serious crashes (Models 11 to 15)

Serious crashes (injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 3,325 serious crashes were identified in the period, including 2,788 that occurred on case streets and 537 that occurred on control streets. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 16 to 18. Models 11 to 14 are plotted in Figures 24 to 26. In Models 11 and 13, trends in serious crash counts for case streets showed decreases post-intervention, where the intervention was Intervention 1 (Model 11) or the camera begin-date (Model 13). A substantial drop occurred in mid-2002 (around 40% in raw numbers) and was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend following Intervention 2 (Model 11) steadily increasing up to 2013 to the same levels when cameras were first introduced. It should be noted that this rising trend in serious injury crashes from around 2004 to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period.

Serious crash counts for control streets were at much lower levels at around one quarter that of the case streets. Trends for control streets (Models 12 and 14) were similar, however the drop in 2002 was much less pronounced. Negative estimates for CAMERA in Models 11 to 14 indicates that crash counts were generally lower following Intervention 1/begin-date, while positive estimates following Intervention 2 indicates crash counts were higher. CAMERA estimates were generally not significant, however this may have been influenced by the relatively small serious crash counts.

Annual trend magnitudes for case streets were a decrease of 3.2% prior to Intervention 1, decrease of 3.7% between Intervention 1 and 2, and increase of 7.1% following Intervention 2. An increase of 1.1% prior to the begin-date and decrease of 10.3% following the begin-date were evident. Trend magnitudes for control streets were an increase of 4.7% prior to Intervention 1, a decrease of 24.5% between Intervention 1 and 2, and an increase of 1.4% following Intervention 2.

Decreases of 6.1% prior to the begin-date and 2.5% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 18. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, however this may reflect the relatively small serious crash counts.

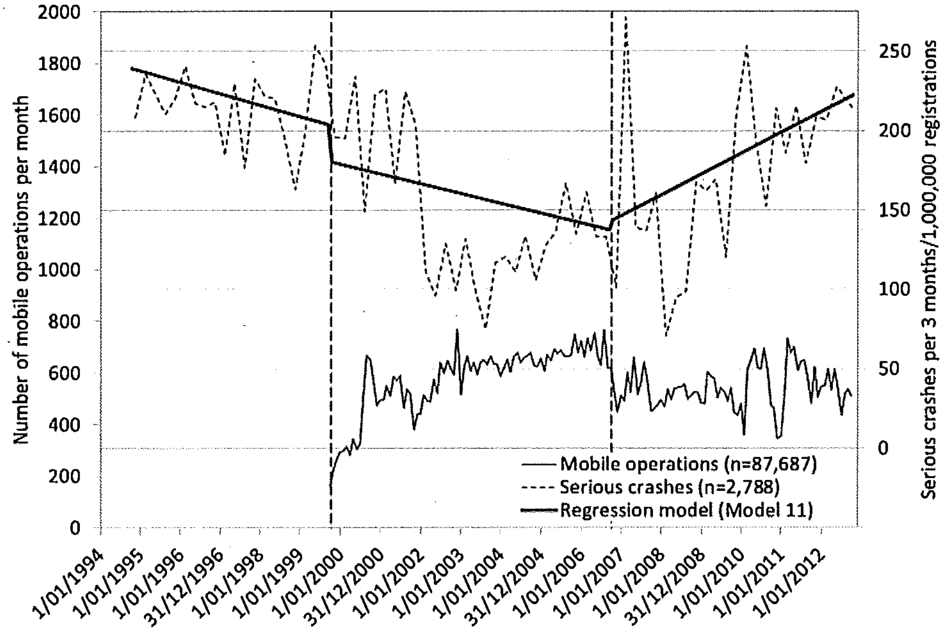

Figure 24: Serious crash data relative to the overall camera program – case streets

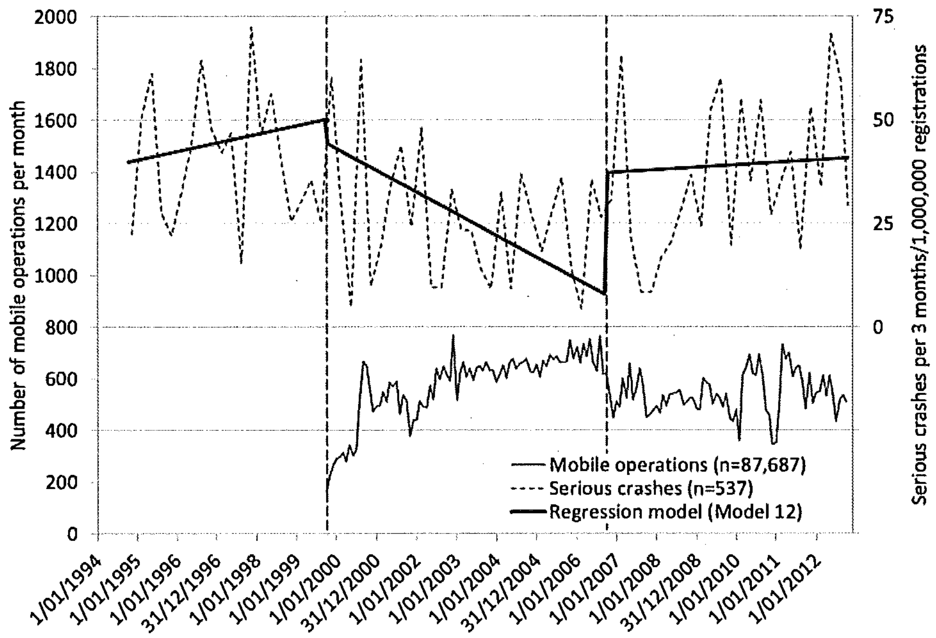

Figure 25: Serious crash data relative to the overall camera program – control streets

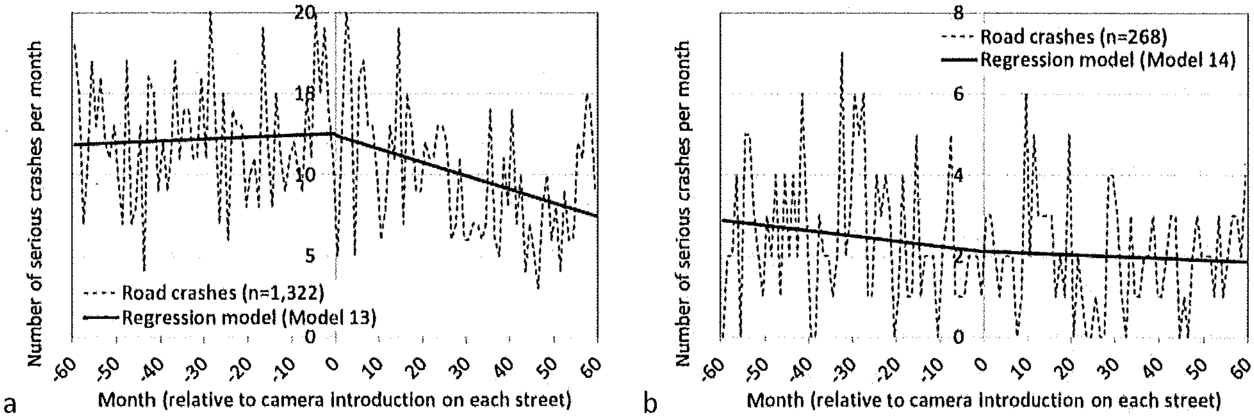

Figure 26: Serious crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

	MODEL 11 Cases (streets with mobile cameras)								MODEL 12 Controls (streets without mobile cameras)							
	(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012				(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-13.381	-13.873	-12.889	<.0001	-13.776	-14.238	-13.314	<.0001	-14.634	-15.092	-14.176	<.0001	-16.482	-17.397	-15.567	<.0001
Time (T)	-0.003	-0.009	0.003	0.353	-0.003	-0.009	0.002	0.265	0.004	-0.010	0.018	0.596	-0.021	-0.036	-0.005	0.011
Camera (C)	-0.122	-0.533	0.289	0.561	0.043	-0.266	0.353	0.785	-0.119	-0.824	0.586	0.742	1.550	0.678	2.423	0.001
T x C	0.000	-0.008	0.007	0.916	0.009	0.002	0.016	0.016	-0.024	-0.042	-0.007	0.007	0.022	-0.002	0.045	0.068

Table 16: Serious crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 13 Cases (streets with mobile cameras)				MODEL 14 Controls (streets without mobile cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.998	-1.460	-0.536	<.0001	-2.886	-3.189	-2.583	<.0001
Time (T)	0.001	-0.004	0.006	0.720	-0.005	-0.011	0.001	0.108
Camera (C)	-0.007	-0.247	0.233	0.955	-0.002	-0.377	0.373	0.991
T x C	-0.010	-0.017	-0.002	0.010	0.003	-0.007	0.013	0.566

Table 17: Serious crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

	MODEL 15			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-2.885	-3.188	-2.582	<.0001
Time (T)	-0.005	-0.011	0.001	0.108
Camera (C1)	-0.002	-0.376	0.372	0.991
Case (C2)	1.889	1.337	2.441	<.0001
T x C1	0.003	-0.007	0.013	0.566
T x C2	0.006	-0.002	0.014	0.135
C1 x C2	-0.005	-0.449	0.440	0.983
T x C1 x C2	-0.013	-0.025	0.000	0.050

Table 18: Serious crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.8 Road crash analyses – effects of mobile cameras on all crashes (Models 16 to 20)

All road crashes (property damage, injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 57,809 road crashes were identified in the period, including 48,733 that occurred on case streets and 9,076 that occurred on control streets. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 19 to 21. Models 16 to 19 are plotted in Figures 27 to 29. In Models 16 and 18, trends in crash counts for case streets showed decreases in both the pre- and post-intervention periods, where the intervention was Intervention 1 (Model 16) or the camera begin-date (Model 18), and following Intervention 2 (Model 16). Large positive CAMERA estimates were evident for case streets at Intervention 1/begin-date, which were statistically significant, which indicates a significant increase in crash counts at this time. Crash counts for control streets indicated very similar trends (Models 17 and 19), however the changes that occurred at the time of the interventions was less pronounced.

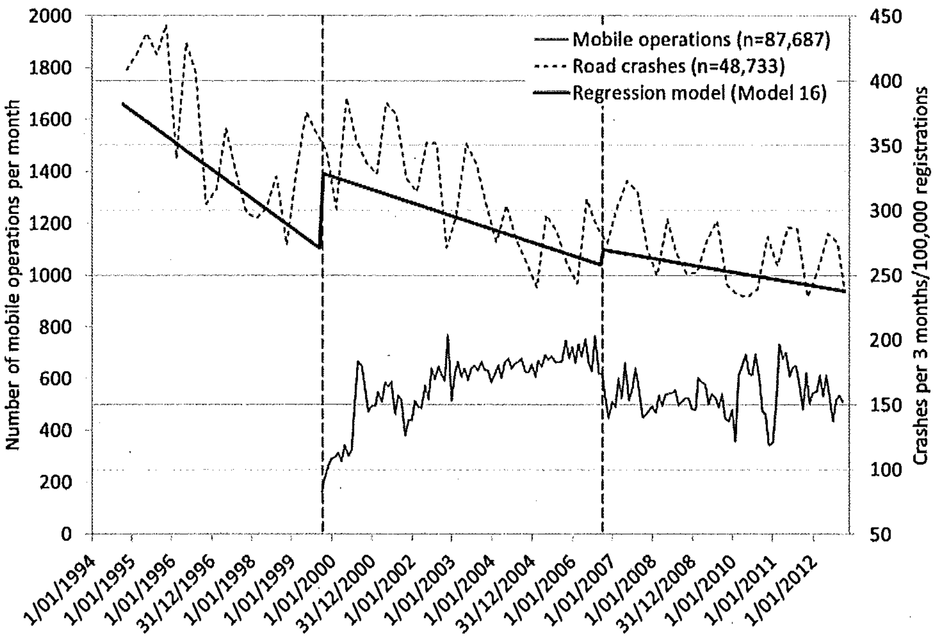

Figure 27: All crash data relative to the overall camera program – case streets

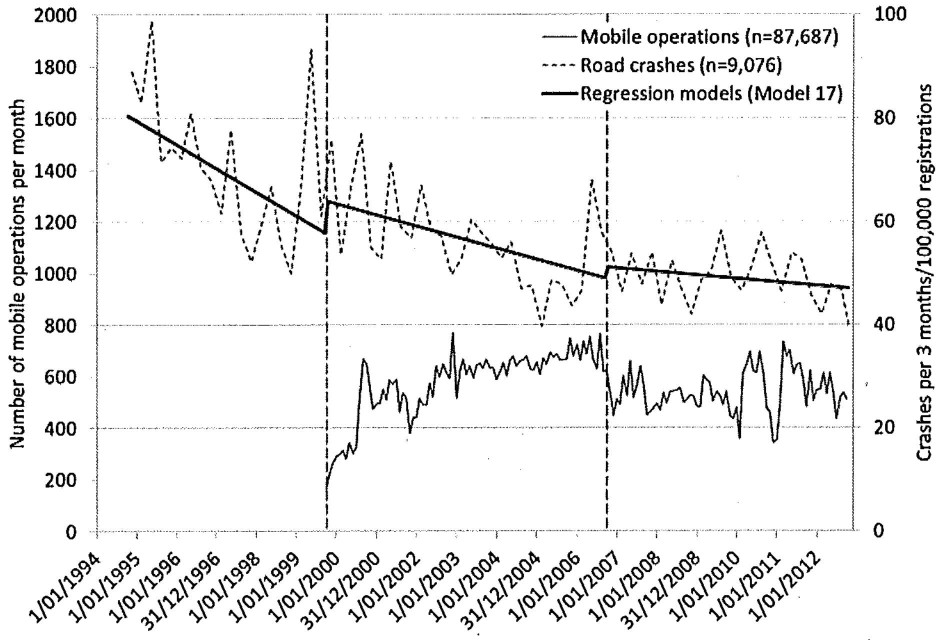

Figure 28: All crash data relative to the overall camera program – control streets

Annual trend magnitudes for case streets were decreases of 6.9% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 2.0% following Intervention 2. Decreases of 3.6% prior to the begin-date and 1.7% following the begin-date were evident. Trend magnitudes for control streets were decreases of 6.7% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 1.0% following Intervention 2. Decreases of 2.9% prior to the begin-date and 3.6% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 21. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, indicating that the effect of the intervention (begin-date) was not significantly different between case and control streets. However, another explanation may be that limitation concerning the selection of control streets, i.e. that the control streets identified for the analyses do not represent a true 'control area'.

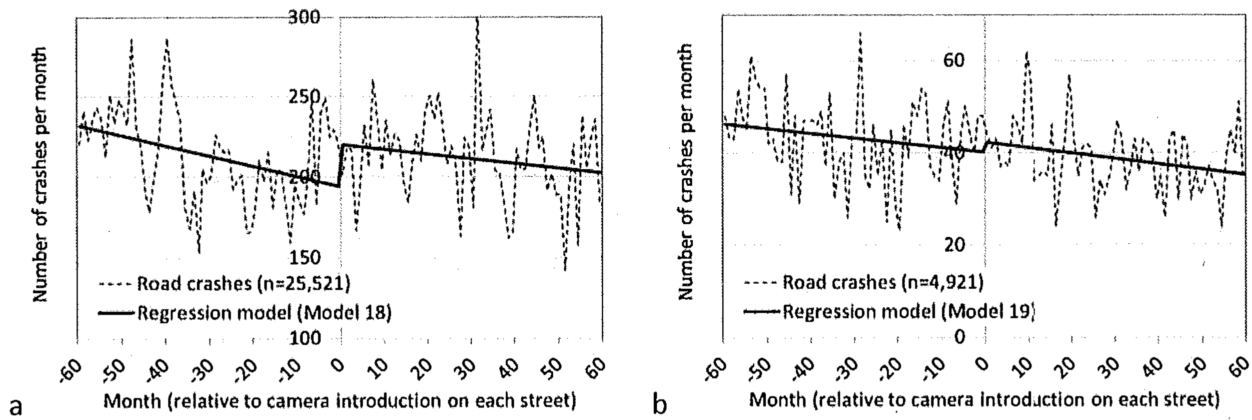

Figure 29: All crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

	MODEL 16 Cases (streets with mobile cameras)								MODEL 17 Controls (streets without mobile cameras)							
	(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012				(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-10.796	-11.240	-10.351	<.0001	-10.844	-11.276	-10.413	<.0001	-12.245	-12.669	-11.821	<.0001	-12.409	-12.858	-11.960	<.0001
Time (T)	-0.006	-0.007	-0.004	<.0001	-0.004	-0.005	-0.002	<.0001	-0.006	-0.008	-0.004	<.0001	-0.004	-0.006	-0.001	0.006
Camera (C)	0.196	0.136	0.255	<.0001	0.047	-0.024	0.117	0.193	0.104	0.014	0.194	0.024	0.044	-0.093	0.181	0.532
T x C	0.002	-0.001	0.005	0.119	0.002	0.000	0.004	0.104	0.002	-0.002	0.006	0.262	0.002	-0.001	0.005	0.102

Table 19: All crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 18 Cases (streets with mobile cameras)				MODEL 19 Controls (streets without mobile cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	1.741	1.300	2.182	<.0001	0.004	-0.413	0.420	0.986
Time (T)	-0.003	-0.005	-0.001	0.000	-0.002	-0.005	0.000	0.063
Camera (C)	0.127	0.081	0.173	<.0001	0.052	-0.053	0.157	0.331
T x C	0.002	-0.002	0.005	0.371	-0.001	-0.005	0.004	0.788

Table 20: All crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

	MODEL 20			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	0.001	-0.415	0.417	0.997
Time (T)	-0.002	-0.005	0.000	0.063
Camera (C1)	0.052	-0.053	0.157	0.332
Case (C2)	1.742	1.136	2.348	<.0001
T x C1	-0.001	-0.005	0.004	0.789
T x C2	-0.001	-0.004	0.002	0.698
C1 x C2	0.075	-0.040	0.190	0.201
T x C1 x C2	0.002	-0.003	0.008	0.446

Table 21: All crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.9 Road crash analyses – effects of fixed cameras on serious intersection crashes (Models 21 to 23)

A total of 152 serious (injury or fatality) intersection crashes were identified in the period for the 26 intersection locations, including 78 that occurred at case intersections and 74 that occurred at control intersections. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 22 and 23, and Models 21 and 22 are plotted in Figure 30. The negative estimates for CAMERA indicates that serious intersection crash counts for case and control intersections were generally lower following the introduction of fixed cameras, and the similar magnitudes indicates that the drop was similar at case and control locations. Model results were not significant, including those for the case-control Model 23, likely a result of the small crash counts.

Annual trend magnitudes for case intersections were a decrease of 5.2% prior to the begin-date and an increase of 0.4% following the begin-date. Trend magnitudes for control intersections were a decrease of 5.0% prior to the begin-date and an increase of 8.2% following the begin-date. All trend magnitudes are per year.

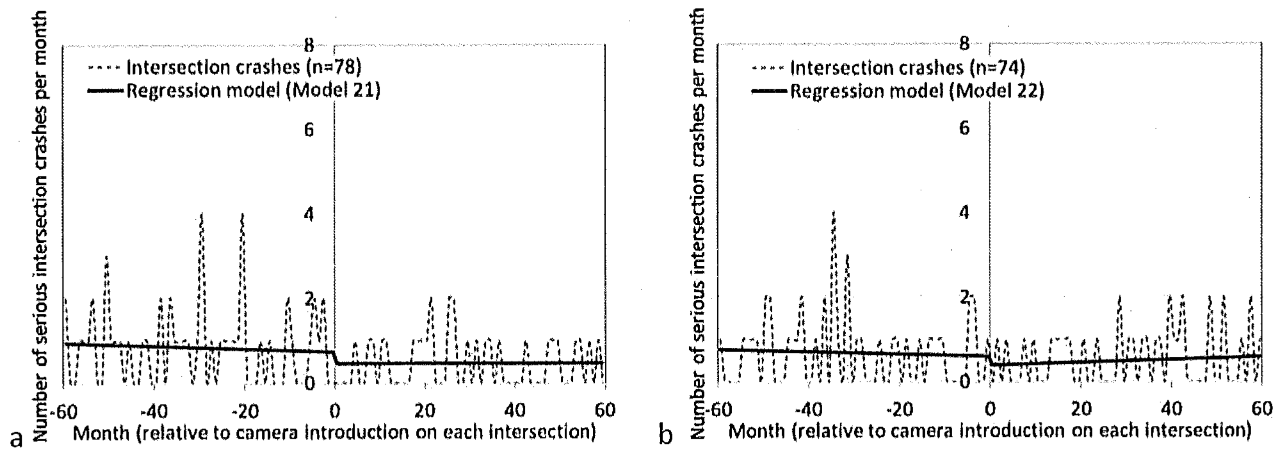

Figure 30: Serious intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

	MODEL 21	Cases (with fixed cameras)			MODEL 22	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.315	-0.891	0.261	0.283	-0.509	-1.167	0.149	0.130
Time (T)	-0.004	-0.020	0.012	0.598	-0.004	-0.023	0.014	0.656
Camera (C)	-0.454	-1.396	0.488	0.345	-0.430	-1.438	0.578	0.403
T x C	0.005	-0.022	0.031	0.738	0.017	-0.011	0.044	0.230

Table 22: Serious intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 23 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.509	-1.156	0.138	0.123
Time (T)	-0.004	-0.022	0.014	0.650
Camera (C1)	-0.430	-1.421	0.561	0.395
Case (C2)	0.194	-0.679	1.067	0.664
T x C1	0.017	-0.010	0.044	0.222
T x C2	0.000	-0.025	0.024	0.991
C1 x C2	-0.024	-1.403	1.355	0.973
T x C1 x C2	-0.012	-0.051	0.026	0.534

Table 23: Serious intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

3.10 Road crash analyses – effects of fixed cameras on all intersection crashes (Models 24 to 32)

A total of 4,261 intersection crashes (property damage, injury or fatality) were identified in the period for the 26 intersection locations, including 2,826 that occurred at case intersections and 1,435 that occurred at control intersections. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 24 to 28 and are plotted in Figures 31 to 33. Trends in crash counts for case intersections showed an increase in crashes following the introduction of the fixed cameras followed by a decline to rates slightly lower than baseline levels. On the other hand, crash counts for control intersections were relatively consistent before and after. The positive estimate for CAMERA in Model 24 indicates that case intersection crash counts were generally higher following the introduction of fixed cameras, and this result was significant. Disaggregating intersection crashes by rear-end crashes indicates that, at intersections where fixed cameras were introduced, this increase resulted from an increase in rear-end crashes which then returned to levels slightly below baseline levels. This is evidenced in the estimates for CAMERA, where a large positive value was estimated for rear-end crashes (0.277, Model 27), and this result was significant. Conversely, a small value was estimated for non-rear-end crashes (0.007, Model 29).

Comparison with the generally consistent frequency of rear-end crashes before and after at intersections without fixed cameras (small negative value for CAMERA estimate in Model 28), indicates that the initial increase in rear-end crashes at intersections with fixed cameras was likely a result of the introduction of these cameras. This is further evidenced by the statistical results for the case-control analysis in Model 26, where the estimate for CAMERA × CASE was highly significant, indicating that the effect of the introduction of fixed intersection cameras was significantly different between case and control streets.

Negative estimates for CAMERA in the models for right angle collision/right turn into oncoming vehicle intersection crashes indicate that crash counts were generally lower following the introduction of fixed cameras, at both case and control intersections.

Annual trend magnitudes for case intersections were decreases of 3.4% prior to the begin-date and 6.2% following the begin-date. This included decreases of 0.5% prior to the begin-date and 6.5% following the begin-date for rear-end crashes, decreases of 8.9% prior to the begin-date and 5.5% following the begin-date for non-rear-end crashes, and decreases of 1.6% prior to the begin-date and 2.2% following the begin-date for right angle collision/right turn into oncoming vehicle

crashes. Trend magnitudes for control intersections were a decrease of 1.6% prior to the begin-date and an increase of 2.2% following the begin-date. This included an increase of 1.2% prior to the begin-date and an increase of 2.2% following the begin-date for rear-end crashes, a decrease of 6.0% prior to the begin-date and an increase of 0.7% following the begin-date for non-rear-end crashes, and a decrease of 13.6% prior to the begin-date and an increase of 3.0% following the begin-date for right angle collision/right turn into oncoming vehicle crashes. All trend magnitudes are per year.

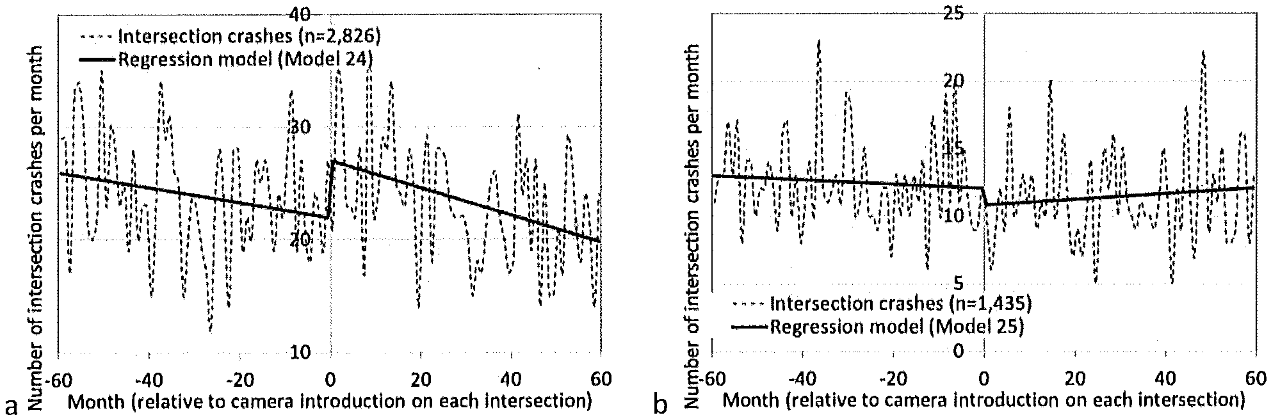

Figure 31: Intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

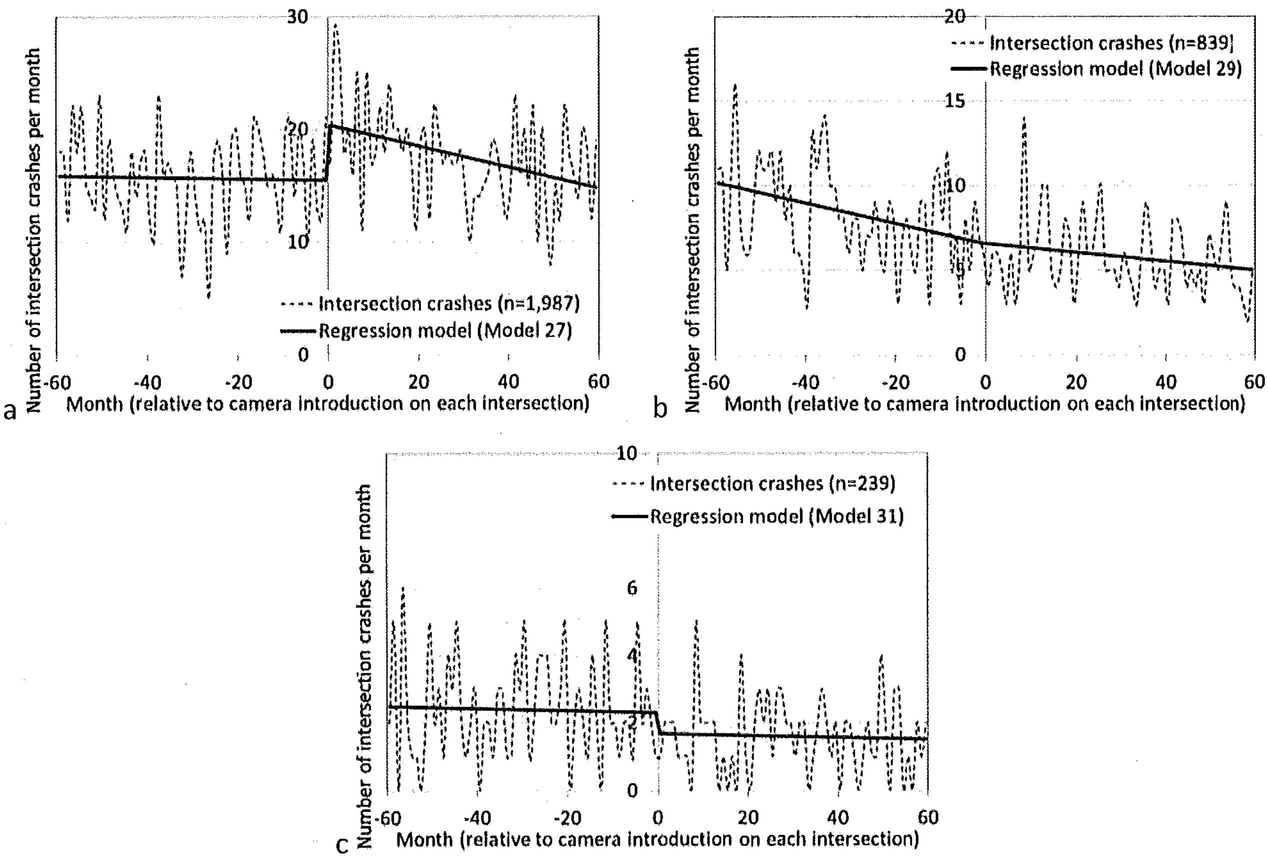

Figure 32: Case intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

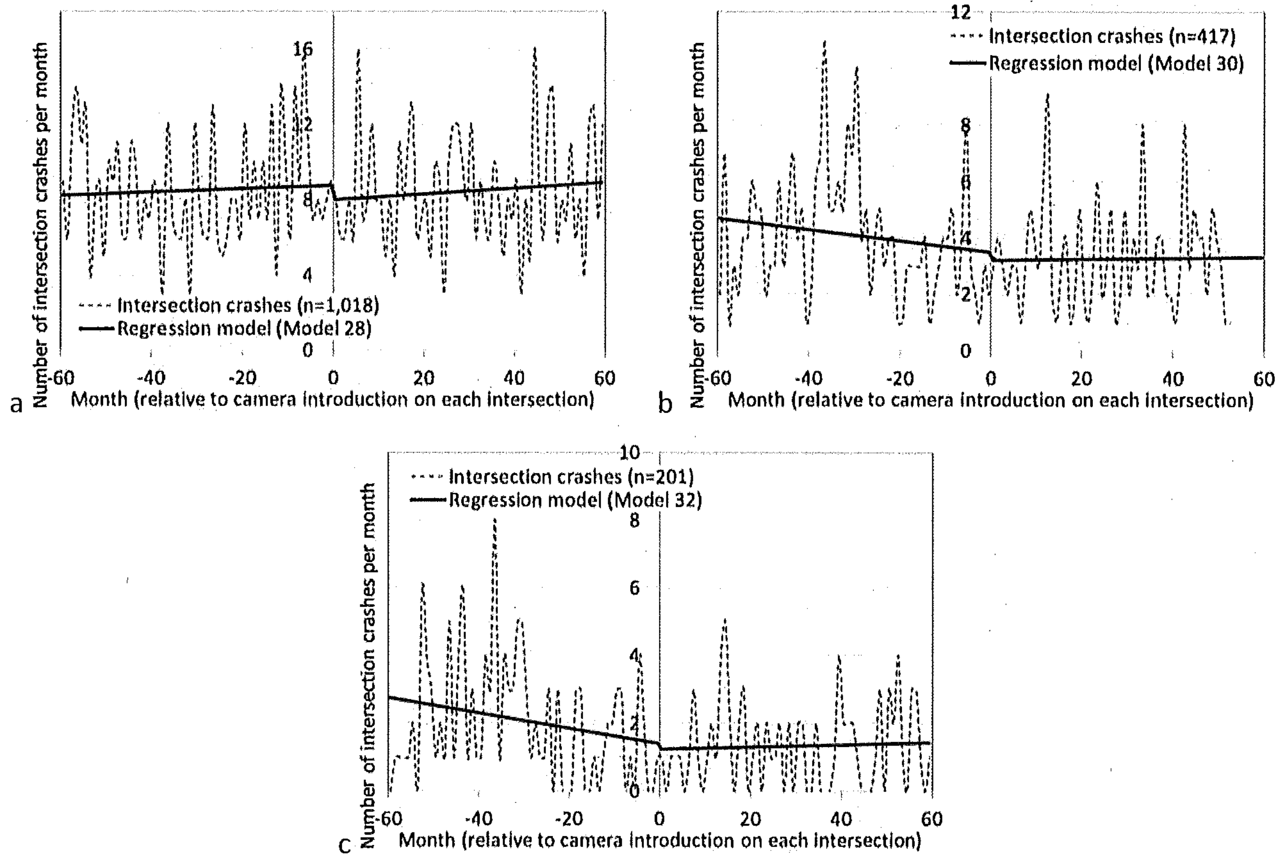

Figure 33: Control intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

	MODEL 24	Cases (with fixed cameras)			MODEL 25	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	3.089	2.977	3.200	<.0001	2.487	2.346	2.628	<.0001
Time (T)	-0.003	-0.006	0.000	0.082	-0.001	-0.005	0.003	0.520
Camera (C)	0.207	0.053	0.362	0.009	-0.107	-0.312	0.097	0.303
T x C	-0.002	-0.007	0.002	0.298	0.003	-0.003	0.009	0.297

Table 24: Intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 26			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	2.487	2.340	2.634	<.0001
Time (T)	-0.001	-0.006	0.003	0.537
Camera (C1)	-0.107	-0.321	0.106	0.323
Case (C2)	0.601	0.420	0.783	<.0001
T x C1	0.003	-0.003	0.009	0.318
T x C2	-0.002	-0.007	0.004	0.575
C1 x C2	0.315	0.055	0.575	0.018
T x C1 x C2	-0.006	-0.013	0.002	0.149

Table 25: Intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 27	Cases (with fixed cameras)			MODEL 28	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	2.740	2.611	2.868	<.0001	2.171	1.995	2.348	<.0001
Time (T)	0.000	-0.004	0.003	0.834	0.001	-0.004	0.006	0.690
Camera (C)	0.277	0.103	0.451	0.002	-0.090	-0.342	0.163	0.487
T x C	-0.005	-0.010	0.000	0.056	0.001	-0.007	0.008	0.839

Table 26: Rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 29	Cases (with fixed cameras)			MODEL 30	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	1.878	1.706	2.050	<.0001	1.250	0.975	1.525	<.0001
Time (T)	-0.007	-0.012	-0.003	0.002	-0.005	-0.013	0.003	0.193
Camera (C)	0.007	-0.249	0.262	0.959	-0.085	-0.498	0.327	0.686
T x C	0.003	-0.005	0.010	0.458	0.006	-0.006	0.017	0.344

Table 27: Non-rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 31	Cases (with fixed cameras)			MODEL 32	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.836	0.498	1.173	<.0001	0.343	-0.147	0.833	0.170
Time (T)	-0.001	-0.011	0.008	0.789	-0.011	-0.024	0.002	0.090
Camera (C)	-0.322	-0.850	0.205	0.231	-0.130	-0.875	0.615	0.733
T x C	-0.001	-0.016	0.015	0.950	0.014	-0.007	0.034	0.190

Table 28: Right angle collision/right turn into oncoming vehicle intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

4. Discussion

The views of drivers about speeding and enforcement of speed limits is likely to influence their on-road behaviour. For this reason, in evaluating the effects of road safety initiatives like safety cameras, it is useful to take into account changes in driver and community views about speed and enforcement. The community attitude surveys conducted between 1992 and 2012 provide some insights into changes in attitudes over the period of introduction of safety cameras in the ACT.

Drivers choose the speed of travel from moment to moment based on a range of factors that might be loosely grouped into the driving environment and their preferred driving style. The driving environment includes the physical conditions that can have a large impact on the driver's chosen speed and the regulatory speed limits. Driving style also undoubtedly plays a considerable role in speed choice with the behavioural style of individual drivers influencing their perception of speed and of the importance of regulating speed according to the environment. The majority of drivers make considerable effort to conform to speed limits. Compliance with speed limits and, as a consequence, to general driving conditions is encouraged primarily through enforcement such as the use of speed cameras, but drivers differ in their reactions to such enforcement measures. Driver experience of enforcement may also differ depending on the type of camera in use which will also affect whether and how drivers respond to the presence of speed cameras.

The following is a discussion of what was found to be available in the wide literature in terms of evidence base concerning the effectiveness or otherwise of the different camera types, a discussion of the review of community attitudes to speeding, and a discussion of the speed survey and road crash data study. It is hoped that this discussion and the conclusions (placed at the front of report for convenience) will provide insight into some of the questions raised.

4.1 Literature review

Evaluations of red light cameras clearly yield mixed effects. There is good evidence that they have the effect that we expect and hope for: reduce red light running in the form of violations and most importantly produce reductions in right angle crashes. These effects are clearly road safety benefits.

On the other hand, there is consistent evidence that they also increase rear-end crashes, which is clearly not a benefit for road safety, but again might be expected if drivers are responding rapidly to the onset of red lights when cameras are present. It has been argued that the difference in likely severity of crashes offsets the increase in rear-end crashes. Kloeden et al (2009), for example argued that the damage caused in side impact crashes are often much more extreme than that produced in rear-end crashes, so the trade-off for road safety by the presence of red light cameras is in the positive direction. However, it should be noted that whiplash injury, which is often associated with rear-end crashes, may have long term chronic effects which result in both pain and suffering. Whiplash injuries can also result in a substantial financial burden, where a recent study of road-crash related personal injury insurance claims noted that the average injury claim made for the treatment of whiplash injuries was $90,700 (Bambach et al 2013). Clearly, good road safety practice needs to also consider how to reduce increased rear-end crashes even if the severity of the crash is much less extreme than for example a side impact crash resulting in serious injuries. One way may be to consider light phases at intersections.

The available research provides some guidance on the best approaches to implementation of red light cameras. Some focus on the length of phase sequences. Yang, Han and Cherry (2013) reviewed the evidence for modifying signal sequences as a method of sustaining red light camera operations in order to balance safety benefit with revenue raised. They concluded that safety benefits would be obtained by lengthening the all-red clearance phase and from shortening overall cycle length, whereas shortened yellow light sequences increased the likelihood of rear-end crashes. It seems that providing greater opportunity for drivers to make the decision to stop may be effective in reducing red light running. Further, providing an all-red clearance period at intersections reduces red light violations (Schattler, Datta and Hill, 2003) by requiring drivers to pause between the change in direction of traffic flow. However, it needs to be noted that the ACT already has an all-red phase and the other phasing features noted above.

Evaluations of fixed cameras also clearly show they are effective for reducing speeds and crashes in the location where the camera is installed. The results also show a large variation. There are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

Critical to any evaluation is the choice of a control comparison site. Even if a Random Location Control (RLC) non-camera site is chosen some distance away in order to avoid distance or time halo effects, the site is likely to be influenced by the information about the general presence of cameras in the area by the community. The level of enforcement is also likely to increase driver awareness as people are 'caught' when they are speeding at the camera site and then drive through control sites elsewhere. Drivers tend to watch what they are doing through signalised intersections and drivers have warnings of the presence of the camera in the general vicinity.

Another factor that may account for the large variation is the issue of the effectiveness of enforcement using camera technology. For enforcement to be effective, just as for any behaviour change, the punishment and the infringement need to be linked closely; the consequence and the act must be clearly tied. Since cameras produce automatic enforcement, when drivers receive fines or notification of demerit points some considerable time after they have committed the violation, this presents a problem. The link between committing the violation and being made aware of it and/or the consequence is weakened by the length of time between them. Drivers need to know that they have been caught as close as possible to committing the offence. Information available from red camera sites can provide this in the form of camera flashes or feedback to drivers from mobile camera units.

Evaluations of mobile cameras also clearly show they are effective for reducing speed and crash outcomes. The results similarly show some variation between the different studies. Again there are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

The same issue exists for this camera type as for fixed cameras in terms of timeliness of issuing the infringement notice and demerit points in relation to the time the violation was committed. Evaluations of this camera type (and for the fixed camera type) likely have not considered this factor in any analysis. A related issue is the extent to which drivers are even aware that they have been detected violating speed limits. The question is whether drivers should be warned they are about to pass a mobile camera or whether no warning should be provided. For example in Victoria, the policy for mobile cameras is that they remain covert. In Victoria the flash of a camera has been removed, and as a result the link between committing the violation and its consequence is significantly weakened. If drivers are not warned that there are cameras in a particular location or even in a general location, the arrival of an infringement notice may be the first time they learn about it. The strategy behind this approach is to impart to the driver the notion that they can be photographed 'any time anywhere' if they are found to exceed the speed limit. Aeron Thomas (2005) noted that the strongest evidence came from a study that had signs at the entrance to the monitored area but not at the camera site itself. It is assumed that making the cameras covert motives the behavioural change in drivers to travel at the speed limit everywhere however the validity of this assumption has not been demonstrated adequately to date.

An associated issue with a weak association between the unsafe act and the consequence is its effect on driver attitudes. Speed enforcement is generally supported by the community, at least in principle, but this support is tempered by a view, unfortunately shared by more than half of the community that speed enforcement is revenue raising (Austroads, 2013). Clearly the belief that speed enforcement does not have a road safety objective is likely to be a significant impediment to drivers complying with speed limits.

This issue that drivers perceive that speed enforcement does not have a road safety objective, is discussed in a paper by Belin et al (2010). They compare speed camera programs in Sweden and Victoria. They state that the *"approach adopted in Victoria is based on the concept that speeding is a deliberate offence in which a rational individual wants to drive as fast as possible and is prepared to calculate the costs and benefits of* their *behaviour. Therefore, the underlying aim of the intervention is to increase the perceived cost of committing an offence whilst at the same time decrease the perceived benefits, so that the former outweigh the latter. The Swedish approach, on the other hand, appears to be based on a belief that road safety is an important priority for the road users and one of the reasons to why road users drive too fast is lack of information and social support."* The Swedish approach is to assist the driver with making a safe speed choice and thus bring about a general cultural behavioural change. On the other hand, in Victoria the system is punitive and treats the offending driver as intentionally carrying out a criminal act. In Sweden however, it is accepted that drivers need to be assisted with making the right speed choice. The approach is engineering based where the choice in what system is used to achieve a particular road safety target can be either through the use of speed cameras or through upgrading the road system.

The relative benefits of the Victorian or Swedish approaches are still to be formally evaluated. There is evidence, however, that the covert approach adopted by Victoria resulted in significant proportions of drivers believing that camera technology was being used for revenue raising (Smith and Senserrick, 2004) and the approach also involves a weak link between the unsafe behaviour that we wish to change (speeding) and the punishment that is intended to change that behaviour. There is evidence that the Victorian approach has produced some benefits of reduced speeding and crashes (Cameron et al, 2003). However, it is unclear what aspects of the approach produced these effects given that it included covert cameras, greater enforcement, increase media and lower speed limits. It is likely, however, that the benefits could be greater if elements of the Swedish approach were included. For example, the underlying premise of the Victorian approach that drivers make deliberate decisions to speed so making them believe that they must always drive slower than the speed limit as they could be caught anywhere and anytime has not been rigorously evaluated. Exceeding the speed limit can occur when drivers are not focussing on their speed due to other activities including driving-related activities. This means that drivers can inadvertently exceed the speed limit even when they did not intend to do so. Current statistics on speed camera infringements in Victoria show that only a smaller percentage of all drivers (around 30%) are caught speeding by speed cameras, but this corresponds to over one million drivers each year. If only a proportion of these drivers, e.g. half did not intend to speed, this may have an impact on community attitudes to speed cameras, which is likely to be negative particularly if they were not immediately aware that they had actually committed the infringement.

Delaney et al (2005) highlight the various controversies which they suggest need to be considered in any speed camera enforcement program. The examples they listed are that speed cameras are seen by some as: revenue raising; unfair in that they do not identify offenders on the spot; not timely in terms of issuing the infringement notices; placed in locations where speed is perceived to be safe because it is felt that the speed limits are too low; lack reliability in terms of instrument measurement; not addressing road safety, i.e. speeding may not be perceived as a road safety problem; intruding into the Privacy of individuals, i.e. big brother is watching. They noted in the case of Victoria: '*Public opinion surveys conducted in Victoria identified the controversies associated with camera use. In the initial years few controversial issues arose, thought to be a result of carefully planned strategies of camera implementation. These strategies included independent technical testing and quality assurance of equipment and procedures, identification of safety (not revenue) as the primary objective, winning public support even though the level of fines was high, and subjecting the program to independent evaluation research to establish its road safety potential.*' Nevertheless, they found that despite Victoria deploying covert cameras across the road network without warning signs, and taking an aggressive approach of reducing the speeding threshold tolerance to 3 km/h, the camera program was widely supported by the public. They advised that any jurisdiction planning to introduce a speed camera program should at a minimum: '*involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important. Finally, it is essential that the equipment and operating procedures used are reliable.*'

The evaluation of the point-to-point cameras in Italy by Montella et al (2012) also clearly show they are effective for reducing speed in the location where the camera system is installed. However, compared to other speed enforcement approaches, point-to-point systems are relatively expensive (Austroads 2012). Nevertheless the cost-benefit ratios appear high and compliance extends over longer distances. A four year evaluation of speed cameras of all types in Britain (Austroads 2012), showed that all types of cameras produced reductions in speeds at the camera site. In all, fixed cameras produced the greatest reductions, followed by point-to-point cameras and mobile speed cameras. However, it should be noted that fixed cameras also produce their effects over the shortest distances.

4.2 Review of community attitudes to speeding

The introduction of mobile and red light cameras occurred fairly close in time: 1999 and 2000. This means that individual effects of each camera are likely to be difficult to disentangle. Nevertheless, a number of changes were found that were associated with the introduction of safety cameras in the ACT. First, initial introduction of mobile and red light cameras was associated with increased perception that enforcement had increased so ACT residents noticed the additional enforcement. Aligned with this finding was the increased reporting of being booked for speeding over the last two years in the two years following the introduction of mobile and red light cameras, although this effect trended down between 2006 and 2008. Furthermore, more ACT respondents reported decreasing their own driving speed in the period following the introduction of mobile and red light cameras. Combined, these findings suggest that the initial implementation of the safety camera programme with mobile and red light cameras may have influenced the amount and impact of speed enforcement and even had effects on driver behaviour through reducing their driving speed. The data shows that around this time serious injury crashes dramatically fell by around 40% from around mid-2002 and was maintained until 2004 after which the trend began to steadily rise.

The introduction of fixed cameras in 2007 was not associated with increased perception of increased enforcement, even though more respondents reported being booked for speeding over the past two years and six months in 2009 and 2011 following the introduction of fixed cameras. Alternatively, the lack of reported change in perception of enforcement may reflect an insensitivity of the question (lack of detailed questioning) which has only a few available responses compared with the question on being booked. In addition, the personal experience of being booked is memorable whereas the amount of enforcement years earlier may not be.

Interestingly, there was a relationship between increased reporting of being booked for speeding between 2002 and 2005 and a clear drop in the percentage of ACT respondents who supported no tolerance for speeding in 60 and 100kph zones, especially after 2002. It may be that the more widespread experience of being booked made ACT respondents review their attitude to speed limits so fewer supported a tougher 'no tolerance' approach.

Many attitudes to speeding in the ACT seem to have changed little since 1995, although there are a few exceptions. Since the introduction of safety cameras, far fewer ACT respondents agree with the idea of safe speeding. Similarly, support for increasing levels of enforcement and even severity of penalties has increased or at least stayed the same following introduction of safety cameras. The initial introduction of safety cameras in the ACT was also associated with a marked increase in support for lowering residential speed limits. While there may not have been a direct causal relationship between the effect of safety cameras and views in the ACT about speed limits, the presence of cameras clearly did not have a significant influence on attitudes about speed limits as in 2003 over 90 percent of respondents supported lower speeds.

On the other hand, around half of respondents in the ACT agree with the view that speeding fines are for revenue raising. Unfortunately, support for this view increased in the two years immediately following the introduction of fixed cameras. Although this effect dropped in the most recent survey, to the same levels as before the introduction of fixed cameras.

These findings suggest some clear targets for further consideration in order to enhance community support for speed management in the ACT. There seem to have been some very clear benefits for community perceptions and attitudes from the first introduction of safety cameras in the ACT. People noticed their effect and at least reported reducing their driving speed but they maintained support for establishing lower speed limits, increased enforcement and stricter penalties for speeding. Factors that challenge these encouraging findings include the suggestion from this research that being booked may have an effect of reducing support for stricter enforcement of limits and potentially general support for speed management. Also, the commonly held view that speeding fines are revenue-raising is clearly not supportive of programmes that include speeding fines. Further understanding is needed of both of these factors, in order to encourage more supportive community attitudes towards speed management programmes in general.

This analysis of changes in community attitudes also suggests that the implementation of fixed cameras may not have been as successful as the introduction of the mobile and red light cameras. It is possible that the difference is related to a general reduction in effectiveness of the whole safety camera programme, since a number of other studies have demonstrated that most benefits of camera programmes occur immediately after implementation. Even so, the introduction of fixed cameras did not produce the same initial changes in enforcement perception, and self-reported speed behaviour as the mobile and red light cameras. Furthermore, fixed cameras were associated with a temporary increase in community perceptions of the revenue-raising nature of speeding fines. Based on these patterns of community attitude change, it would be worthwhile to review communications strategies that articulate the rationale for speed cameras and how they are being used, and also simultaneously review the operation of fixed cameras in the ACT in order to determine whether there are specific aspects of their operation that may have had negative effects on community support for the safety camera programme.

4.3 Speed survey and road crash data study

The infringements data indicate that the rate of fixed camera infringements (per vehicle checked) has been very low, where after the first year the rate remained below 0.2%. The rate of mobile camera infringements decreased consistently for approximately three years following the introduction of cameras in late 1999. After approximately late 2002, the rate of mobile camera infringements levelled off to a long-term rate of around 0.6%. Several issues may have been influencing these rates, including; drivers were not infringed at the same rate, drivers may not have been communicated to via various media outlets adequately and consistently that their speeding could result in a ticket, location of the camera, and the tolerance levels used by the cameras (i.e. the speed above the speed limit at which an infringement is issued – however camera tolerance levels are not publicly available information). During this approximately three year period of reducing infringement rates, vehicle speeds were also reducing. This indicates that drivers were getting used to the cameras and adjusting their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding.

However, following 2004, mean vehicle speeds began increasing back to the same levels when cameras were first introduced. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. Possibly when they found that they were not being caught very much or at all, or they found the penalty was not severe, or drivers have learnt how to speed and yet avoid detection, their speed started to return to customary levels. In other words, the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Alternatively, it could be other factors like initial bursts of enforcement and the relevant new publicity, which were not able to sustain mean speed reduction over longer periods. Evaluation of these possible accounts through further research is recommended. Moreover, it is recommend that the ACT examine how to make all aspect of mobile cameras less predictable in terms of location, time and vehicle used, and whether this is effective in reducing speeds and hence serious injury crashes.

It is notable that vehicle mean speeds on control streets decreased substantially immediately prior to the introduction of cameras in late 1999, which indicates that the publicity about their presence and likely effects was possibly having the desired effect of getting drivers to slow down. The introduction of cameras possibly increased the perception that drivers were likely to be caught if they exceeded the speed limit because cameras will photograph all who infringe. The effect will of course diminish when drivers find that this is not actually the case. It could be expected that speeds decrease where cameras are first introduced (and as above, even before) due to the community expectations about their effects. But then it would be expected for drivers mean speed to return to levels previous to their mention and introduction on control streets, because there are no cameras, but on camera streets the speeds would be expected to reduce as a result of the cameras photographing infringing drivers who are speeding and a ticket being issued. This effect was found initially for case streets although the effect dissipated over time.

The longer term mean and 85th percentile speed data indicated that vehicle speeds on control streets remained relatively constant, indeed annual trends remained below 1% for the full period from 1999 to 2012. These results indicate that mobile speed camera operations likely had minimal effect on speeds on streets in which cameras were not introduced.

Meanwhile, case streets saw an increase in speeds followed by a decrease in speeds before and after Intervention 2, indicating that after increases in speeds, speeds levelled off and decreased slightly with long-term mobile camera operations. Changes that occurred around Intervention 2 were small in magnitude and insignificant, indicating little effect on speeds from the drop in mobile camera operations that occurred at this time. As noted in the discussion of the literature review, many studies have shown that the effect of cameras on mean speeds is typically small in magnitude. Nevertheless, these small values can have a significant effect on casualty crashes as demonstrated in Figure 2 by Nilsson (2004). With a very small percentage of people speeding (which is known from the infringement rates), the mean speed will not decrease much but will actually reflect a significant effect on the number of speeding drivers.

It is noted that prior to the introduction of mobile cameras, speeds in case streets were higher than those in control streets. This is likely related to the fact that streets with known speed problems and/or speed-related crash problems were targeted for mobile camera operations. The drop in speeds on camera streets could be related to RTM and, as a consequence may overestimate camera effects when comparing pre and post camera introduction. However, the opposite effect might be expected due to spillover since control streets will have also been influenced by the general community awareness of cameras, which is likely to have an effect of underestimating camera effects if differences between camera and control sites is looked at.

Serious injury crashes (injury or fatality) generally decreased on streets following the introduction of mobile cameras although there was a continuing smaller trend that was evident for the five years prior to their introduction. There was a large drop in mid-2002, i.e. around two and half years after the introduction of cameras. Careful inspection of the both the number of mobile operations and serious injury crashes shows an alignment of the sudden fall of serious injury crashes with the camera operation rise over a 12 month period from around 400 to around 600 (30% increase). Fatal crashes also appeared to generally decrease after the introduction of cameras commencing around 2001. This appears to align with the period when casualty crashes started to drop. Further analysis of the nature of the serious crashes would be helpful in understanding the circumstances surrounding this sudden fall in mid-2002. Additionally, it appears the trends in serious crashes do not align well with trends in vehicle speeds. While speeds increased slightly from 2004 to 2007, they then decreased slightly until present, meanwhile serious crash counts increased steadily albeit interspersed with sudden oscillations of large increases and large decreases. Further analysis of the nature of crashes would be useful to attempt to understand these changes. If the causes of crashes varied across the study period, it may be possible to understand whether speed indeed played a role consistently across the period and whether speed cameras were likely the likely source of the casualty crashes.

Nevertheless, this two-fold increase (normalised to vehicle registrations) in serious crashes over the most recent ten years is a major road safety concern for the ACT. It was noted earlier that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. Whilst the serious crashes were normalised to vehicle registrations, the road network may not have changed significantly. In other words, vehicle density is likely rising and as a result traffic conflicts have risen. This increase in exposure may be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Further research is recommended to understand these changes in injury crashes, and develop countermeasures and prevention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties. It is possible that changes in police-reported injury crash rates might be related to changes in how police identify individuals as 'injured', thus linkage to hospital records provides a more accurate assessment of crash casualties (and allows assessments of individual injuries and injury severity).

Considering all road crashes (property damage, minor injury, serious injury or fatality), before and after the introduction of cameras there was a relatively consistent decreasing trend in all crash counts for both streets with and without mobile cameras. Increases in crashes around the time of the introduction of cameras were evident on both streets with and without mobile cameras, and were more pronounced on streets with cameras, likely because this was the basis for choosing camera streets. It is noted that the magnitudes of crash counts were substantially higher for the case streets compared with the control streets (by an average of 5.4 times), which is likely a result of the fact that mobile camera operations were more likely to be located on streets with high crash counts and/or traffic volumes. It could be argued that both of these effects may be at least partly due to RTM.

The results of the analyses of all intersection crashes (property damage, injury or fatality) indicated that the introduction of fixed red light and speed cameras increased the frequency of crashes followed by a decline to a level slightly lower than baseline levels, while serious intersection crashes decreased slightly along with non-rear-end crashes/right angle collision/right turn crashes. This initial increase in intersection crashes resulted directly from an increase in rear-end crashes at intersections where the cameras were installed but then declined to baseline levels. This trend that did not occur at intersections where fixed cameras were not installed, i.e. rear end crashes continued to rise on control streets. As noted in the literature review, many studies have noted a similar result (Erke 2009, Hoyos 2013, Vanlaar et al 2014, Pulugurtha and Otturu 2014). It is clear that the road safety benefit is confounded, because it is more crashes in the initial stages of camera installation albeit in this study the crashes reduced to levels slightly below baseline levels. Some authors have argued that road safety might tolerate a trade-off of reducing serious speed-related side-impact crashes for increased lower severity rear-end crashes (Kloeden et al 2009). However, this needs to be further researched.

5. Limitations

It should be noted that trends in mean vehicle speeds may have been influenced by other factors not considered in this study. However, driving speeds are, in the main, a very deliberate action by the vehicle operator, and are likely to be influenced directly by enforcement operations that monitor vehicle speeds and penalise operators when they exceed limits, or indirectly by drivers' perceptions of the operation of cameras and related enforcement. Even inadvertent speeding can be influenced by cameras through creating more care to avoid speeding.

The crash study considered nearly two decades of data, over which time many changes may have occurred in the ACT with regards to roadway infrastructure, roadway design, safety devices, vehicle designs, road user type (cyclist, motorcyclists) and road user behaviours (including speeding, alcohol and drug use, protective device use, etc.) in addition to the introduction of speed cameras. There have also been many road safety initiatives in the ACT addressing particular road user groups and behaviours. These factors may have affected crash frequencies, however were not considered in the present study.

As mentioned in the methodology, it should also be considered that the control streets identified for the analyses do not represent a true 'control area'. The issue of spillover effects in evaluation studies of safety cameras has been discussed at length in the literature (Retting, Ferguson & Hakkert 2003; Aeron-Thomas 2005; Erke 2009; Hoyos 2013; Ko, Geedipally, Walden 2013; Porter, Johnson, Bland 2014; McCartt, Hu 2014; Pulugurtha, Otturu 2014; Vanlaar, Robertson, Marcoux 2014). It is acknowledged that in evaluations such as this study, spillover effects may result in an underestimation of the effects of cameras although they may indicate that the public awareness aspect of the camera introduction has been effective.

Another limitation of the study is that road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations considered could not be directly assessed in this study. Moreover, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

The speed survey data used in the present study was derived from surveys on particular streets that were undertaken at irregular intervals. As a result, for any given month all speed survey results were averaged (aggregated separately by case and control streets). Thus the monthly speed survey results used in the statistical models were discrete time data, which may limit the specificity and applicability of the results. It is preferable that each street location had continuous data, such that the statistical models could be stratified by location, such as was the case for the monthly crash counts. However, such data were not available for the speed surveys. It is recommended that subsets of streets with and without cameras are identified, and future surveys be performed on these streets in a regular manner (with the period being defined by resource limitations). This would provide more meaningful results in future speed meta-assessments. It is also noted that assessments of several speeding-related indicators could not be assessed in the present study, including proportion of vehicles speeding, proportion more than 20km/h over the speed limit, etc. More detailed information on the speed surveys performed might have provided further insights into driver speeding. These data are stored on an old computer system from which it was not possible to extract bulk data (i.e. for the 1,758 speed surveys assessed in the present study). Consequently, the present study used data from the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

6. Final brief conclusions

Along with the conclusions listed at the front of this report, the following summary conclusions are provided for completeness of the report.

Mobile cameras seem to have been effective initially as seen by reductions in serious crashes in the period 2002-2006 and the pre/post analysis for cases but not for controls. The serious injury crashes increased in case streets following 2006 and seemed to coincide with decreasing and less consistent enforcement which is what would be expected if the cameras were located in the high risk streets compared to controls.

Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. The increase in speeds would explain the increase in serious crashes. Avoidance mechanisms could be based on prediction of location and/or time/ and or/day and/or the vehicles being used, or provision of information from various sources.

Fixed cameras did not seem to be as effective in regards to all crashes as they showed increases on case locations compared to controls which then returned to baseline levels. However, this may have been the result of changes in rear-end crashes which may have been because drivers became aware of where the fixed cameras were. This in turn may have had an effect on rear end crashes mostly. The continuing increase in traffic demand could also have played a role. Nevertheless, there appeared to be a fall in serious injury crashes.

These results suggest that more work needs to be done to understand why serious crashes have increased since 2007 and what can be done to improve the effectiveness of cameras since the initial introduction and the research literature demonstrates that they can be effective. In the ACT it would be beneficial for road safety to develop a more sustained programme of re-implementation and evaluation of safety cameras and road safety public awareness campaigns.

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Appendix A: Case and control streets and intersections

STREETS

CASES	CONTROLS
Anthill St	A'Beckett St
Athllon Drv	Archibald St
Barry Drv	Ballumbir St
Barton Hwy	Boldrewood St
Bateman St	Brigalow St
Beasley St	Canopus Cr
Belconnen Way	Chrisholm St
Canberra Ave	Condamine St
Carruthers St	Cowper St
Chuculba Cr	Culgoa Cct
Clift Cr	Dalrymple St
Clive steele Ave	Davenport St
Darwinia Ter	De Burgh St
David St	Emu Bank
Drakeford Drv	Fincham Cr
Dryandra St	Flemington Rd
Ellerston Ave	Forbes St
Federal Hwy	Foveaux St
Florey Drv	Goodwin St
Gilmore St	Grey St
Ginninderra Drv	Hawdon St
Gladstone St	Hopetoun St
Goyder St	Knox St
Groom St	Krefft St
Gungahlin Drv	Langdon Ave
Heyson St	Mackennal St
Hindmarsh Dr	Macpherson St
Kent St	McCaughey St
Kitchener St	McCulloch St
La perouse St	Melba St
Lady Denman Drv	Miller St
Launceston St	Moore St
Learmonth Drv	Mortimer Lewis
Livingston Ave	Murranji St
Macgregor St	Palmer St
Melrose Drv	Paul Coe Cr
Monaro Hwy	Ratcliffe Cr
Namatjira Drv	Scrivener St
Northbourne Ave	Spalding St
Novar St	Vanisttart Cr
Officer Cr	Verbrugghen St
Petterd St	Victoria St
Phillip Ave	Watson St
Ross smith Cr	Wattle St
Theodore St	William Slim Dr
Tillyard Drv	Windeyer St
Tuggeranong Pkwy	Wisdom St
Williamson St	

INTERSECTIONS

CASES	CONTROLS
Northbourne Ave and London Circuit	Northbourne and Swinden
Northbourne Ave and Barry Drive	Northbourne, Eloura and Gould
Drakeford Drive and Marconi Cres	Drakeford, Sulwood and Tuggeranong
Northbourne Ave and Antill Street	Northbourne, Girrahween and Masson
Ginninderra Drive and Aikman Drive	Ginninderra and Kingsford Smith
Hindmarsh Dr and Tuggeranong Pkwy	Hindmarsh and Monaro
Ginninderra Drive and Coulter Drive	Ginninderra and Lance Hill
Barry Drive and Marcus Clarke Street	Barry and McCaughey
Hindmarsh Drive and Yamba Drive	Hindmarsh and Streeton
Hindmarsh Drive and Ball Street	Hindmarsh and Jerrabomberra
Hindmarsh Drive, Newcastle St and Canberra Ave	Hindmarsh and Larakia
Canberra Ave, Captain Cook Cres and Manuka Circle	Canberra and Dalby
Gungahlin Drive and Gundaroo Drive	Gungahlin and Sanford

Appendix B: Results of literature searches

Table B1: Results of review of peer-reviewed scientific published literature for each search engine

Database	Search Term	# Retrievals	Repeats	Remaining	Final	Search Strategy
Web of Science	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "topic")	7				Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	25				Search in "Topic"
	Red light camera + Enforcement + Evaluation	14				Search in "Topic"
	Speed (search in "title") + Camera (search in "title") + Enforcement (search in "topic")	27				
Subtotal		**73**	**19**	**54**	**51**	
PsycINFO	Speed + Camera + Evaluation	3	22			Search in "Abstract", Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	0				Search in "Abstract"
	Red light camera + Enforcement + Evaluation	1				Search in "Abstract"
	Speed (search in "abstract") + Camera (search in "abstract") + Enforcement (search in "all fields")	16				
Subtotal		**20**	**3**	**17**	**8**	
Scopus	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "abstract")	5	12			Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	27				Search in "Article title, abstract, keywords"
	Red light camera + Enforcement + Evaluation	19		The		Search in "Article title, abstract, keywords"
	Speed + Camera + Enforcement	12				Search in "Article title"
Subtotal		**63**	**14**	**49**	**14**	
PAIS International	Speed + Camera + Evaluation	0	49			Search in "Anywhere"
	Speed enforcement camera* + Evaluat*	1				Search in "Anywhere"
	Red light camera + Enforcement + Evaluation	1				Search in "Anywhere"
	Speed + Camera + Enforcement	7				Search in "Anywhere"
Subtotal		**9**	**1**	**8**	**6**	
Final repeats			**49**			
Total		**165**	**86**	**128**	**79**	

Table B2: Australian government road safety authority websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
NSW - Roads & Traffic Authority	1	0	0	1	0	0	0	1
NSW - Transport for NSW - Centre for Road Safety	1	1	1	1	0	0	0	1
VIC - VicRoads	0	0	0	0	0	0	0	0
VIC - Cameras Save Lives	1	0	0	0	0	0	0	0
WA - Department of Transport	0	0	0	0	0	0	0	0
QLD - Department of Transport and Main Roads	1	1	1	1	1	0	0	0
SA - Department of Planning, Transport and Infrastructure	1	1	1	1	1	1	1	0
SA - Government of South Australia	0	0	0	0	0	0	0	0
NT - Northern Territory Transport Group	0	0	0	0	0	0	0	0
TAS - Department of Infrastructure, Energy & Resources - Transport	0	0	0	0	0	0	0	0
AU - Department of Infrastructure and Transport	1	1	0	0	0	0	0	1

Table B3: Individual Road Safety organisation websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
US - National Highway Traffic Safety Administration (NHTSA)	0	0	0	0	0	0	0	0
US - Liberty Mutual Research Institute for Safety	0	0	0	0	0	0	0	0
CA - Transport Canada	1	1	0	0	0	0	0	0
UK - Department for Transport (DfT)	1	1	1	1	1	0	0	1
EU - Eurosafe (European Association for Injury Prevention and Safety Promotion)	0	0	0	0	0	0	0	0
EU - European Agency for Safety and Health at Work	0	0	0	0	0	0	0	0
AU - Australian Transport Safety Bureau (ATSB)	0	0	0	0	0	0	0	0
AU - Austroads	1	1	1	1	1	0	0	1
AU - Roadwise	0	0	0	0	0	0	0	0
AU - Standing Council on Transport and Infrastructure (SCOTI, formerly Australian Transport Council)	1	0	0	1	1	0	0	0
AU - Australian Bureau of Statistics (ABS)	1	0	1	1	0	0	0	0
AU - Australiasian College of Road Safety (ACRS)	1	0	1	1	0	0	0	1
AU - RACV	1	1	1	1	1	0	0	0
AU - Queensland Travelsafe Committee	1	1	1	1	0	0	0	1
AU - NSW Bureau of Crime Statistics	0	0	0	0	0	0	0	0
AU - NRMA	0	0	0	0	0	0	0	0
AU - NRMA - ACT Road Safety Trust	0	0	0	0	0	0	0	0
AU - NSW StaySafe Committee	0	0	0	0	0	0	0	0
AU - NSW Motor Accidents Authority	0	0	0	0	0	0	0	0
AU - Transport Accident Commission (TAC) in Victoria	0	0	0	0	0	0	0	0
AU - The State Attorney-General's Departments	0	0	0	0	0	0	0	0

NZ - Transport Agency	1	1	0	0	1	0	0	1
NZ - Ministry of Transport	0	0	0	0	0	0	0	0
SW – Swedish Transport Administration (Trafikverket)	1	0	1	0	0	0	0	1
Ireland – Road Safety Authority	1	0	1	0	0	0	0	0
The Netherlands – EuroRAP	0	0	0	0	0	0	0	0
France – Institut National De Recherche Sur Les Transports Et Leur Securite (INRETS)	0	0	0	0	0	0	0	0

Table B4: Research centre websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
QLD - Queensland University of Technology - CARRS-Q	1	0	1	1	0	0	0	1
VIC - Monash University - MUARC	1	1	1	0	1	0	0	1
SA - University of Adelaide - Centre for Automotive Safety Research	1	1	0	1	0	0	0	1
NSW - Sydney University - Institute of Transport and Logistics Studies	0	0	0	0	0	0	0	0
NSW - UNSW - TARS	1	1	1	1	0	0	0	1
AU - Australian Road Research Board	1	1		1	0	0	0	0
US - Research and Innovative Technology Administration: National Transportation Library	1	1	1	1	0	1	0	1
US - Transportation Research Board	0	0	0	0	0	0	0	0
US - American Transportation Research Institute	0	0	0	0	0	0	0	0
UK - Transport Research Laboratory	1	1	0	1	0	0	0	1

Appendix C: Results of ACT community attitudes to speeding surveys

"In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"

Year	Increased (%)	Same (%)	Decreased (%)	Don't Know (%)
2011	64	27	5	4
2009	65	26	4	6
2008	63	27	8	2
2006	69	22	4	5
2005	72	21	3	3
2004	71	15	8	7
2003	77	15	5	3
2002	62	22	7	8
2001	74	13	7	5
2000	69	29	7	4
1999	58	30	6	5
1998	56	34	8	2
1997	55	33	7	5
1996	54	26	8	13
1995	59	28	4	9

"Have you personally been booked for speeding in the last two years?"
...and, if so, "Have you personally been booked for speeding in the last six months?"

Year	Last 2 years (%)	Last 6 months (%)
2011	20	9
2009	19	9
2008	15	6
2006	17	6
2005	24	9
2004	21	3
2003	28	8
2002	21	9
2001	17	8
2000	16	4
1999	11	3
1998	13	5
1997	25	11
1996	20	10
1995		9

"Thinking about 60km/h speed zones in urban areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	64	31	64	20
2009	65	34	64	22
2008	64	36	65	21
2006	64	32	64	15
2005	64	33	64	12
2004	65	28	65	13
2003	64.2	33	65.4	10
2002		51	64.9	15
2001		44		
2000		38		
1999		49		
1998		49		
1997		49		
1996		42		
1995		34		

"Thinking about 100km/h speed zones in rural areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	106	25	106	21
2009	110	23	107.9	15
2008	105.5	28	108	14
2006	107	18	107	5
2005	109	20	109	7
2004	110	23	109	8
2003	106.8	22	108.7	6
2002		35	109.2	10
2001		26		
2000		25		
1999		28		
1998		36		
1997		23		
1996		27		

Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:

- Fines for speeding are mainly intended to raise revenue
- I think it is okay to exceed the speed limit if you are driving safely
- Speed limits are generally set at reasonable levels
- If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
- An accident at 70km/h will be a lot more severe than an accident at 60km/h

Year	Speeding fines mainly intended to raise revenue (%)	OK to speed if driving safely (%)	Speed limits generally reasonable (%)	More likely to be involved in accident if increase speed by 10km/h (%)	Accident at 70m/h more severe than 60km/h (%)	TOTAL: Cautious / Conservative attitude to speeding / speed limit enforcement (%)
2011	51	29	85	62	92	26
2009	59	21	86	73	92	25
2008	55	38	85	65	94	22
2006	50	29	88	71	96	26
2005	51	28	87	67	91	28
2004	51	34	87	66	93	
2003	49	33	86	70	91	
2002	48	34	89	63	95	
2001	51	34	87	71	95	
2000	48	38	85	67	89	
1999	53	39	94	69	89	

"Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?" ... and then,
"Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"

Year	Level of enforcement			Severity of penalties		
	Should increase (%)	Should decrease (%)	Stay the same (%)	Should increase (%)	Should decrease (%)	Stay the same (%)
2011	44	8	44	27	6	63
2009	46	7	43	24	9	61
2008	45	5	48	23	6	63
2006	37	7	54	23	8	62
2005	37	10	52	20	8	68
2004	47			25		
2003	34			17		

"Do you think that 50km/h in residential area is too low or too high, or about right?" and
"Do you think that limits below 60km/h should be set on more streets, fewer streets, or is it about right as is?"

Year	50km/h speed limit in residential areas are:			Speed limits below 60km/h should be set on:		
	Too low (%)	Too high (%)	About right (%)	Increase the number of <60km/h streets	Decrease the number of <60km/h streets	About right
2009	13	7	80	20	6	74
2008	11	4	86	20	7	73
2006	20	3	77	16	18	66
2005	20	2	78	22	13	65
2004	20	<1	80	24	19	57

"Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways"

They were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"

Year	Approve strongly (%)	Approve somewhat (%)	Total approve (%)	Not care either. way (%)	Disapprove somewhat (%)	Disapprove strongly (%)	Don't Know (%)
2003			91				
2002	42	34	77	4	10	10	0
2001	45	27	72	6	15	6	1
2000	28	27	55	8	13	22	1
1999	27	33	60	4	15	20	2
1998	39	18	58	13	12	18	0
1997	17	24	41	13	26	20	1
1996	38	20	58	3	19	20	0
1995	17	28	45	9	26	18	2

"How often do you drive at 10km/h or more over the speed limit?"

Year	%
2011	5
2009	11
2008	5
2006	9
2005	8
2004	9

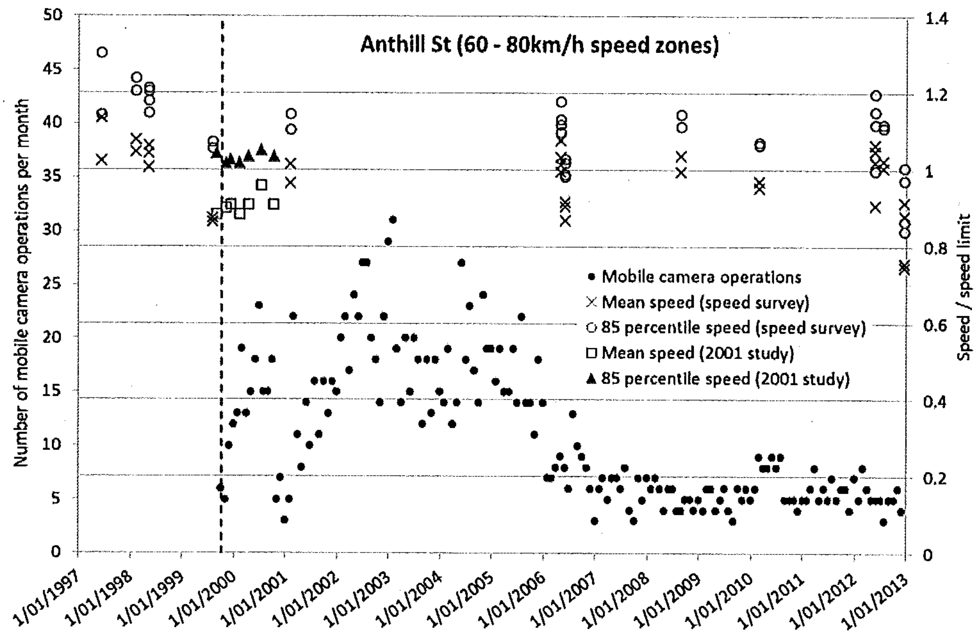
"In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

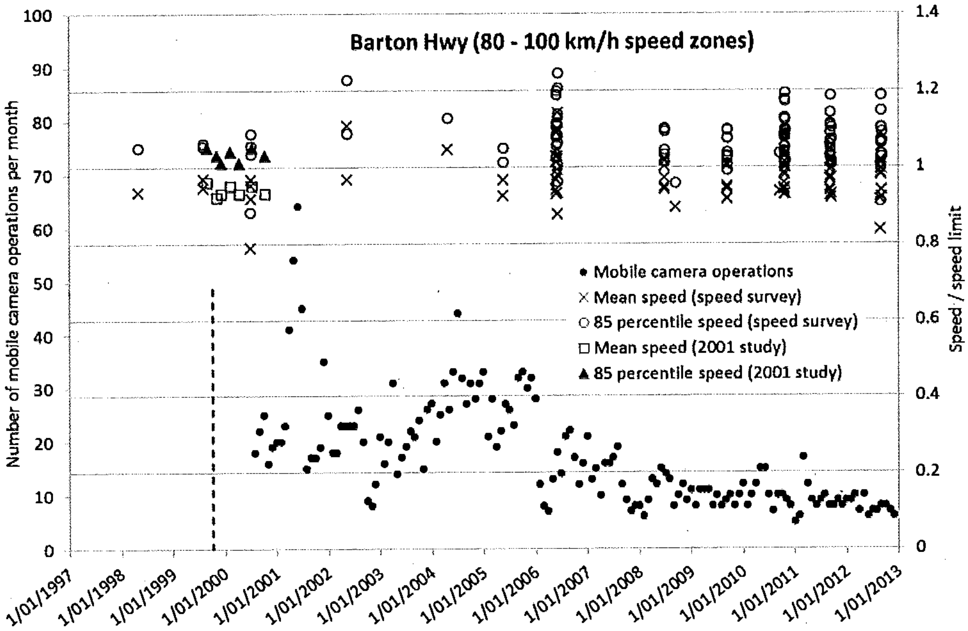
Year	Increased (%)	Stayed the same (%)	Decreased (%)
2011	1	76	23
2009	4	73	23
2008	4	73	23
2006	7	68	25
2005	2	69	29
2004	5	65	28
2003	6	67	25
2002	5	66	28
2001	5	62	32
2000	4	61	33
1999	6	70	21
1998	4	73	23
1997	6	62	32
1996	7	52	41
1995	11	62	26

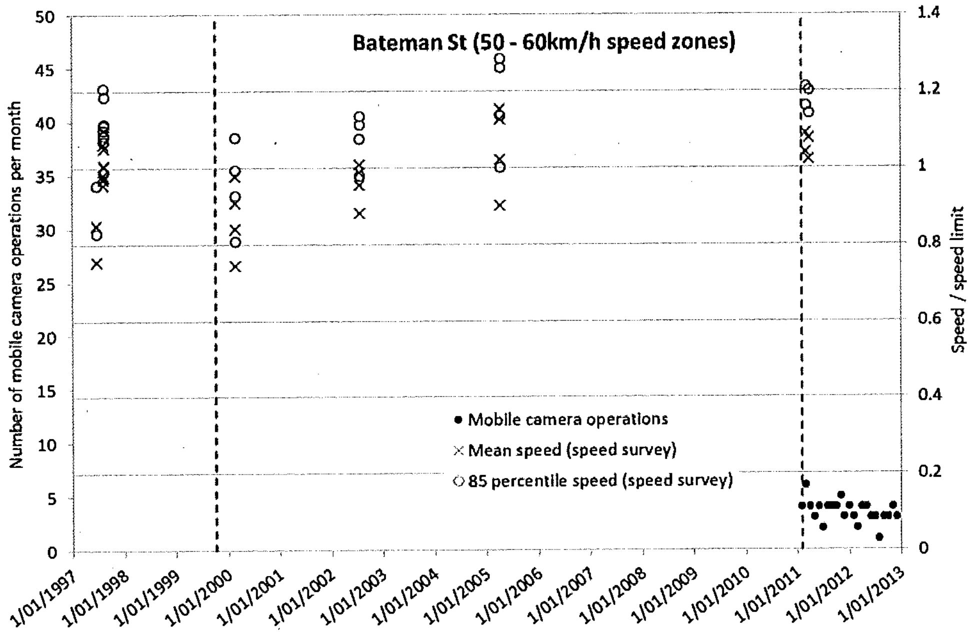
Appendix D: Individual speed survey results for case and control streets

This appendix contains plots for most of the case and control street locations used in this study (a few streets were excluded due to plotting issues). The available speed surveys provided by the Territory and Municipal Services Directorate are plotted for all streets, where mean and 85th percentile speeds are normalised to the speed zone in which the survey was undertaken (in some cases surveys were undertaken on sections of the same street with different speed limits). Additional speed surveys undertaken by ARRB in the 18 months following the introduction of cameras in October 1999 are also plotted where available (Edgar, A., 2001. Evaluation of the Effectiveness of Speed Cameras in the ACT, Final Report 1. NRMA-ACT Trust Project Evaluation Reports, ARRB Transport Research). The start date of October 1999 is identified on all plots. For case streets the number of mobile operations undertaken per month along that particular street are also plotted.

CASE STREETS




Barton Hwy (80 - 100 km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Bateman St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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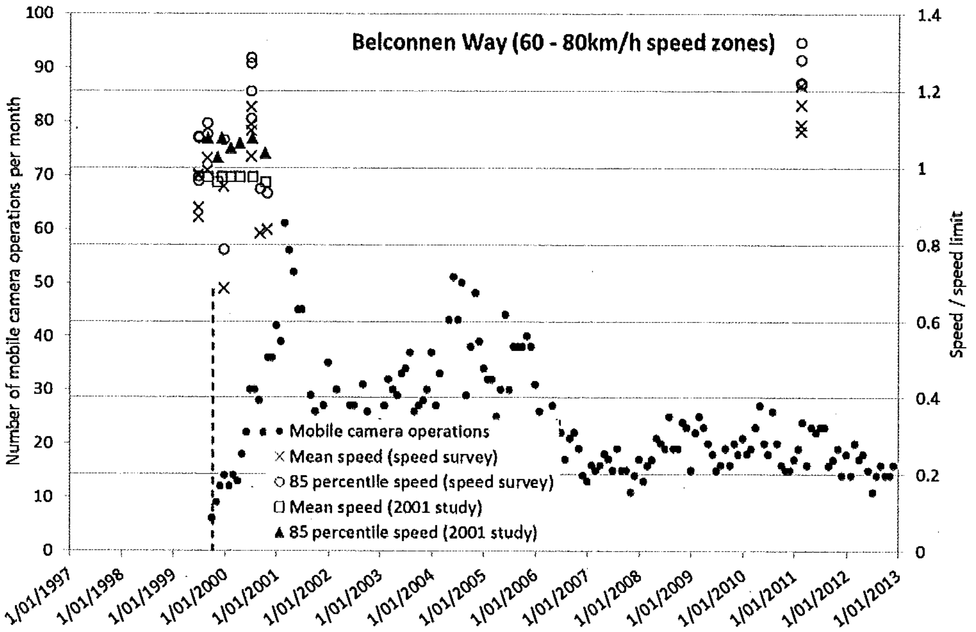
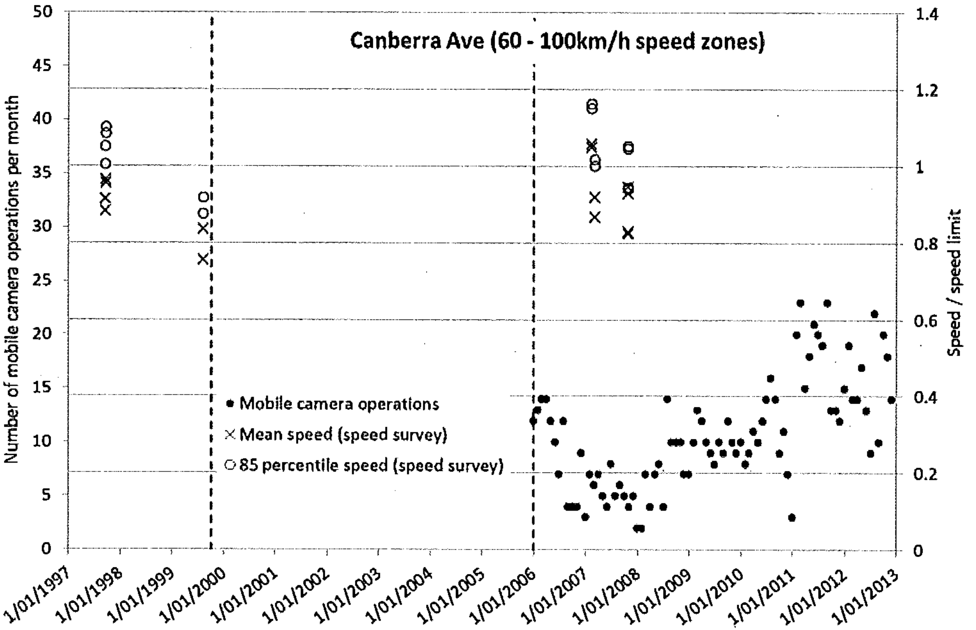
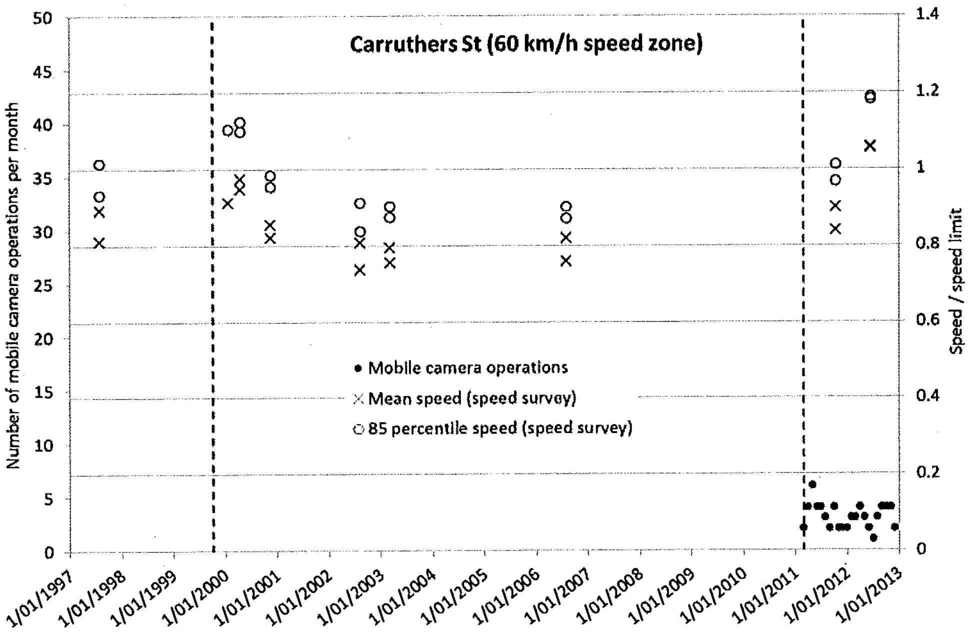
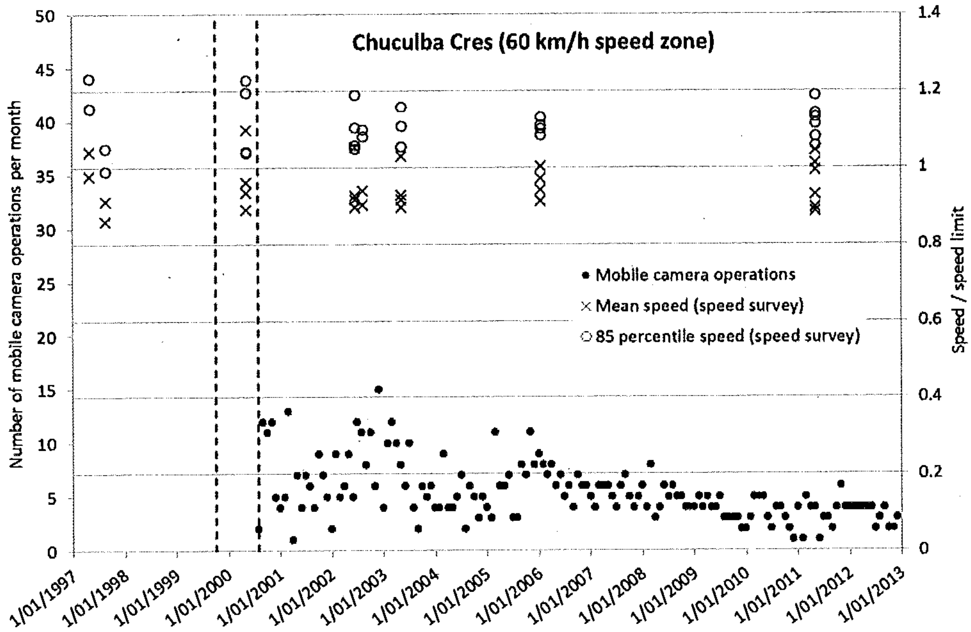
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Belconnen Way (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

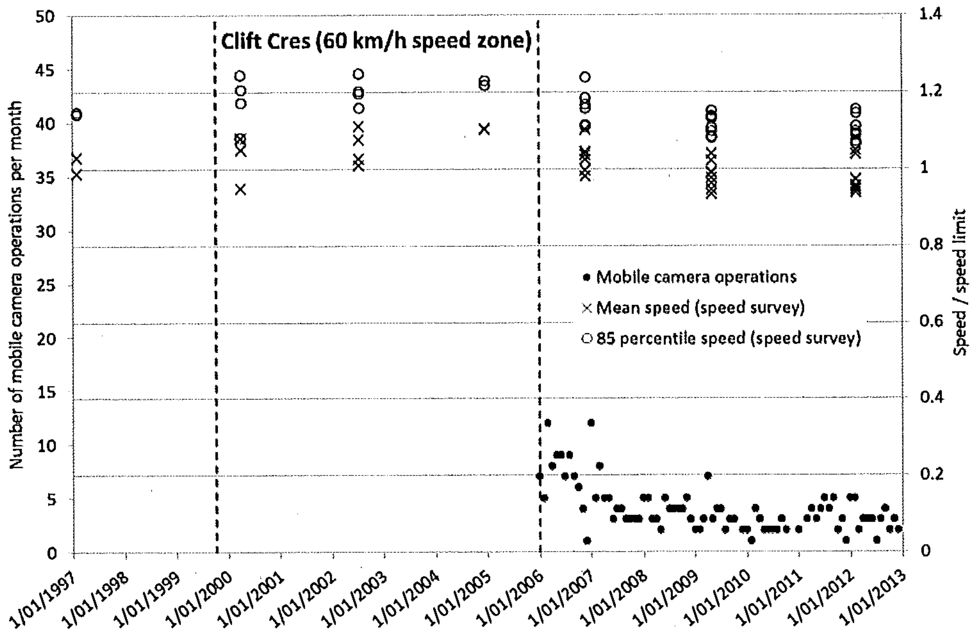

Canberra Ave (60 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

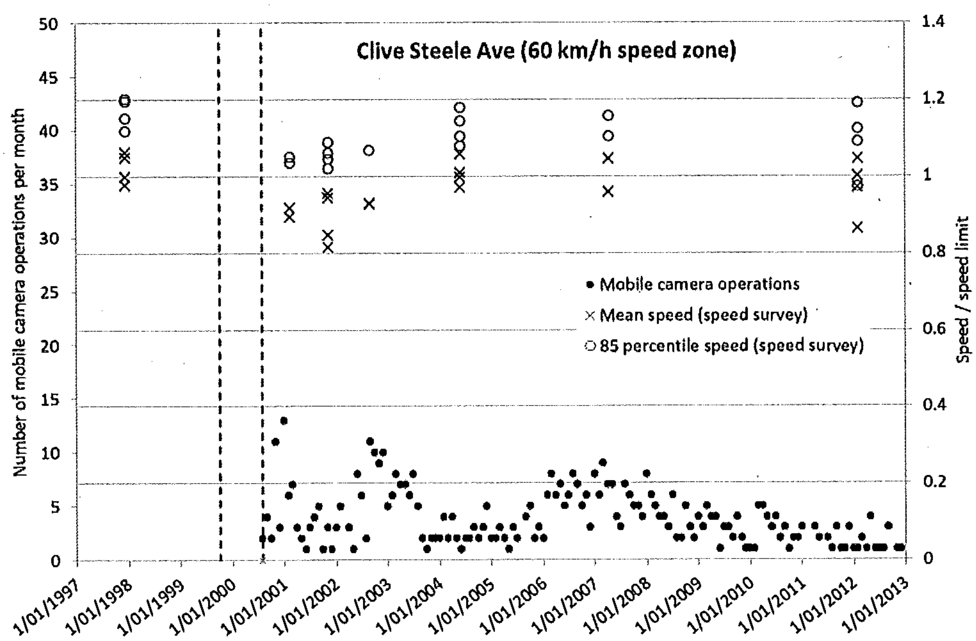


Carruthers St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



Chuculba Cres (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Clift Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Clive Steele Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
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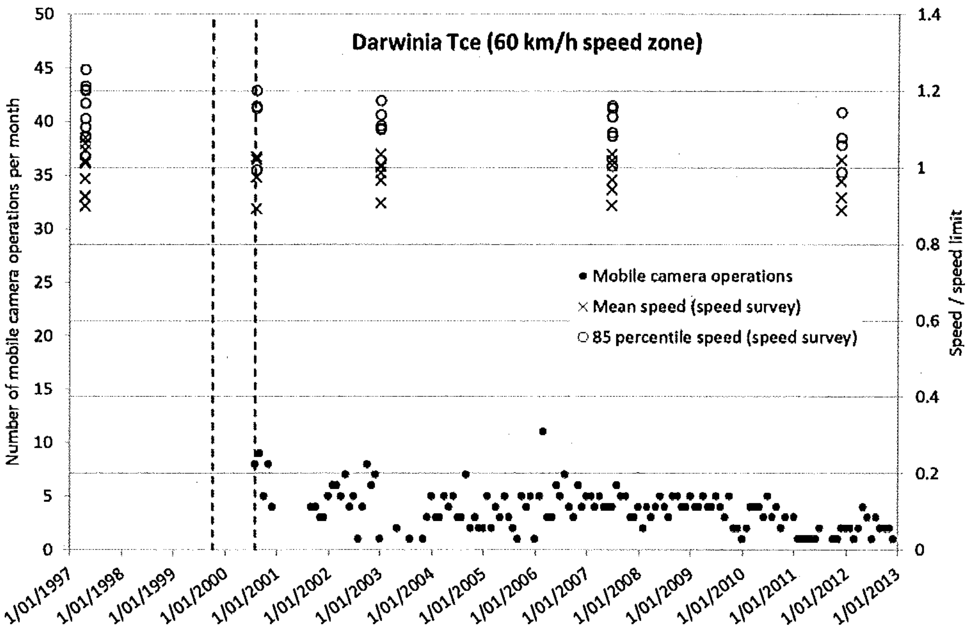
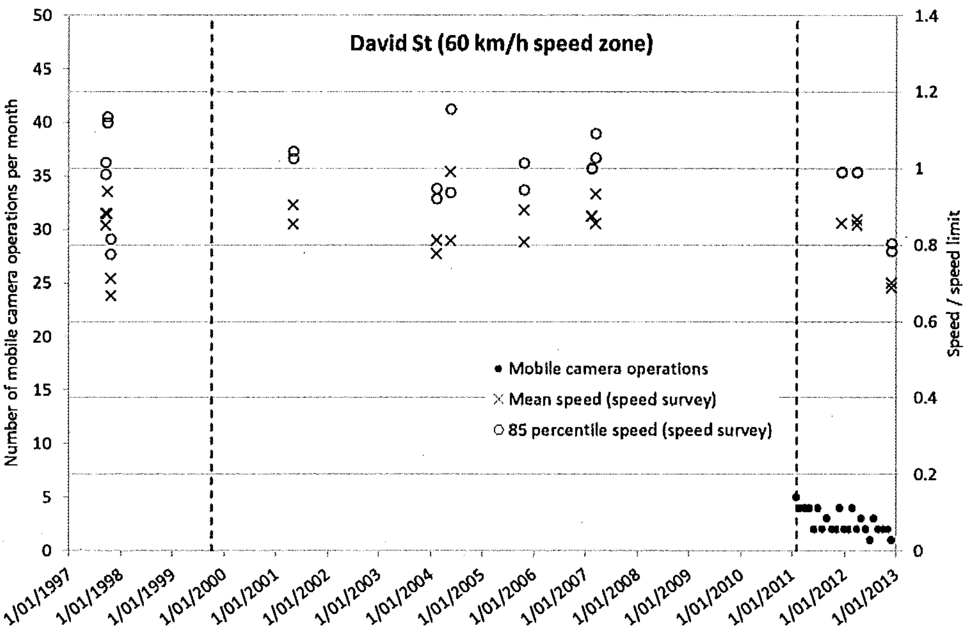
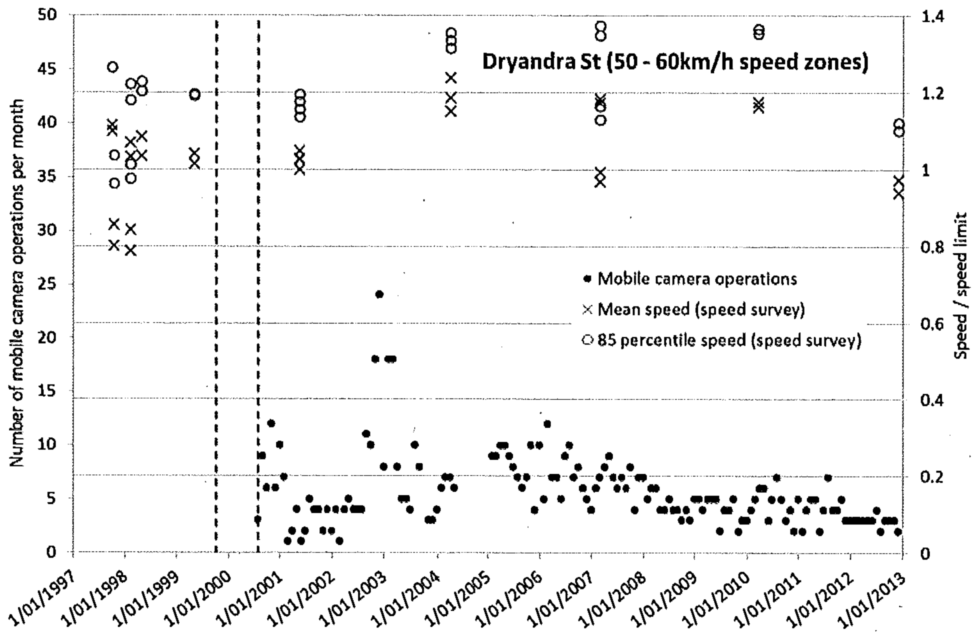
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

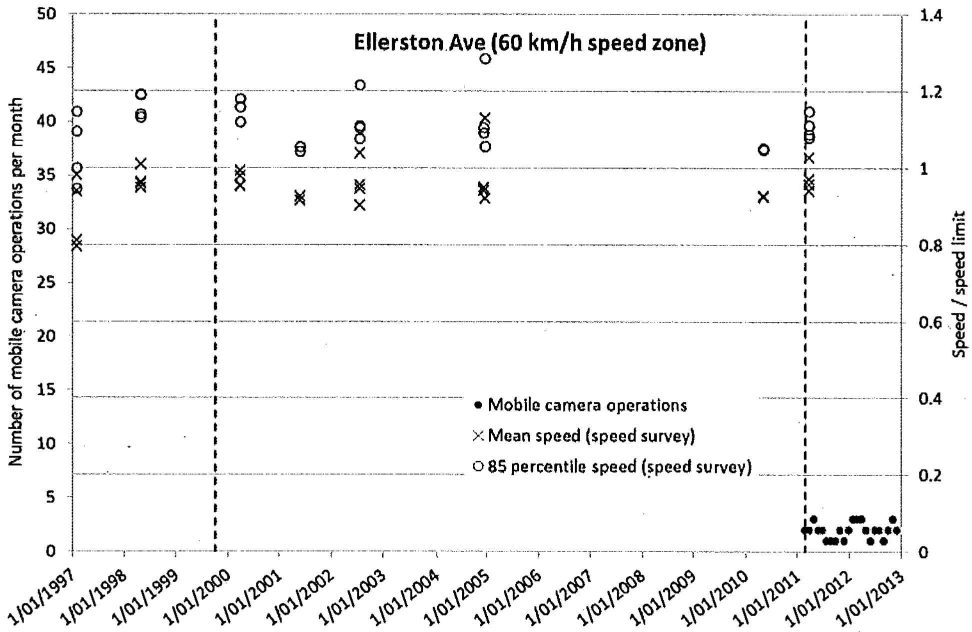


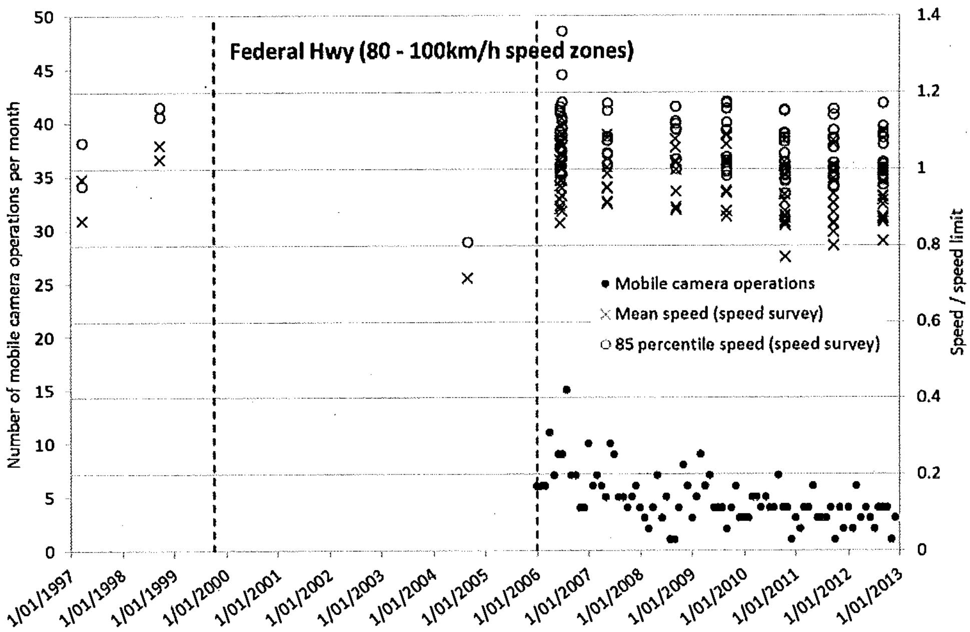
Darwinia Tce (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit

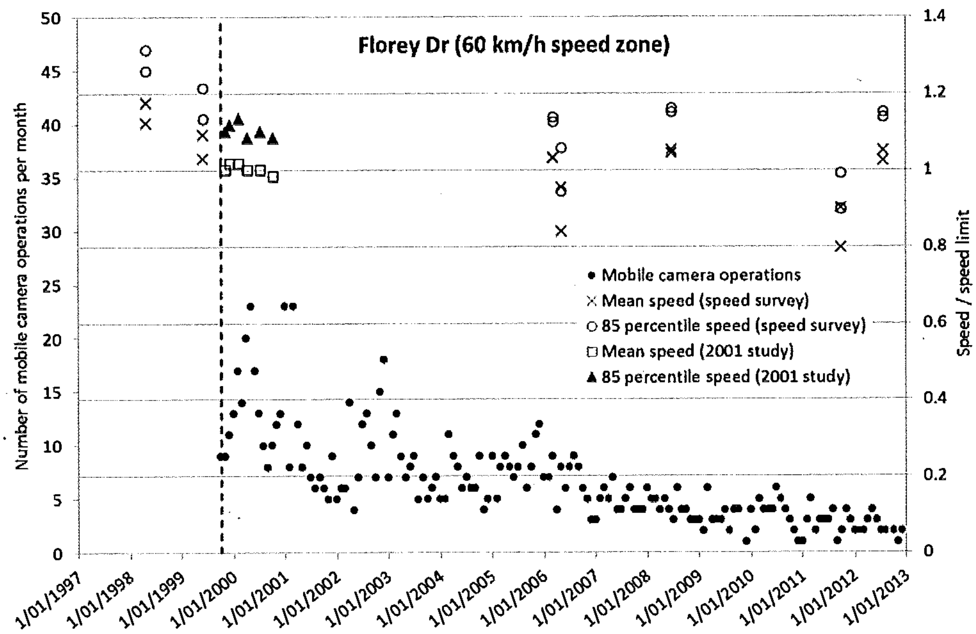


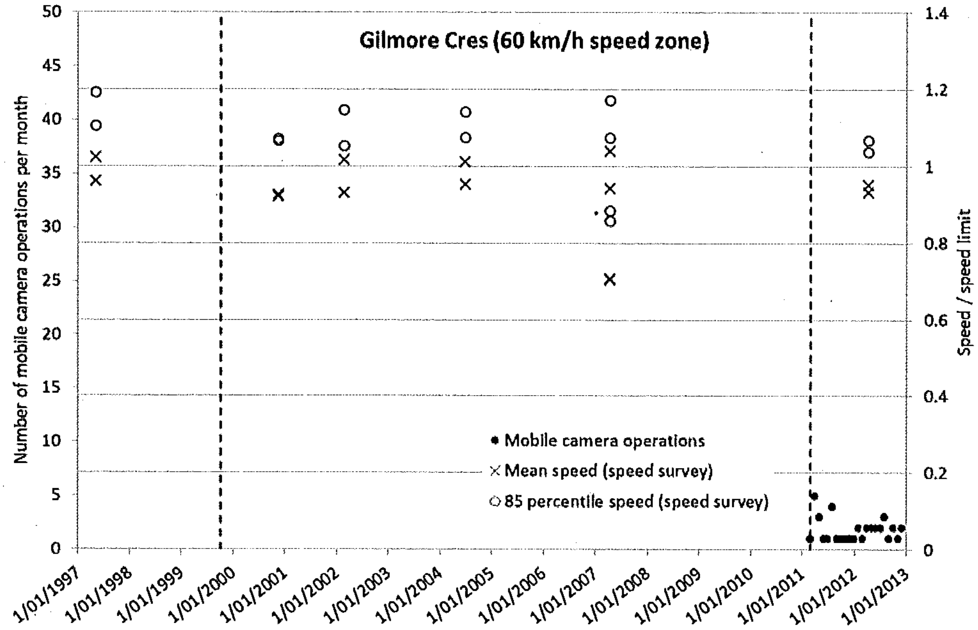
David St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit

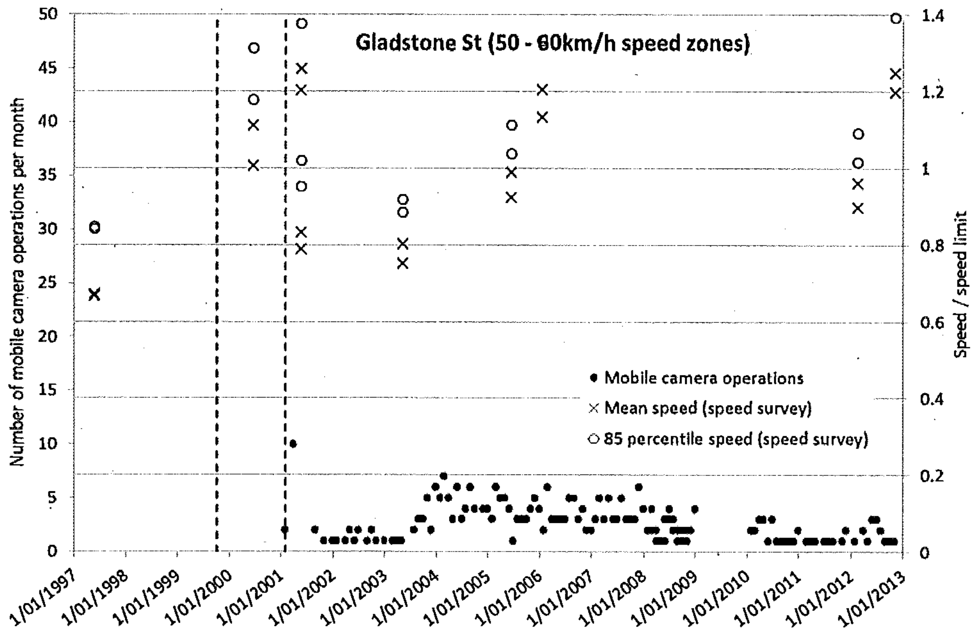

Dryandra St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

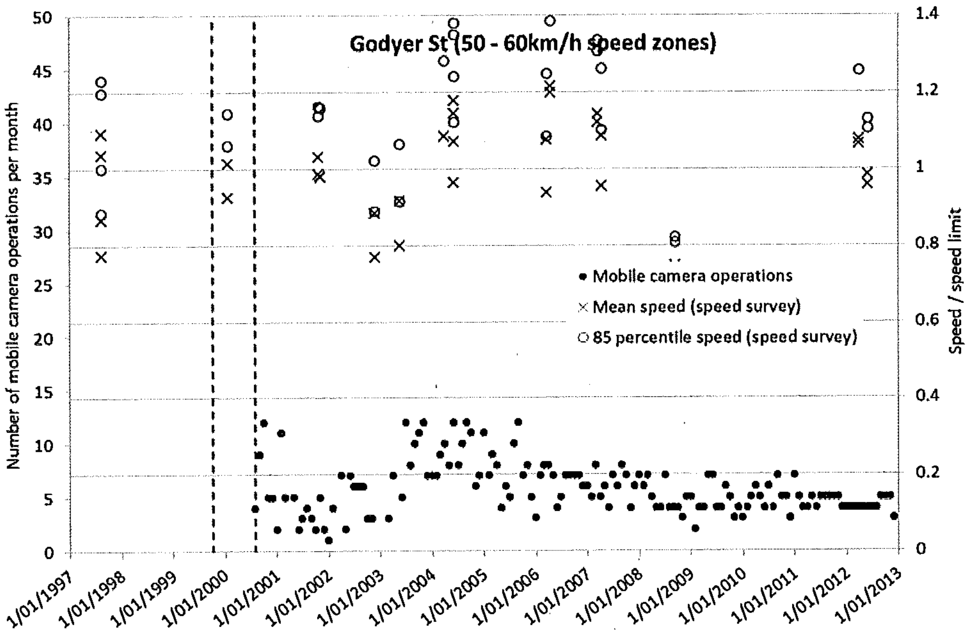

Ellerston Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

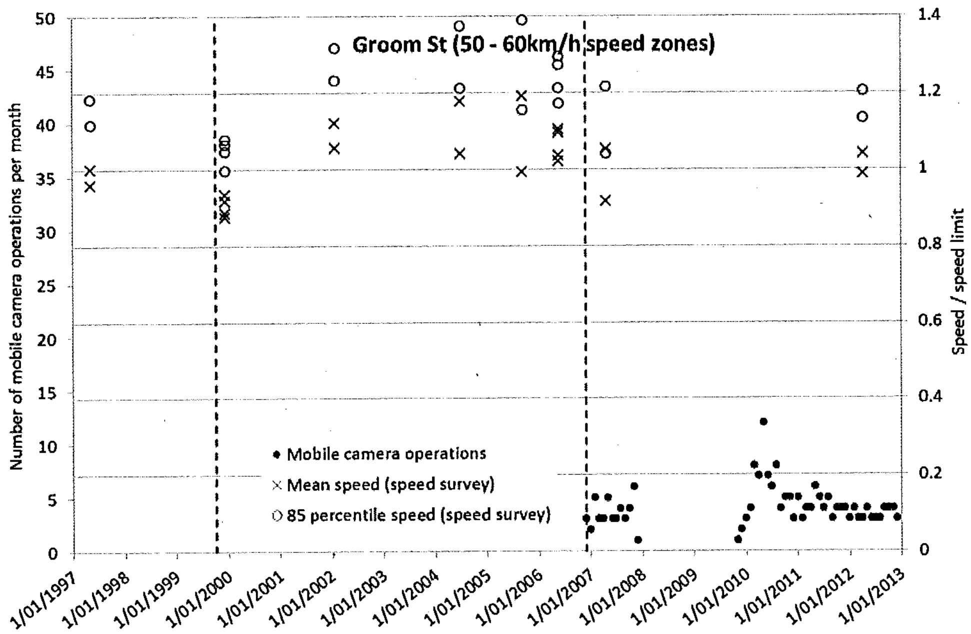

Federal Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

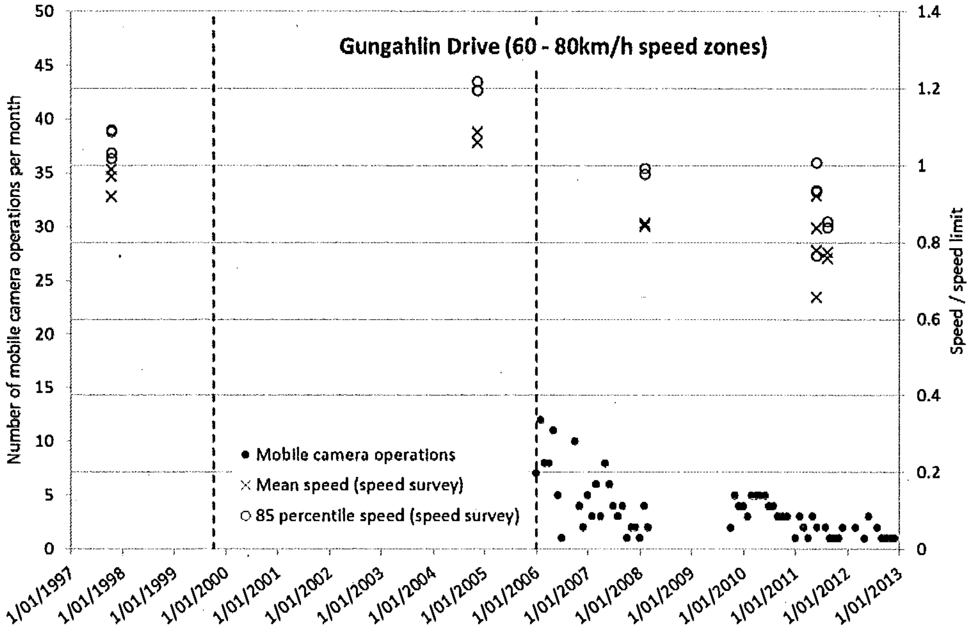

Florey Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
□ Mean speed (2001 study)
▲ 85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

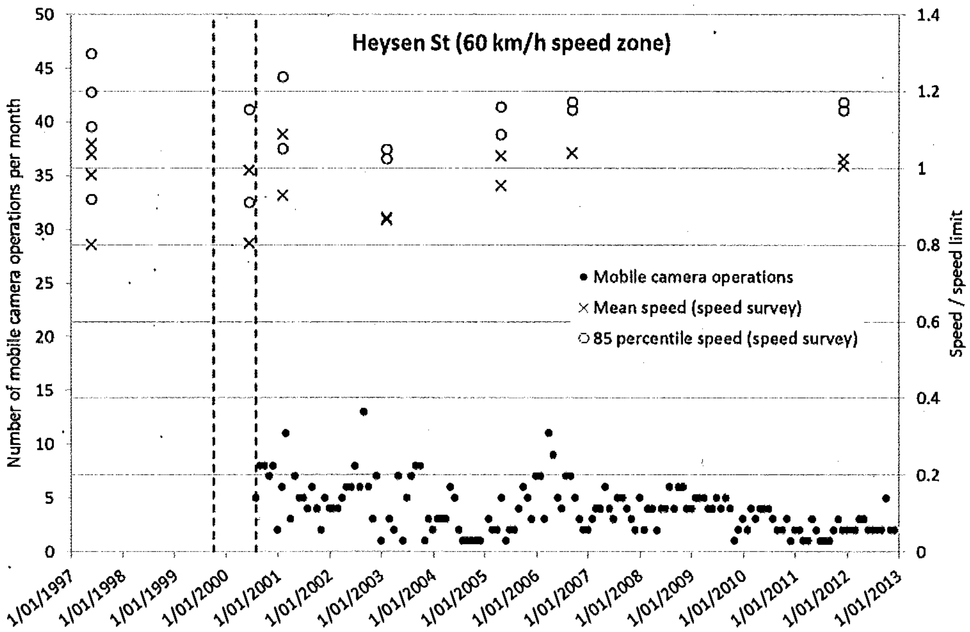

Gilmore Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

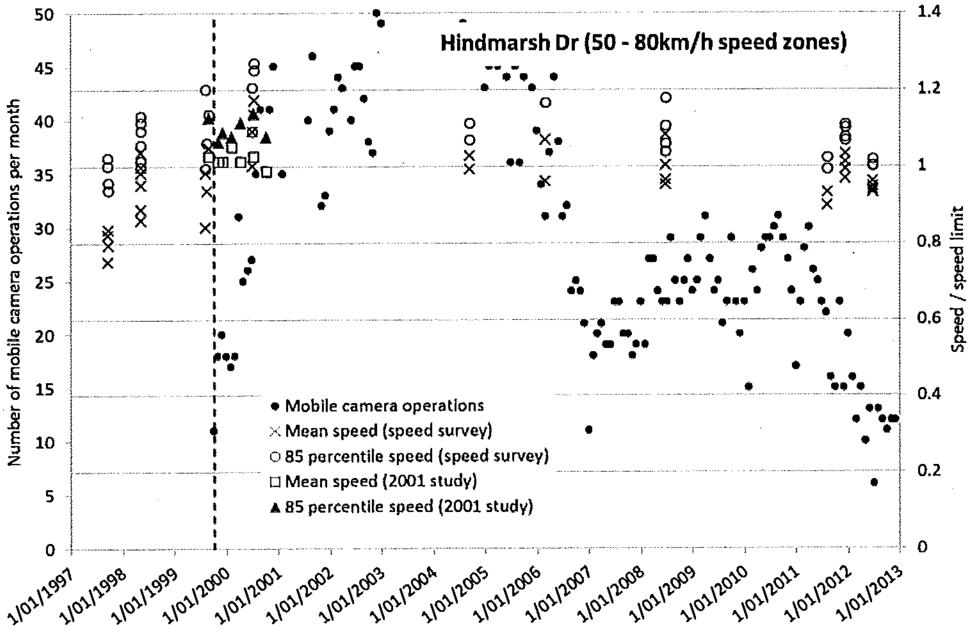

Gladstone St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

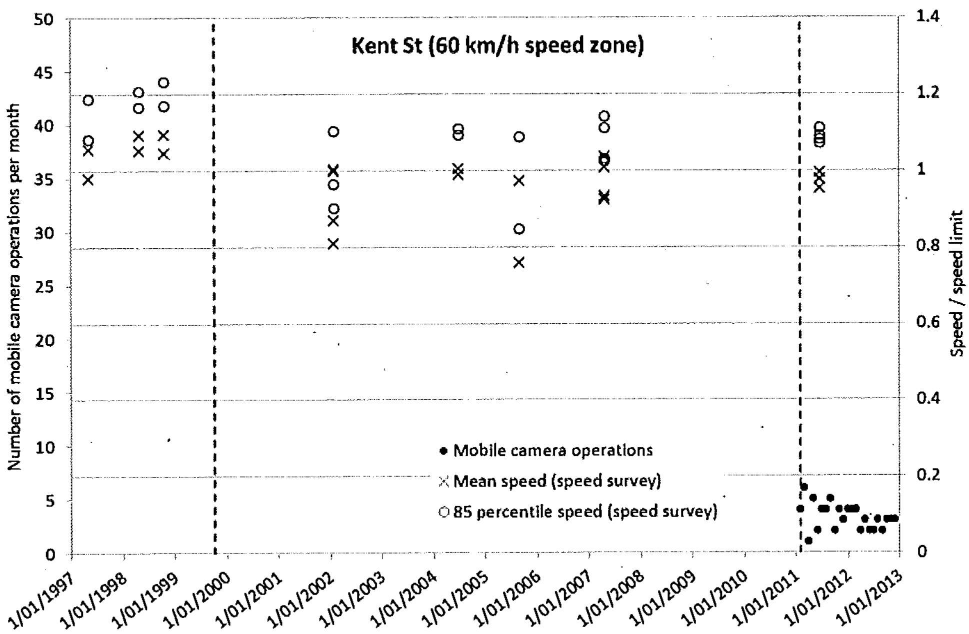

Godyer St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

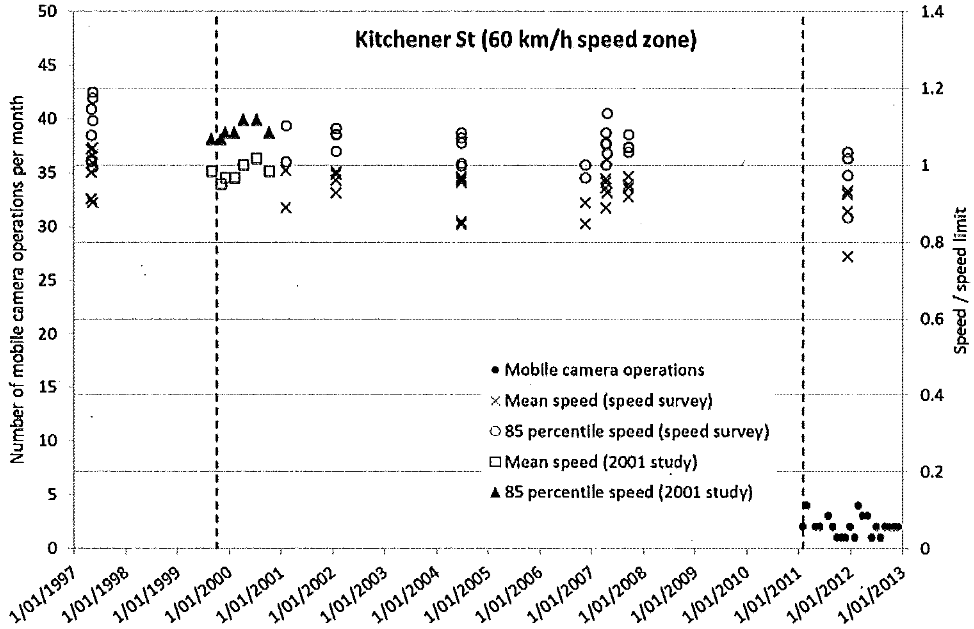

Groom St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Gungahlin Drive (60 - 80km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Heysen St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hindmarsh Dr (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Kent St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Kitchener St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
□ Mean speed (2001 study)
▲ 85 percentile speed (2001 study)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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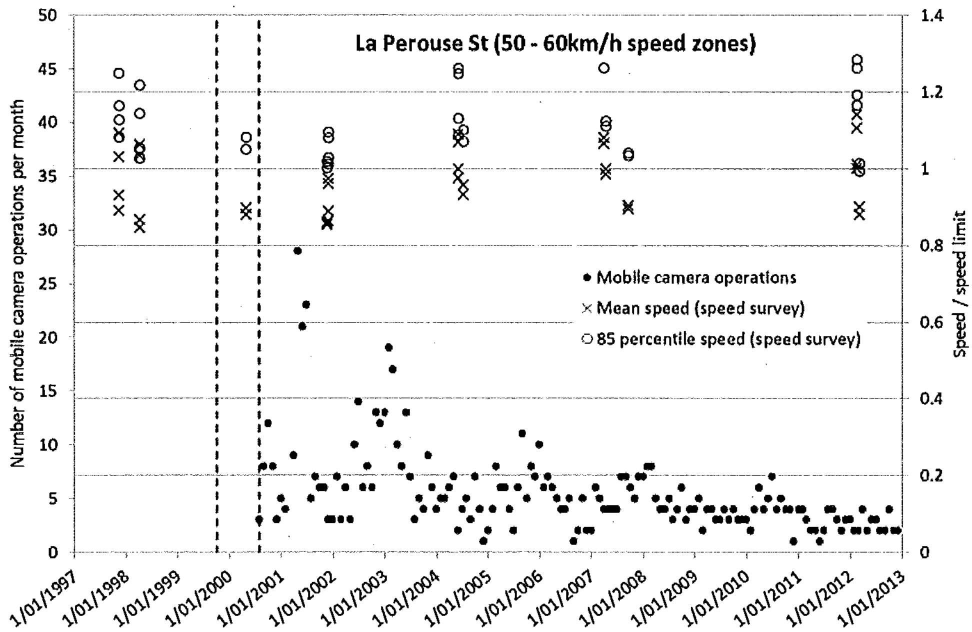
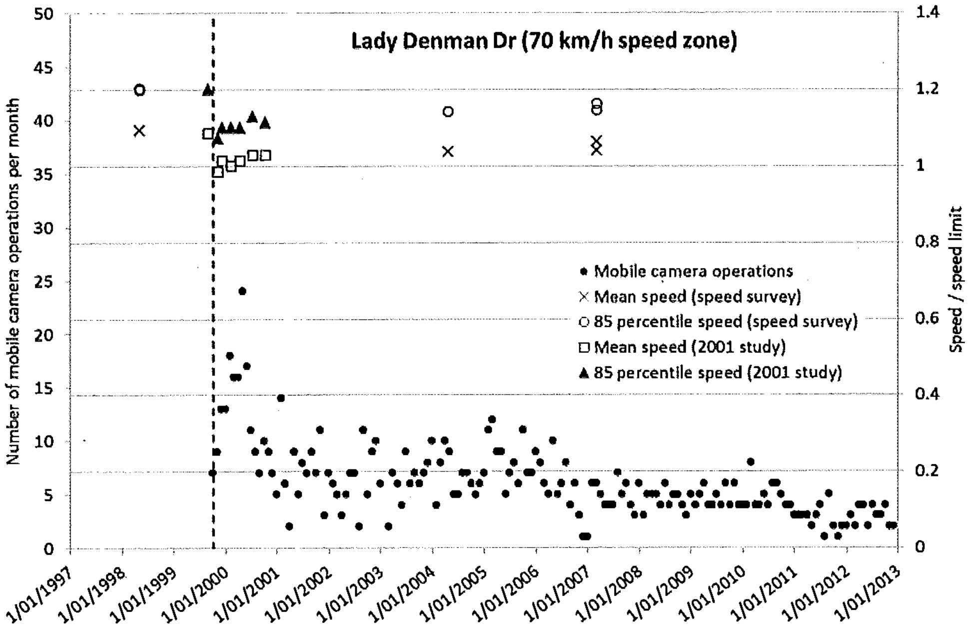
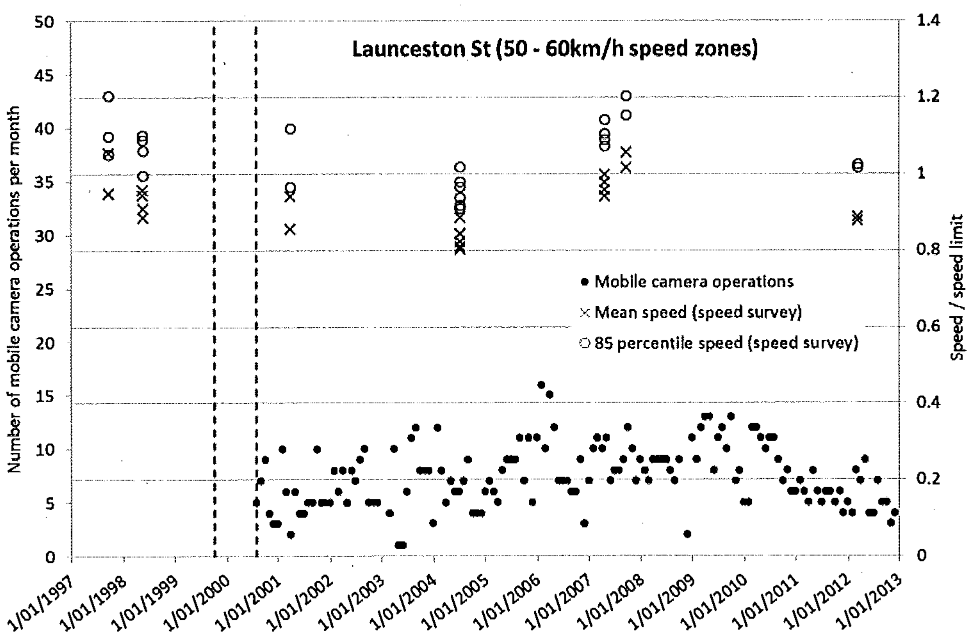
1/01/2012
1/01/2013


La Perouse St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Lady Denman Dr (70 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Launceston St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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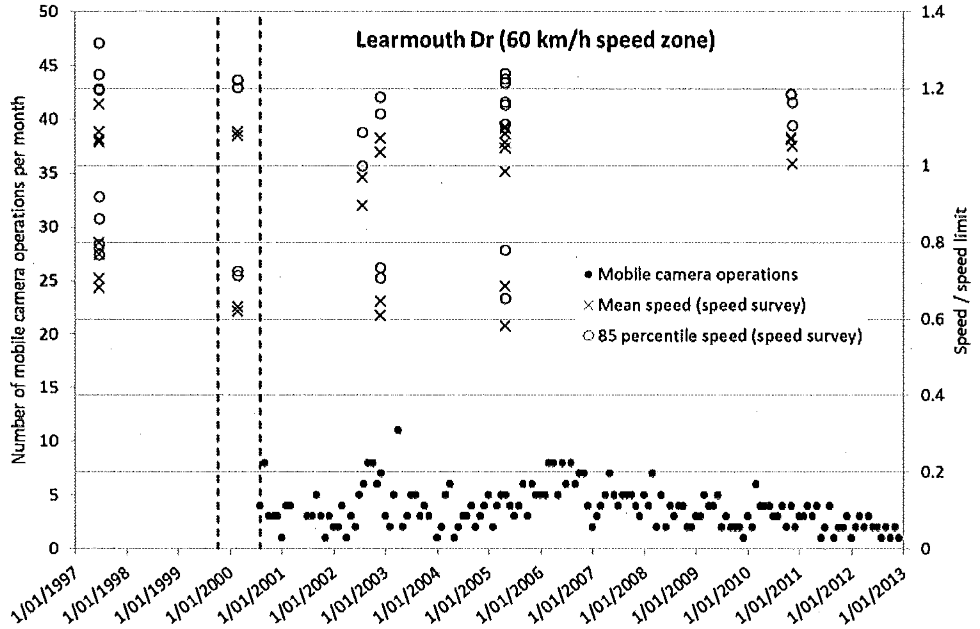
1/01/2011
1/01/2012
1/01/2013


Learmouth Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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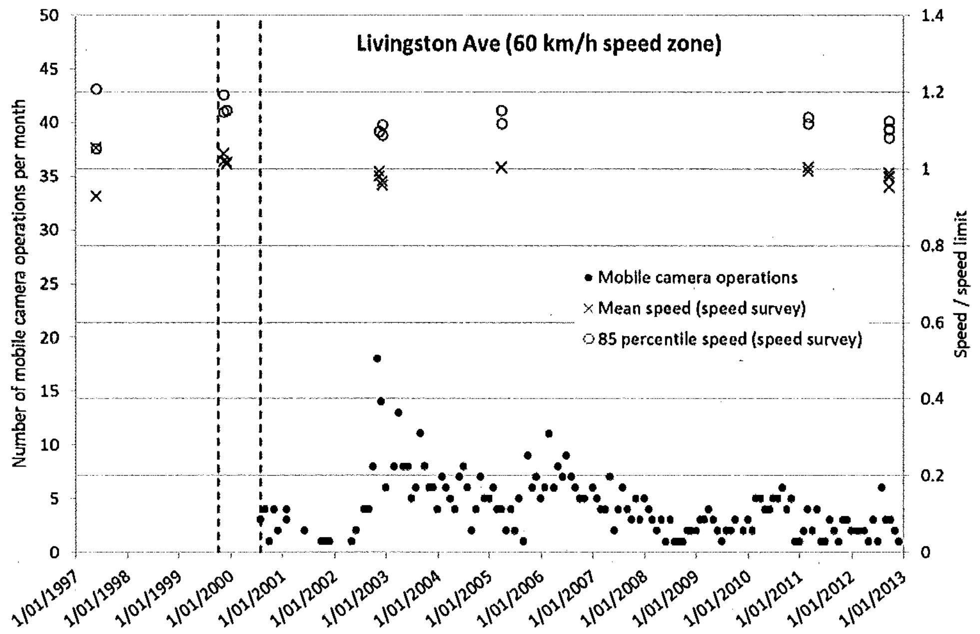
1/01/2012
1/01/2013


Livingston Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2008
1/01/2009
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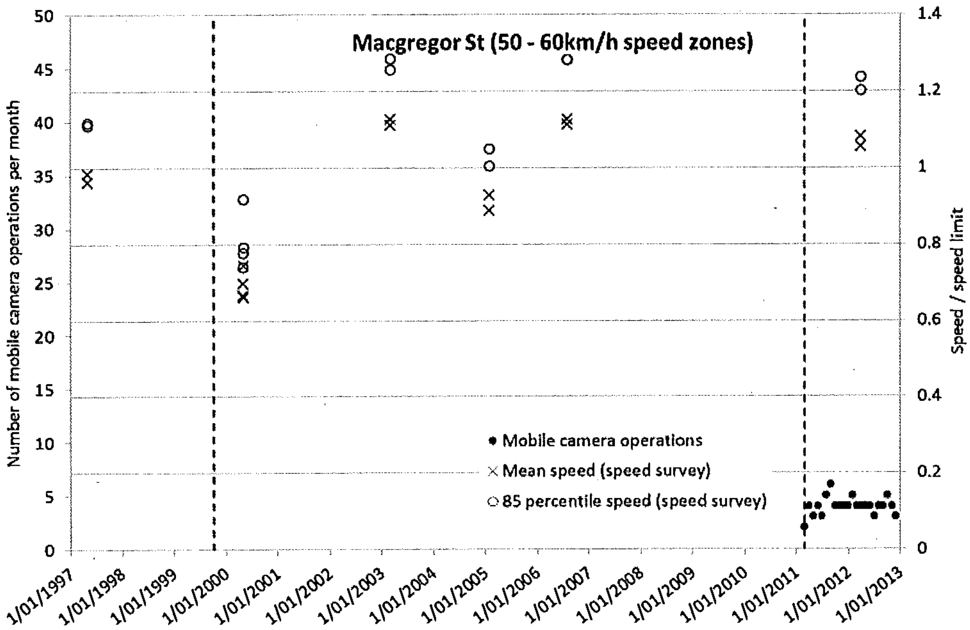
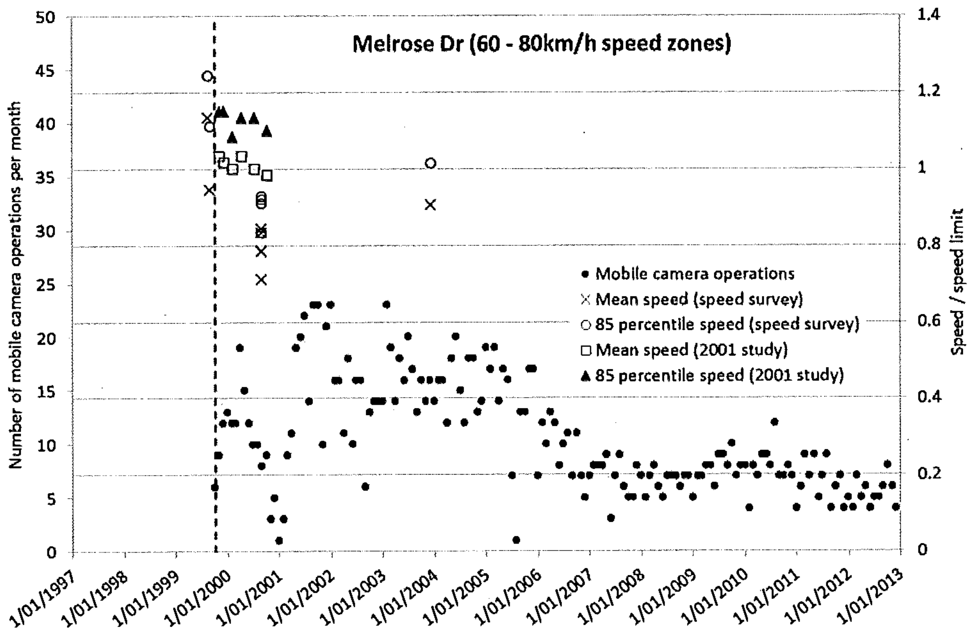
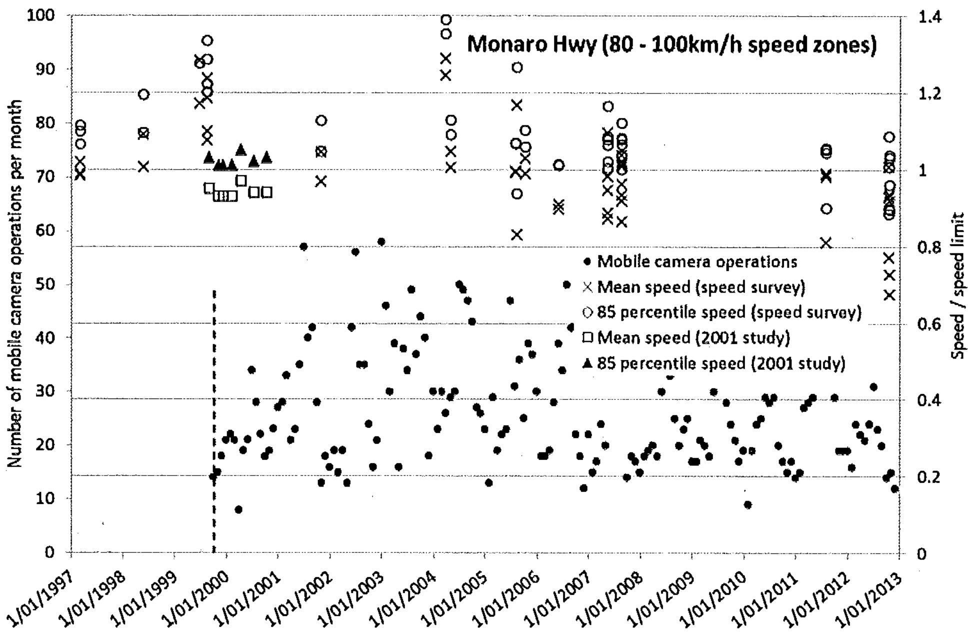
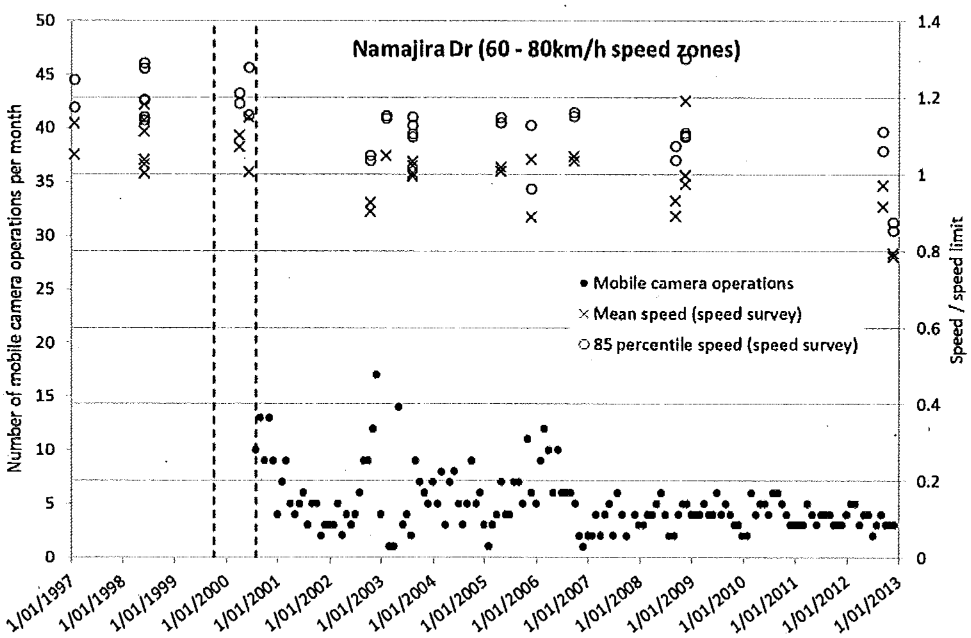
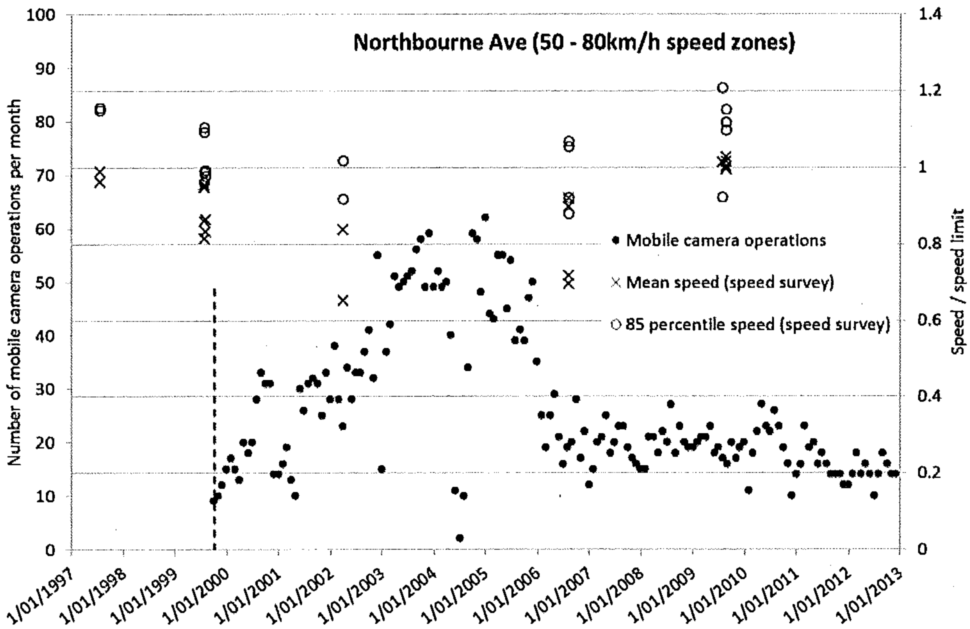
1/01/2012
1/01/2013

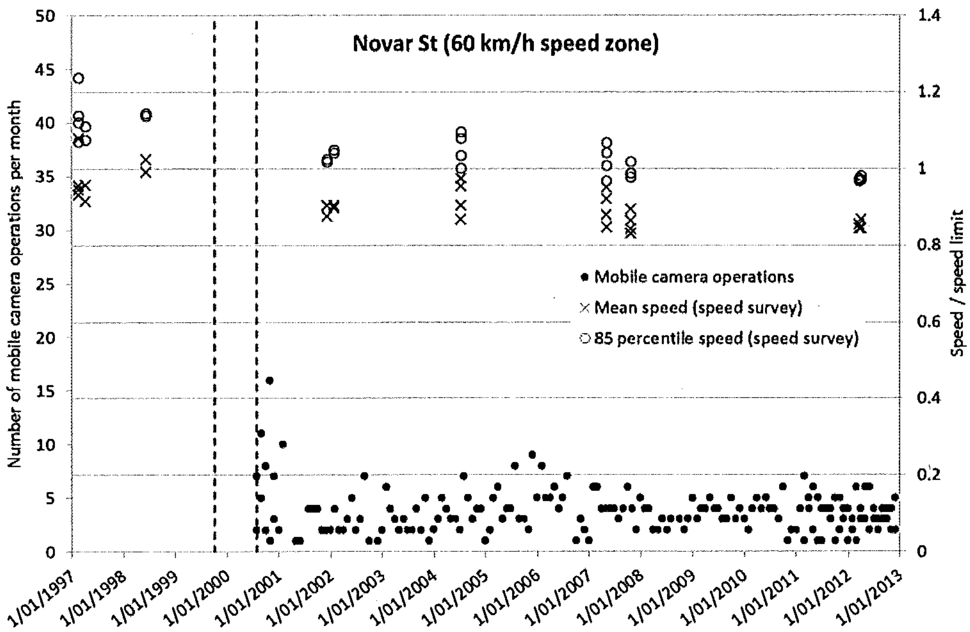

Macgregor St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

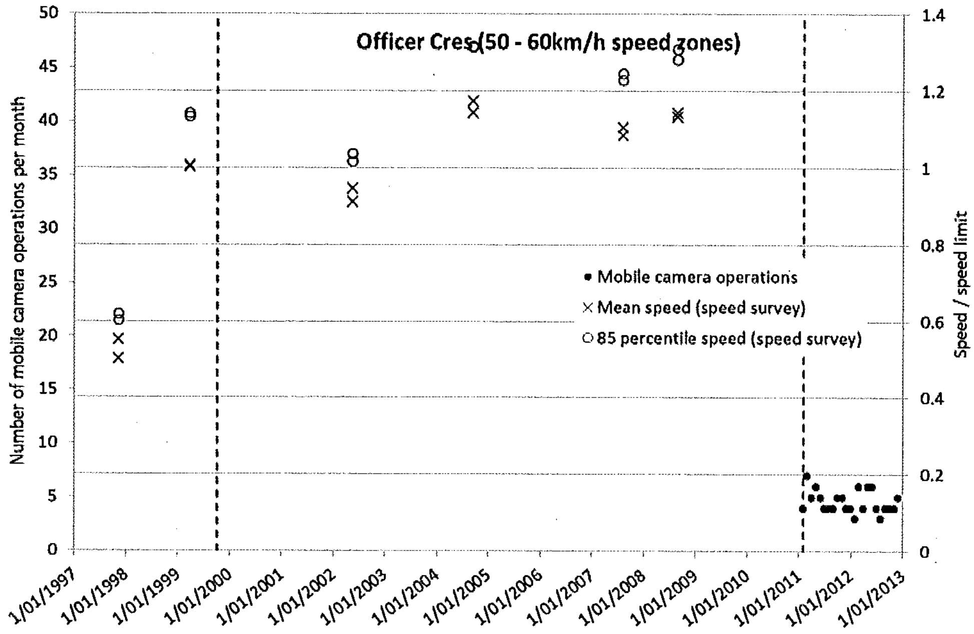

Melrose Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

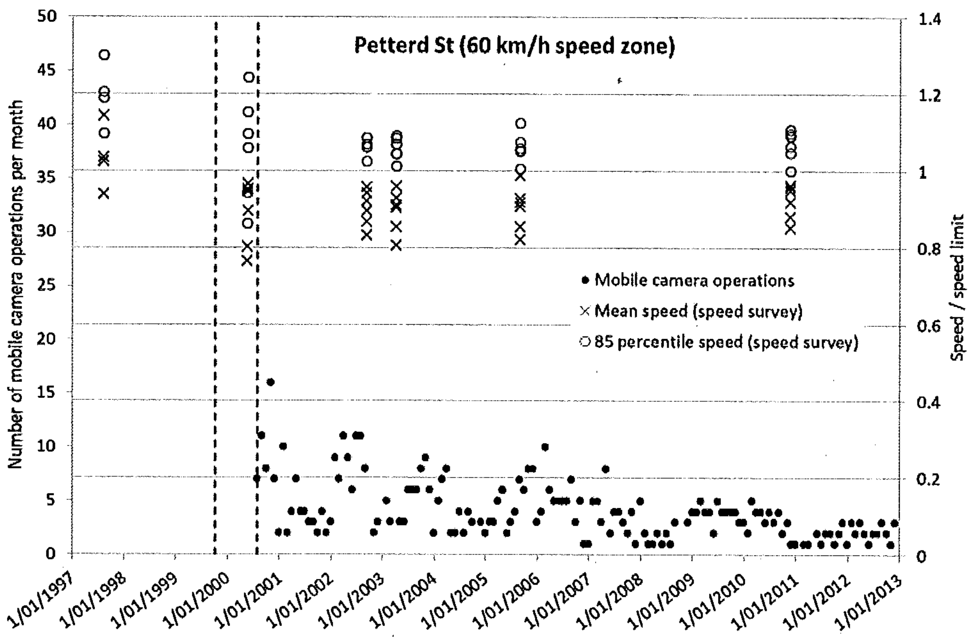

Monaro Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
□ Mean speed (2001 study)
▲ 85 percentile speed (2001 study)
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

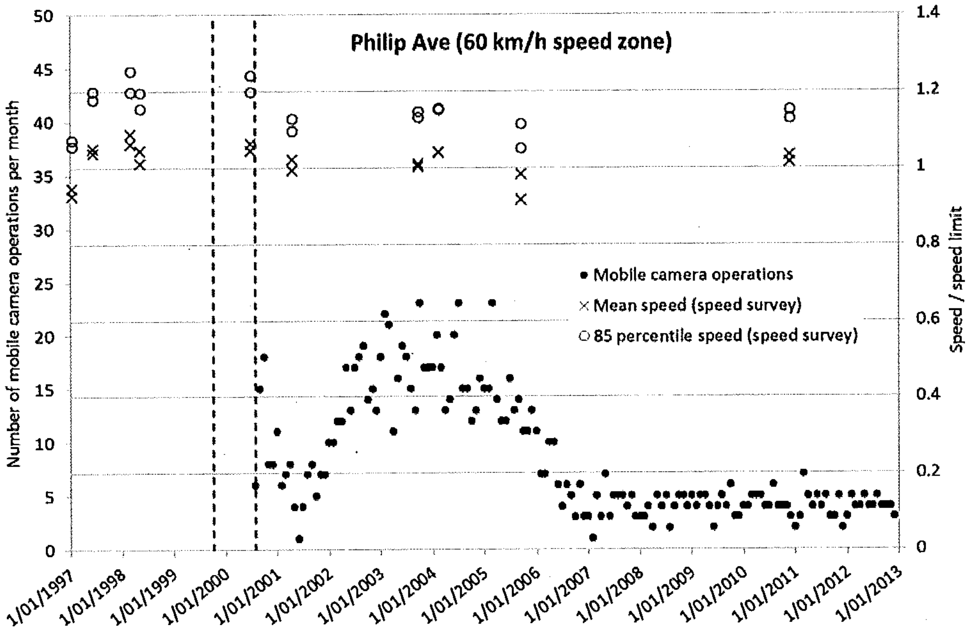

Namajira Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

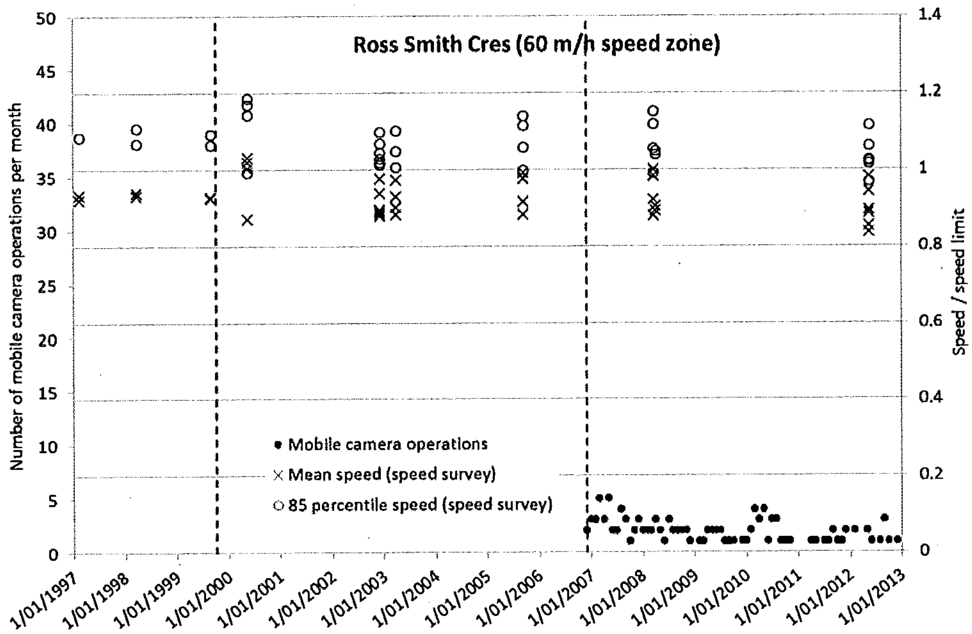

Northbourne Ave (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
100
90
80
70
60
50
40
30
20
10
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

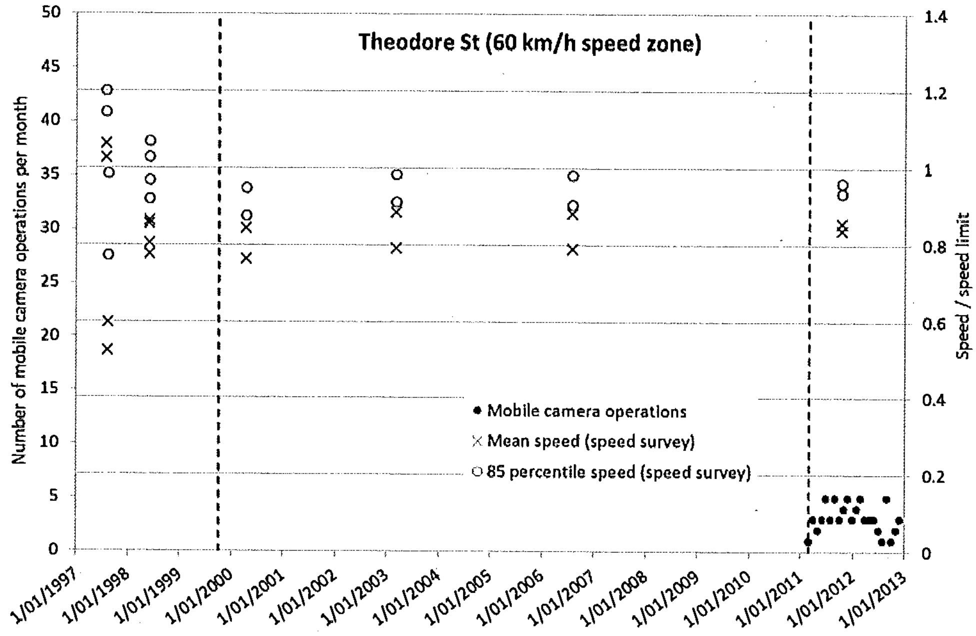

Novar St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Officer Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Petterd St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Philip Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Ross Smith Cres (60 m/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
• Mobile camera operations
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Theodore St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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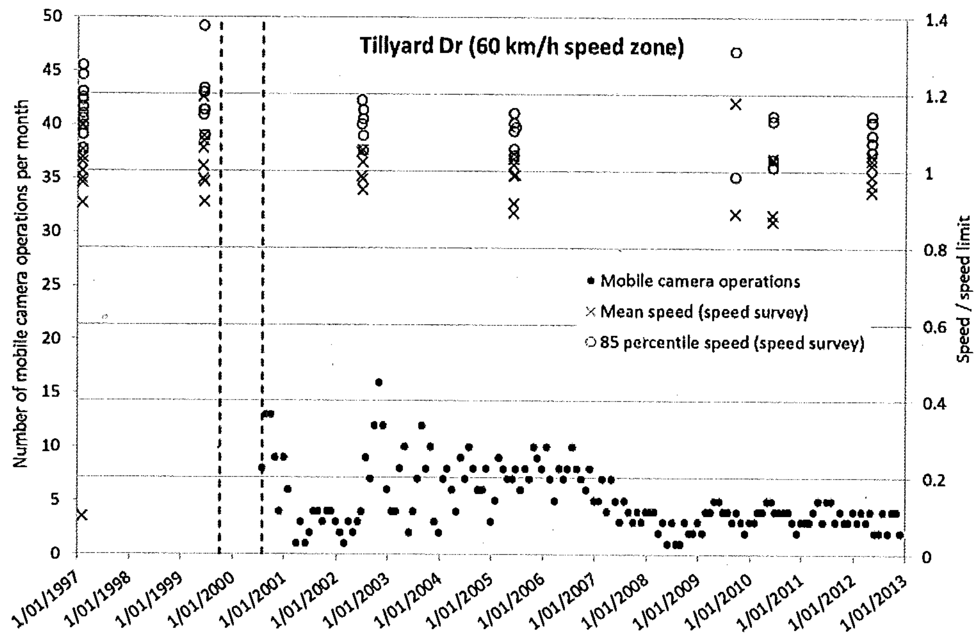
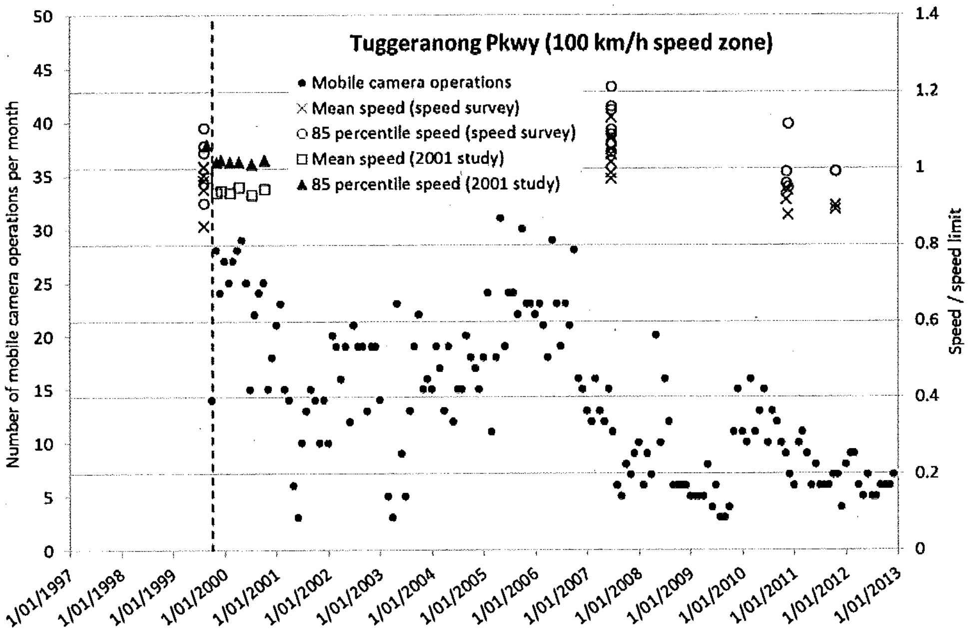
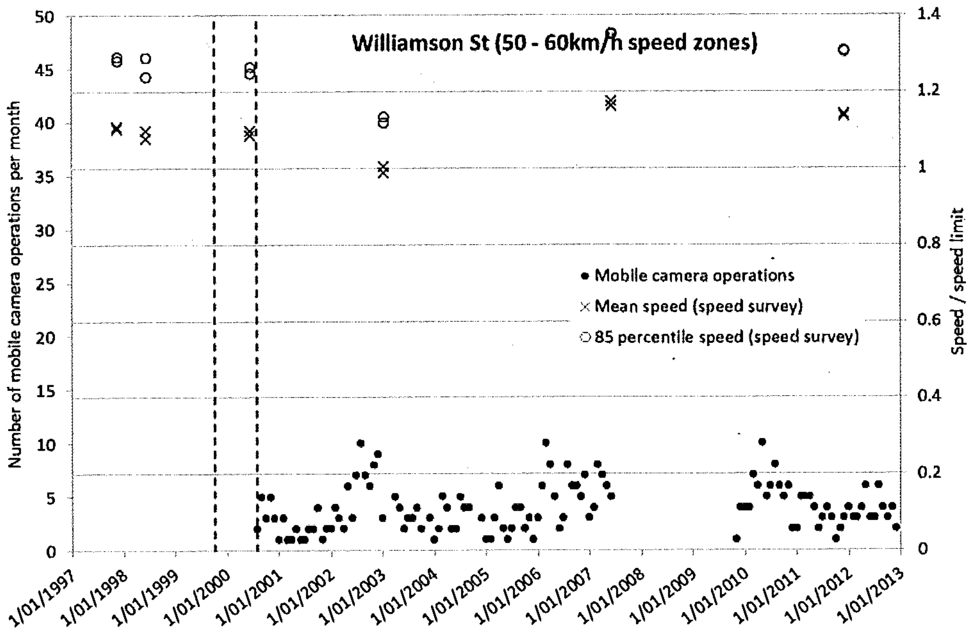
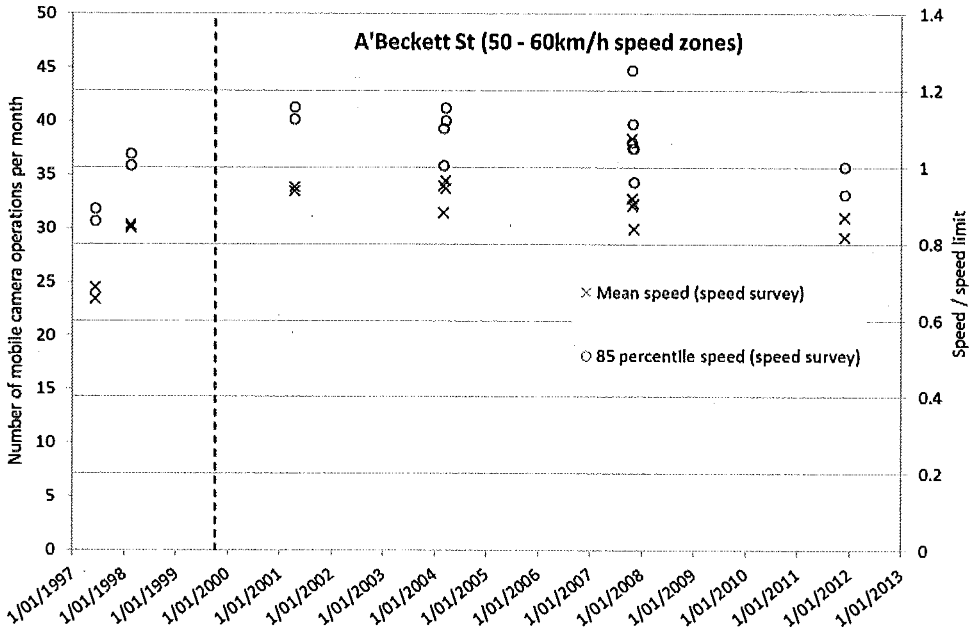
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

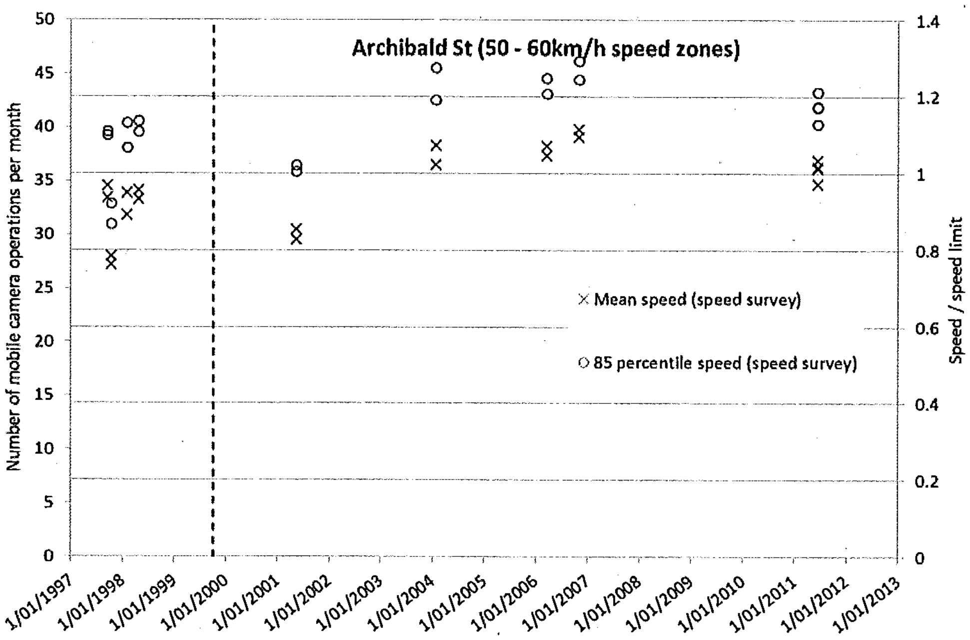

Tillyard Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

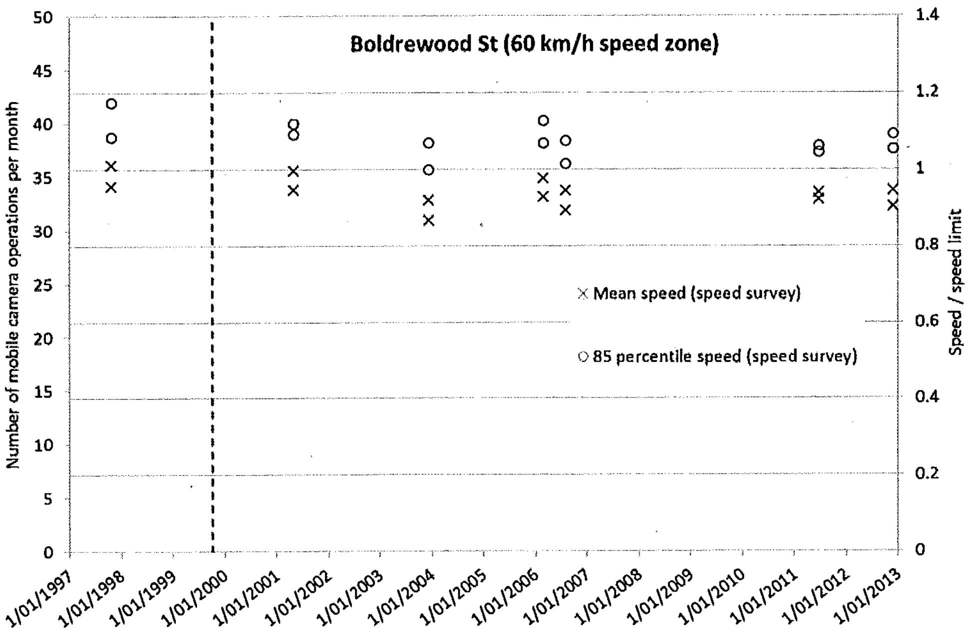

Tuggeranong Pkwy (100 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

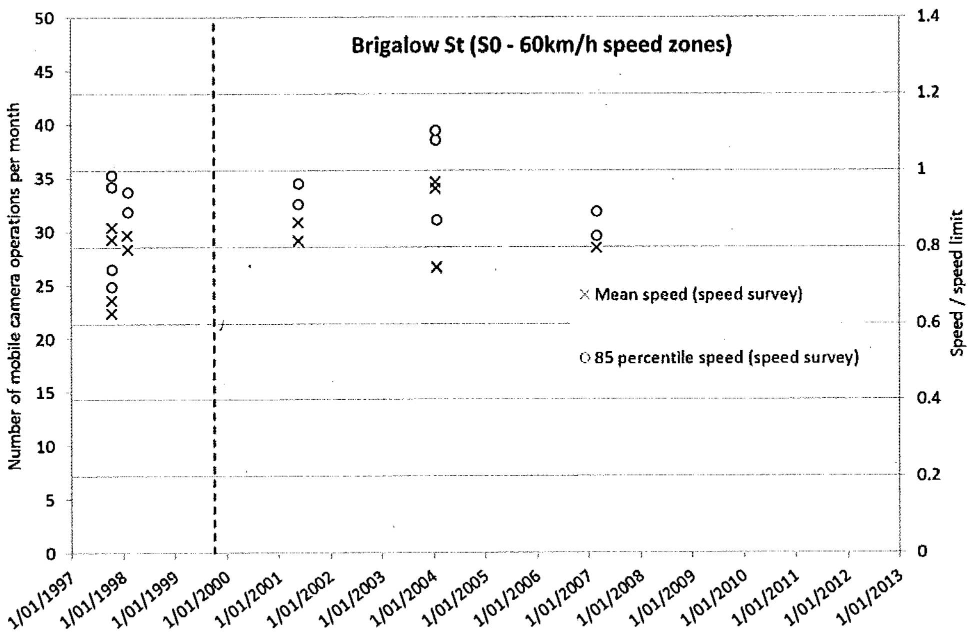

Williamson St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

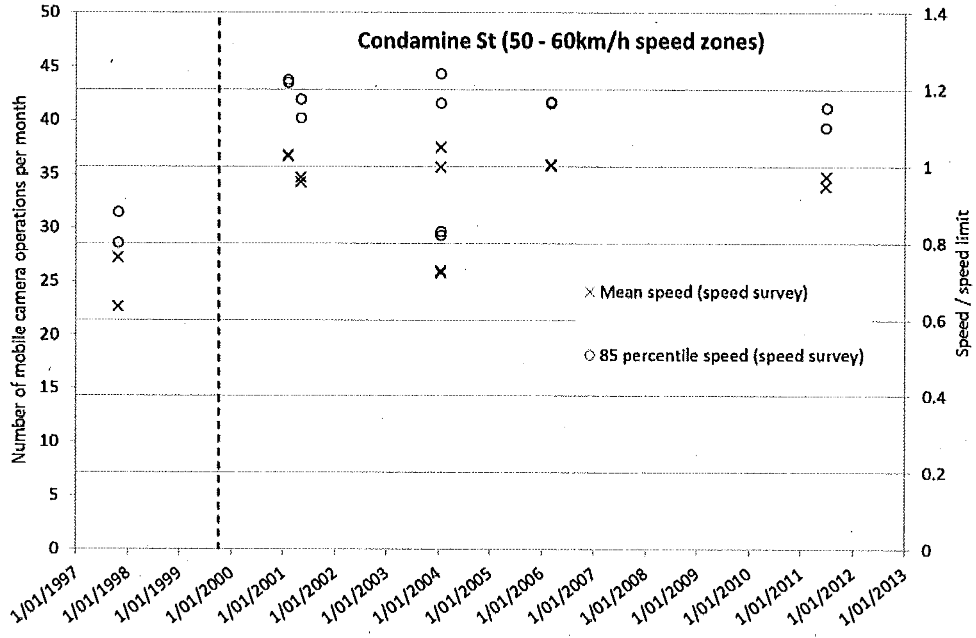
CONTROL STREETS

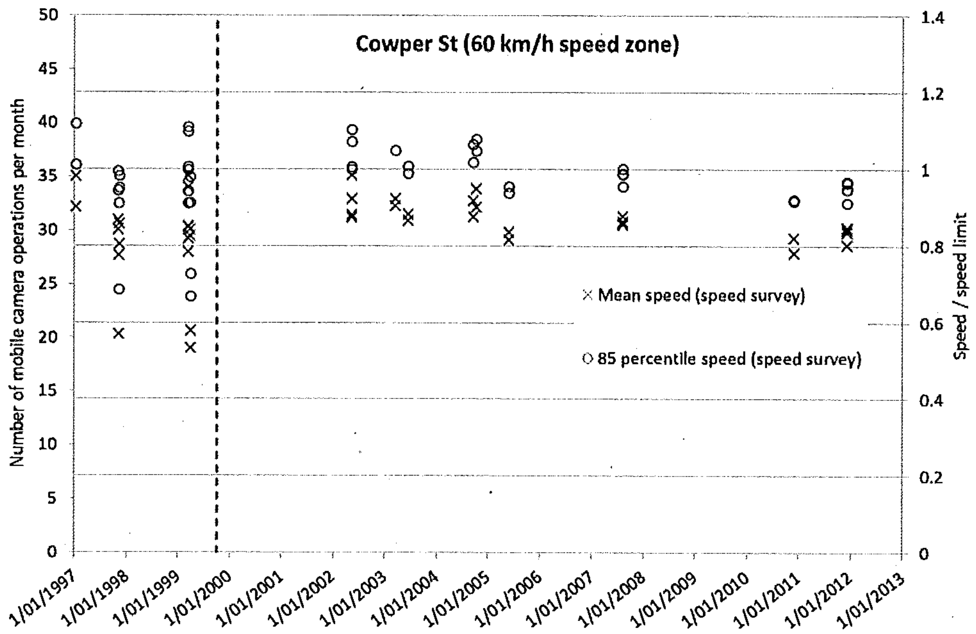


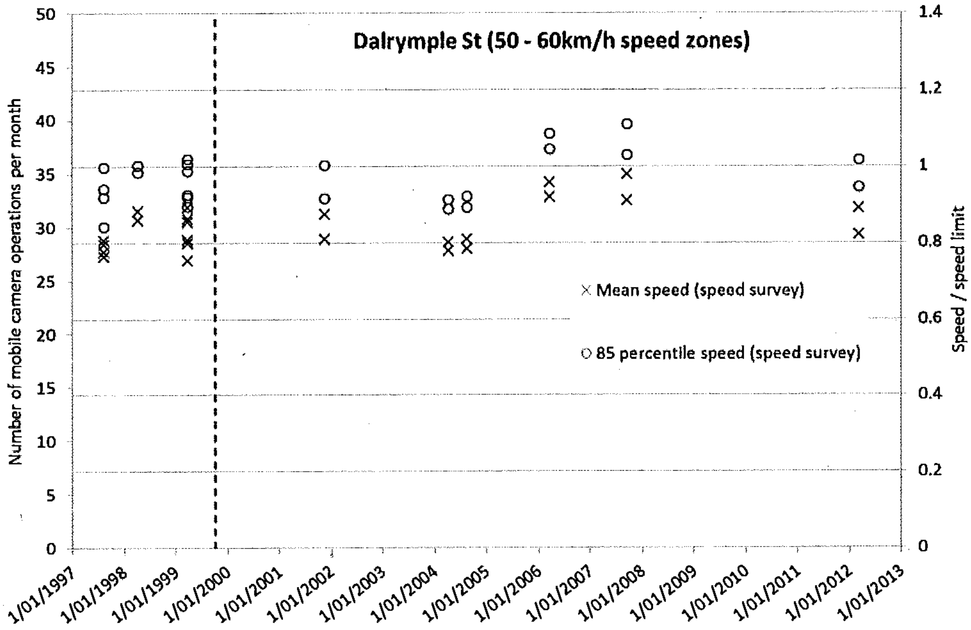


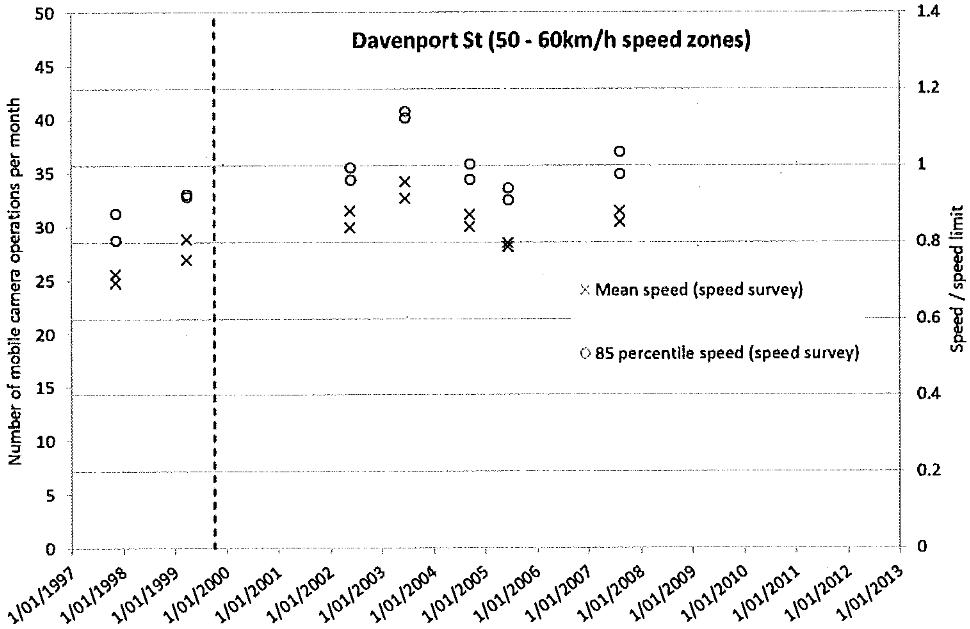

Boldrewood St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

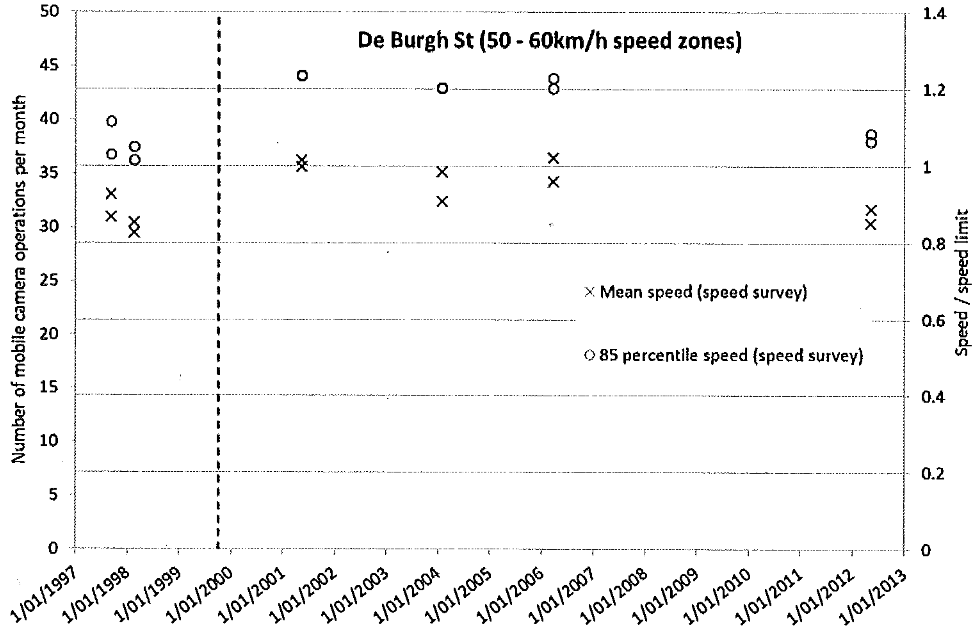

Brigalow St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Condamine St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Cowper St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Dalrymple St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Davenport St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


De Burgh St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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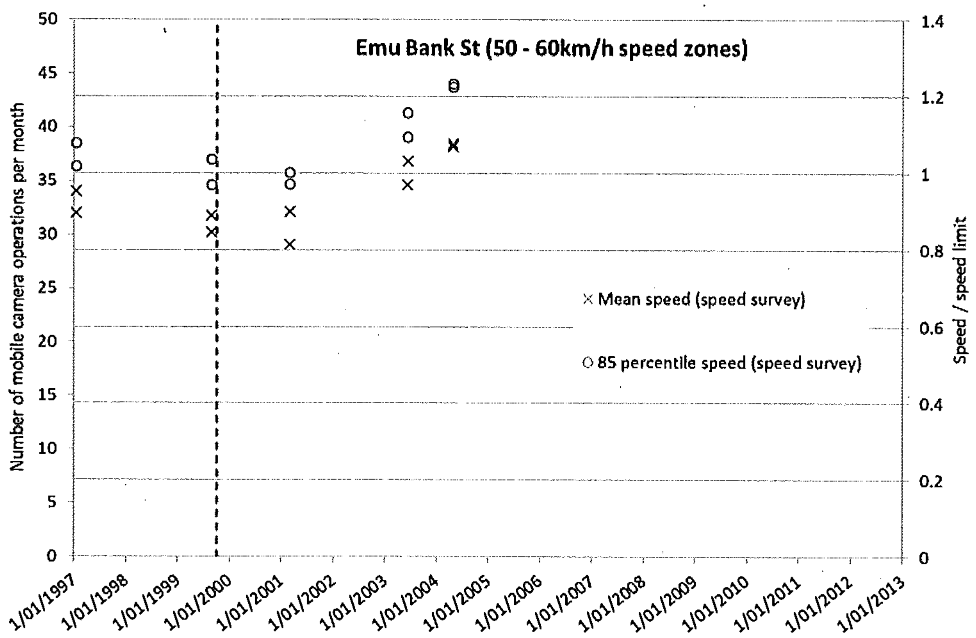
1/01/2012
1/01/2013


Emu Bank St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2008
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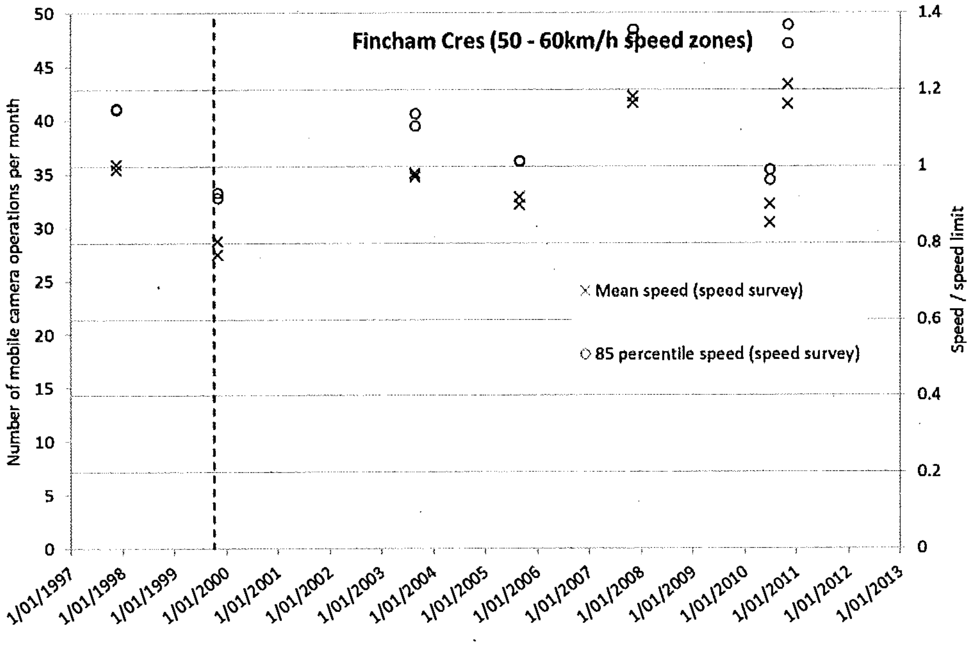
1/01/2011
1/01/2012
1/01/2013


Fincham Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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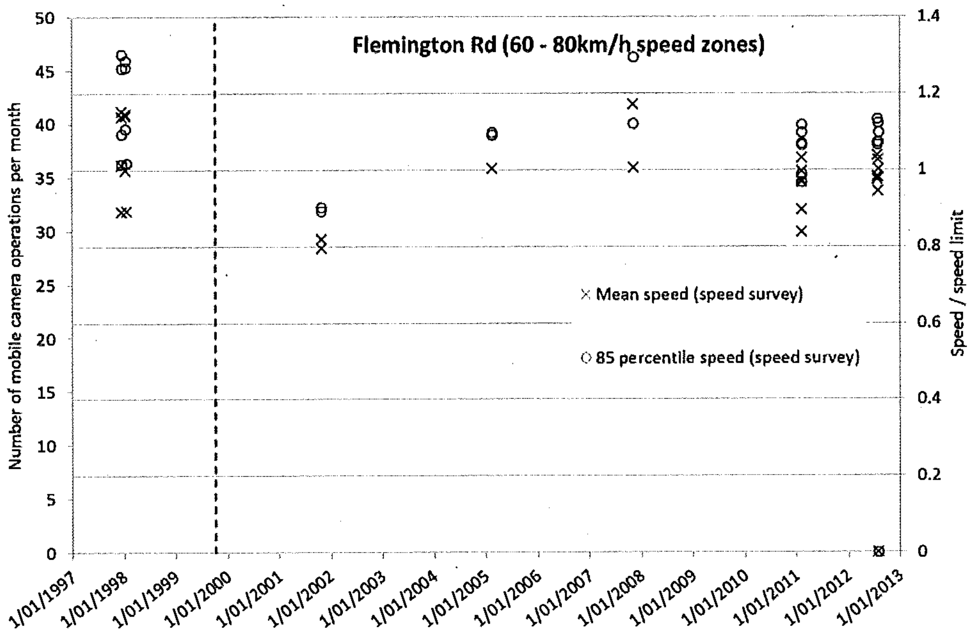
1/01/2011
1/01/2012
1/01/2013


Flemington Rd (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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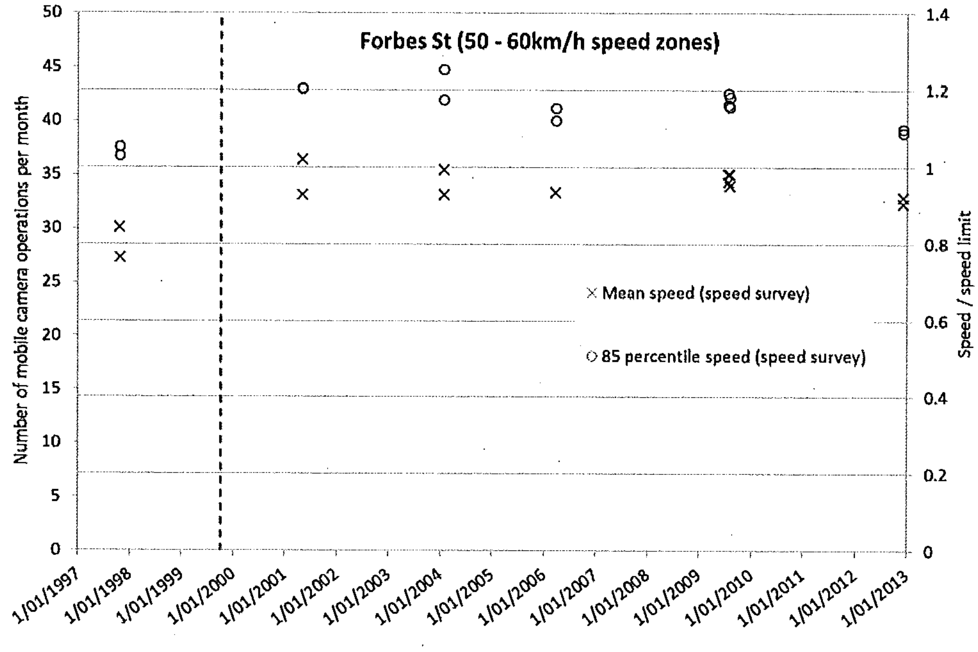
1/01/2012
1/01/2013


Forbes St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
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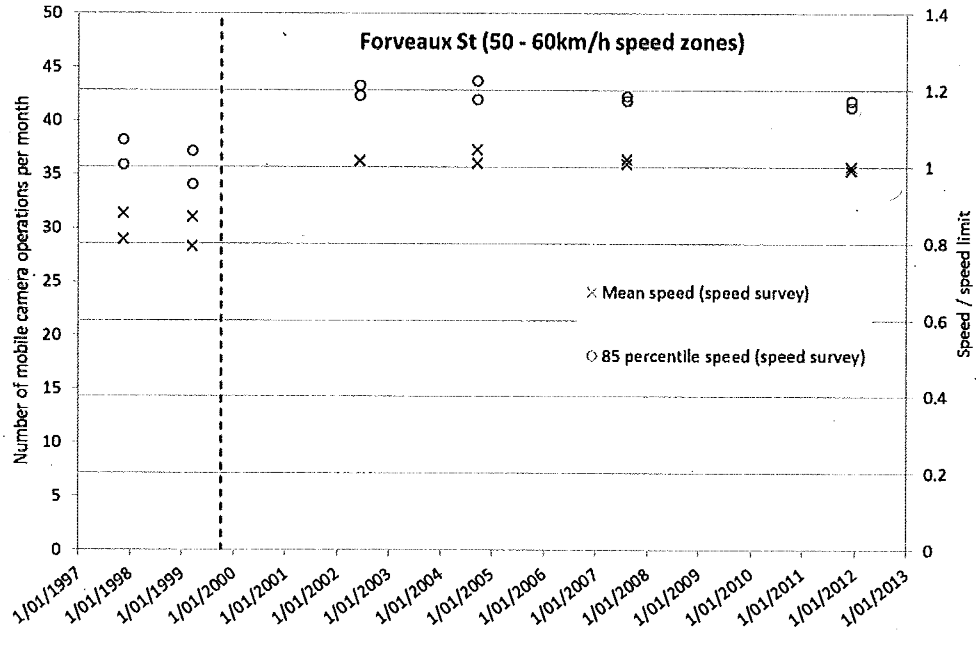
Forveaux St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
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1/01/2005
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1/01/2012
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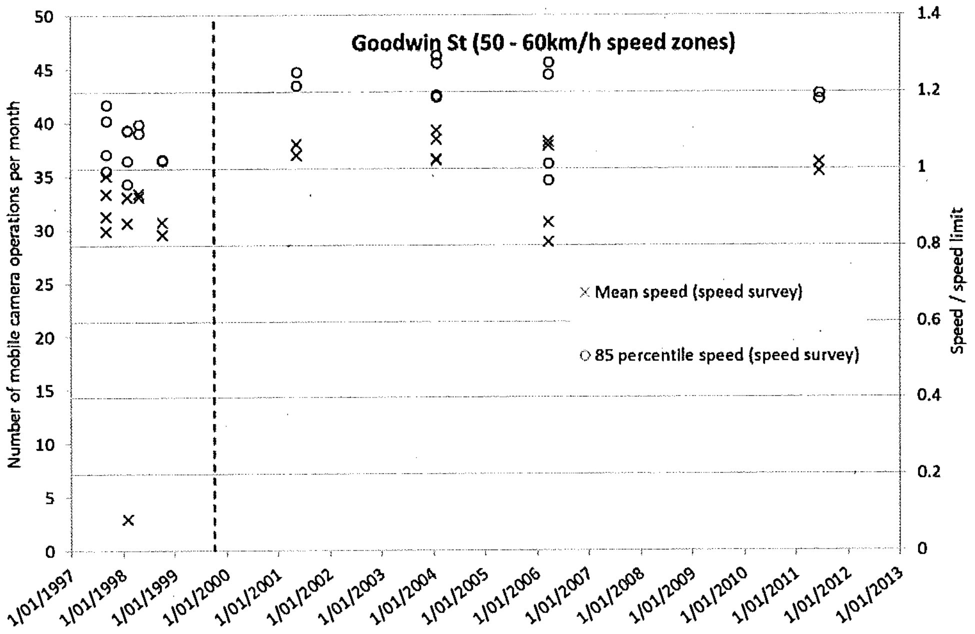

Goodwin St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
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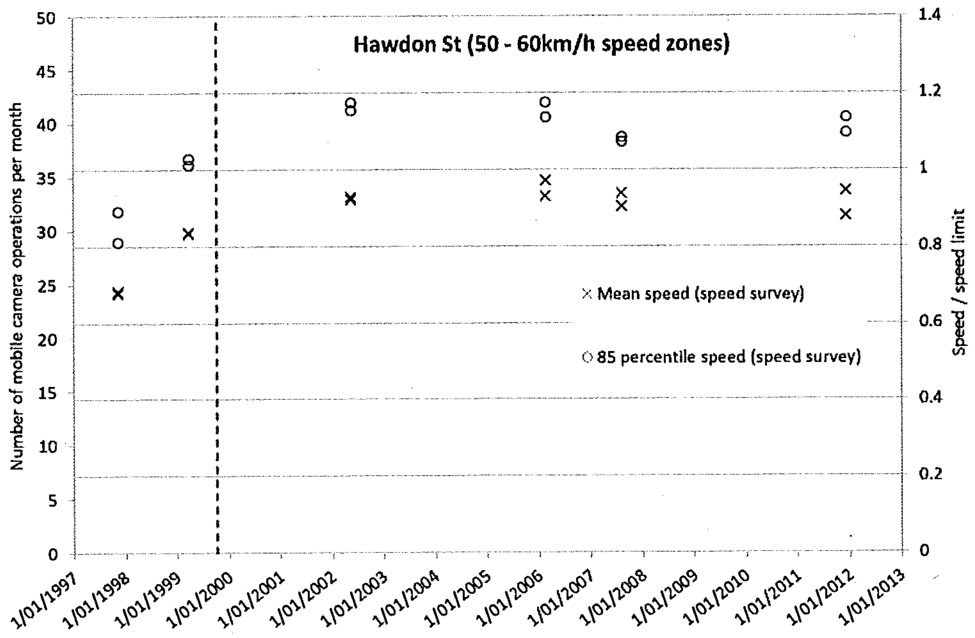

Hawdon St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
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1.2
1.4
1/01/1997
1/01/1998
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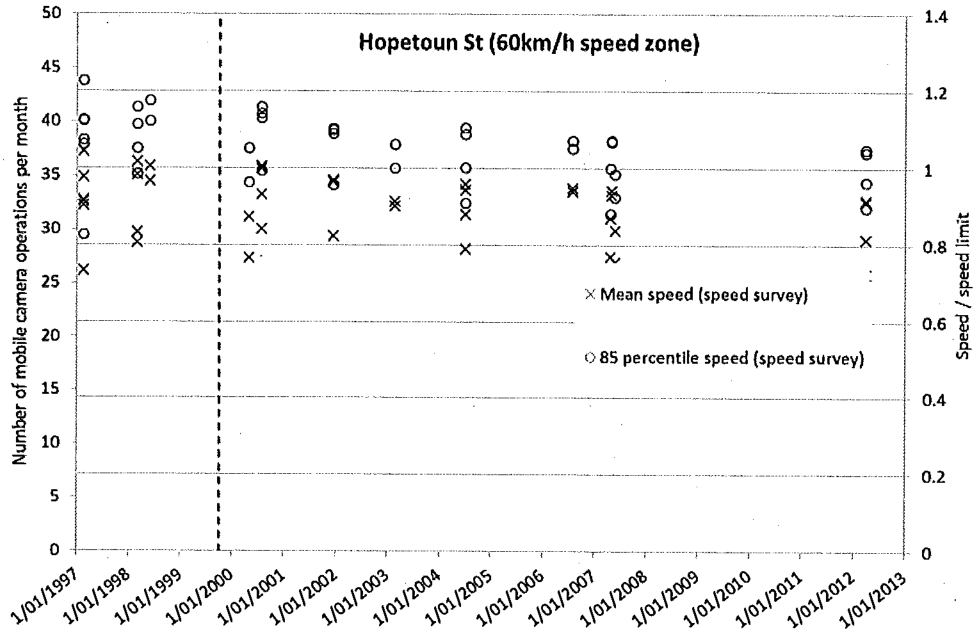
Hopetoun St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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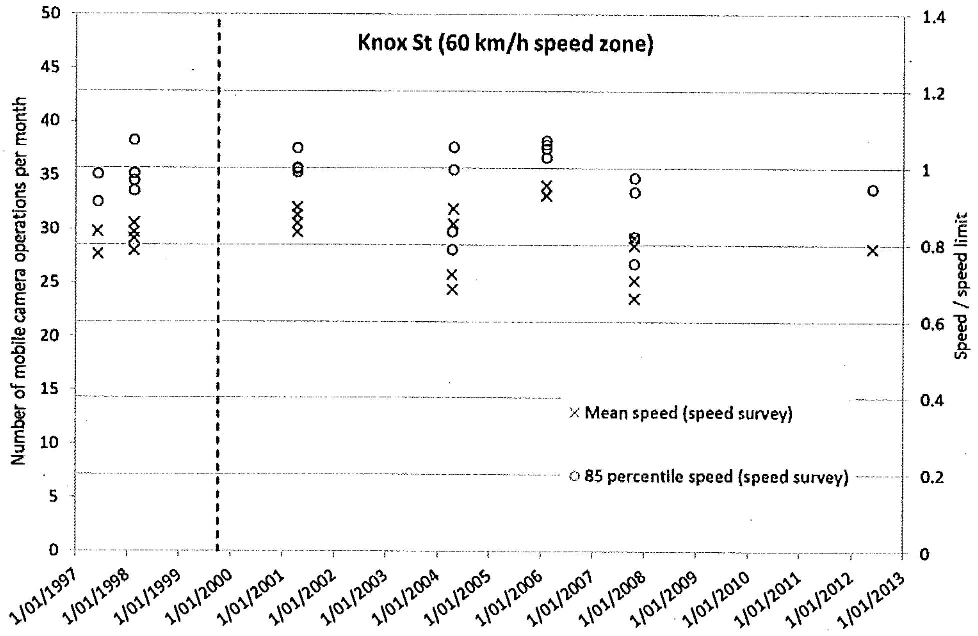
Knox St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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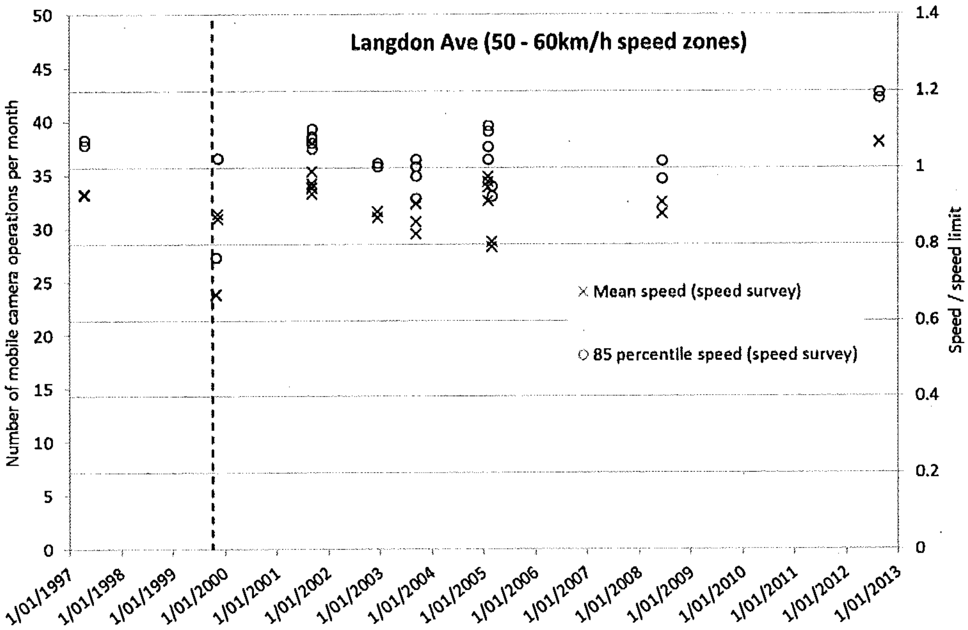
Langdon Ave (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2010
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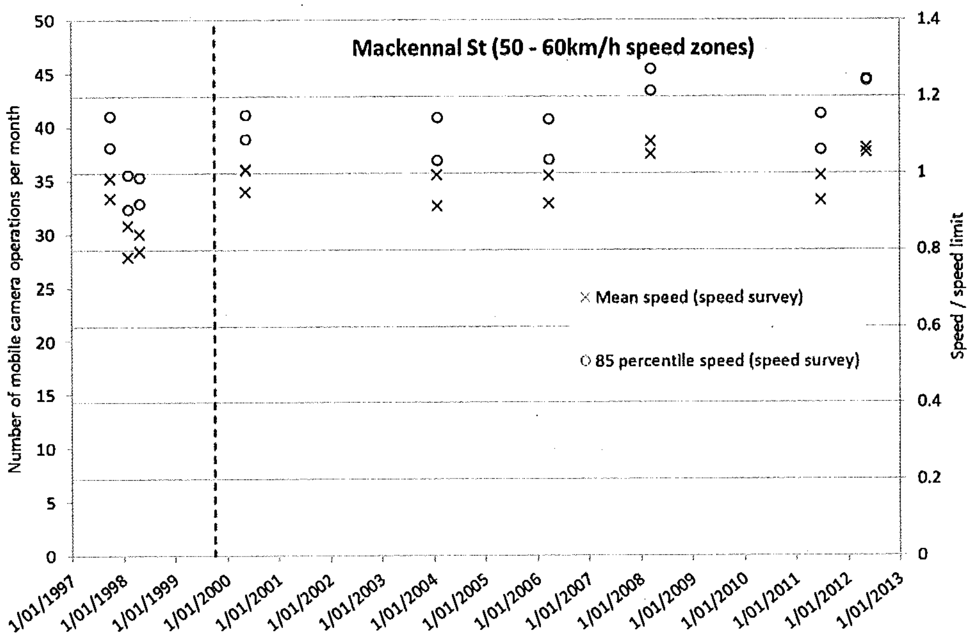
1/01/2012
1/01/2013


Mackennal St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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15
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25
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40
45
50
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0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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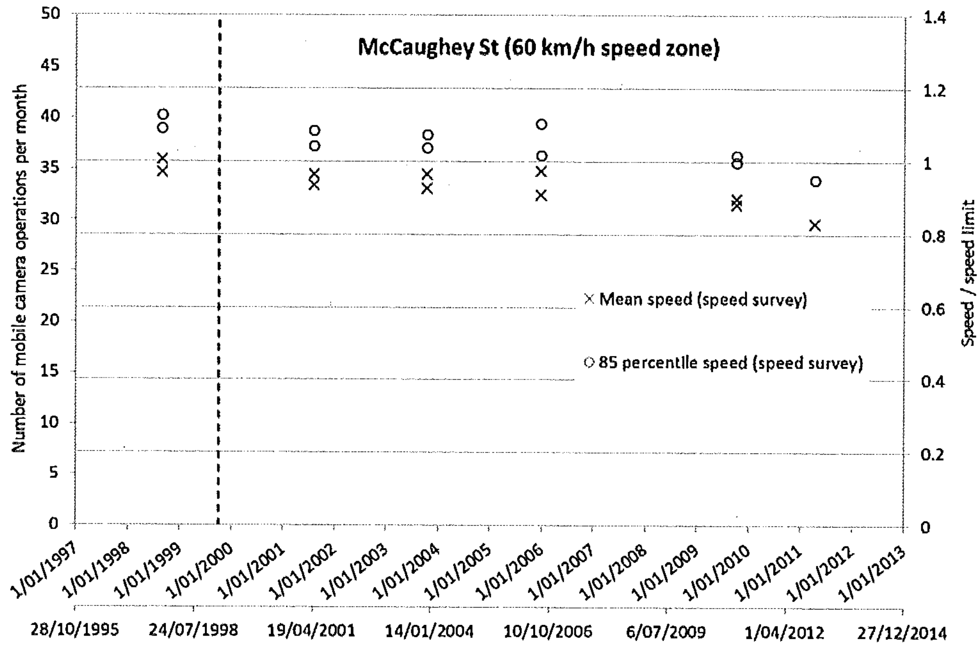
1/01/2012
1/01/2013


McCaughey St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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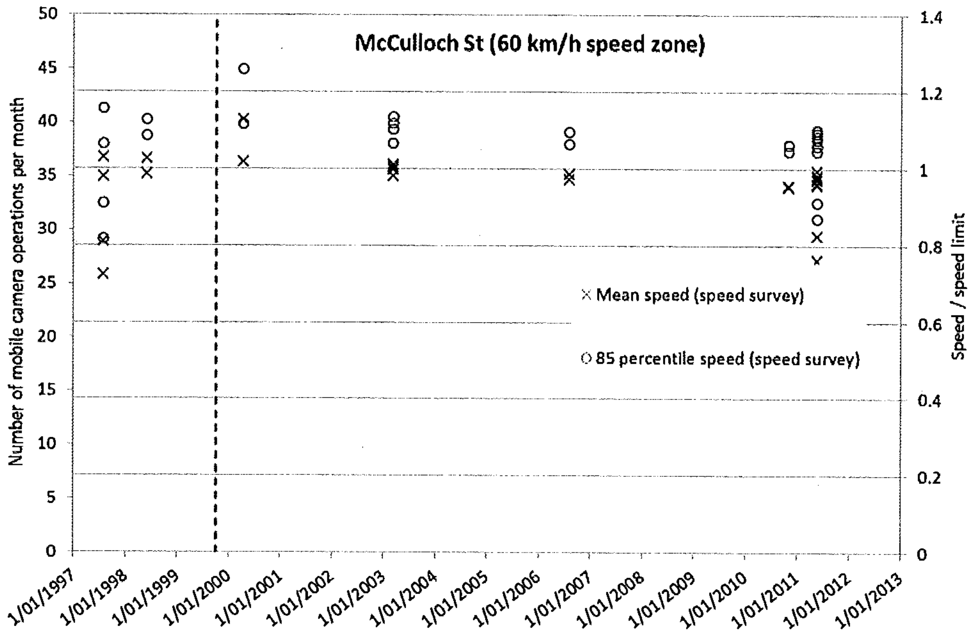
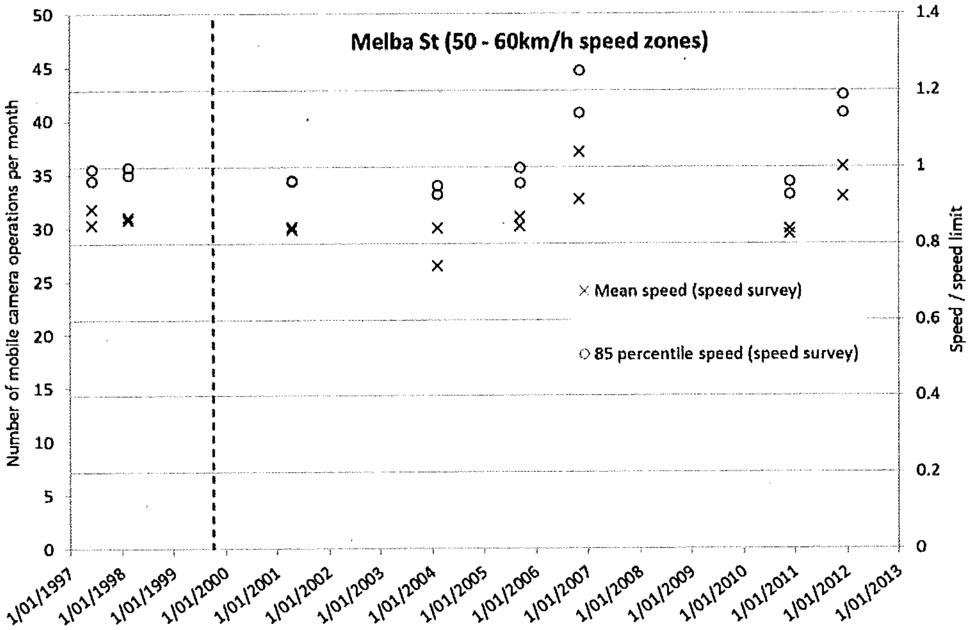
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014


McCulloch St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)


Melba St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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0.6
0.8
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
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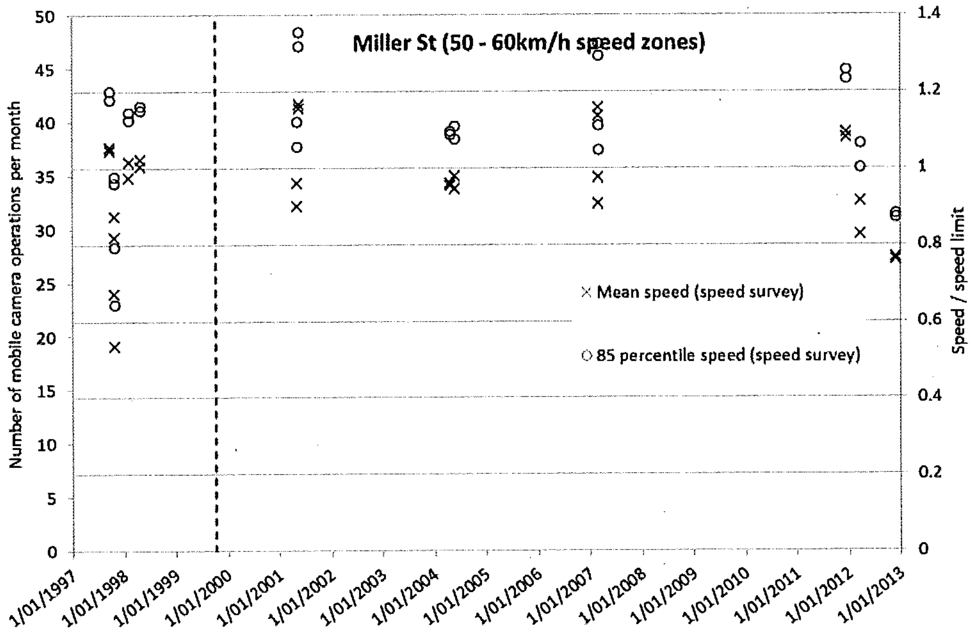
1/01/2013


Miller St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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20
25
30
35
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45
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0.2
0.4
0.6
0.8
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1.4
1/01/1997
1/01/1998
1/01/1999
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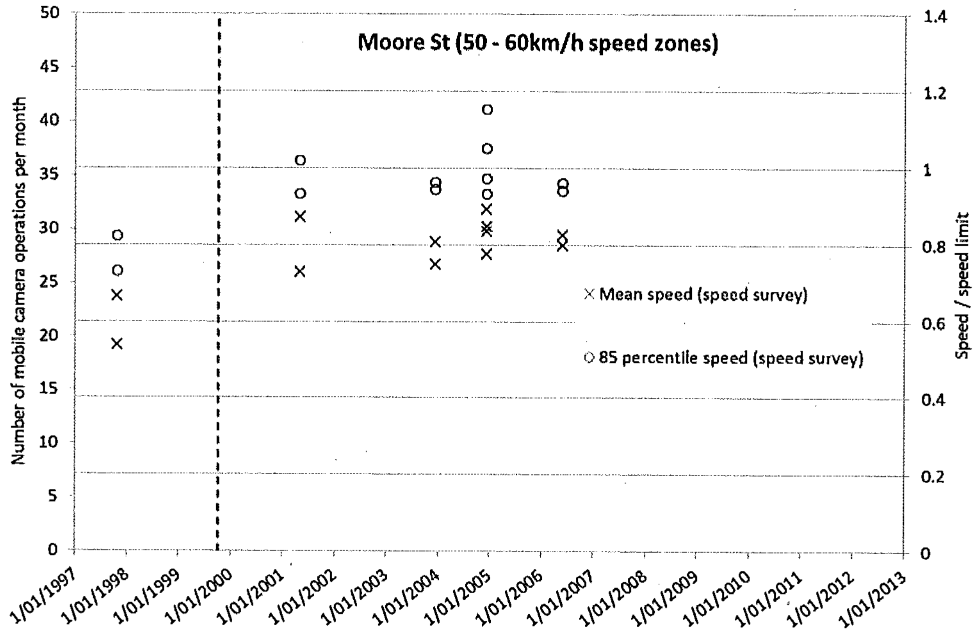
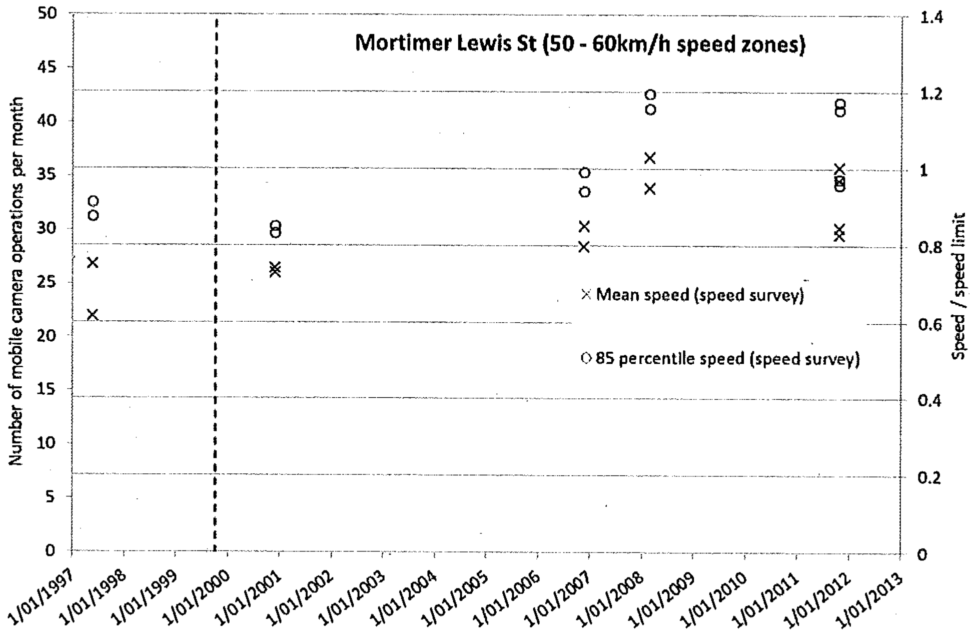
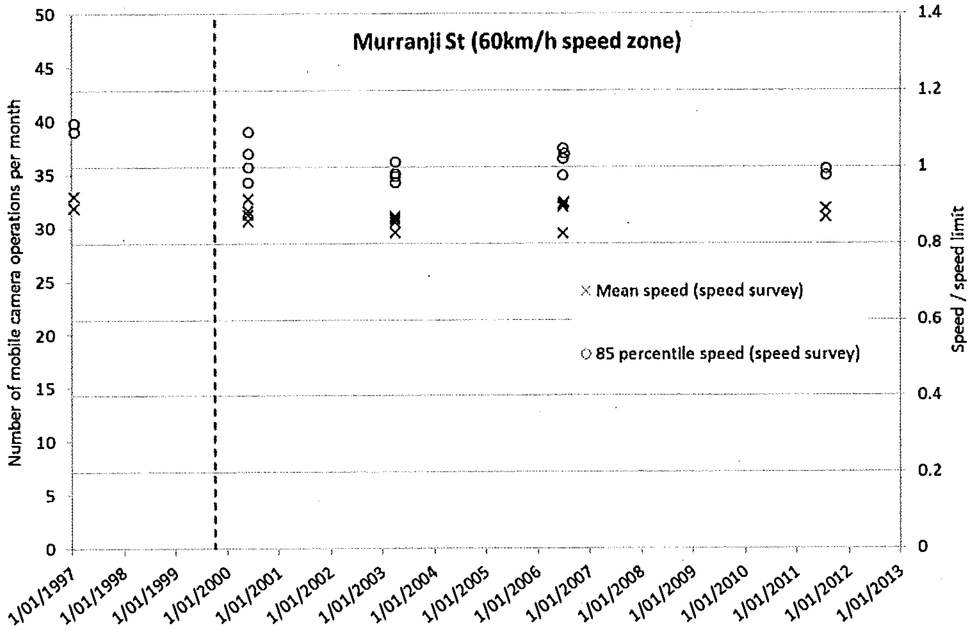

Moore St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)


Mortimer Lewis St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)


Murranji St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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1/01/2004
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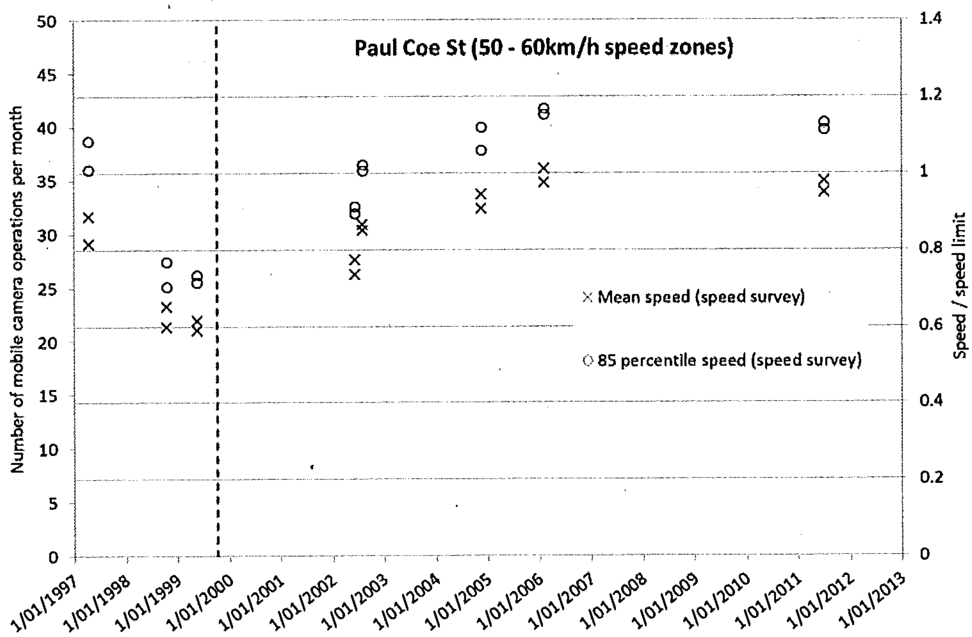
1/01/2012
1/01/2013


Paul Coe St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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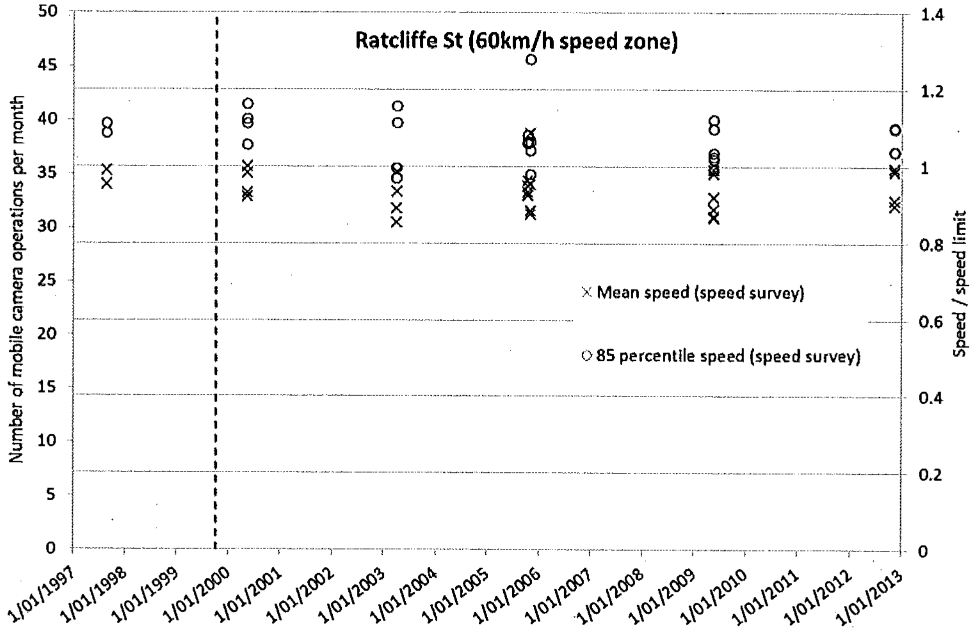
1/01/2013


Ratcliffe St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
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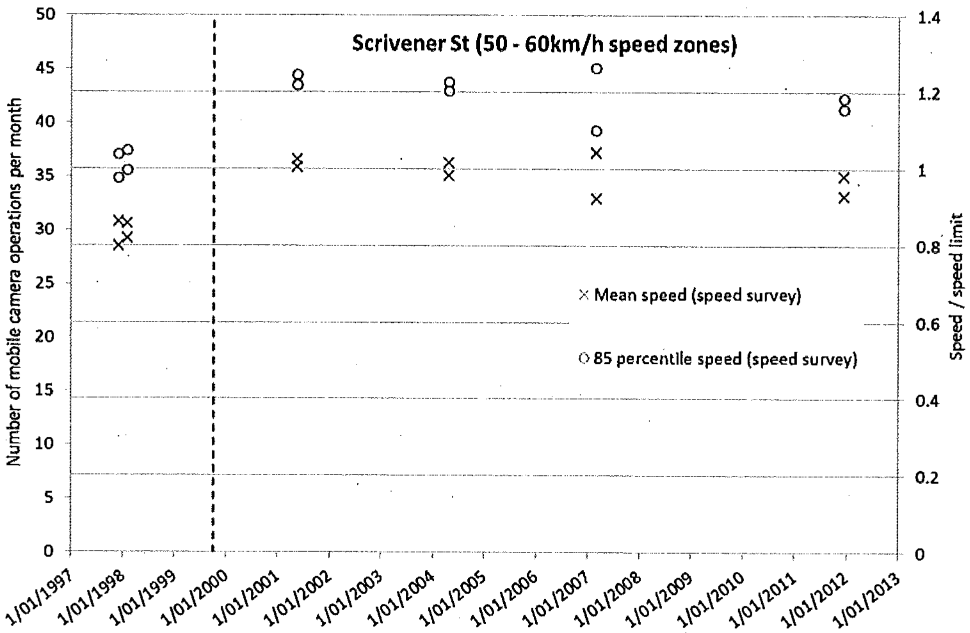
Scrivener St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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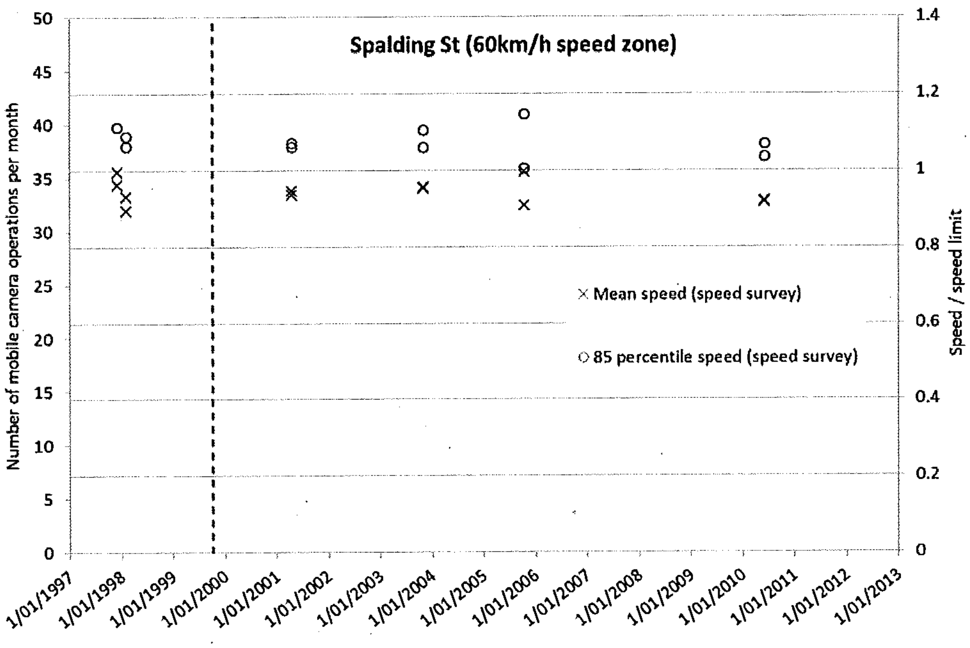
1/01/2013


Spalding St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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20
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30
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50
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1/01/1997
1/01/1998
1/01/1999
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1/01/2002
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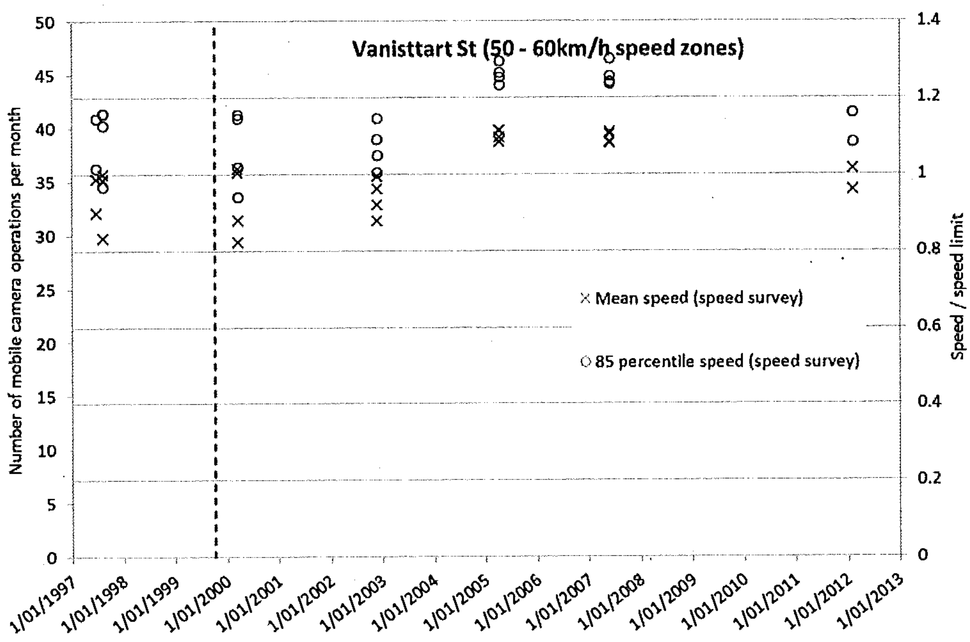
Vanisttart St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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15
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25
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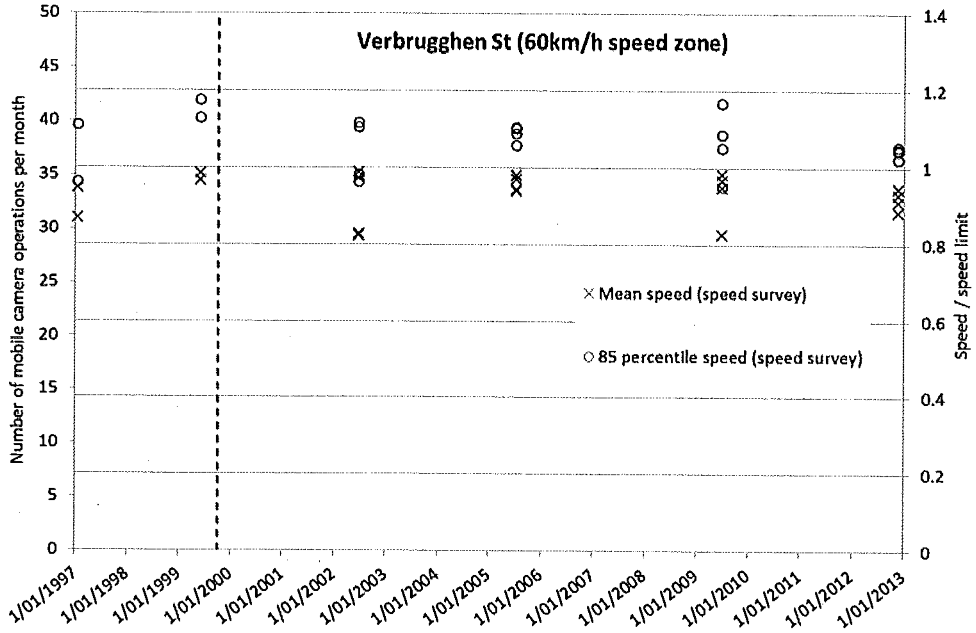
Verbrugghen St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
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25
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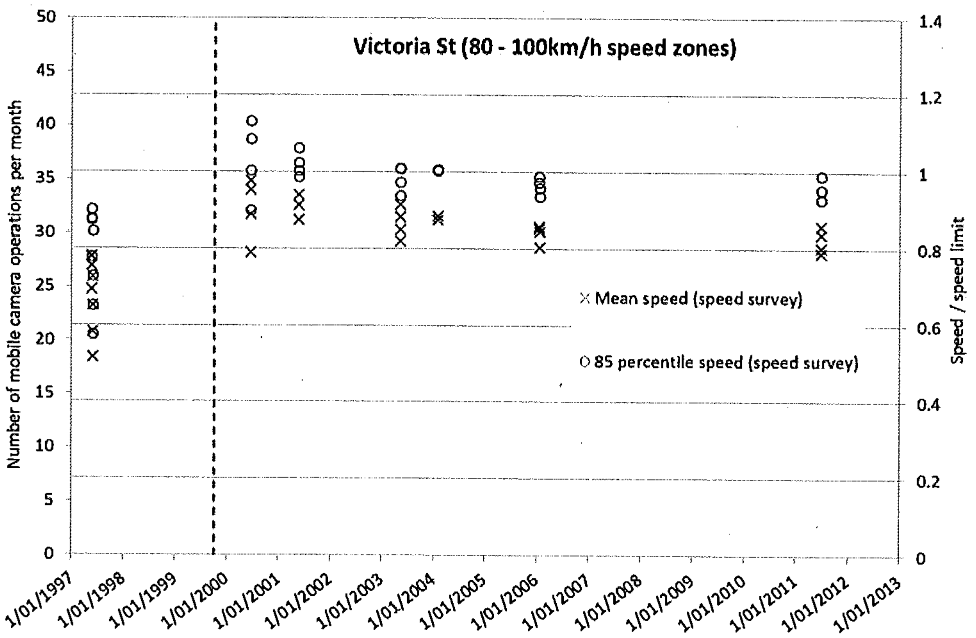
Victoria St (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
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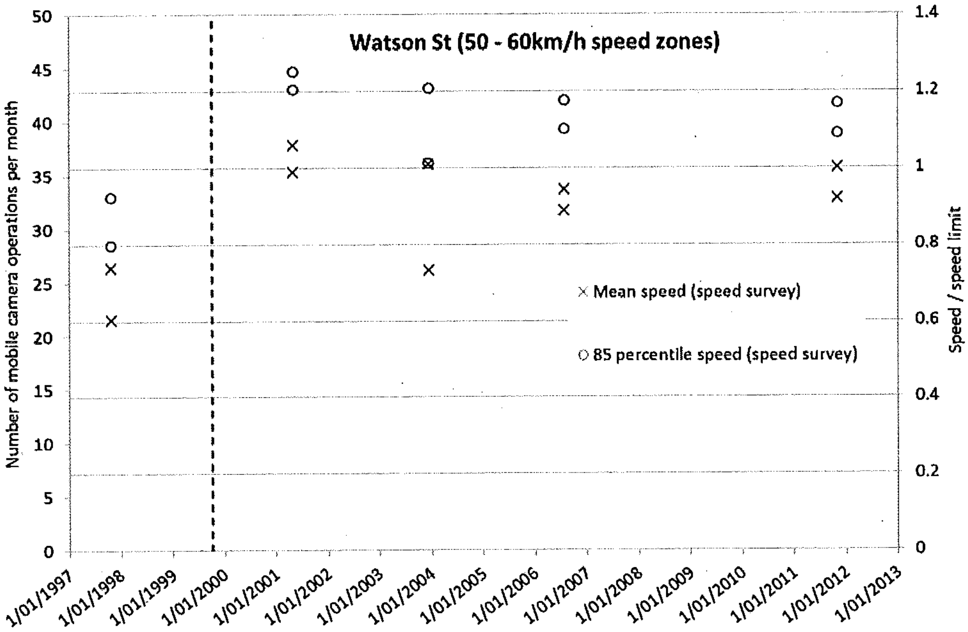
Watson St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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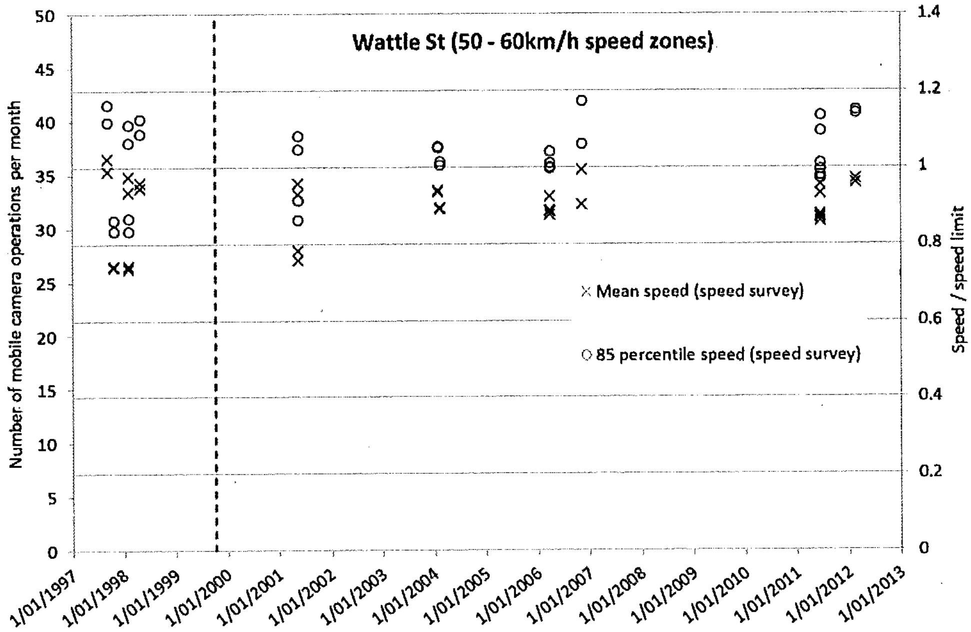
Wattle St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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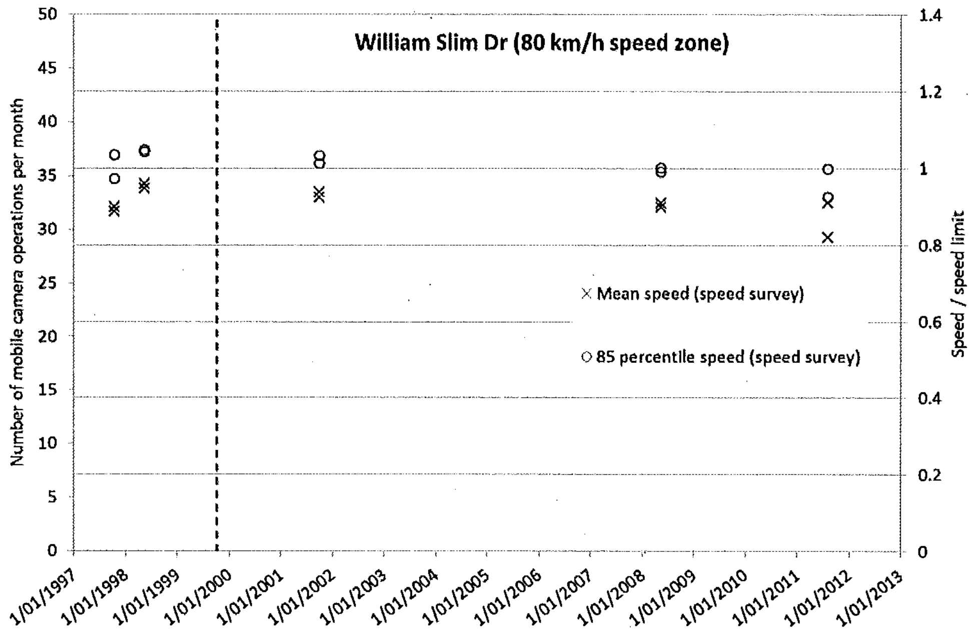
William Slim Dr (80 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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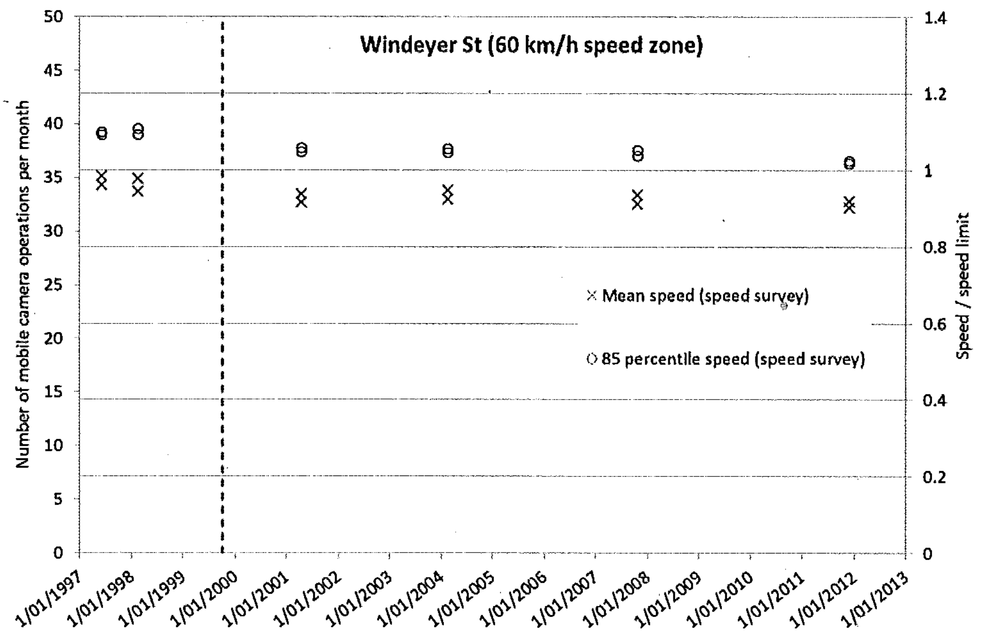
Windeyer St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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1/01/2012
1/01/2013

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Davidson, Geoffrey

From: Raphael Grzebieta
Sent: Wednesday, 16 July 2014 1:20 PM
To: Davidson, Geoffrey
Cc: Ann Williamson; Jake Olivier; Mike Bambach
Subject: Re: Final Report Evaluation of ACT Camera Report
Attachments: ACT Camera Report_Final.pdf

Hi Geoff,

Please find attached the final report.

I finally managed to scrap up some time in between cat naps to finish it off.

Please let me or Ann know if there is anything further you would like us to do.

Kind Regards

Raphael

Raphael Grzebieta PhD
(Professor, Road Safety)

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DECADE OF ACTION FOR ROAD SAFETY 2011-2020

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Report:

Evaluation of the ACT Road Safety Camera Program

A TARS Research report for the ACT Government Justice and Community Safety Directorate

July 2014

TRANSPORT AND ROAD SAFETY
(TARS) RESEARCH

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A/Prof. Jake Olivier (UNSW Maths)
Ms. Amy Chung (UNSW Aviation)
Mr. David Hicks (TARS)

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Definitions

Road crash – police-reported road crash that occurred on a public ACT roadway, resulting in property damage, injury or fatality
Serious road crash – police-reported road crash that occurred on a public ACT roadway, resulting in injury or fatality
Casualty crash – fatal and serious injury crashes
Case streets – ACT streets on which road safety cameras were installed/operated
Control streets – ACT streets on which road safety cameras were not installed/operated
Driver – Vehicle driver including light and heavy drivers and motorcycle riders
Intervention 1 – Introduction of the ACT Road Safety Camera Program, on the 6th October 1999
Intervention 2 – Reduction of mobile camera operations on ACT streets, around October 2006
Begin-date – Date of the introduction of cameras on a particular street/intersection
CL_L – Lower 95% confidence limit
CL_U – Upper 95% confidence limit
Statistically significant – a statistical result with a *p* value less than 0.05
Mean speed – the mean of all vehicle speeds measured during a speed survey
85th percentile speed – the speed below which 85% of vehicles were travelling during a speed survey (conversely, the speed 15% of vehicles were exceeding)
RTM – Regression to the mean
Spillover effect – when the effects of a fixed camera extend further along a roadway from the camera location

Executive Summary

Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, in order to guide improvement of the Program. The evaluation process is outlined in the Detailed Statement of Requirements provided in Appendix E. This report delivers that independent evaluation.

Aim

The key aim of this study was to investigate the performance of the ACT Road Safety Camera Program as a whole, including its impact on speeding and road crashes, and identify opportunities for improvement.

Whilst the above aim has been addressed in this report, emphasis in terms of evaluation of the camera program's effectiveness has been placed on whether the program has reduced serious and fatal injury crashes. This emphasis was implemented based on the National Road Safety Strategy (ATC, 2011) vision that no person should be killed or seriously injured on Australia's roads, where the strategy presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. In this context the following statements from that strategy document are particularly relevant: '*Crashes will continue to occur on our roads because humans will always make mistakes no matter how informed and compliant they are. But we do not have to accept a transport system that allows people to be killed or severely injured as a consequence….. This means we must manage the combined effects of the speeds at which we travel, the safety of the vehicles we use, and the level of protection provided by our roads — not only to minimise the number of crashes, but to ensure that when crashes do occur they do not result in death or serious injury.*'

<u>Thus a key question in this evaluation the Authors decided to further consider is whether casualty crashes in the ACT have reduced as a result of the introduction of the ACT Road Safety Camera Program.</u>

Methods

Speed surveys and road crash data were assessed for the period from 1994 to 2012 (inclusive). A sample of 95 ACT streets and 26 ACT intersections were assessed, including 48 case streets (with mobile cameras), 47 control streets (without mobile cameras), 13 case intersections (with fixed cameras) and 13 control intersections (without fixed cameras). It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

Data were collected for a total of 57,809 road crashes, 3,325 serious road crashes, 100 fatal road crashes, 4,261 intersection crashes, 1,758 speed surveys and 87,687 mobile camera operations. The sample represents 40% of the total number of ACT road crashes that occurred in the period. Statistical models were developed to assess speed and crash trends, effects of interventions (introduction of cameras) and perform case-control analyses. Additionally, 66 assessments of road safety camera programs in the scientific literature were summarised, as were surveys of community attitudes to speeding collected from 1995 to 2011 (inclusive).

Results

- The evaluation process outlined in the Detailed Statement of Requirements provided in Appendix E has been addressed as outlined in Section 4.4.
- The number of mobile camera operations undertaken in the ACT increased following their introduction until late 2006, after which they decreased (around 30%) due to resource limitations;
- Mobile camera infringement rates decreased from approximately 6% to 0.6% of vehicles passing cameras during the first three years of operations, and remained thereafter steady at this low rate;
- Mean percentile speeds reduced by 6% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- mean 85th percentile speeds reduced by 8% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- Over the next two years, speeds on streets with mobile camera operations returned to levels similar to those before their introduction (mid-2004 to mid-2006);
- Mean and 85th percentile speeds then reduced by 7% and 9%, respectively, on streets with mobile cameras (mid-2006 to 2012);
- Mean and 85th percentile speeds on streets without mobile cameras were generally constant in the long term, and were lower in magnitude than speeds on streets with cameras reflecting the original reasons for the selection of some streets for camera enforcement;
- 85th percentile speeds were higher in magnitude than mean speeds, and although reduced by the cameras remained above the speed limit during the study period;
- Fatal crashes on streets with cameras generally decreased over the study period;
- Serious injury crashes at intersections were generally lower following the introduction of fixed cameras;
- Crashes at intersections with fixed cameras increased after their installation due to an increase in rear-end crashes which was then followed by a decline to levels slightly below baseline levels;
- Crashes at intersections without fixed cameras remained relatively constant although trending slightly upwards, and were lower in magnitude than crashes at intersections with fixed cameras reflecting the original reasons for the selection of some intersections for camera enforcement;

- There was a decreasing trend in serious crashes around the time of the introduction of mobile cameras, on both streets in which mobile cameras were operating and not;
- There was a large decrease in serious injury crashes in mid-2002 on streets with mobile cameras when mobile camera operations increased from around 400 per month to over 600 per month;
- The large decrease (around 40%) in serious injury crashes commencing in mid-2002 was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend steadily increasing up to 2013 to the same levels when cameras were first introduced;
- The rising trend in serious injury crashes starting from around 2004 through to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period;
- The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006;
- The large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras occurred in the year immediately following the period when more than two-thirds of survey participants reported that enforcement had increased in 2001;
- In the surveys conducted between 1999 and 2001 and in 2001 the percentage of people reporting no change in enforcement clearly fell to its lowest level in the survey period. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years up to 2006, perception of increased speed enforcement remained high. This increased awareness of speed enforcement coincides with the large 40% decrease in serious injury crashes commencing in mid-2002 until the end of 2004;
- More ACT residents reported decreasing their own driving speed in 2000 up until around 2005, being the period following the introduction of mobile and red light cameras and the period when there was a large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras. However, since 2008 around three quarters of drivers reported no change to their speed coinciding with the period of steady increase in serious injury crashes;
- More ACT residents reported supporting lowering residential speed limits following the introduction of mobile and red light cameras;
- Since the introduction of cameras in, the proportion of residents that agree that safe speeding is ‘OK’ has decreased, however around one half agree with the view that speeding fines are for revenue raising;
- Evaluations of red light cameras in the literature have identified mixed effects: benefits include reduced red light running and right-angle crashes; detriments include increased rear-end crashes (a less severe crash type) during the initial phase when introduced however, right angle crashes are on average more severe than the rear end crashes;
- Evaluations of fixed speed cameras in the literature have identified benefits such as reduced speeds in the vicinity of the camera and reductions in injury and fatal crashes;
- Evaluations of mobile speed cameras in the literature have identified benefits such as reductions in speeds and speeding, and reductions in crashes;

- Evaluations of point-to-point cameras in the literature have identified benefits such as reductions in crashes;

Conclusions

Beginning at the start of 2000, mobile cameras reduced speeds by around 6%-8% in the short-term (late-1999 to mid-2002), and remained at the lower speed until 2004 (a total period of four to five years). Speeds then began to rise back to pre-camera levels over a period of approximately four years (mid-2004 to mid-2007). The 6%-8% fall in speed reached by mid-2002 coincided with a 25% to 30% reduction in serious injury crashes on streets where cameras were present. This reduction in serious injury crashes was sustained until mid-2005. If this fall in serious injury crashes is attributed to the average speed reduction it would be consistent with the Nilsson power model where a 6% to 8% reduction in speed is estimated to result in around 20% serious and fatal (casualty) crashes. This short-term effect of speed cameras is consistent with camera evaluations in other jurisdictions and countries.

It is noted that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. This increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Coinciding with this 25% to 30% fall in serious injury crashes from mid-2002 to the end of 2004 period, the survey of community attitudes to speeding indicated a marked increase in survey participants' awareness from 2001 to 2004 that speed enforcement had increased. This indicates that drivers (includes motorcycle riders) likely adjusted their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. When they found that they were not being caught as often as they thought they would be, their speed started to return to customary levels. Associated with this rise in average speed was a rise in serious injury crashes to the same rates as those when cameras operations started in 1999. Alternatively, it could be other factors like initial bursts of enforcement, which slowed drivers (and riders) down.

The introduction of cameras had a short-term effect on vehicle mean and 85th percentile speeds. This short term effect coincided with driver's awareness that enforcement of speeds had increased. As a result serious crashes fell around mid-2002. However, serious crashes and speeds started to trend upwards since around 2005-2006, finally reaching the same levels of serious injury crashes as when cameras were first introduced. Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. Further speculating, the loss of this benefit may be reflecting an unrelated background trend such as an increase in traffic activity. It could also be due to drivers realising the low risk of detection and possibly weak penalties. When a driver receives an infringement and little changes with respect to penalty fees and to loss of their license, then the impact of detection is weakened. For example, in NSW when the law was introduced that any speeding by a P1 driver would cause them to lose their licence, the speed related fatalities dropped by over on third (Job, 2013). However, it appears that the main cause may have been the drop in mobile camera hours from a peak of 700 operations per month to an average of around 500 per month (around 30% reduction) in 2007. This pattern of data over time, with the decreases in severe crashes and decreases in speeding and then increases in both serious crashes and speed, reinforce the key role of speed in road trauma. Regardless, this increase in serious crashes over the last five to six years presents a substantial road safety challenge to the ACT.

Intersection cameras produced reductions in right angle crashes and small decrease in serious crashes offset by increases in rear end crashes. Concurrently rear-end crashes were on an upward slope at control intersections. Thus, the initial increase in rear-end crashes followed by a steady return to baseline rates at case intersections resulted in a net reduction in serious crashes. On average, whilst the number of injuries resulting from rear end crashes can be substantial in terms of number of lower severity injury claims, and can have long term chronic effects related to whiplash injuries, they are often significantly less severe than side impact crashes, mainly as a result of the crashworthiness crush and occupant protection characteristics of the struck vehicle.

Recommendations

The results strongly suggest that the cameras had a positive effect on reducing speeds and thus serious injury crashes when first introduced, but that this effect began to dissipate starting around the mid-2000's. The reasons for the increases in speeding and in crashing are not clear, but factors that may have played a role were a distinct reduction in the number and consistency of mobile camera operations in approximately late 2006, and avoidance mechanisms by drivers. Simply the threat or even presence of cameras is unlikely to have an effect of reducing speeds unless there is a clear consequence of doing so. A review is recommended of the information sources available for avoidance and improved management of camera operations to create true unpredictability (along with strong publicity warning that these changes are occurring)

Other factors that may have played a role could include less media and community awareness raising of the presence of cameras and the importance of speed as a factor in road safety around 2006 to 2007. The survey data indicates an increase of survey participants reporting no change in enforcement around then. It is therefore recommended that the ACT government re-engages with the community regarding the benefits of reducing speeds for road safety and the role of cameras in reducing speeds.

Alternative accounts of the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Evaluation of these possible accounts through further research is recommended.

Serious crashes have been increasing in the ACT since around mid-2005. It is also worth noting that the total ACT vehicle fleet has increased 25% over the period 2004–2013, and transport modelling of car trips during the morning peak period suggests the total number increase by 7% from 2006 to 2011 and by 13.5 % from 2001 over a ten year period. Given the infrastructure remains relatively constant (approximately the same road area and intersections) this increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes. It is therefore recommended that further research on injury crashes during this period is performed, in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

The need to monitor and refine the camera program according to the data is critical. Timely regular monitoring and evaluation is essential to the success of any enforcement program by decision makers. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix.

The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006. Hence it is clear operation needs to increase back to the similar levels per 2006 as a first step. However this needs to be carried out hand in hand with strong communication via various media outlets and timely notices. The community must be taken along with the increase in operations and provided transparency and clear reasoning regarding the strong link between drivers who reduce their speeding to the speed limit and the safety benefits they gain.

There needs to be timely data gathering on speed surveys that are regular and consistent and allow immediate analysis of the number/percentage of drivers exceeding the limit. Again this should be transparent to the community.

Appropriate staffing and financial resources to support that scheme are essential, i.e. highly skilled data analysts that can communicate results to decision makers, sufficiently resourced enforcement agencies for increased mobile operations, sufficient resources for timely processing of infringement notices, and sufficient financial resources for community communication and media advertising with an appropriate communication strategy that takes the community along with the increased enforcement program that demonstrates obvious safety benefits.

It is also strongly recommended that further research on injury crashes during this period is performed, i.e. a linked data analysis between crashes and hospitalisations in order to understand the causes for these changes, and identify priority areas and possible intervention strategies.

History (evidence base) has proven time and again that the presence of a mix of safety camera types (fixed, mobile of both overt and covert, and point-to-point) and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. Promotion and communication and consistent enforcement that are perceived to be wide spread in different forms are a key part of any enforcement program cannot be overstated. Returning the number of mobile operations to the same levels prior to 2006 and including point-to-point cameras in the mobile camera programme would be a first step.

It is important that communications and advertising are related to enforcement, not simply to speeding. Experience and evaluations of the greatest successes in road safety via behaviour change have all been achieved through the close association of strong media promotion of enforcement and the enforcement itself. The immediate effects of these campaigns, which started at or even before the enforcement started, attest to the key role of the communications in these successes. Many communication messages do not alter behaviour because messages are not aligned and based on the threat of enforcement.

An evaluation program that continues to add data each year to the current data set presented in this report would be essential to the development of a successful camera program strategy that improves on the current status. It is critical for decision makers to receive timely feedback from surveys, speed data and crash data and this should be done in a round table mode so that it promotes a culture of team work, focusing on reducing casualties and receiving valuable input from a number of experienced participants at senior level.

In terms of evaluating the effectiveness of mobile cameras on mid-block crashes and point-to-point cameras, this cannot realistically be started until around 2016 because of the reasons of RTM and spillover effects.

Better data gathering on speed surveys that is regular and consistent and allows for regular analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also important.

The need to monitor and refine the program according to the data is critical. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix.

Finally, appropriate staffing to support these proposed improvements is critical.

1. Introduction

1.2 Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, as well as the governance of the program. The key reason for conducting this evaluation is to identify opportunities for improvement. This report delivers that independent evaluation.

1.2 General

Camera technology has been adopted widely as a means of encouraging drivers to reduce their driving speed. Lack of control of speed is a major challenge to road safety, and is a large contributor to road crashes, especially more severe crashes. The use of photographic or camera enforcement automates and extends the reach of enforcement in an effort to encourage drivers to comply with speed limits.

Red light cameras are used to encourage compliance with traffic signals and by doing so promote lower driving speeds around signalised intersections. Fixed speed cameras being located at specific points in the road network are used to encourage lower speeds usually in areas of higher traffic risk, often regarded as traffic 'black spots'. As fixed cameras become a standard fixture they can be expected to have local effects on driving speeds. On the other hand, mobile speed cameras can be placed at any position in the road network and this position can be varied so drivers will not expect their presence. Mobile cameras therefore would be expected to have a more general effect on driving speeds as drivers cannot predict their presence around the road network. Some jurisdictions, including the ACT, operate mobile cameras overtly and provide information to drivers about the presence of mobile cameras. Others operate mobile cameras covertly, providing only general information to drivers that cameras may be operating 'anywhere, anytime'. Different outcomes might therefore be expected from overt and covert operation of mobile cameras. Overt operations that make the need to reduce speeds clear to drivers might be expected to have effects in their immediate vicinity. The general deterrence effect might be expected to be stronger in situations where mobile cameras are used covertly although this effect is likely to be much weaker as the effect will require drivers to reduce speeds 'just in case' there are cameras in their vicinity, and many other factors are likely to influence this effect including driver attitudes towards road safety and enforcement.

Evaluation of the effectiveness of safety camera programmes requires well-designed studies. Evaluation studies that only include measurement before and after cameras are implemented only provide weak evidence. At the least, study design needs to include appropriately chosen controls where measures are taken at the same time as the camera measures in order to be able to show that any changes seen after the cameras are in place are not simply due to changes in driver behaviour over time. An ideal study design would also include randomisation of locations for cameras and controls to ensure that choice of location does not bias measures of effectiveness of the cameras. In road safety, however, interventions like safety cameras are almost never randomly assigned; rather they are implemented in locations where they are likely to achieve the best improvements in road safety. Nevertheless, evaluation studies should still involve the best design possible and at least a before-after design with control groups.

In evaluating the effectiveness of safety cameras in particular, two other factors commonly cited as potential threats to the validity of safety camera evaluations are Regression to the Mean (RTM) and spillover effects. Non-random assignment of cameras to locations makes these types of evaluations vulnerable to RTM effects. Cameras are almost always implemented at sites that have high demonstrated crash risk and crash risk will be significantly lower after cameras are implemented if they operate as expected. It is possible, however, that the high initial crash risk is due to natural variation in crashing that occurs potentially in any location in the road network, in which case crash risk will decrease for the same reason, rather than due to the presence of cameras. RTM effects can lead to overestimation of the effects of safety cameras and so should be avoided if we want to reveal the effect of the presence of safety cameras. Best study designs for avoiding RTM effects include using long periods for before and after measurement so natural variation can be captured in the study and using statistical means such as empirical Bayes methodology (Hallmark et al, 2010).

It is argued that spillover effects, sometimes also referred to as halo effects, threaten the validity of the evaluation of safety cameras in studies where the chosen control sites may be influenced by the presence of the safety camera such as a similar location in the next section of road. In such locations, it is argued that driver speed may still be low due to a lasting effect of the camera. Spillover effects will underestimate the effectiveness of safety cameras and again invalidate the evaluation of the effect of the camera. It should be recognised, however, that spillover effects are also likely to occur due to general community awareness of speeding and speed-related enforcement that usually occurs around the introduction of safety cameras. Where this is the case, the finding of improvements in road safety outcomes at comparison locations with no camera should be viewed as another outcome of the road safety intervention rather than a nuisance factor in the evaluation. The comparison between camera and no camera sites will then be showing the additional effect of cameras to a road safety program rather than necessarily the whole program itself. Spillover effects of cameras may be less likely for some types of safety cameras. In particular, where camera locations are known and expected, such as fixed location cameras (red light and fixed speed), people come to anticipate their presence and so would be expected to produce less spillover effect as drivers respond to the particular sites that they know are enforced. Overall, to evaluate the effect of a safety camera program in its entirety would ideally ensure that control sites are in areas that will not be influenced by any facets of the program, not just the presence of cameras.

Finally, good evaluation designs should include measures relevant to the outcome expected to change as a result of the intervention. The objective of introducing safety cameras is to reduce driving speeds and as a result to reduce crashes and casualties. As shown in Figure 1, it is expected that the presence of safety cameras and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication is a key part of any enforcement program. The relationship between speed and casualty crashes is well known and has been modelled by many researchers. For example, Figure 2 shows the often cited Nilsson (2004) power model showing the relationship between the change in mean speed and fatal and serious injury crashes. It shows that a 7% reduction in mean speed will result in around 20% fall in Fatal and Serious injury crashes.

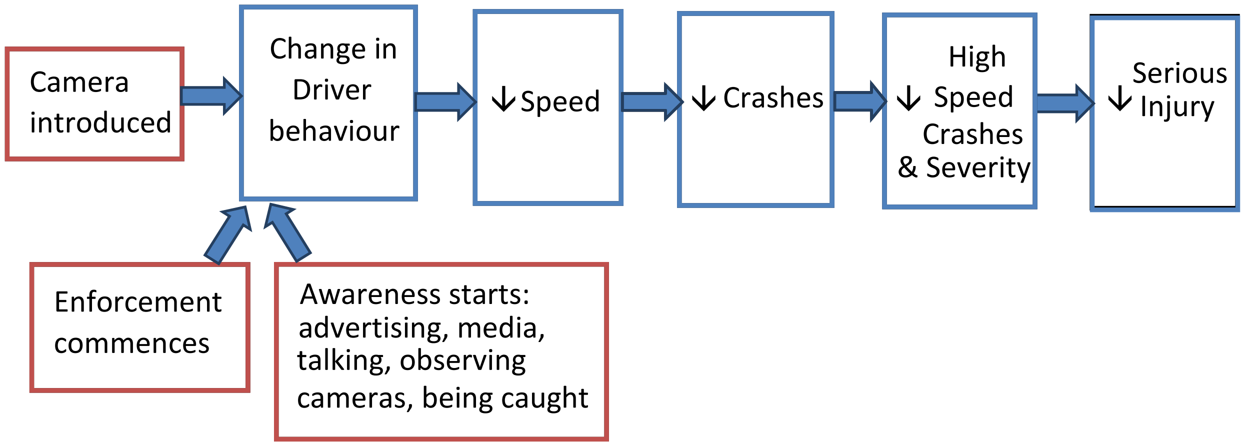

Figure 1: Schematic of the expected effects of safety cameras on road safety outcomes.

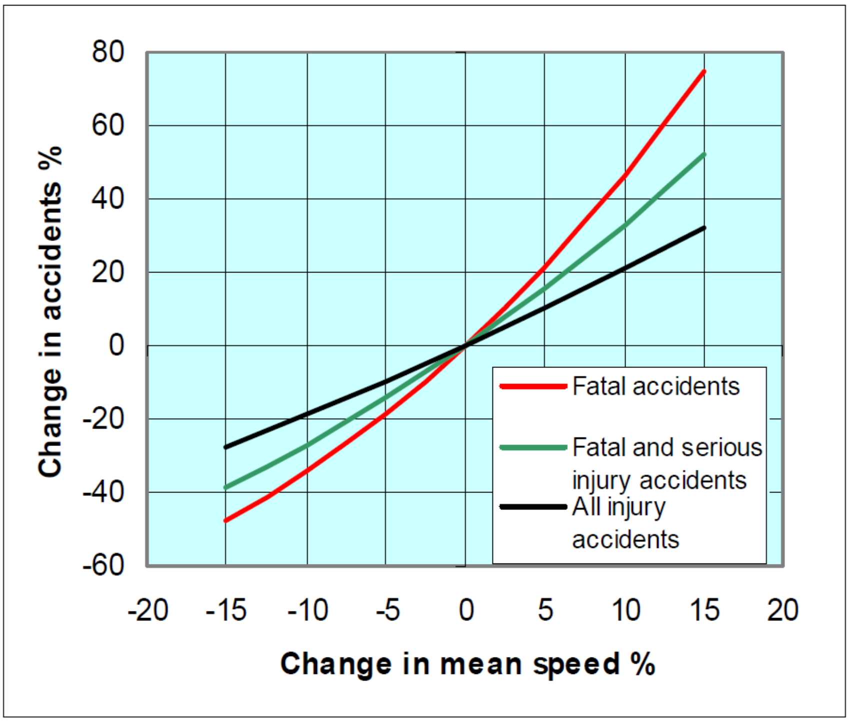

Figure 2: Nilsson (2004) power model showing relationship between casualty crashes and mean speed.

It must not be overlooked that the effect of safety cameras is also through punishment or enforcement of speed limits which also encourages changes in driver behaviour to produce lower speeds, crashes and injury. In this way, simply the presence of safety cameras can have a general deterrence effect on driver behaviour due to the fear of being caught, whereas the use of enforcement together with communication tends to have a specific effect on individual driver behaviour, mainly influencing speeding drivers who are caught.

These three effects of cameras, communication and enforcement are also likely to produce different changes in behaviour in parts of the road network in which cameras are introduced or not. The strongest effects naturally should occur in the safety camera locations where the presence of cameras combined with enforcement and communication provides the greatest encouragement for drivers to comply. It would be expected, that cameras will also influence driver behaviour in areas where some drivers might suspect that cameras are operating and so modify their behaviour accordingly. In most settings, the introduction of safety cameras is publicised and justified through media and other means of dissemination. This will also raise awareness amongst the community of the general presence of safety cameras which would be expected to add incentives for some drivers to change their behaviour and reduce speed because they want to avoid penalties and because they believe that compliance is safer.

The presence of enforcement and consequent speeding infringements for drivers who violate the speed limit, is likely to create further incentive for drivers to reduce their speed in locations where the enforcement occurs. Following the introduction of safety cameras it would be expected that infringements may be initially high, but will reduce as drivers learn about the presence of cameras and enforcement either through their own experience or the publicised experiences of others. With time, infringement rates would be expected to reduce as driver speed is reduced because of the cameras having an effect.

Safety camera evaluations should therefore include measures of changes in driver behaviour, especially speed around speed cameras and speed and red light running around red light cameras. As the ultimate outcome of camera programmes is to reduce injury crashes, these measures should also be included. Measures of enforcement should also be included in camera evaluations because enforcement is an integral aspect of the road safety intervention. Numbers of infringements are not a direct outcome of camera programmes. However, they would be expected to influence driver behaviour both independently and in combination with the presence of cameras. In the present study, efforts have been made to include all the relevant measures (infringement rates, speed, injury and crash data), while minimising the potential confounders (RTM and spillover effect).

2. Method

2.1 Literature review

The review of existing scientific literature on the impact and effectiveness of road safety cameras looked at published studies in the international peer-reviewed literature and unpublished reports from English-speaking countries including all Australian jurisdictions, Canada, UK, NZ and USA and from the top road safety performing countries in the OECD where their websites are translated into English (e.g., Sweden, Netherlands, France). The objective of these literature searches was to identify evidence of best practice in implementation of road safety cameras in order to evaluate the impact of different types of cameras, identify any issues that need to be taken into account in implementing safety camera programs and to determine whether there are new opportunities to improve the effectiveness of the current program in the ACT.

A search of the available published scientific literature was conducted using four major search engines including Web of Science, PsycINFO, Scopus and PAIS International. The key words used included speed, camera, red light camera, evaluation and enforcement in different combinations.

A search of reports of evaluations of safety camera effectiveness was also conducted. This involved a website search of the main websites of road authorities in the different jurisdictions of Australia, Canada, UK, NZ and USA as well as Sweden, Netherlands, France (where their website is in English). The purpose of this search was to identify any grey literature that was not located from the conventional literature search.

2.2 Review of community attitudes to speeding

This review used existing literature to understand changes in community attitudes to speeding in the ACT following the introduction of different types of speed cameras, including the results of the series of community attitude surveys conducted for the Department of Infrastructure and Development and related entities over nearly 25 years. Changes in respondent’s views of speeding were linked to the introduction of the different types of cameras in the ACT (i.e., mobile cameras from 1999, fixed red light/speed cameras from 2000, fixed speed cameras from 2007). As community attitudes are an important component of compliance with speed limits, this analysis may provide some other insights into the comparative effectiveness of the road safety camera program.

A series of community attitude surveys have been conducted for the Australian government's transport portfolio, currently the Department of Infrastructure and Regional Development. A total of 22 surveys have been conducted on a regular basis since the late 1980's. Questions about speeding were included in all surveys but since 1995 there has been a standard series of questions about speeding included in each survey. Answers to many of these questions are also available by jurisdiction so that it is possible to track changes in the perceptions and attitudes of ACT residents about speeding over the 15 years between 1995 and 2011. This data also allows investigation of the influence of the introduction of safety camera's on community attitudes towards speed and speeding over the period. With the staggered introduction of different types of cameras in the ACT, it was possible to look at the relative impact of each type of camera on community attitudes. This will allow examination of the general deterrence effect of mobile cameras which were introduced from 1999, the effects of fixed red light cameras operating in specific locations which were introduced from 2000 and fixed speed cameras from 2007.

Each of the 22 Community Attitude surveys conducted by the federal transport authority between 1995 and 2011 were reviewed to establish the series of questions on speeding that had remained the same across each survey.

The questions included were:

- "In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"
- "Have you personally been booked for speeding in the last two years?" And, if so "Have you personally been booked for speeding in the last six months?"
- "Thinking about 60km/h speed zones in urban areas:
    1. How fast should people be allowed to drive without being booked for speeding? (i.e. the 'acceptable' speed tolerance)
    2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)”
- "Thinking about 100km/h speed zones in rural areas,
    1. How fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance)

2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)”

- Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:
  1. Fines for speeding are mainly intended to raise revenue
  2. I think it is okay to exceed the speed limit if you are driving safely
  3. Speed limits are generally set at reasonable levels
  4. If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
  5. An accident at 70km/h will be a lot more severe than an accident at 60km/h
- "Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?"
- "Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"
- "Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways", they were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"
- "In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

Each survey looked at a national sample of residents 15 years and over. Survey was by telephone with a letter in advance advising the household about the survey. Sampling of all states and territories was stratified by regional probability sampling, but from 1999 the sampling strategy was modified to ensure at least 150 interviews in each jurisdiction. Sample size for the 1995 to 1998 surveys was around 100 interviews in each survey.

2.3 Speed survey and road crash data study

2.3.1 Data collections

The data collections that were accessed for the data study are summarised in Table 1.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 1: Data collections used for the study

Speed survey data was available from 1997 to 2012 (inclusive), and consisted of the annual summaries indicating the site location, speed limit, survey date, 24 hours traffic volume, mean and 85th percentile speeds of the survey. The road crash data consisted of all police-reported crashes that occurred on public ACT roadways, resulting in either property damage, injury or fatality. In order to have five years of crash data prior to the start of the camera program, crash data was extracted from 1994 to 2012 (inclusive). Enforcement data for both fixed and mobile cameras consisted of the number of vehicles checked by the camera, and the number of infringements issued, and was available from the implementation of each camera.

2.3.2 Selection of case and control mobile camera locations

The present study considered two types of roadway locations; streets in which mobile cameras were implemented anytime during the period 1999 to 2012, and streets in which they were not. Streets with mobile camera operations are hereafter termed ‘case’ streets, while those without cameras are termed ‘control’ streets. It should be noted that the control streets do not represent a true ‘control area’, since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

During the implementation of the mobile camera program since 1999, a total of 177 ACT streets were approved for mobile camera operations. Road crash data was available for all public ACT streets on a continuous basis. Speed survey data was available for selected ACT streets on a discontinuous basis, since surveys have been performed in a non-systematic way since 1997. In order to select locations for the present study of mobile camera operations, the speed survey data was deemed to be the limiting data collection and was therefore used.

Initially, streets on which mobile camera operations were introduced were identified in the speed surveys undertaken in 1997. This allowed for as much pre-camera data as possible. These streets were then tracked temporally and the number of years in which at least one survey was undertaken up to 2012 (inclusive) was established. Streets were then ranked according to the total number of years available, resulting in a total of 48 streets with five or more survey years. Streets on which mobile camera operations were not introduced were then selected in the same manner, resulting in a total of 47 streets with five or more survey years available. These analyses were performed manually using the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

This resulted in a total of 95 streets for the mobile camera analysis. The full list of case and control streets is provided in Appendix A. Crash data located anywhere along these streets was then provided by the ACT Territory and Municipal Services Directorate. Each street was then treated as a single location, a location number was assigned to it, and any crash or speed survey located at any position along the full length of that street, was assigned to that location number.

2.3.3 Selection of case and control fixed camera locations

There are three different types of fixed cameras operating in the ACT; combined red light and speed cameras located at intersections, speed cameras located along mid-block sections and point-to-point cameras. Point-to-point cameras were recently installed in 2012, thus insufficient data was available to assess these cameras in this study. Road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. However, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis.

Intersection crashes are identified specifically in the road crash data collection, thus particular intersections were easily identified, and an assessment of the association of the introduction of fixed intersection cameras with crash outcomes could be assessed. Case and control intersections were identified in a similar manner to the mobile cameras, where case intersections were those on which fixed red light and speed cameras were installed. Since there was a relatively small number of these (thirteen), all fixed camera intersection locations were selected. Thirteen control intersections were then identified by randomly selecting other intersections located on the same street as each of the case intersections. This resulted in a total of 26 intersections for the fixed intersection camera analysis. The full list of case and control intersections is provided in Appendix A.

2.3.4 Time periods

The ACT road safety camera program began on the 6th October 1999 with the introduction of mobile camera operations on 22 streets. Fixed cameras began to be introduced shortly thereafter in 2000. There was a reduction in mobile operations in 2006, where due to various resource limitations mobile camera vans performed fewer operations. In order to assess associations with the overall camera program, the two key dates of the introduction (October 1999) and the change (October 2006) were identified, and are hereafter termed Intervention 1 and Intervention 2, respectively.

For each case street, the date on which mobile camera operations began in that street was established, and is hereafter termed the 'begin-date'. Begin-dates for the selected streets ranged between October 1999 and March 2011. In order to perform the case-control analyses, each control street was matched to a case street, based upon traffic volume and speed zone. Since every case and control street had a speed survey performed in 1997, the traffic volume in 1997 was used to establish matched street pairs. Each control street was matched to a unique case street, and the begin-date of the case street was then allocated to the matched control street.

For each case intersection, the date of the installation of the fixed red light and speed camera was established as the begin-date for that street, and ranged between June 2000 and August 2007. Begin-dates were then assigned to control intersections, as the date corresponding to the begin-date of the matched case intersection.

2.3.5 Statistical analysis

The statistical analyses were divided into two categories, assessing the association of the camera program with changes in; vehicle speeds and road crashes. Vehicle speeds were assessed using speed survey mean and 85th percentile values. Road crashes were aggregated into intersection and non-intersection crashes. Intersection crashes were aggregated into serious (injury or fatality), rear-end, non-rear-end and right angle/right turn into oncoming vehicle crashes. Non-intersection crashes were aggregated into fatal, serious and all crashes. Within these categories the analyses were divided into two further categories, assessing associations with regards to; the implementation of the overall camera program and the implementation of cameras at particular streets/intersections. A total of 32 models were developed, as outlined in Table 2. All outcomes of vehicle speeds and crash counts were aggregated into monthly counts.

The aim of assessing the implementation of the overall camera program was to identify the effect of the camera program on the network generally. For this purpose the case and control streets were aggregated and assessed individually, in order to assess the effect of the camera program on streets that had, or did not have, camera operations. These analyses were relative to the start date of the camera program (Intervention 1) and the change date of mobile operations (Intervention 2).

Model #	Outcome	Type	Intervention	Intervention dates
1	Speed surveys – mean	cases	Overall program	Interventions 1 and 2
2	Speed surveys – mean	controls	Overall program	Interventions 1 and 2
3	Speed surveys – mean	cases	Individual mobile cameras	Begin-date of cameras on each street
4	Speed surveys – mean	controls	Individual mobile cameras	Begin-date of cameras on each street
5	Speed surveys – mean	case-control	Individual mobile cameras	Begin-date of cameras on each street
6	Speed surveys – 85th percentile	cases	Overall program	Interventions 1 and 2
7	Speed surveys – 85th percentile	controls	Overall program	Interventions 1 and 2
8	Speed surveys – 85th percentile	cases	Individual mobile cameras	Begin-date of cameras on each street
9	Speed surveys – 85th percentile	controls	Individual mobile cameras	Begin-date of cameras on each street
10	Speed surveys – 85th percentile	case-control	Individual mobile cameras	Begin-date of cameras on each street
11	Serious road crashes	cases	Overall program	Interventions 1 and 2
12	Serious road crashes	controls	Overall program	Interventions 1 and 2
13	Serious road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
14	Serious road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
15	Serious road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
16	Road crashes	cases	Overall program	Interventions 1 and 2
17	Road crashes	controls	Overall program	Interventions 1 and 2
18	Road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
19	Road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
20	Road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
21	Serious intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
22	Serious intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
23	Serious intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
24	Intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
25	Intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
26	Intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
27	Intersection crashes-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
28	Intersection crashes-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
29	Intersection crashes-non-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
30	Intersection crashes-non-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
31	Intersection crashes-right A/T	cases	Individual fixed cameras	Begin-date of cameras on each street
32	Intersection crashes-right A/T	controls	Individual fixed cameras	Begin-date of cameras on each street

Table 2: Statistical models

The aim of assessing the implementation of cameras on particular streets/intersections was to identify the local effect of introducing individual cameras or camera operations. These analyses were relative to the begin-date for case streets/intersections, or the assigned begin-date for control streets/intersections (i.e. the begin-date of the matched case street/intersection). Case and control streets/intersections were first aggregated and assessed individually, then aggregated and assessed in a case-control study. The latter analysis provides statistical measures of the difference between the implementation of cameras on case and control streets/intersections. However, this comes with the caveat concerning the limitations outlined earlier regarding the selection of the control streets and the spillover effects that may be occurring.

Poisson regression was used for all models, and Pearson deviance was used to correct for over-dispersion. Poisson regression fits a log-linear model to the data, and is therefore most appropriate when the data approximates a log-linear trend. Before-and-after studies typically use the same temporal length both before and after, however are not bound by this. For the assessment of the implementation of camera operations on each individual street/intersection, this seemed a rational approach and the temporal period was set by the minimum amount of pre-data available (60 months for the crash data and 33 months for the speed survey data). For the assessment of the implementation of the overall camera program, the raw data was first assessed. For the crash data a relatively linear trend was observed between Intervention 1 and Intervention 2, therefore a single model was fit for this period. For the speed survey data a bilinear trend was observed during this period, therefore two models were fit. The first model used the same temporal length as the pre-camera speed survey data (33 months), while the second model used the remaining period up to Intervention 2. Accordingly, the crash data model was continuous between Intervention 1 and Intervention 2, while the speed survey model was not.

The outcome (COUNT) for the models was either monthly speed survey results (Models 1 – 10) or monthly crash counts (Models 11 – 32). The former were expressed as the measured speed divided by the speed limit (speed rate). Since speed surveys were not continuous over time, for each month all the speed rates for case streets were averaged, as were all the rates for control streets. Monthly crash counts were normalised to monthly vehicle registrations in the ACT (where monthly values were linear interpolations of annual values), for models considering the overall camera program (1994 to 2012). For all statistical models the following two covariates were assessed; TIME and CAMERA. The variable TIME represents monthly intervals and was a continuous covariate centred on the intervention date being considered. CAMERA was a binary variable which had the value zero prior to the intervention, and one following the intervention. For all models of crash counts, the locations (i.e. individual streets) were treated as subjects, where responses from different subjects were assumed to be statistically independent, while responses within subjects were assumed to be correlated. These models took the form of Equation 1. For the case-control models (Models 5, 10, 15, 20, 23, and 26), the identification of the location as a case or control street was included as an additional binary variable CASE. These models took the form of Equation 2. Interactions between variables were also considered. It should be noted that in all 32 statistical models the outcome considered was based on a period of one month, however in many results figures plotted in the following sections the raw crash counts are plotted with respect to three months, purely for clarity in the figures. SAS version 9.3 was used for all statistical analyses. Statistical significance was measured at the 0.05 level.

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,(\text{TIME} \times \text{CAMERA}) \quad (1)$$

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,\text{CASE} + \beta_4\,(\text{TIME} \times \text{CAMERA}) + \beta_5\,(\text{TIME} \times \text{CASE}) + \beta_6\,(\text{CAMERA} \times \text{CASE}) + \beta_7\,(\text{TIME x CAMERA} \times \text{CASE}) \quad (2)$$

3. Results

3.1 Literature review

3.1.1 Evaluations of red light cameras

Appendix B provides a summary of the papers and reports identified in the literature search. Four existing reviews of literature on the effectiveness of red light cameras were identified (Table 3a). The first was a critical review of international literature (Retting, Ferguson and Hakkert, 2003) looking at outcomes of violations and crashes, however no information was provided about how studies were chosen for inclusion in the review, except that they were all controlled evaluations of before and after effects. Only some of the studies included in this review accounted for RTM and spillover effects. The second was a Cochrane Collaboration meta-analysis review (Aeron-Thomas et al, 2005) of violations and different crash types from studies selected based on searches of electronic databases that fulfilled established criteria for inclusion. This review included only studies with controlled before-after designs and controls for regression to the mean (RTM) and spillover effects. The third was a meta-analysis of studies investigating intersection crashes that were identified from searches of electronic databases (Erke, 2009). This review included all designs including uncontrolled before-after studies and only some of the studies included controls for RTM and spillover effects. The fourth was an update and extension of the third review and again involving studies of intersection crashes that were identified from electronic searches, but with no restrictions on design or whether or not RTM and spillover was accounted for (Hoyos 2013). As might be expected there was a significant degree of overlap between the four reviews. Of the 10 papers included in the Cochrane review, 60 percent were shared with the Retting et al (2003) review and all were included in the two most recent reviews which included 14 and 11 new studies respectively. The Retting et al (2003) review included seven studies that were not included in any of the recent reviews.

In addition, the search in the current review of literature found four more recent evaluation studies of red light cameras (Table 3b). Two of these studies were well-designed before-after evaluations of the installation of red cameras (Ko, Geedipally and Walton, 2013; McCartt and Hu, 2014) and the other two involved studies comparing before and after the removal of red light cameras (Porter, Johnson and Bland, 2014; and Pulugurtha and Otturu, 2014). All studies involved controls of some type and all took steps to control for RTM and spillover effects.

The review also identified four evaluation studies of safety cameras that incorporated red light and speed cameras (Table 4). These were included in this review as they were the only evaluations found specifically of safety cameras which combine the two types. Three of these studies involved before and after with control designs (Vanlaar, Robertson and Marcoux, 2014; Kloeden, Edwards and McClean, 2009; Budd, Scully and Newstead, 2011) and one involved description of the change after cameras were introduced and did not include before measures or controls (McKenzie, Kloeden and Hutchinson, 2012). Only two of these studies accounted for RTM effects (Vanlaar et al, 2014; Budd et al, 2011) and only one accounted for spillover effects (Vanlaar et al., 2014)

Overall, each of the reviews concluded that the presence of red light cameras decreased injury crashes especially right angle crashes, however, the extent of the decrease varied between reviews and the extent to which the reviewers took into account RTM and spillover effects. Both

Retting et al (2003) and the Cochrane review concluded that injury crashes were reduced by 25-30%. It is notable however that the conclusion from the Cochrane review was based on a single well-designed study with appropriate controls. In contrast, the most recent reviews concluded either that there was no statistically significant change in casualty crashes (Hoyos, 2013) or a 13 percent increase in such crashes (Erke, 2009). While these reviews were the most comprehensive, including the largest number of studies, unlike the Cochrane review approach, they included all studies regardless of design flaws. Lund et al (2009) criticised the Erke (2009) review and cautioned against accepting its conclusions on the basis that it included a number of poorly designed studies. In response, Hoyos (2013) conducted a revised review that included extensive analysis of the role of potential moderator variables. Hoyos (2013) concluded that when RTM is controlled there is no evidence of significant effects of red light cameras on overall injury crashes, but the presence of red light cameras reduced right angle casualty crashes by 33 percent. The earlier review by Erke (2009) also found a significant, but smaller reduction of 10 percent in right angle crashes once RTM and spillover effects were accounted for. Two recent evaluation studies of the presence of red light cameras (Ko et al, 2013; Pulugurtha and Othuru, 2014) also showed a 24 and 69 percent decrease respectively in right angle crashes. Similarly the three recent A-B/control evaluation studies of red light and speed camera combinations (Vanlaar, et al, 2014; Kloeden et al, 2009; Budd, et al, 2011) all found significant decreases in right angle crashes of over 40 percent. The Cochrane review found no significant effect on right angle crashes but this was based on only two studies with partial control of moderator variables and the Retting et al (2003) review did not look at specific types of crashes. The evidence therefore leads to the conclusion that the presence of red light cameras have a significant benefit of reducing right angle crashes. This conclusion is supported by the nature of the crash that shows the most benefit. We would expect that red light cameras should reduce right angle crashes the most, and the evidence suggests that they do.

On the other hand, almost all of the reviews and studies that included measures of rear-end crashes made the opposite conclusion: rear-end crashes increased by around 40 percent after the introduction of red light cameras (Erke, 2009; Hoyos, 2013; Vanlaar et al, 2014; Pulugurtha and Otturu, 2014) and by around 19 percent for injury crashes (Hoyos, 2013). The exceptions were the Cochrane study which found no significant change across three studies, and two of the red light/speed camera combination evaluations (Kloeden et al, 2009; Budd et al, 2011), none of which accounted for the effects of all moderator variables.

In combination, the above studies indicate that red-light cameras reduce right angle crashes and increase rear-end crashes. While both crash types can be severe, on average right angle crashes are significantly more severe than rear-end crashes mainly as a result of the vehicle's structure and hence occupant protection crashworthiness. For example, in a side impact, the crush distance is small and hence there is little opportunity for ride-down to reduce the severity of the impact. On the other hand, in rear-end impacts, the crush distances are much larger (both the front end of the impacting vehicle and the rear end of the struck vehicle), and with current improved seat back and head rest anti-whiplash design, the severity of the crash would be substantially reduce compared to a side impact.

Red light cameras would also be expected to influence violations in the form of reductions in red light running. The Retting et al (2003) review concluded that these cameras reduced violations by 40 to 50 percent and two recent studies (Ko et al, 2013; McCartt and Hu, 2014) made similar conclusions, with McCartt and Hu (2014) finding that violations involving making very late decisions to run the red light (up to 1.5 seconds after red) were almost eliminated. Again, the

Study	Study design	RTM	Spill over	Outcome	Conclusions
a) Reviews of evaluations: Red light cameras					
Retting, Ferguson & Hakkert (2003)	Review but no detail on study selection	N	Y	Violations (7 studies)	↓ camera sites (22-78%), but ↓ noncamera sites (27-69%) (4 studies) = for control sites (3 studies)
	A-B + controls (15 studies)	some (4)	some (1)	Crashes/injury (8 studies)	↓ camera sites: noncamera (10-39%) (7 studies)
Aeron-Thomas (2005)	Cochrane review A-B+controls (10 studies)	Y	Y	Injury crashes, (5 studies)	↓ camera sites: noncamera/controls (29%)* 1 study ↓ camera sites: noncamera (13%)* (3 studies)
				right-angle (2 studies)	not significant
				rear-end (3 studies)	not significant
				Violations (1 study)	not significant
Erke (2009)	Meta-analysis varied designs (21 studies)	Y	Y	All crashes	↑ camera sites (if control RTM & Spillover effects) (+15%) ↓ camera sites (if no/some controls) (-16-19%)
				Injury crashes	↑ camera sites (if control RTM & Spillover effects) (+13%) ↓ camera sites (if no/some controls) (- 17-25%)
				Right angle	↓ camera sites (if control RTM & Spillover effects) (-10%) ↓ camera sites (if no/some controls) (- 14-49%)
				Rear end	↑ camera sites (if control RTM & Spillover effects) (+43%) ↓ camera sites (if no/some controls) (- 4- +17%)
Hoyos (2013)	Meta-analysis (28 studies)	Y	Y	All crashes	not significant (+6%)
				Injury crashes	not significant (+13%)
				Right angle	↓ camera sites (non-injury: -13%; injury: - 33%)
				Rear end	↑ camera sites (non-injury: +39%; injury: +19%)

Table 3: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
b) Recent evaluations: Red light cameras					
Ko, Geedipally, Walden (2013)	A-B +empirical Bayes (245 cameras, 66 no cameras)	Y	Y	Red light running Right angle Rear end	↓ camera sites (-20%) ↓ camera sites (-24%) ↑ camera sites (+37%)
Porter, Johnson, Bland (2014)	A-B + controls: Cameras removed (4 cameras, 2 local no cameras, 2 outside no cameras)	Y	Y	Red light running	Change 3.1% with cameras to 11.3% after removal Non-treated - 14%
McCartt, Hu (2014)	A-B +controls (4 camera, 4 local no camera, 4 outside no cameras	Y	Y	Violations 1 yr after ticketing commenced	↓ camera sites (-39% for 0.5secs after red) ↓ camera sites (-86% for 1.5secs after red)
Pulugurtha, Otturu (2014)	A-B -C: Cameras removed, empirical Bayes (32 cameras)	Y	Y	intersections with reduced crashes intersections with reduced rear end/ sideswipe crashes	↓ camera sites (-50% for before - after cameras) ↓ camera sites (-16% for before - termination of cameras) ↑ camera sites (+>50%)

Table 3 cont'd: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
Vanlaar, Robertson, Marcoux (2014)	A-B +controls Time series (4 cameras, 4 local no cameras), no cameras comparison)	Y	Y	Right angle Rear end Speed	↓ camera sites (-46%) ↑ camera sites (+42%) No change
McKenzie , Kloeden, Hutchinson, 2012)	Change after cameras introduced (21 cameras)	N	N	Red light Violations Speed violations	↓ over 12 months (slow change) ↓ over 12 months (rapid change, especially higher range speeding)
Kloeden, Edwards, McClean (2009)	A-B +controls (1988: 8 cameras, all no camera sites in Adelaide) (2001: 24 cameras, all no camera sites)	?	N	Casualty crashes Right angle Rear end	1988 study: ↓ camera sites (-21%) 2001 study: no change 1988 study: ↓ camera sites (-491%) 2001 study: no change No change
Budd, Scully, Newstead (2011)	A-B+controls (76 camera sites: Camera activated, camera not activated)	Y	N	Casualty crashes Right angle/right turn Rear end	↓ camera sites (-47% direction of travel monitored by camera; -26% for all) ↓ camera sites (-44%) No change

Table 4: Summary of literature on red light and speed camera evaluations

Cochrane review failed to find evidence of changes in violations due to red light cameras, but only one study included this measure. One study (Porter et al, 2014) studied the effect of removing red light cameras and found an increase in violations of around 8 percent after they were removed.

3.1.2 Evaluations of speed cameras

The literature search identified three reviews of speed cameras generally (fixed and mobile). This included a meta-analysis by Pilkington and Kinra (2005), which reviewed 14 controlled trials and observational studies and a systematic, narrative review by Thomas, Srinivasan, Decina and Stapin (2008) containing 13 studies chosen because of their methodological strengths. The most recent review was a Cochrane Collaboration review by Wilson, Willis, Hendrika, Brocque and Bellamy (2010), which examined the use of speed cameras for the prevention of road injuries and fatalities. The three reviews overlapped considerably. The Pilkington and Kinra (2005) and Thomas et al. (2008) reviews shared seven studies and the Cochrane review contained all of the studies in the Thomas review and 64.3 percent of those in the Pilkington and Kinra review as well as 20 additional studies, most of which were more recent. The Cochrane review was therefore the most comprehensive and became the basis of the current review.

Overall, the Cochrane review concluded that in the presence of speed cameras, average speed reduced by between 1 and 15 percent and the proportion of vehicles speeding by 14 to 65 percent compared to controls. They also concluded that in the vicinity of cameras, all crashes reduced by 8 to 49 percent and fatal and serious injury crashes by 11 to 44 percent, leading to an overall improvement of between 8 to 50 percent compared to control sites. This provides a good appraisal of the existing well-designed evaluations of speed cameras, however the review did not distinguish fixed and mobile cameras. As the action of these two types of cameras is quite different, the current review included the studies in the Wilson et al review but separated them into those looking at each type of camera in order to determine the separate effects of each type. Additional studies published since the Cochrane review were also included in this analysis.

3.1.3 Evaluation of fixed speed cameras

The Cochrane review (Wilson et al., 2010) included 17 studies of the effectiveness of fixed speeding cameras which were judged to have adequate study designs. In addition to those included in the Cochrane review, the electronic searches for this review identified two additional more recent studies so the review for this report included 19 studies of fixed speed cameras (Table 5).

The studies included in the review involved study designs with pre/post camera implementation measures and control or comparison sites (78.9%) or interrupted time series analysis (21.1%). Using the Cochrane collaboration criteria which require random assignment of treatment and controls, these studies designs would be classified as only of moderate methodological quality. Around half addressed the problem of potential bias due to RTM (52.6%). None of the studies formally addressed spillover effects, although it could be argued that the inclusion of appropriate control or comparison groups provided an opportunity to assess these effects by showing the extent of additional change due to the presence of the camera itself. Around half of the studies looked at the effect of cameras on both speeding and crashes (52.6%), with half of the remainder looking at effects only on speed (21.1%) or crashes (26.3%). The studies were conducted in a

broad range of countries including Australia, Canada, Germany, Spain, Finland, UK, Hong Kong, Netherlands, New Zealand and USA.

All studies showed benefits of fixed speed cameras for reducing speed in the location of the cameras. Overall, the studies showed reductions in mean speed in the vicinity of cameras of 3 to 10 percent or 2 to 8kph reductions in mean speed. Studies that included control of RTM effects showed similar reductions in speed. Of the five studies that looked at the proportion of speeding vehicles in the vicinity of fixed cameras, all showed reductions but there was a very large variation between studies, ranging from 10 to 70%, although the two studies that controlled for RTM showed similar reductions of around 30 percent. Twelve studies measured injury crashes and all found reductions following implementation of fixed cameras ranging from 7 to 32 percent. In studies that controlled for RTM effects, the reductions tended to be greater (20-56%). Only five studies measured fatal crashes specifically, and again all showed reductions after implementation of fixed cameras ranging from 11 to 89 percent.

The greatest effects of fixed cameras are likely to be in their immediate vicinity. In some studies, the effects of cameras may have been underestimated as the effects were measured 2km from the treatment area (Chen et al, 2002; Makinen, 2001) although studies that directly measured distance halo effects showed decreases in road safety benefit with increased distance from the fixed camera site (Mountain, et al., 2004; Hess and Polack, 2003; De Pauw et al, 2013). Figure 3 shows the 85th percentile speeds around a speed camera in NSW and shows that speeding drivers slow for the cameras and speed up again after the camera, i.e. deliberate slowing for the camera (Job 2014).

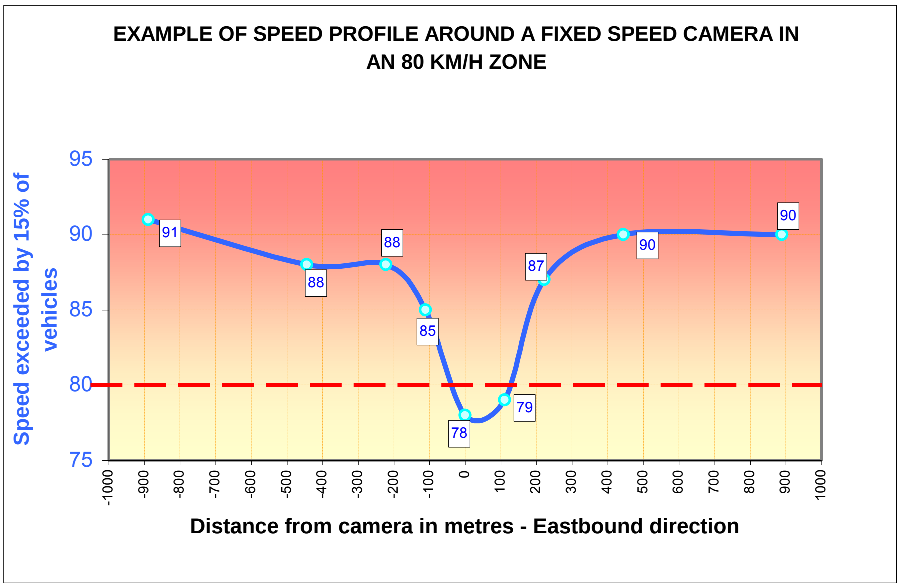

Figure 3: 85th percentile speeds recorded on approach and departure around a sign-posted speed camera in in an 80km/h speed limit in New South Wales

The duration of the benefit of fixed cameras over time was examined in some studies, with findings of fatal crash reductions for up to two years (ARRB, 2005; Perez et al, 2007; Makinen, 2001), but Retting, Kyrychenko and McCartt (2008) showed that positive speed reductions diminished when the enforcement period ended.

Study	Design	RTM	Spillover	Outcome	Conclusions
ARRB Group Project Team (2005)	A-B+Control	N	N	Speed fatal crashes injury crashes	↓ 6.3 km/h mean speeds, 5.8kh/h at 2 years ↓ 70% exceeding speed limit, maintained at 2 years ↓ 86% exceeding speed limits by at least 10 km/h, 88% at 2 yrs. ↓ 22.8% all fatal and injury crashes ↓ 89.8% fatal crashes ↓ 20.1% injury crashes at 1 yr
Diamantopoulou, Corben (2002) (2 reports)	A-B+Control.	N	N	Speed reduction	↓ 3.4% speed reduction ↓66% drivers exceeding the 80km/h posted speed limit ↓ 79% drivers speeding over 90km/h ↓ 76% drivers speeding over 110km/h ↓ 13% fatal crashes ↓ 10% serious injury ↓ 7% overall injuries
Chen, Meckle, Wilson (2002)	A-B+Control	Y	N	crashes Mean speed	↓2.8km/h mean speed at monitoring site 2km from treatment area ↓14% expected crashes at photo-radar locations ↓ 19% at non-Photo-Radar locations ↓ 16% along the study corridor as a whole
Lamm, Kloeckne (1984)	A-B+Control	N	N	Median speed crashes (injury and fatal)	↓ 30kph median speed ↓ 42kph 85th percentile speed ↓ 18 times in injury crash frequency ↓ fatal crashes
Perez, Mari-Dell'Olmo, Borrell (2007)	Interrupted time series	N.	N	crashes injured	RR= 0.69 (95% CI = 0.54 - 0.89) crash 2 years post implementation RR= 0.70 (95% CI = 0.53-0.92) injury = comparison sites.
Makinen (2001)	A-B+Control	N	N	speeding crashes	↓ 8% speeding at 80kph limit in year one, further ↓2% in year two. ↓ 5% speeding at 100km/h in year one, further ↓2% in year two. Distance halo of 3km upstream and 2km downstream. no change in crashes compared to controls

Mountain, Hirst, Maher (2004)	A-B+Control	Empirical Bayes	N	speeds	↓4.4mph mean speeds ↓5.9 mph 85th percentile speeds ↓35% percentage exceeding the speed limit. ↓ 25% personal injury crashes, 11% fatal and serious at 500m post camera ↓ 24% personal injury crashes, 13% fatal and serious at 1km post camera
Hess (2003) (2 reports)	Interrupted time series	Y	N	Injury crashes	↓ 45.74% weighted injury crashes in 250m from camera sites ↓ 20.86% injury crashes in 2000m from the camera.
Gains, Heydecker, Shrewsbury, Robertson (2004) (3 reports)	A-B+Control	empirical Bayes	N	speed Fatal/serious injury injury crashes	↓ 6% mean speed ↓7% 85th percentile speed ↓ 30% exceeding speed limit ↓43% exceeding speed limit > 15 mph ↓42% fatal/serious injury ↓ 24% injury crashes
Highways Agency's London Network and Customer Services (LNCS) (1997)	A-B+Control	N	N	crashes (fatal, serious, and injury)	↓ 12.4% all crashes. ↓69.4% fatal crashes pre/post and 55.7% relative to controls. ↓ 25% serious injuries ↓ 31% fatal/serious crashes combined.
Hung-Leung (2000)	A-B+Control	N	N	speeding cars injury, fatal crashes	↓ 65% speed > 15 km/h over limit. ↓ 23% injury crashes pre/post; ↑32% in the control group. ↓66% fatal crashes.
Oei (1996) (2 reports)	A-B+Control	N	N	speed crashes	↓3 - 5kph mean speed ↓3-8kph 85 percentile speed ↓ 10% to 27% drivers speeding over limit ↓ 35% crashes pre/post and control
Elvik (1997)	A-B+Control	Y	N	injury crashes	↓20% injury crashes
Tay (2000)	A-B+Control	N	N	crashes speed	↓ 9.17% all crashes ↓ 32.4% serious injury = speed, pre/post
Shin, Washington, van Schalkwyk (2009)	A-B+Control	Y	N	crashes	↓44 to 55% crashes ↓ 46-56% injury crashes = rear-end crashes

Retting, Kyrychenko, McCartt (2008)	A-B+Control	N	N	speed	↓ 5mph mean speeds pre/post no change control site ↓ 13% exceeding speed limit after speed camera enforcement suspended both increased.
Retting, Farmer, McCartt (2008)	A-B+Control	N	N	speed	↓10% mean speed ↓ 70% > 10 mph above the speed limits (with warnings and camera enforcement), ↓ 39% > 10 mph above the speed limits (with warning signs only) ↓ 16% on 40 mph residential streets (no warnings or speed cameras).
De Pauw, Daniels, Brijs, Hermans, Wets (2013)	A-B	N	N	injury crashes	↓ 29% serious/fatal injuries in 500m of camera
Novoa, Perez, Santamarina-Rubio, Mari-Dell'Olmo, Tobias	Time series analyses	N	N	Crashes injuries	↓ 30% and 26% on enforced and non-enforced arterial road respectively.

Table 5: Summary of literature on fixed speed camera evaluations

Only eight of the studies mentioned the speed limit at the fixed camera sites. In five studies the cameras were on high speed roads (80+ kph) and the remainder were in the 50-80 kph regions. There were no obvious patterns of effects on speeding or crashes on different speed limit areas. Novoa et al (2010) found benefits of fixed speed cameras on a high speed beltway, but not on lower speed arterial roads, suggesting that there may be influences of speed limit on the effectiveness of fixed cameras.

3.1.4 Evaluation of mobile cameras

A total of 19 of the studies included in the Cochrane review (Willis, et al., 2010) involved an evaluation of mobile cameras. The electronic searches found one further evaluation study (Moon and Hummer, 2010) so the current review involved 20 studies in total (Table 6).

As for the fixed camera evaluations, the majority of studies included involve a pre/post implementation with control design (80%) with the remainder an interrupted time series design. Few studies (25%) included control for RTM effects although this may not be as great a concern for mobile cameras which by definition are moved around so they may not necessarily be located only in locations of high concern for road safety. Spillover effects were also managed indirectly by inclusion of control locations in all studies. Most of the evaluations looked at either speed (40%) or crash (35%) outcomes and only 25% looked at both. Evaluations were from a broad range of countries including Australia, Canada, Denmark, UK, Norway, New Zealand and the USA.

Across evaluation studies, consistent benefits were found for mobile speed cameras. Seven studies cited reductions of mean speeds in the location of mobile cameras with effects ranging from around 1 to 6kph. There was a very large range in the proportion of vehicles exceeding the speed limit, from 10 to 70 percent across five studies. Similarly, the reductions in injury crashes also varied considerably between the six studies that included this measure, from 21 to 71.3 percent although reductions in fatal crashes were more consistent (31-44% across three studies).

As might be expected, there is evidence that the effect of mobile cameras extend well-beyond the immediate vicinity of the camera. Cairney (1988) found effects of reduced speed for up to 14 km downstream of mobile cameras. The study by Newstead and Cameron (2003) measured crashes within 2 kms, 2-4kms and 4-6kms of camera sites and found a decreasing effect on crashes with increasing distance away from cameras, although even at the greatest distance, there were still 10.7 percent reductions in all severity crashes.

A number of studies looked at the time halo or duration of the effect of mobile cameras. Time halo effects ranged from at least two days of continued lower proportion of speeding vehicles (Armour, 1984), three days of lower mean speeds after a single day of enforcement (Hauer and Ahlin 1982) to up to eight weeks of lower mean speeds (Vaa, 1997). On the other hand, Legget (1988) found no time halo effect on mean speed.

The effects of speed cameras may vary with the speed limit of roads, however most studies (55%) failed to mention the speed limit on which the cameras were placed. In seven studies (35%) mobile cameras were sited on higher speed roads of 80kph or greater. Only two studies involved mobile cameras on roads of 60kph or lower.

In the majority of studies, mobile cameras were marked with warning signs to alert drivers to their presence. Two studies looked at the effect of covert or overt placement of mobile cameras.

Diamantopoulou and Cameron (2002) compared the two strategies of camera use and concluded that the best effect on injury crashes occurred when a mix of overt and covert cameras were in

Study	Design	RTM	Spillover	Outcome	Conclusions
Amour (1984)	A-B +Control	N	N	speeders	↓ 70% proportion vehicles exceeding the speed limit with camera Time halo effect ≥ two days
Cairney (1988)	A-B +Control	N	N	Mean speed	↓ 2-3kph mean speed at camera and control sites. Distance halo up to 14km downstream with aerial surveillance
Kearns & Webster (1988)	A-B +Control	N	N	crashes	↓ 23% crashes at camera sites during the day, ↓ 21% at other times, compared to controls
Newstead, Cameron, Leggett (2001)	A-B with comparison group	N	N	fatal crashes	↓ 31% fatal crashes. ↓ 11% total crashes outside of metropolitan Brisbane.
Newstead, Cameron (2003) (2 reports)	A-B +Control	N	N	No. of crashes (fatal and injury)	↓ 45% fatal crashes in 2km of camera sites ↓ 31% hospitalisation crashes in 2km of camera sites ↓ 39% medically-treated crashes in 2km of camera sites ↓ 19% other injury crashes in 2km of camera sites ↓ 21% non-injury crashes in 2km of camera sites All crashes: ↓ 17.5% all severity crashes in 2km of camera sites ↓ 11.4% all severity crashes in 2 - 4km of camera sites ↓ 10.7% all severity crashes in 4 - 6km of camera sites
Cairney, Fackrell (1993) (2 reports)	A-B +Control	N	N	Median traffic speed	↓ 5kph median speeds reduced sharply by 5 km/h on camera roads but then little change despite intensified enforcement, control sites no change
Leggett (1988)	A-B +Control	N	N	Mean speed No. of crashes (injury or fatal)	↓ 3-6kph mean speeds compared to pre, only during enforcement no time halo effect. ↓ 58% serious injury crashes. ↑ 33% serious injury during non-enforced times of day
Cameron, Cavallo, Gilbert (1992) (2 reports)	Interrupted time series	N	N	No. of injury crashes	↓ 30% injury crash on 60km/h city roads with camera over12mths ↓ 20% injury crash on rural 60km/h zones with camera over 12 mths ↓ 14% injury crash on rural 100km/h zones with camera over 12 mths
Diamantopoulou, Cameron (2002) (3 reports)	A-B +Control	N	N	No. of injury crashes	↓ 71.3% injury crashes within 4 days of presence of enforcement ↓73.9% injury crashes with mix of overt/covert enforcement in use.
Chen, Wilson, Meckle, Cooper (2000)	A-B +Control	Y	N	No. of speeding vehicles No. of crashes	↓ 31% speeding vehicles pre/post cameras ↓ 12% speeding at control sites ↓ 17% reduction in daytime crash fatalities

Hauer, Ahlin (1982)	A-B +Control	N	N	Average speed	time halo for three days with1 day enforcement, for six days after five days enforcement
Agustsson (2001)	A-B +Control.	N	N	Mean speed % drivers exceeding spee limit by 10km/hr No. of injury crashes	↓ 2.4 km/ h mean speed ↓ 10.4% exceeding speed limit ↓ 4.5% exceeding the speed limit by 10km. ↓ 22% injury crashes in first year, ↓ 20% in second year post intervention compared to pre
Jones, Sauerzapf, Haynes (2008)	A-B +Control	Y	N	No. of crashes	↓ 19% all crashes at camera sites ↓ 44% for fatal and serious crashes at camera sites .
Christie, Lyons, Dunstan, Jones (2003)	A-B +Control	N	N	No. of injury crashes	↓ 50% injury crashes sustained for two years at camera sites
Goldenbeld, van Schagen (2005)	A-B +Control	Y	N	speeds speeders over the targeted speed limit	↓ 12% speeders at camera sites, ↓ 5% speeders at controls ↓ 21% injury crashes for enforcement period compared to pre
Vaa (1997)	A-B +Control	N	N	Average speed No. Speeding drivers	↓ 0.9 to 4.8kph mean speeds time halo effect of up to eight weeks ↓ 10% speeding drivers
Keall, Povey, Frith (2002) (2 reports)	Interrupted time series	N	N	Mean speed 85th percentile speed No. of injury crashes	↓1.3kph mean speed over 2 years ↓ 4.3kph 85th percentile speeds on open roads ↓ 11% all crashes compared to control areas ↓ 19% injury crashes additional effect for covert cameras period compared to overt cameras ↓ 17% for crashes at camera sites compared to controls ↓ 31% for injury crashes
Cunningham, Hummer, Moon (2005)	A-B +Control	Y	N	crashes, speeds	↓ 12% total crashes in camera corridors compared to expected ↓0.91 miles/hr mean speeds at camera sites, control sites no change ↓ 0.99mph in 85th percentile speeds, controls no change.
Retting, Farmer (2003)	A-B +Control	N	N	Mean speed Proportion of vehicles exceeding the speed limit by more than 10mph	↓ 14% mean speeds at camera sites compared to control sites. ↓ 82% exceeding the speed limit by more than 10mph
Moon, Hummer (2010)	A-B with comparison sites.	Y	N	No. of crashes	↓ crashes in camera sites pre/post.

Table 6: Summary of literature on mobile speed camera evaluations

place, although the additional reductions in injury crashes were not pronounced. A study by Keall, Povey and Frith (2002) compared the effect on injury crashes of a period of overt camera use with a period where camera use was covert and found an additional 19 percent reduction in injury crashes with covert use of cameras. It should be noted however that covert camera use occurred following overt use so some of the effect may be due to the fact that drivers were aware the cameras were in operation.

3.1.5 Point-to-point cameras

The literature for this camera system type is sparse. There are three articles discussing the benefits of point-to-point in terms of reduced speeds and crash reduction. However, only one study by Montella et al (2012) was adequate in its design in terms of providing a rigorous statistical evaluation of a system installed in Italy (Table 7). The system is composed of steel gantries at the section entrance and exit, with one camera and inductive loop detectors for each lane. Data were collected and processed by police at a central monitoring station.

The study analysis period was over 9 years, with a before period of 6.5 years and an after period of 2.5 years. The number of crashes per kilometre in the before period was 4.2, which decreased to 2.2 during the after period. A reduction in crashes per kilometre was observed for all crash types.

The authors used an empirical Bayes methodology evaluation which accounted for regression to the mean, changes over time not due to the treatment being evaluated and overcoming exposure crash rates in normalising volume differences.

The evaluation of the point-to-point cameras revealed a total crash reduction of 31.2%. The greatest crash reductions were observed for 55.6% severe crashes and 43.3% crashes at curves. However they noted an effectiveness decrease over time, i.e. 39.4% total crashes for the first semester and 18.7% in the fifth semester after activation. The authors suggest that the decrease system effectiveness over time may have been due to a reduction in speed enforcement and driver adaptation. They suggest that higher compliance to the speed limits might be achieved by a better strategy of communication and information to the road users and a speed limit management strategy synergic between the highway agency and the Police who actually manage the commitments of fines.

Study	Design	RTM	Spillover	Outcome	Conclusions
Montella, Persaud, D'Apuzzo, Imbriani (2012)	Empirical Bayes observational before-and-after study. Crash data disability lasting at least 15 days.	Y	N	No. of crashes	↓ 31.2% total crash The greatest crash reductions were observed for ↓ 55.6% severe crashes and 43.3% crashes at curves, effectiveness decreased over time ↓ 39.4% total crashes - first semester ; ↓ 18.7% - fifth semester after activation.

Table 7: Summary of literature on point-to-point speed camera evaluations

3.2 Review of community attitudes to speeding

This section summarises the results of the Community Attitude surveys for ACT residents over 1995 to 2011. The detailed collated results are shown in Appendix C.

3.2.1 Perceptions of changes in enforcement

The year following the introduction of mobile speed cameras was associated with an increase in the percentage of ACT residents who perceived that the amount of speed enforcement had changed over the past two years (Figure 4). In the surveys conducted between 1999 and 2001 more than two-thirds of survey participants reported that enforcement had increased and in 2001 there was a clear fall in the percentage reporting no change in enforcement. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years, perception of increased speed enforcement remained high. Interestingly, the introduction of fixed speed cameras in 2007 was not associated with increased perception of more enforcement activity. However, this question only has a few broad options to choose from and may likely have been too coarse to determine accurate perceptions of change in enforcement.

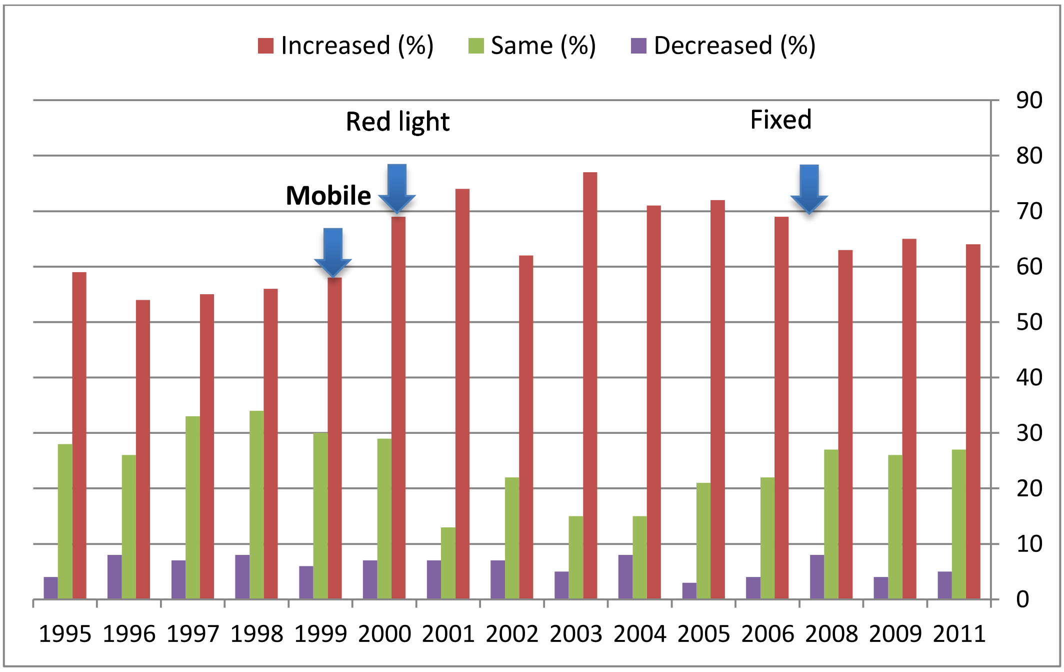

Figure 4: Perceptions of whether the amount of speed limit enforcement has changed over the last two years

The reported likelihood of being booked for speeding varied considerably across the survey years (Figure 5). Reports of being booked in the last two years were lowest in 1999 when mobile cameras were introduced, but between 1999 and 2003 the percentage of survey participants reporting being booked for speeding increased more than two-fold to more than one in four participants. Reports of speeding infringements decreased again to 2008, but following the introduction of fixed speed cameras, there was some increase in reported infringements to 2011. Reports for the last 6 months showed similar patterns. Notably, reports of being booked in the last 6 months were lowest in 2004 compared to all other years, and were lowest compared to other jurisdictions as well.

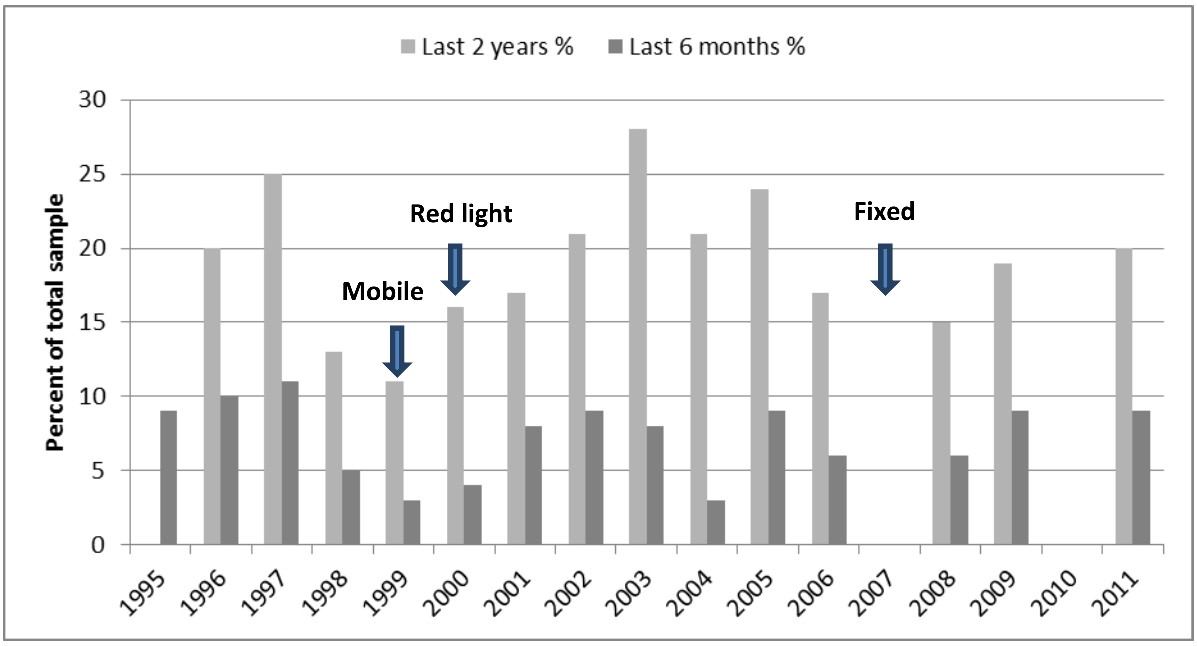

Figure 5: Incidence of being booked for speeding in the last 2 years and the last 6 months

3.2.2 Perceptions of acceptable and actual speed tolerances

ACT residents believe that the median acceptable speed in 60kph urban zones should be around 65 km/h (Table 8). Interestingly, this is almost identical to the median of their reported actual speed. Neither of these judgements showed much variation across the seven surveys in which these questions were asked. Around one-third of Survey participants across all surveys between 2003 and 2011 agreed that there should be no tolerance of speeding in 60kph zones. However in surveys before 2003 nearly half of respondents felt that there should be no tolerance for speeding in 60kph zones. This was coincident with the introduction of the first mobile and red light cameras. It is possible that the strong community response for no tolerance for speeding in 60kph zones that preceded the introduction of cameras may have played a role in their introduction. However, community acceptance of no tolerance for speeding clearly decreased a few years after the first wave of the introduction of cameras so by 2003 and subsequent years, there has been considerably lower support for no tolerance of speeding in these zones.

For 100kph zones, acceptable speeds for respondents were between 105 and 110kph and actual reported speeds were very similar, or higher (Table 9). There were no consistent patterns for judgements of acceptance of no tolerance for speeding with between one in four and one in three respondents supporting no tolerance. In contrast, between 2002 and 2011 there has been notable change in ACT residents perceptions of no tolerance of actual speeding. Where in 2006 almost no ACT respondent perceived no tolerance for speeding over 100kph and this was lower than all other jurisdictions, by 2011 the situation had reversed. Over one in five respondents felt that there was no tolerance for speeding in 100kph zones in the ACT which was significantly higher than other jurisdictions.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1995		34		
1996		42		
1997		49		
1998		49		
1999 **Mobile**		49		
2000 **Red light**		38		
2001		44		
2002		51	64.9	15
2003	64.2	33	65.4	10
2004	65	28	65	13
2005	64	33	64	12
2006	64	32	64	15
2008 **Fixed**	64	36	65	21
2009	65	34	64	22
2011	64	31	64	20

Table 8: Perceived acceptable and actual speed in 60kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1996		27		
1997		23		
1998		36		
1999 **Mobile**		28		
2000 **Red light**		25		
2001		26		
2002		35	109.2	10
2003	106.8	22	108.7	6
2004	110	23	109	8
2005	109	20	109	7
2006	107	18	107	5
2008 **Fixed**	105.5	28	108	14
2009	110	23	107.9	15
2011	106	25	106	21

Table 9: Perceived acceptable and actual speed in 100kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

3.2.3 Attitudes to speeding, speed enforcement and penalties

ACT survey respondents attitudes to speed-related issues did not change greatly across the 1999 to 2011 period for most questions. The majority of respondents (>85% in all years) viewed speed limits as generally reasonable. Similarly, almost all respondents (>89% in all years) agreed that an accident at 70kph would be more severe than one at 60kph. Notably, fewer felt that they would be more likely to be in an accident if they increased their speed by 10kph, but there was no pattern of change across the survey years on this question.

Two questions showed some evidence of attitudinal changes between 1999 and 2011 that may be associated with safety camera use in the ACT. Associated with the introduction of the mobile and red light cameras in 1999 and 2000 there has been a decrease in respondents agreeing that exceeding the speed limit is okay if you are driving safely. The percentage increased again for the 2008 survey following the introduction of fixed cameras, but decreased to the lowest level in 2009 and remained fairly low in 2011. In contrast, there was no change in the percentage of respondents viewing speeding fines as revenue raising associated with mobile or red light cameras, but 2008 and 2009 following the introduction of fixed cameras saw the highest percentage of respondents viewing speed fines as revenue raising (Figure 6).

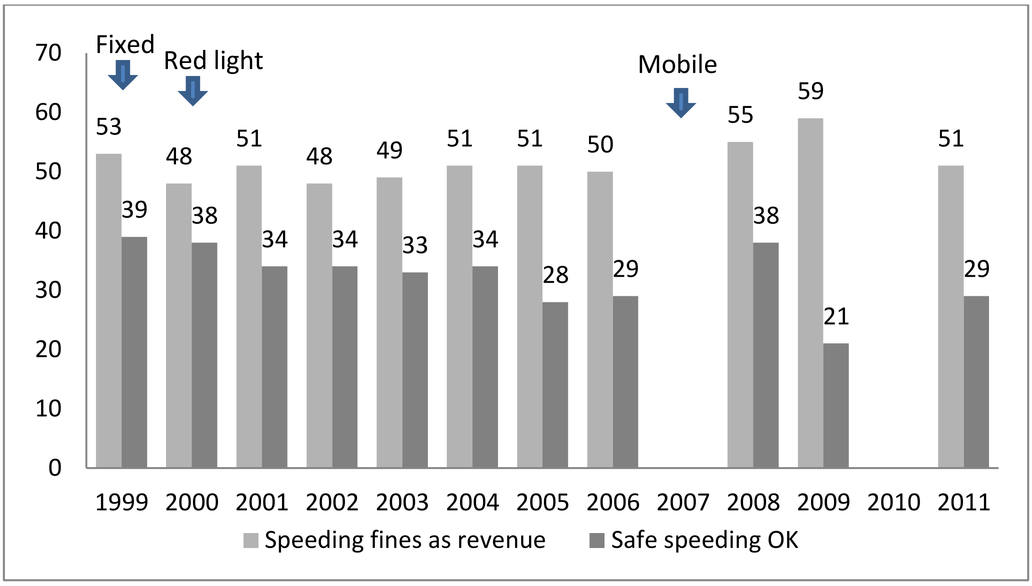

Figure 6: Percentage of ACT resident agreeing with the statements 'Fines for speeding are mainly intended to raise revenue' and 'I think it is okay to exceed the speed limit if you are driving safely'

Questions were asked about their views of the level of enforcement and severity of penalties from the 2003 survey (Figures 7 and 8). Increasing percentages of ACT residents believed the level of enforcement and severity of penalties should increase for 2003 and 2004, but this decreased in the next two years. In the survey following the introduction of fixed speed cameras the percentage of respondents who felt enforcement should increase grew to nearly half and this remained high to the most recent survey in 2011. For severity of penalties, there was not much change before and after the introduction of fixed cameras, although the most recent survey had the highest percentage of respondents reporting that they should be increased.

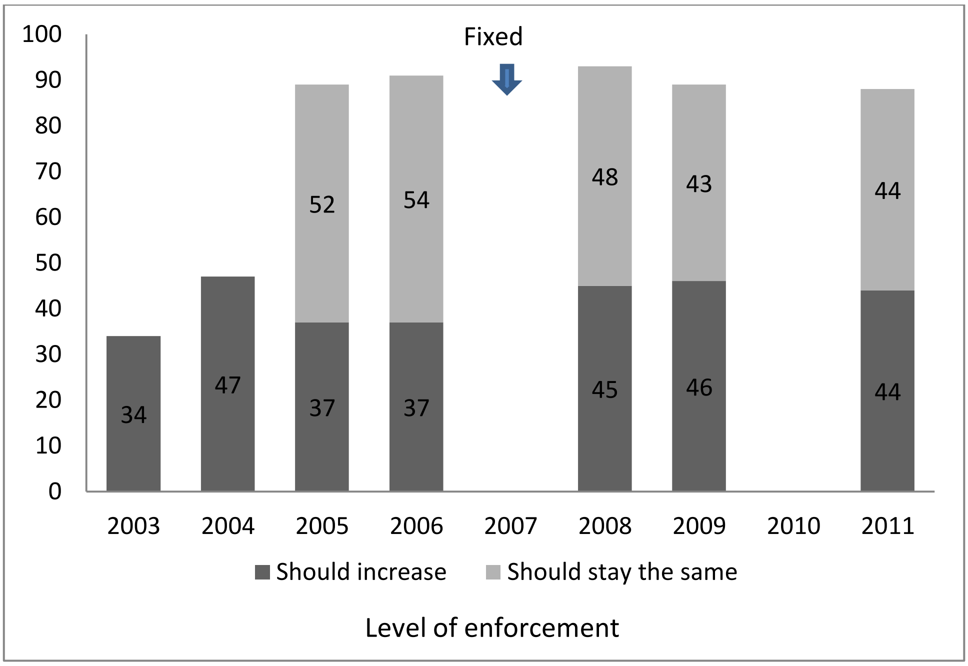

Figure 7: Percentage of ACT residents responding that the level of enforcement should increase or stay the same

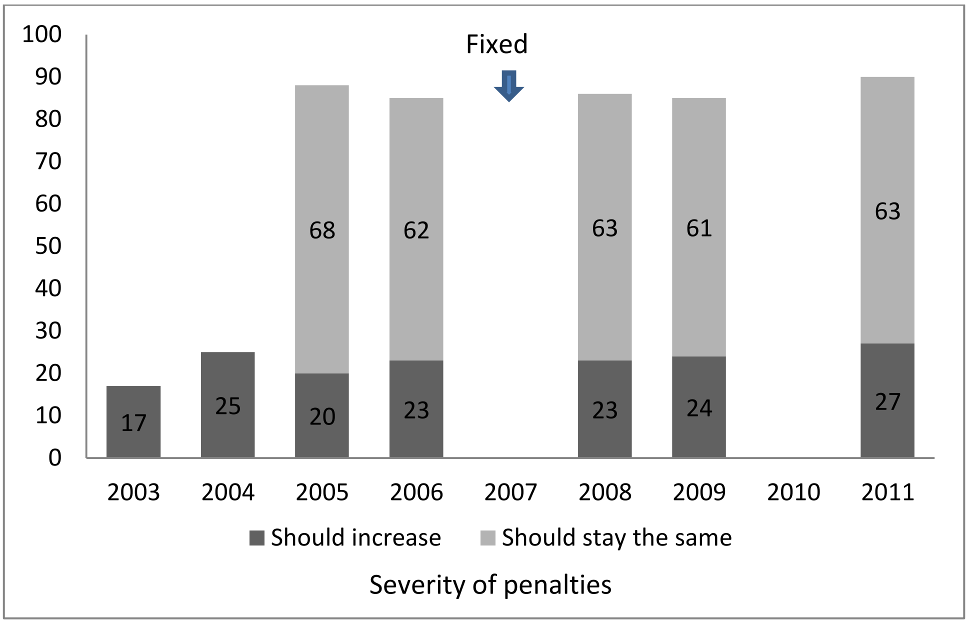

Figure 8: Percentage of ACT residents responding that the severity of penalties should increase or stay the same

The patterns of approval for lowering residential speed limits from 60 to 50 kph show an association with the introduction of mobile and red light cameras (Figure 9). Since 2000 when both types of cameras were in operation, there has been a clear increase in the percentage of survey respondents who showed approval for such a change so that by 2003 the greater majority of respondents were in agreement.

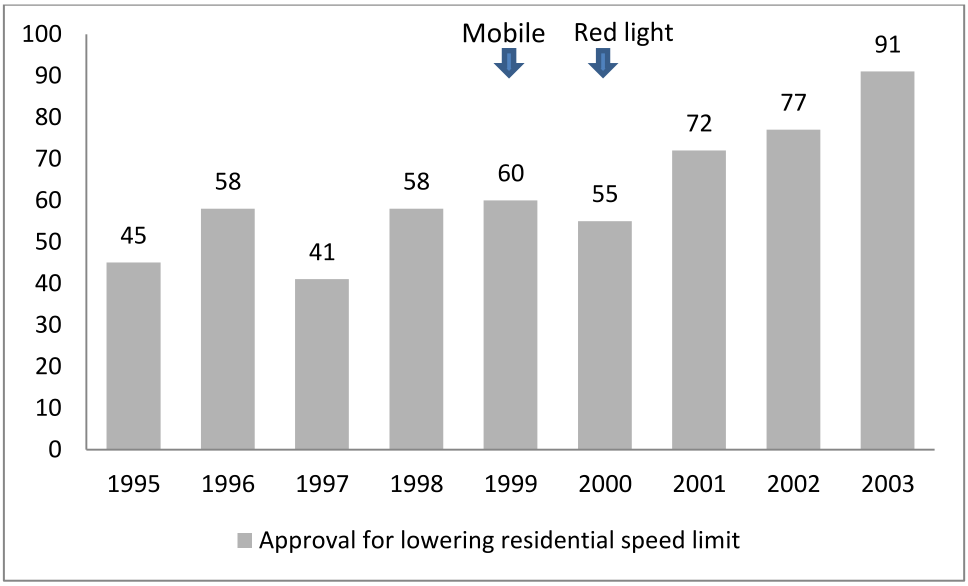

Figure 9: Percentage of ACT residents approving (somewhat and strongly) a potential decision to lower the speed limit in residential areas to 50kph

3.2.4 Changes in self-reported driving speed

Following the introduction of mobile and red light cameras a larger percentage of ACT respondents reported that their driving speed had decreased over the past two years, however since 2008 this effect has decreased somewhat with around three-quarters of drivers reporting no change to their speed (Figure 10).

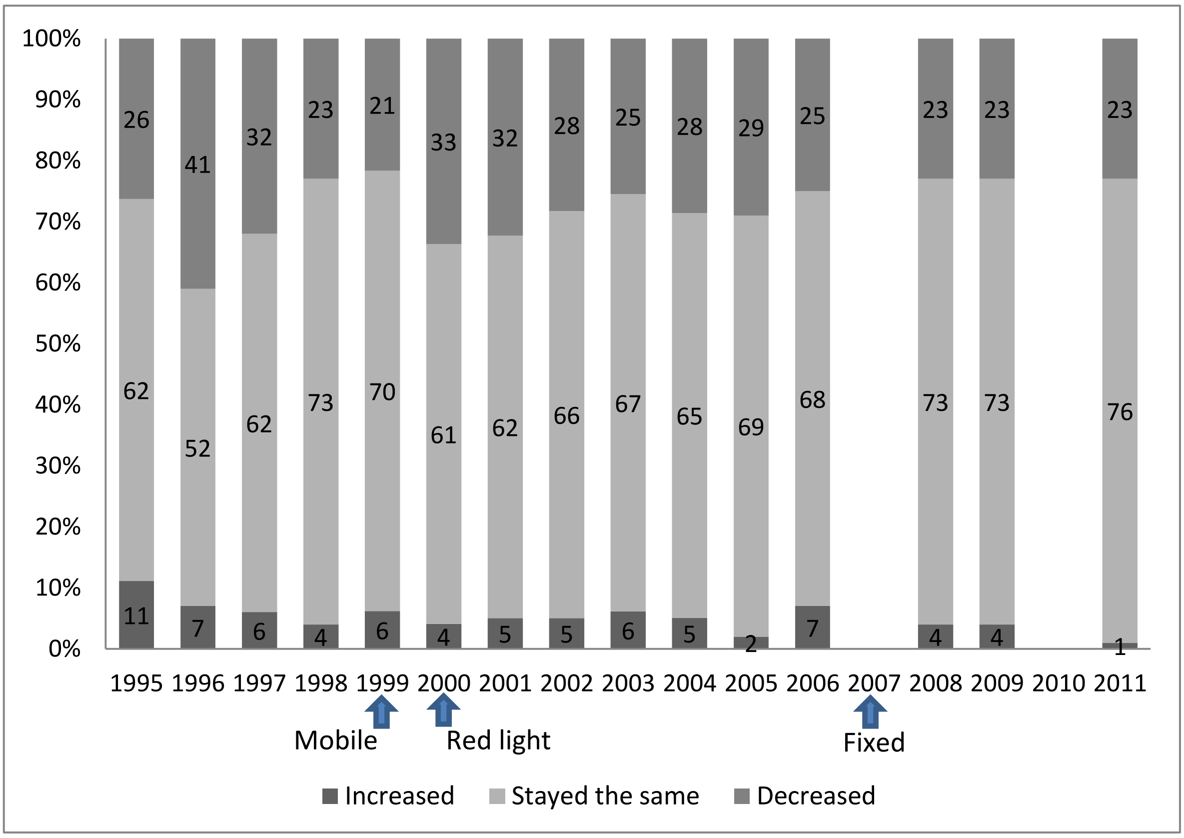

Figure 10: Reported changes in driving speed over the last two years

3.3 Infringements data

The infringements data are expressed as the proportion of infringements issued to vehicles checked, and data were available for the 14 year period from 1999 to 2012 (inclusive). It is noted that all fixed and mobile camera operations data were included, not only those related to the case and control streets/intersections selected for this study. Infringement rates for fixed and mobile cameras over the period are plotted in Figure 11. For the mobile cameras, mean infringement rates were up to 10% initially, however dropped to an average long-term value of approximately 0.6% during a period extending to approximately late 2002. For the fixed intersection cameras, mean infringement rates reduced rapidly to less than 0.2%. It is noted that due to data issues, the fixed camera infringement rates are not plotted beyond 2008 in Figure 11.

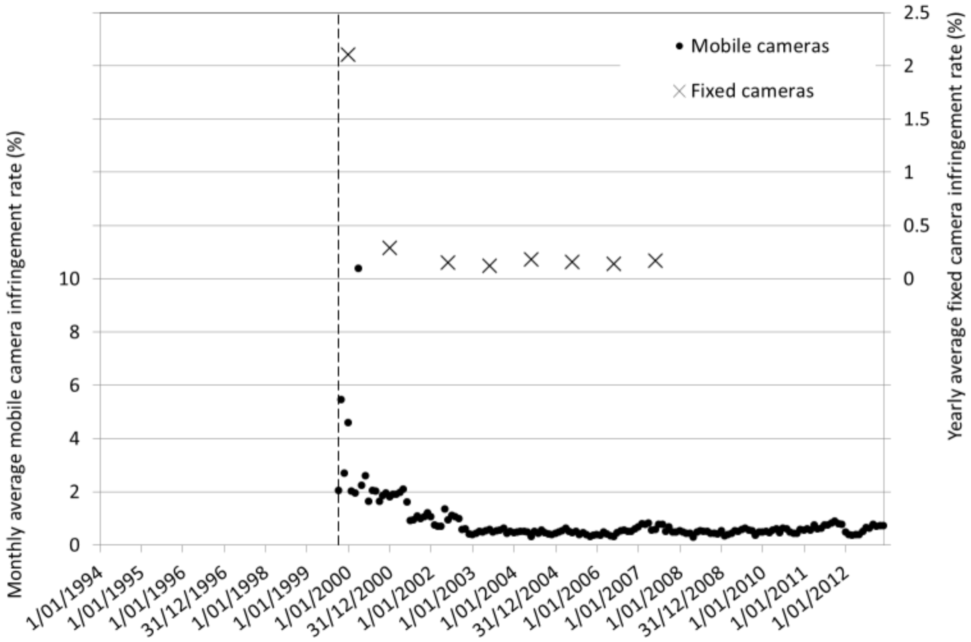

Figure 11: Infringement rates for fixed and mobile cameras

3.4 Speed survey analyses – effects of mobile cameras on mean vehicle speeds (Models 1 to 5)

Speed surveys were assessed for the 95 street locations for the 16 year period from 1997 to 2012 (inclusive). A total of 1,758 speed surveys were identified in the period, including 1,032 that were undertaken on case streets and 726 on control streets. The speed survey results are plotted for case and control streets, and compared with mobile camera operations on each individual street, in Appendix D. Considering an outcome of monthly averaged values of the mean survey speed divided by the speed limit, the statistical models are tabulated in Tables 10 to 12. Models 1 to 4 are plotted in Figures 12 to 14. In Models 1 and 3, trends in mean speeds for case streets showed increases in the pre-intervention period (however in Model 3 the value was very small), and decreases in the post-intervention periods, where the intervention was Intervention 1 (Model 1) or the camera begin-date (Model 3). Trends in mean speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 1). Mean speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 2 and 4). CAMERA

estimates were generally not statistically significant, indicating changes that occurred in mean speeds at the intervention times were not generally significant (Tables 10 and 11).

Annual trend magnitudes for case streets were an increase of 0.7% and decrease of 3.2% prior to and following Intervention 1, and an increase of 1.7% and decrease of 0.9% prior to and following Intervention 2. An increase of 0.1% and decrease of 1.8% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 2.4% and decrease of 0.8% prior to and following Intervention 1, and an increase of 0.1% and decrease of 0.2% prior to and following Intervention 2. A decrease of 3.9% and decrease of 3.8% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 12. The estimate for the CASE variable was highly significant, likely a result of the fact that mean speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The speed survey results for case streets are compared with the mobile camera infringement rates in Figure 15, where the change from a decreasing trend in speeds to an increasing trend approximately corresponds to the beginning of the long-term infringement rate of 0.6%. The regression models for case and control streets (Models 1 and 2) are compared in Figure 16. Mean speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The mean speeds on all streets were predominantly below the speed limit for the full time period.

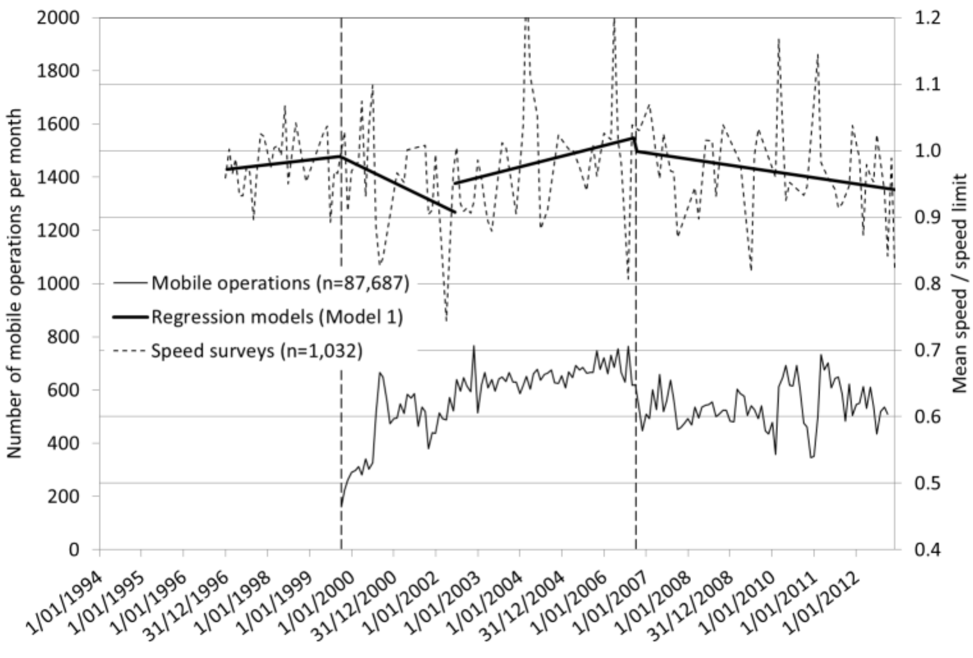

Figure 12: Mean speed survey data relative to the overall camera program – case streets

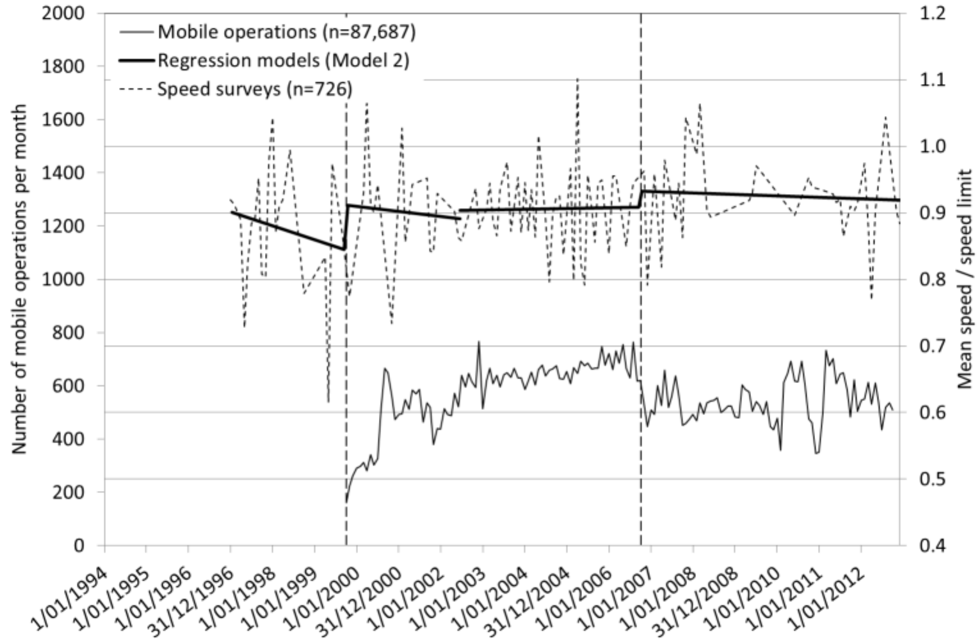

Figure 13: Mean speed survey data relative to the overall camera program – control streets

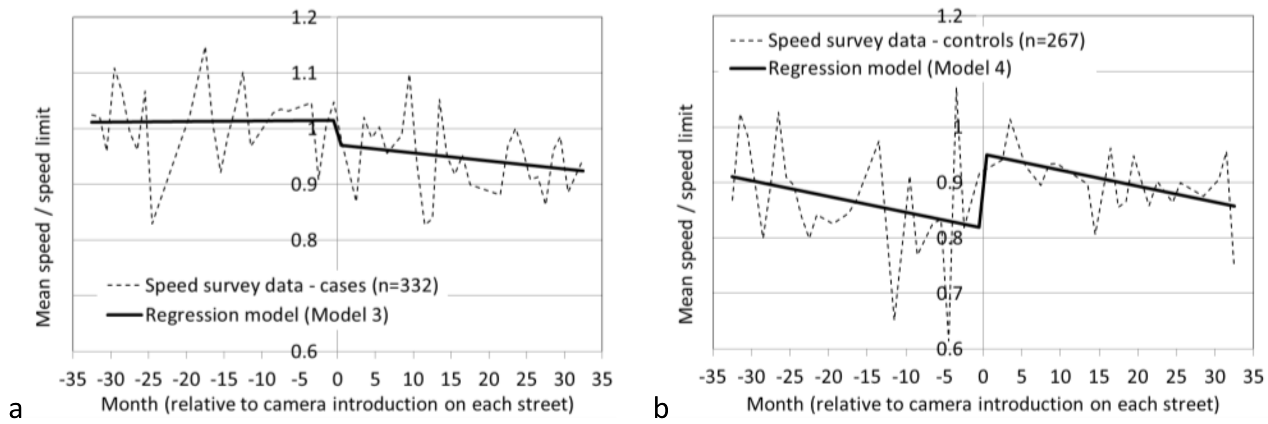

Figure 14: Mean speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

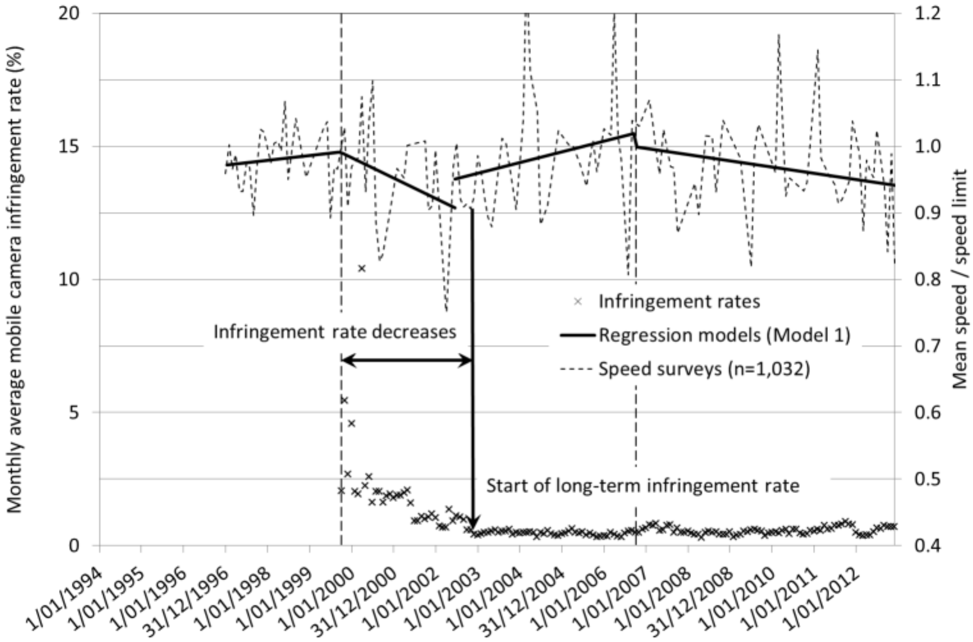

Figure 15: Mean speed survey data relative to the overall camera program – case streets

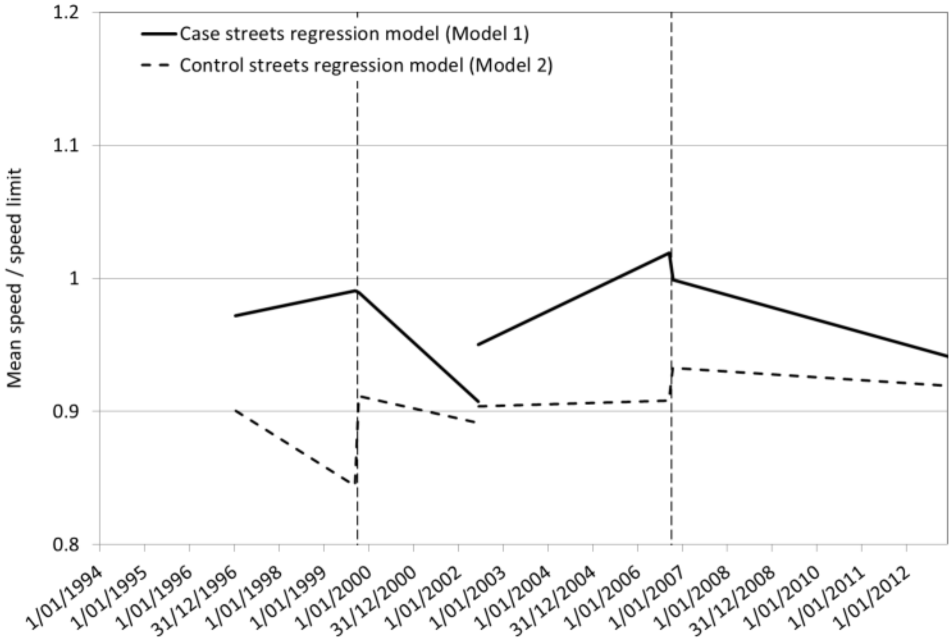

Figure 16: Comparison of the regression models of mean speeds for case and control streets

	MODEL 1 Cases (streets with cameras)								**MODEL 2** Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.009	-0.065	0.047	0.754	0.020	-0.031	0.070	0.442	-0.170	-0.268	-0.073	0.001	-0.096	-0.142	-0.050	<.0001
Time (T)	0.001	-0.002	0.003	0.666	0.001	0.000	0.003	0.087	-0.002	-0.007	0.003	0.386	0.000	-0.002	0.002	0.901
Camera (C)	0.000	-0.079	0.078	0.992	-0.021	-0.090	0.049	0.560	0.078	-0.064	0.220	0.282	0.027	-0.037	0.090	0.408
T x C	-0.003	-0.007	0.001	0.116	-0.002	-0.004	0.000	0.027	0.001	-0.006	0.008	0.711	0.000	-0.002	0.002	0.743

Table 10: Mean speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 3 Cases (streets with cameras)				**MODEL 4** Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.015	-0.037	0.067	0.577	-0.201	-0.280	-0.122	<.0001
Time (T)	0.000	-0.003	0.003	0.977	-0.003	-0.007	0.001	0.087
Camera (C)	-0.044	-0.118	0.029	0.236	0.151	0.031	0.271	0.014
T x C	-0.002	-0.005	0.002	0.409	0.000	-0.006	0.006	0.963

Table 11: Mean speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 5			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.201	-0.270	-0.133	<.0001
Time (T)	-0.003	-0.007	0.000	0.049
Camera (C1)	0.151	0.047	0.256	0.004
Case (C2)	0.216	0.124	0.308	<.0001
T x C1	0.000	-0.005	0.005	0.958
T x C2	0.003	-0.001	0.008	0.145
C1 x C2	-0.196	-0.331	-0.060	0.005
T x C1 x C2	-0.002	-0.009	0.005	0.619

Table 12: Mean speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.5 Speed survey analyses – effects of mobile cameras on 85th percentile vehicle speeds (Models 6 to 10)

Considering an outcome of monthly averaged values of the 85th percentile speed divided by the speed limit, the statistical models are tabulated in Tables 13 to 15. Models 6 to 9 are plotted in Figures 17 to 19. In Models 6 and 8, trends in 85th percentile speeds for case streets were relatively constant in the pre-intervention periods, and decreased in the post-intervention periods, where the intervention was Intervention 1 (Model 6) or the camera begin-date (Model 8). Trends in 85th percentile speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 6). 85th percentile speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 7 and 9). CAMERA estimates were generally not statistically significant, indicating changes that occurred in 85th percentile speeds at the intervention times were not generally significant (Tables 13 and 14).

Annual trend magnitudes for case streets were an increase of 0.1% and decrease of 1.8% prior to and following Intervention 1, and an increase of 1.4% and decrease of 1.1% prior to and following Intervention 2. A decrease of 0.8% and decrease of 1.7% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 3.6% and decrease of 0.7% prior to and following Intervention 1, and an increase of 0.2% and decrease of 0.4% prior to and following Intervention 2. A decrease of 4.6% and decrease of 5.2% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 15. The estimate for the CASE variable was highly significant, likely a result of the fact that 85th percentile speed values were notably higher for case streets. The estimate for CAMERA $\times$ CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The regression models for case and control streets (Models 6 and 7) are compared in Figure 20. 85th percentile speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The 85th percentile speeds on all streets were predominantly above the speed limit for the full time period.

Comparison of the mean and 85th percentile speeds indicates that trends were very similar between the two, however the magnitudes of the 85th percentile speeds were higher than the mean speeds. This is also evident in the speed survey results plotted in Appendix D, where mean and 85th percentile speeds are plotted on the same graphs.

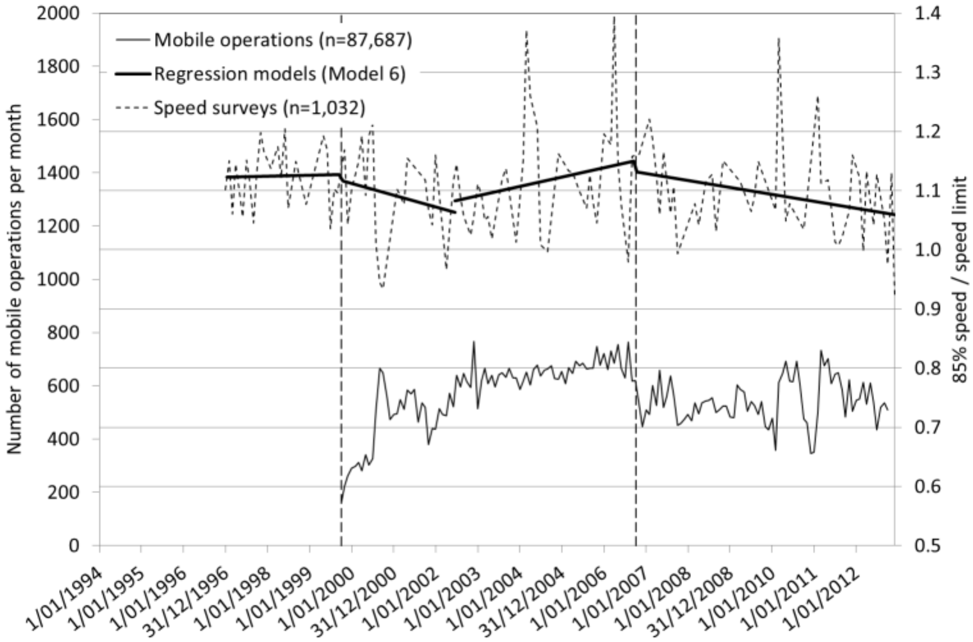

Figure 17: 85th percentile speed survey data relative to the overall camera program – case streets

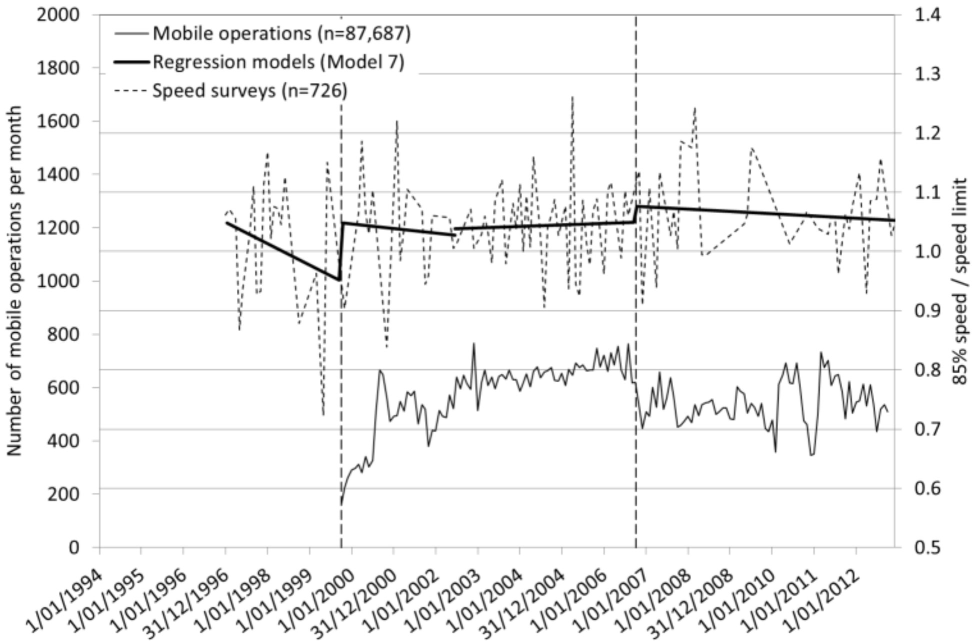

Figure 18: 85th percentile speed survey data relative to the overall camera program – control streets

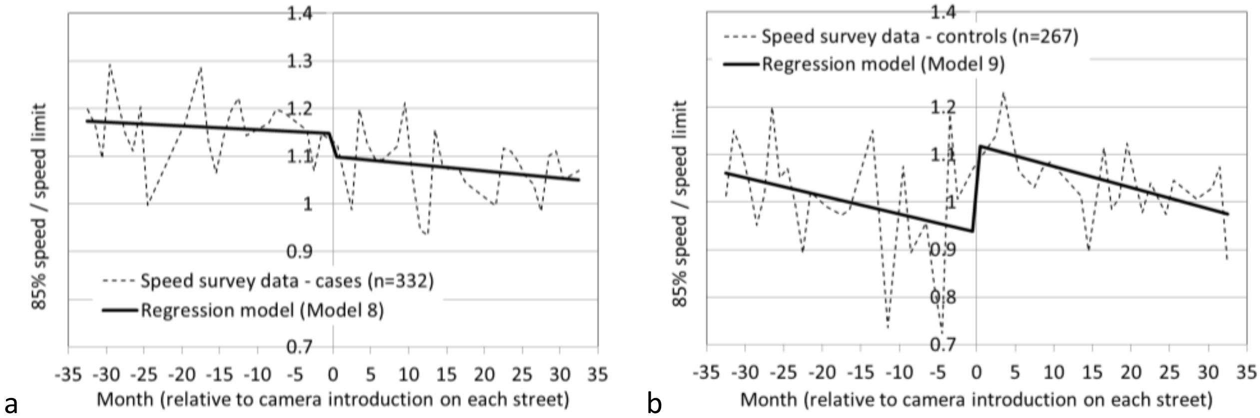

Figure 19: 85th percentile speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

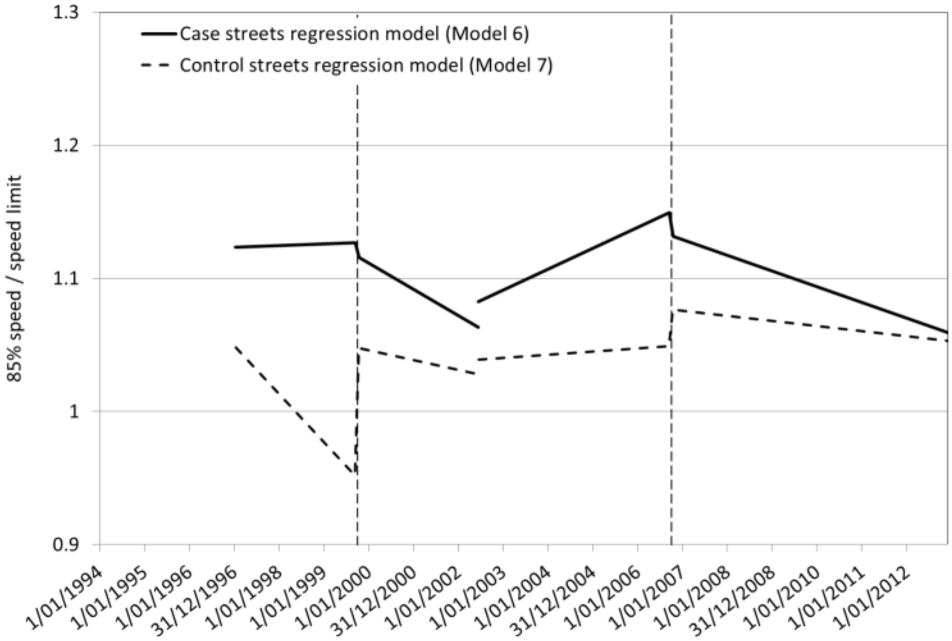

Figure 20: Comparison of the regression models of 85th percentile speeds for case and control streets

Variable	MODEL 6 Cases (streets with cameras) (a) 1/1997 – 10/1999 – 7/2002 Estimate	CL_U	CL_L	*p*-value	(b) 7/2002 – 10/2006 – 12/2012 Estimate	CL_U	CL_L	*p*-value	MODEL 7 Controls (streets without cameras) (a) 1/1997 – 10/1999 – 7/2002 Estimate	CL_U	CL_L	*p*-value	(b) 7/2002 – 10/2006 – 12/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	0.120	0.070	0.169	<.0001	0.140	0.093	0.187	<.0001	-0.051	-0.150	0.048	0.315	0.048	0.002	0.094	0.040
Time (T)	0.000	-0.002	0.003	0.908	0.001	0.000	0.003	0.120	-0.003	-0.008	0.002	0.208	0.000	-0.001	0.002	0.820
Camera (C)	-0.009	-0.079	0.061	0.797	-0.016	-0.081	0.049	0.636	0.098	-0.046	0.241	0.182	0.026	-0.037	0.089	0.426
T x C	-0.002	-0.005	0.002	0.390	-0.002	-0.004	0.000	0.026	0.002	-0.005	0.010	0.508	-0.001	-0.002	0.001	0.618

Table 13: 85th percentile speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	MODEL 8 Cases (streets with cameras) Estimate	CL_U	CL_L	*p*-value	MODEL 9 Controls (streets without cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	0.138	0.092	0.184	<.0001	-0.065	-0.146	0.017	0.120
Time (T)	-0.001	-0.003	0.002	0.578	-0.004	-0.008	0.000	0.060
Camera (C)	-0.043	-0.108	0.022	0.197	0.179	0.055	0.302	0.005
T x C	-0.001	-0.004	0.003	0.697	-0.001	-0.007	0.006	0.867

Table 14: 85th percentile speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

Variable	MODEL 10 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.065	-0.132	0.002	0.059
Time (T)	-0.004	-0.007	-0.001	0.022
Camera (C1)	0.179	0.077	0.280	0.001
Case (C2)	0.202	0.112	0.293	<.0001
T x C1	-0.001	-0.006	0.005	0.839
T x C2	0.003	-0.001	0.008	0.167
C1 x C2	-0.222	-0.354	-0.089	0.001
T x C1 x C2	0.000	-0.007	0.007	0.967

Table 15: 85th percentile speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.6 Road crash analyses – effects of mobile cameras on fatal crashes

Fatal crashes for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 100 fatal crashes were identified in the period, including 91 that occurred on case streets and 9 that occurred on control streets. Fatal crash counts are plotted in Figures 21 to 22. Due to small crash counts statistical models were not fitted to these data, however it is clear from visual inspection of Figure 21 that fatal crashes on case streets generally decreased over the study period.

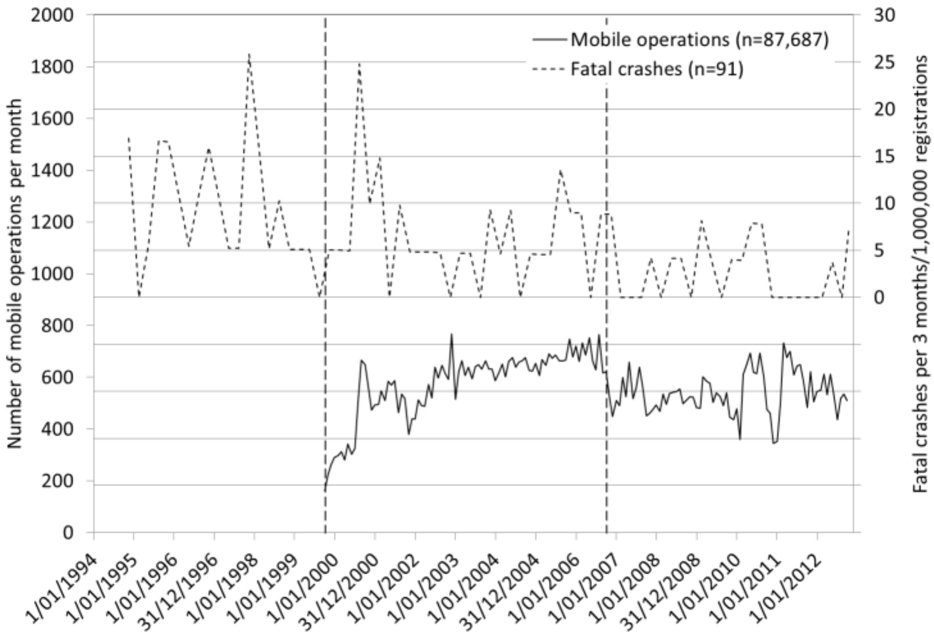

Figure 21: Fatal crash data relative to the overall camera program – case streets

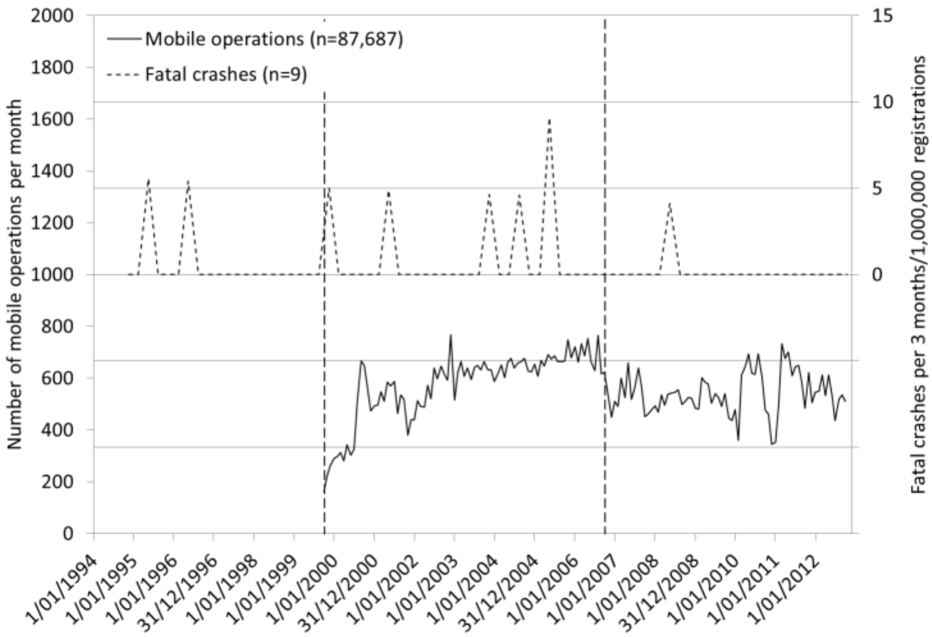

Figure 22: Fatal crash data relative to the overall camera program – control streets

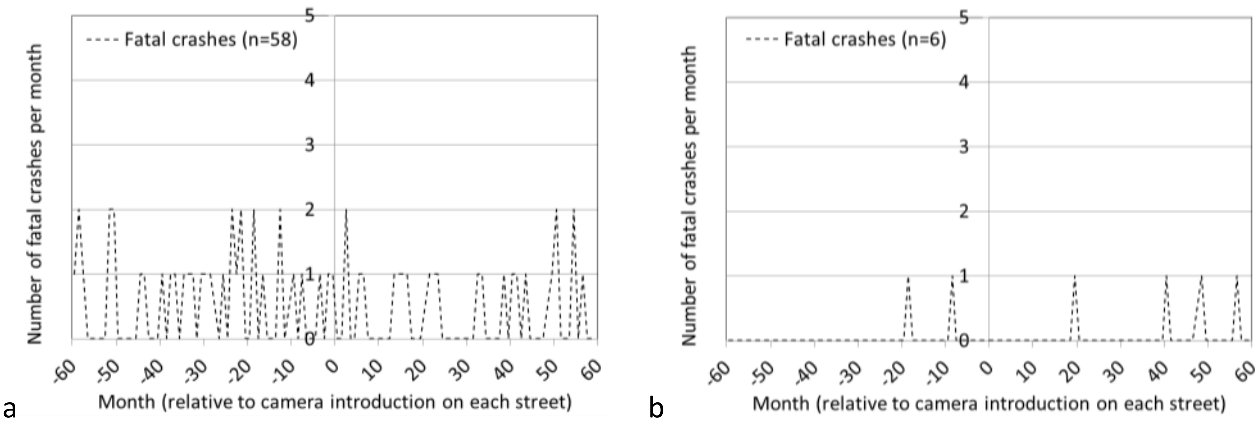

Figure 23: Fatal crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

3.7 Road crash analyses – effects of mobile cameras on serious crashes (Models 11 to 15)

Serious crashes (injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 3,325 serious crashes were identified in the period, including 2,788 that occurred on case streets and 537 that occurred on control streets. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 16 to 18. Models 11 to 14 are plotted in Figures 24 to 26. In Models 11 and 13, trends in serious crash counts for case streets showed decreases post-intervention, where the intervention was Intervention 1 (Model 11) or the camera begin-date (Model 13). A substantial drop occurred in mid-2002 (around 40% in raw numbers) and was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend following Intervention 2 (Model 11) steadily increasing up to 2013 to the same levels when cameras were first introduced. It should be noted that this rising trend in serious injury crashes from around 2004 to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period.

Serious crash counts for control streets were at much lower levels at around one quarter that of the case streets. Trends for control streets (Models 12 and 14) were similar, however the drop in 2002 was much less pronounced. Negative estimates for CAMERA in Models 11 to 14 indicates that crash counts were generally lower following Intervention 1/begin-date, while positive estimates following Intervention 2 indicates crash counts were higher. CAMERA estimates were generally not significant, however this may have been influenced by the relatively small serious crash counts.

Annual trend magnitudes for case streets were a decrease of 3.2% prior to Intervention 1, decrease of 3.7% between Intervention 1 and 2, and increase of 7.1% following Intervention 2. An increase of 1.1% prior to the begin-date and decrease of 10.3% following the begin-date were evident. Trend magnitudes for control streets were an increase of 4.7% prior to Intervention 1, a decrease of 24.5% between Intervention 1 and 2, and an increase of 1.4% following Intervention 2.

Decreases of 6.1% prior to the begin-date and 2.5% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 18. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, however this may reflect the relatively small serious crash counts.

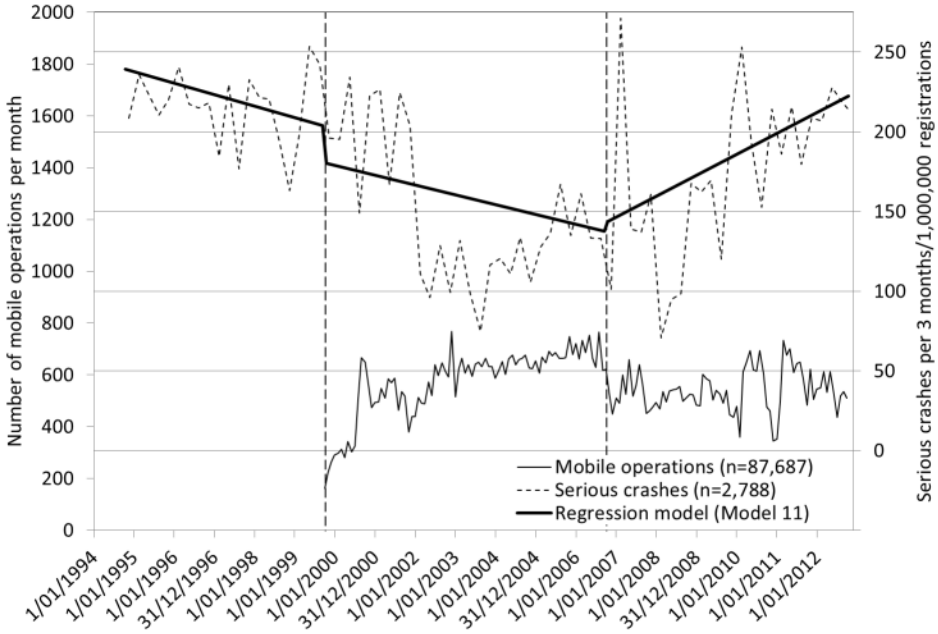

Figure 24: Serious crash data relative to the overall camera program – case streets

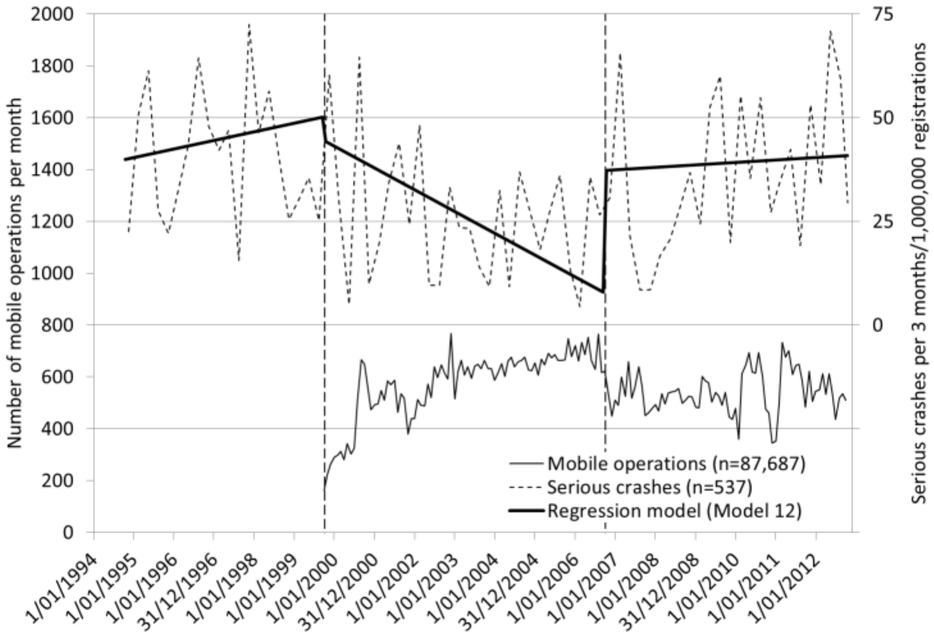

Figure 25: Serious crash data relative to the overall camera program – control streets

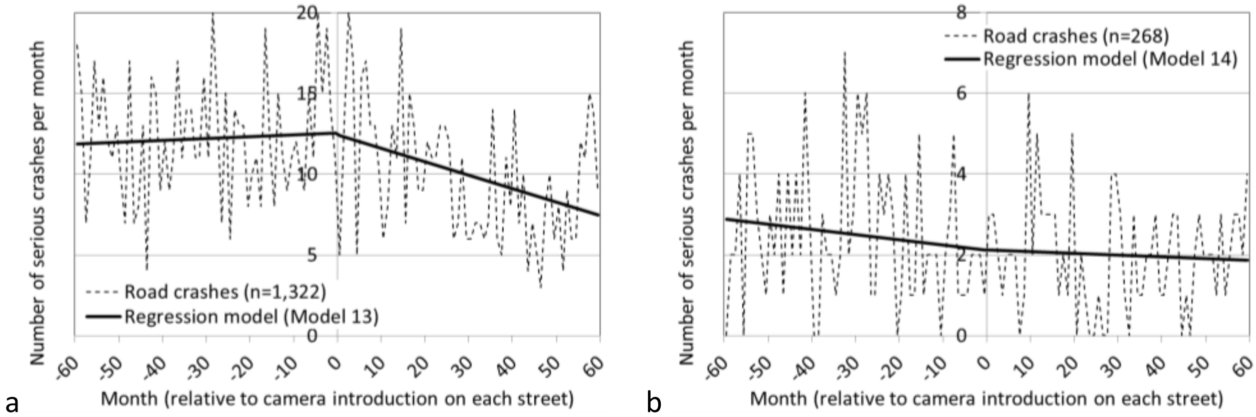

Figure 26: Serious crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

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Variable	MODEL 11 Cases (streets with mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value	MODEL 12 Controls (streets without mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	-13.381	-13.873	-12.889	<.0001	-13.776	-14.238	-13.314	<.0001	-14.634	-15.092	-14.176	<.0001	-16.482	-17.397	-15.567	<.0001
Time (T)	-0.003	-0.009	0.003	0.353	-0.003	-0.009	0.002	0.265	0.004	-0.010	0.018	0.596	-0.021	-0.036	-0.005	0.011
Camera (C)	-0.122	-0.533	0.289	0.561	0.043	-0.266	0.353	0.785	-0.119	-0.824	0.586	0.742	1.550	0.678	2.423	0.001
T x C	0.000	-0.008	0.007	0.916	0.009	0.002	0.016	0.016	-0.024	-0.042	-0.007	0.007	0.022	-0.002	0.045	0.068

Table 16: Serious crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	MODEL 13 Cases (streets with mobile cameras) Estimate	CL_U	CL_L	*p*-value	MODEL 14 Controls (streets without mobile cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	-0.998	-1.460	-0.536	<.0001	-2.886	-3.189	-2.583	<.0001
Time (T)	0.001	-0.004	0.006	0.720	-0.005	-0.011	0.001	0.108
Camera (C)	-0.007	-0.247	0.233	0.955	-0.002	-0.377	0.373	0.991
T x C	-0.010	-0.017	-0.002	0.010	0.003	-0.007	0.013	0.566

Table 17: Serious crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

Variable	MODEL 15 Estimate	CL_U	CL_L	*p*-value
Intercept	-2.885	-3.188	-2.582	<.0001
Time (T)	-0.005	-0.011	0.001	0.108
Camera (C1)	-0.002	-0.376	0.372	0.991
Case (C2)	1.889	1.337	2.441	<.0001
T x C1	0.003	-0.007	0.013	0.566
T x C2	0.006	-0.002	0.014	0.135
C1 x C2	-0.005	-0.449	0.440	0.983
T x C1 x C2	-0.013	-0.025	0.000	0.050

Table 18: Serious crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.8 Road crash analyses – effects of mobile cameras on all crashes (Models 16 to 20)

All road crashes (property damage, injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 57,809 road crashes were identified in the period, including 48,733 that occurred on case streets and 9,076 that occurred on control streets. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 19 to 21. Models 16 to 19 are plotted in Figures 27 to 29. In Models 16 and 18, trends in crash counts for case streets showed decreases in both the pre- and post-intervention periods, where the intervention was Intervention 1 (Model 16) or the camera begin-date (Model 18), and following Intervention 2 (Model 16). Large positive CAMERA estimates were evident for case streets at Intervention 1/begin-date, which were statistically significant, which indicates a significant increase in crash counts at this time. Crash counts for control streets indicated very similar trends (Models 17 and 19), however the changes that occurred at the time of the interventions was less pronounced.

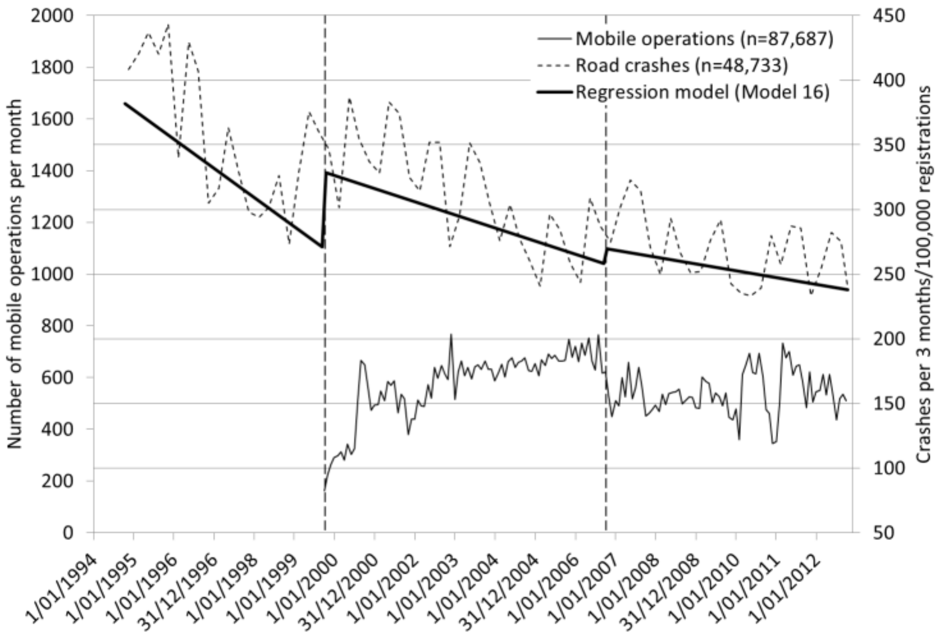

Figure 27: All crash data relative to the overall camera program – case streets

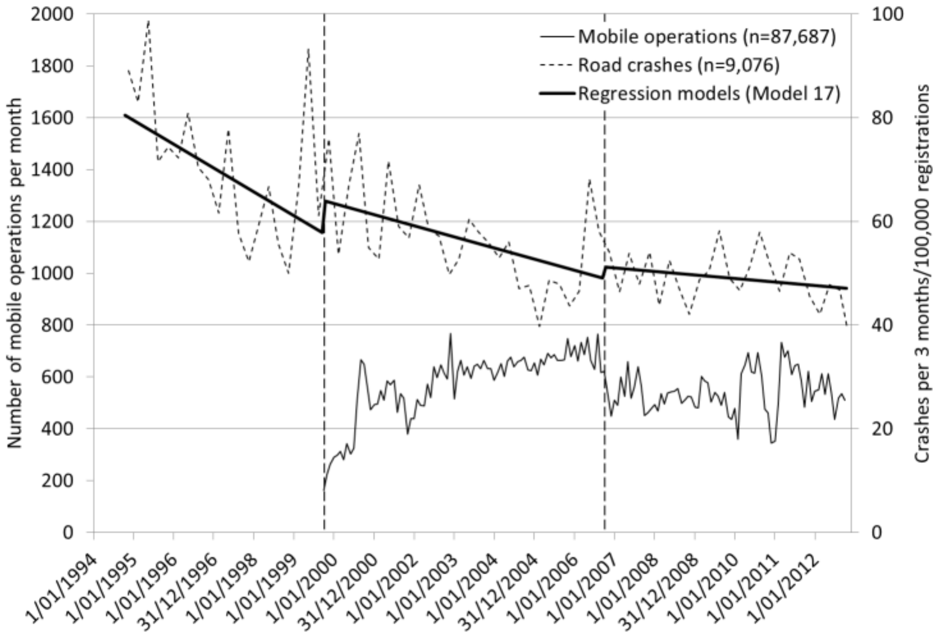

Figure 28: All crash data relative to the overall camera program – control streets

Annual trend magnitudes for case streets were decreases of 6.9% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 2.0% following Intervention 2. Decreases of 3.6% prior to the begin-date and 1.7% following the begin-date were evident. Trend magnitudes for control streets were decreases of 6.7% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 1.0% following Intervention 2. Decreases of 2.9% prior to the begin-date and 3.6% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 21. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, indicating that the effect of the intervention (begin-date) was not significantly different between case and control streets. However, another explanation may be that limitation concerning the selection of control streets, i.e. that the control streets identified for the analyses do not represent a true 'control area'.

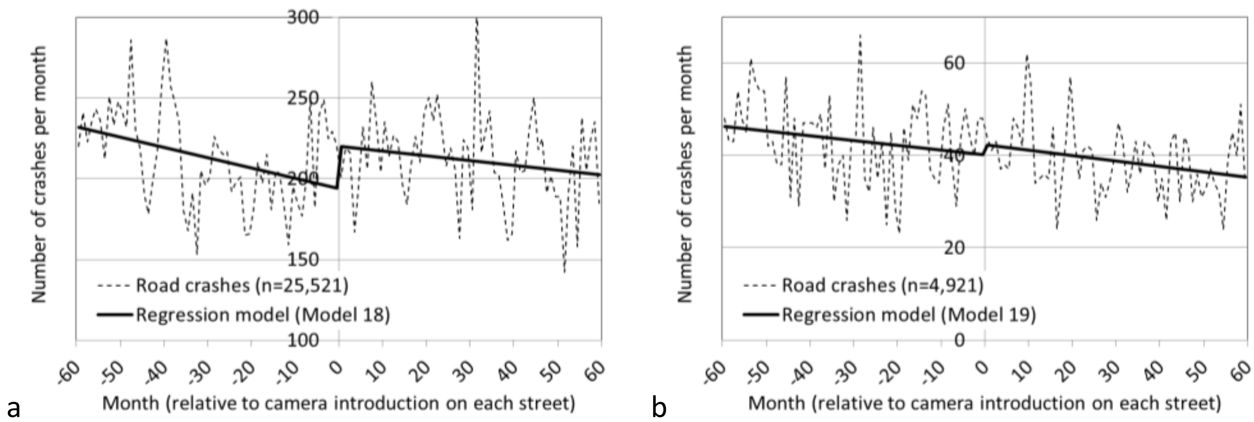

Figure 29: All crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

	MODEL 16 Cases (streets with mobile cameras)								MODEL 17 Controls (streets without mobile cameras)							
	(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012				(a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-10.796	-11.240	-10.351	<.0001	-10.844	-11.276	-10.413	<.0001	-12.245	-12.669	-11.821	<.0001	-12.409	-12.858	-11.960	<.0001
Time (T)	-0.006	-0.007	-0.004	<.0001	-0.004	-0.005	-0.002	<.0001	-0.006	-0.008	-0.004	<.0001	-0.004	-0.006	-0.001	0.006
Camera (C)	0.196	0.136	0.255	<.0001	0.047	-0.024	0.117	0.193	0.104	0.014	0.194	0.024	0.044	-0.093	0.181	0.532
T x C	0.002	-0.001	0.005	0.119	0.002	0.000	0.004	0.104	0.002	-0.002	0.006	0.262	0.002	-0.001	0.005	0.102

Table 19: All crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 18 Cases (streets with mobile cameras)				MODEL 19 Controls (streets without mobile cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	1.741	1.300	2.182	<.0001	0.004	-0.413	0.420	0.986
Time (T)	-0.003	-0.005	-0.001	0.000	-0.002	-0.005	0.000	0.063
Camera (C)	0.127	0.081	0.173	<.0001	0.052	-0.053	0.157	0.331
T x C	0.002	-0.002	0.005	0.371	-0.001	-0.005	0.004	0.788

Table 20: All crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

	MODEL 20			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	0.001	-0.415	0.417	0.997
Time (T)	-0.002	-0.005	0.000	0.063
Camera (C1)	0.052	-0.053	0.157	0.332
Case (C2)	1.742	1.136	2.348	<.0001
T x C1	-0.001	-0.005	0.004	0.789
T x C2	-0.001	-0.004	0.002	0.698
C1 x C2	0.075	-0.040	0.190	0.201
T x C1 x C2	0.002	-0.003	0.008	0.446

Table 21: All crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.9 Road crash analyses – effects of fixed cameras on serious intersection crashes (Models 21 to 23)

A total of 152 serious (injury or fatality) intersection crashes were identified in the period for the 26 intersection locations, including 78 that occurred at case intersections and 74 that occurred at control intersections. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 22 and 23, and Models 21 and 22 are plotted in Figure 30. The negative estimates for CAMERA indicates that serious intersection crash counts for case and control intersections were generally lower following the introduction of fixed cameras, and the similar magnitudes indicates that the drop was similar at case and control locations. Model results were not significant, including those for the case-control Model 23, likely a result of the small crash counts.

Annual trend magnitudes for case intersections were a decrease of 5.2% prior to the begin-date and an increase of 0.4% following the begin-date. Trend magnitudes for control intersections were a decrease of 5.0% prior to the begin-date and an increase of 8.2% following the begin-date. All trend magnitudes are per year.

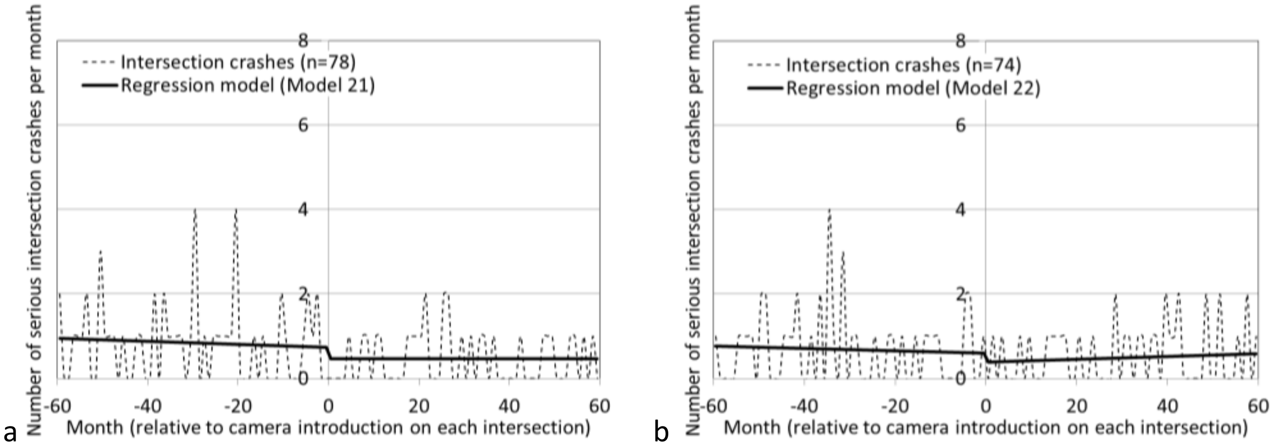

Figure 30: Serious intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

	MODEL 21	Cases (with fixed cameras)			MODEL 22	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.315	-0.891	0.261	0.283	-0.509	-1.167	0.149	0.130
Time (T)	-0.004	-0.020	0.012	0.598	-0.004	-0.023	0.014	0.656
Camera (C)	-0.454	-1.396	0.488	0.345	-0.430	-1.438	0.578	0.403
T x C	0.005	-0.022	0.031	0.738	0.017	-0.011	0.044	0.230

Table 22: Serious intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 23 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.509	-1.156	0.138	0.123
Time (T)	-0.004	-0.022	0.014	0.650
Camera (C1)	-0.430	-1.421	0.561	0.395
Case (C2)	0.194	-0.679	1.067	0.664
T x C1	0.017	-0.010	0.044	0.222
T x C2	0.000	-0.025	0.024	0.991
C1 x C2	-0.024	-1.403	1.355	0.973
T x C1 x C2	-0.012	-0.051	0.026	0.534

Table 23: Serious intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

3.10 Road crash analyses – effects of fixed cameras on all intersection crashes (Models 24 to 32)

A total of 4,261 intersection crashes (property damage, injury or fatality) were identified in the period for the 26 intersection locations, including 2,826 that occurred at case intersections and 1,435 that occurred at control intersections. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 24 to 28 and are plotted in Figures 31 to 33. Trends in crash counts for case intersections showed an increase in crashes following the introduction of the fixed cameras followed by a decline to rates slightly lower than baseline levels. On the other hand, crash counts for control intersections were relatively consistent before and after. The positive estimate for CAMERA in Model 24 indicates that case intersection crash counts were generally higher following the introduction of fixed cameras, and this result was significant. Disaggregating intersection crashes by rear-end crashes indicates that, at intersections where fixed cameras were introduced, this increase resulted from an increase in rear-end crashes which then returned to levels slightly below baseline levels. This is evidenced in the estimates for CAMERA, where a large positive value was estimated for rear-end crashes (0.277, Model 27), and this result was significant. Conversely, a small value was estimated for non-rear-end crashes (0.007, Model 29).

Comparison with the generally consistent frequency of rear-end crashes before and after at intersections without fixed cameras (small negative value for CAMERA estimate in Model 28), indicates that the initial increase in rear-end crashes at intersections with fixed cameras was likely a result of the introduction of these cameras. This is further evidenced by the statistical results for the case-control analysis in Model 26, where the estimate for CAMERA $\times$ CASE was highly significant, indicating that the effect of the introduction of fixed intersection cameras was significantly different between case and control streets.

Negative estimates for CAMERA in the models for right angle collision/right turn into oncoming vehicle intersection crashes indicate that crash counts were generally lower following the introduction of fixed cameras, at both case and control intersections.

Annual trend magnitudes for case intersections were decreases of 3.4% prior to the begin-date and 6.2% following the begin-date. This included decreases of 0.5% prior to the begin-date and 6.5% following the begin-date for rear-end crashes, decreases of 8.9% prior to the begin-date and 5.5% following the begin-date for non-rear-end crashes, and decreases of 1.6% prior to the begin-date and 2.2% following the begin-date for right angle collision/right turn into oncoming vehicle

crashes. Trend magnitudes for control intersections were a decrease of 1.6% prior to the begin-date and an increase of 2.2% following the begin-date. This included an increase of 1.2% prior to the begin-date and an increase of 2.2% following the begin-date for rear-end crashes, a decrease of 6.0% prior to the begin-date and an increase of 0.7% following the begin-date for non-rear-end crashes, and a decrease of 13.6% prior to the begin-date and an increase of 3.0% following the begin-date for right angle collision/right turn into oncoming vehicle crashes. All trend magnitudes are per year.

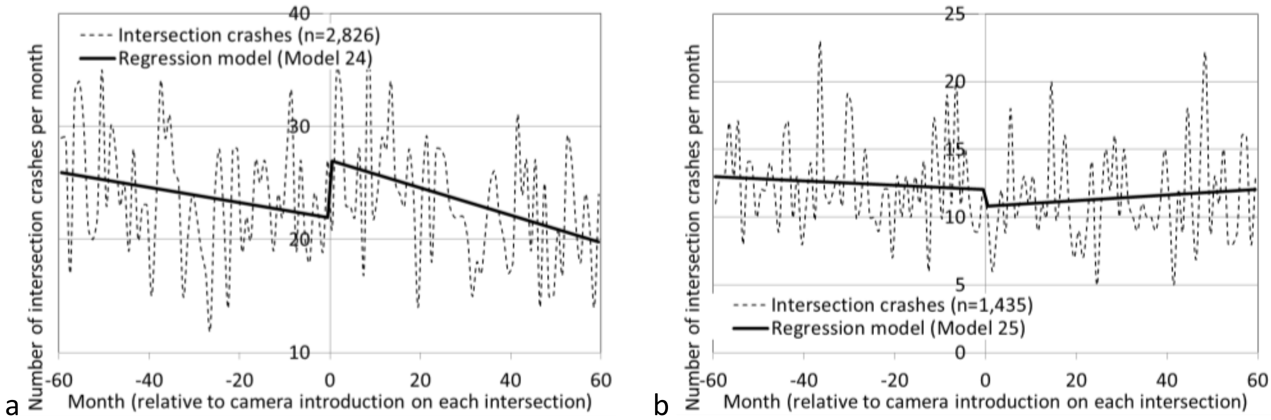

Figure 31: Intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

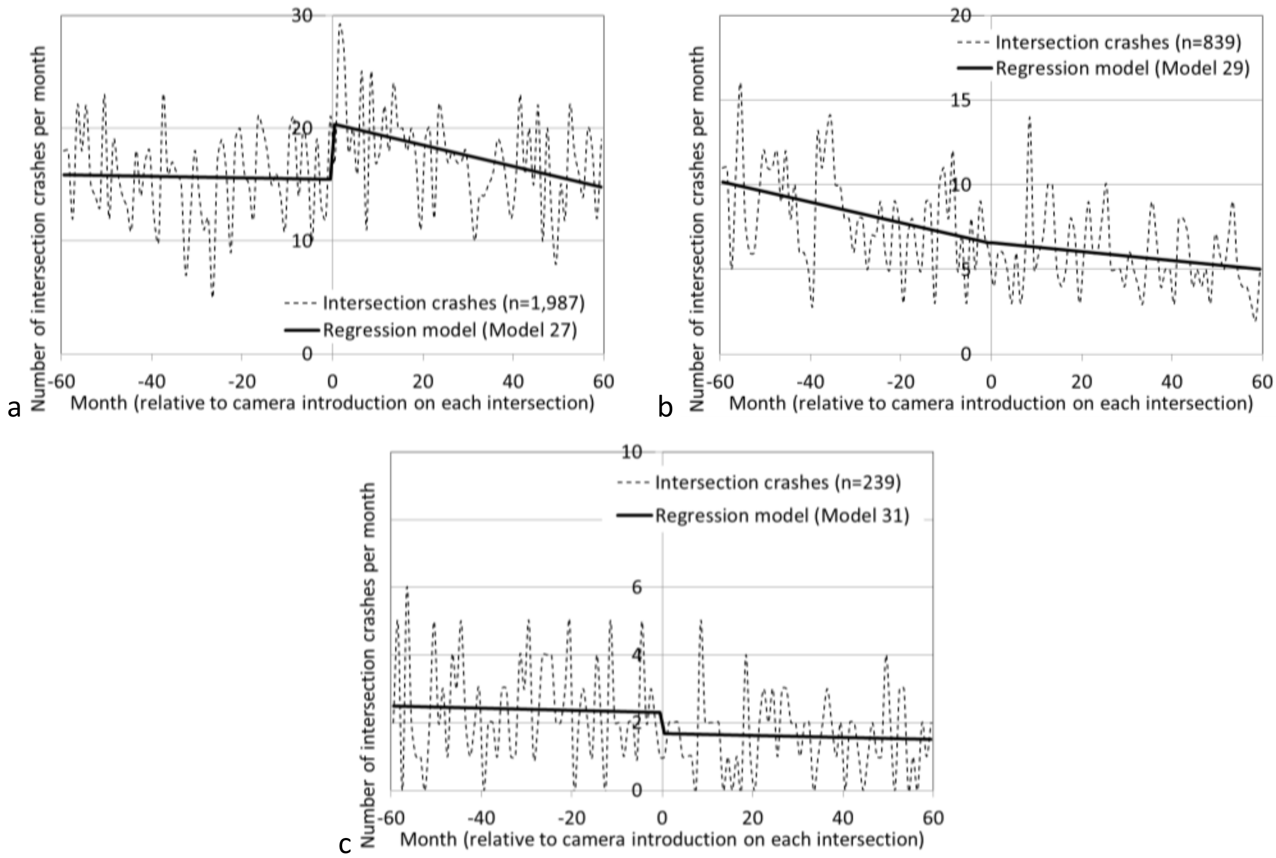

Figure 32: Case intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

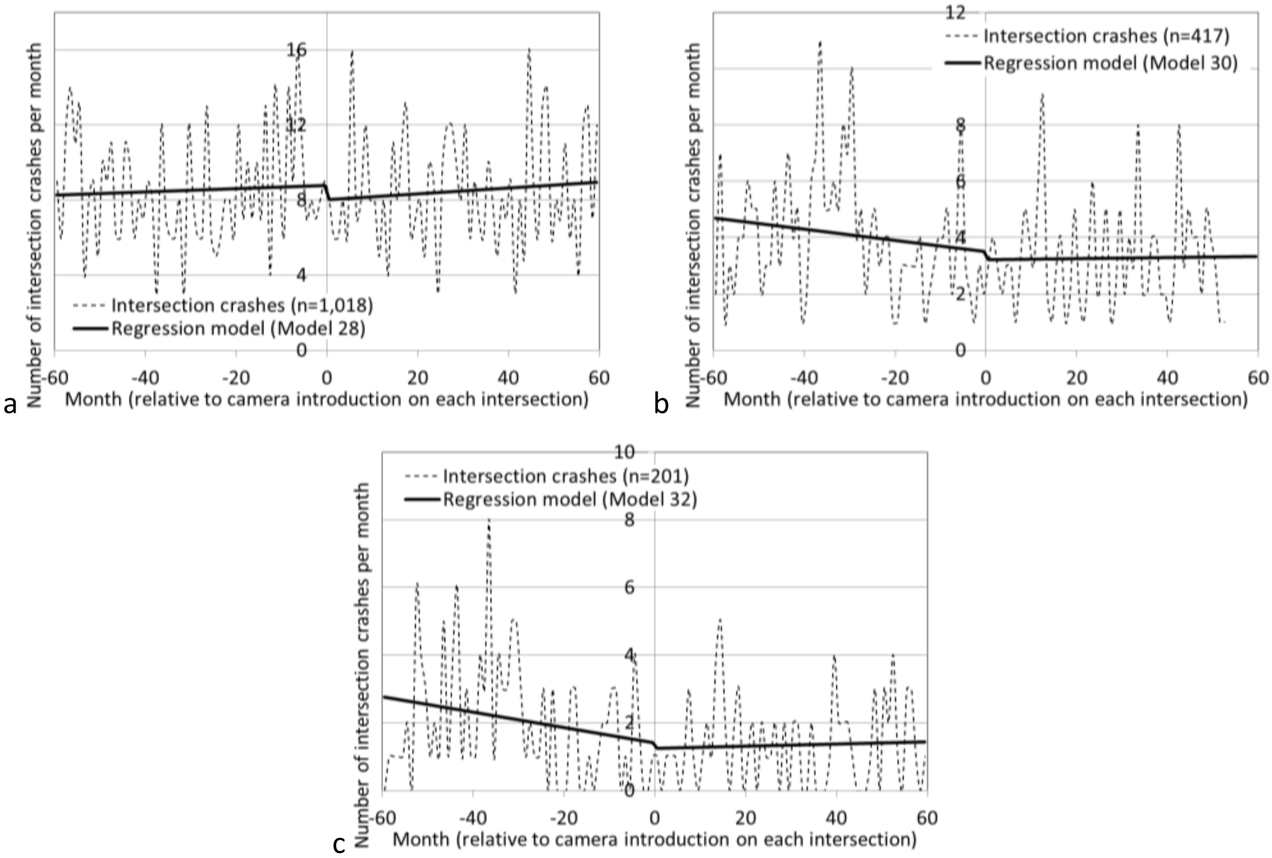

Figure 33: Control intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

	MODEL 24	Cases (with fixed cameras)			MODEL 25	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	3.089	2.977	3.200	<.0001	2.487	2.346	2.628	<.0001
Time (T)	-0.003	-0.006	0.000	0.082	-0.001	-0.005	0.003	0.520
Camera (C)	0.207	0.053	0.362	0.009	-0.107	-0.312	0.097	0.303
T x C	-0.002	-0.007	0.002	0.298	0.003	-0.003	0.009	0.297

Table 24: Intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 26			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	2.487	2.340	2.634	<.0001
Time (T)	-0.001	-0.006	0.003	0.537
Camera (C1)	-0.107	-0.321	0.106	0.323
Case (C2)	0.601	0.420	0.783	<.0001
T x C1	0.003	-0.003	0.009	0.318
T x C2	-0.002	-0.007	0.004	0.575
C1 x C2	0.315	0.055	0.575	0.018
T x C1 x C2	-0.006	-0.013	0.002	0.149

Table 25: Intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 27	Cases (with fixed cameras)			MODEL 28	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	2.740	2.611	2.868	<.0001	2.171	1.995	2.348	<.0001
Time (T)	0.000	-0.004	0.003	0.834	0.001	-0.004	0.006	0.690
Camera (C)	0.277	0.103	0.451	0.002	-0.090	-0.342	0.163	0.487
T x C	-0.005	-0.010	0.000	0.056	0.001	-0.007	0.008	0.839

Table 26: Rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 29	Cases (with fixed cameras)			MODEL 30	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	1.878	1.706	2.050	<.0001	1.250	0.975	1.525	<.0001
Time (T)	-0.007	-0.012	-0.003	0.002	-0.005	-0.013	0.003	0.193
Camera (C)	0.007	-0.249	0.262	0.959	-0.085	-0.498	0.327	0.686
T x C	0.003	-0.005	0.010	0.458	0.006	-0.006	0.017	0.344

Table 27: Non-rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 31	Cases (with fixed cameras)			MODEL 32	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.836	0.498	1.173	<.0001	0.343	-0.147	0.833	0.170
Time (T)	-0.001	-0.011	0.008	0.789	-0.011	-0.024	0.002	0.090
Camera (C)	-0.322	-0.850	0.205	0.231	-0.130	-0.875	0.615	0.733
T x C	-0.001	-0.016	0.015	0.950	0.014	-0.007	0.034	0.190

Table 28: Right angle collision/right turn into oncoming vehicle intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

4. Discussion

The views of drivers about speeding and enforcement of speed limits is likely to influence their on-road behaviour. For this reason, in evaluating the effects of road safety initiatives like safety cameras, it is useful to take into account changes in driver and community views about speed and enforcement. The community attitude surveys conducted between 1992 and 2012 provide some insights into changes in attitudes over the period of introduction of safety cameras in the ACT.

Drivers choose the speed of travel from moment to moment based on a range of factors that might be loosely grouped into the driving environment and their preferred driving style. The driving environment includes the physical conditions that can have a large impact on the driver's chosen speed and the regulatory speed limits. Driving style also undoubtedly plays a considerable role in speed choice with the behavioural style of individual drivers influencing their perception of speed and of the importance of regulating speed according to the environment. The majority of drivers make considerable effort to conform to speed limits. Compliance with speed limits and, as a consequence, to general driving conditions is encouraged primarily through enforcement such as the use of speed cameras, but drivers differ in their reactions to such enforcement measures. Driver experience of enforcement may also differ depending on the type of camera in use which will also affect whether and how drivers respond to the presence of speed cameras.

The following is a discussion of what was found to be available in the wide literature in terms of evidence base concerning the effectiveness or otherwise of the different camera types, a discussion of the review of community attitudes to speeding, and a discussion of the speed survey and road crash data study. It is hoped that this discussion and the conclusions (placed at the front of report for convenience) will provide insight into some of the questions raised.

Lastly, the evaluation process outlined in the Detailed Statement of Requirements provided in Appendix E has been addressed as outlined in Section 4.4.

4.1 Literature review

Evaluations of red light cameras clearly yield mixed effects. There is good evidence that they have the effect that we expect and hope for: reduce red light running in the form of violations and most importantly produce reductions in right angle crashes. These effects are clearly road safety benefits.

On the other hand, there is consistent evidence that they also increase rear-end crashes, which is clearly not a benefit for road safety, but again might be expected if drivers are responding rapidly to the onset of red lights when cameras are present. It has been argued that the difference in likely severity of crashes offsets the increase in rear-end crashes. Kloeden et al (2009), for example argued that the damage caused in side impact crashes are often much more extreme than that produced in rear-end crashes, so the trade-off for road safety by the presence of red light cameras is in the positive direction. However, it should be noted that whiplash injury, which is often associated with rear-end crashes, may have long term chronic effects which result in both pain and suffering. Whiplash injuries can also result in a substantial financial burden, where a recent study of road-crash related personal injury insurance claims noted that the average injury claim made for the treatment of whiplash injuries was $90,700 (Bambach et al 2013). Clearly, good road safety practice needs to also consider how to reduce increased rear-end crashes even if the severity of the crash is much less extreme than for example a side impact crash resulting in serious injuries. One way may be to consider light phases at intersections.

The available research provides some guidance on the best approaches to implementation of red light cameras. Some focus on the length of phase sequences. Yang, Han and Cherry (2013) reviewed the evidence for modifying signal sequences as a method of sustaining red light camera operations in order to balance safety benefit with revenue raised. They concluded that safety benefits would be obtained by lengthening the all-red clearance phase and from shortening overall cycle length, whereas shortened yellow light sequences increased the likelihood of rear-end crashes. It seems that providing greater opportunity for drivers to make the decision to stop may be effective in reducing red light running. Further, providing an all-red clearance period at intersections reduces red light violations (Schattler, Datta and Hill, 2003) by requiring drivers to pause between the change in direction of traffic flow. However, it needs to be noted that the ACT already has an all-red phase and the other phasing features noted above.

Evaluations of fixed cameras also clearly show they are effective for reducing speeds and crashes in the location where the camera is installed. The results also show a large variation. There are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

Critical to any evaluation is the choice of a control comparison site. Even if a Random Location Control (RLC) non-camera site is chosen some distance away in order to avoid distance or time halo effects, the site is likely to be influenced by the information about the general presence of cameras in the area by the community. The level of enforcement is also likely to increase driver awareness as people are 'caught' when they are speeding at the camera site and then drive through control sites elsewhere. Drivers tend to watch what they are doing through signalised intersections and drivers have warnings of the presence of the camera in the general vicinity.

Another factor that may account for the large variation is the issue of the effectiveness of enforcement using camera technology. For enforcement to be effective, just as for any behaviour change, the punishment and the infringement need to be linked closely; the consequence and the act must be clearly tied. Since cameras produce automatic enforcement, when drivers receive fines or notification of demerit points some considerable time after they have committed the violation, this presents a problem. The link between committing the violation and being made aware of it and/or the consequence is weakened by the length of time between them. Drivers need to know that they have been caught as close as possible to committing the offence. Information available from red camera sites can provide this in the form of camera flashes or feedback to drivers from mobile camera units.

Evaluations of mobile cameras also clearly show they are effective for reducing speed and crash outcomes. The results similarly show some variation between the different studies. Again there are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

The same issue exists for this camera type as for fixed cameras in terms of timeliness of issuing the infringement notice and demerit points in relation to the time the violation was committed. Evaluations of this camera type (and for the fixed camera type) likely have not considered this factor in any analysis. A related issue is the extent to which drivers are even aware that they have been detected violating speed limits. The question is whether drivers should be warned they are about to pass a mobile camera or whether no warning should be provided. For example in Victoria, the policy for mobile cameras is that they remain covert. In Victoria the flash of a camera has been removed, and as a result the link between committing the violation and its consequence is significantly weakened. If drivers are not warned that there are cameras in a particular location or even in a general location, the arrival of an infringement notice may be the first time they learn about it. The strategy behind this approach is to impart to the driver the notion that they can be photographed 'any time anywhere' if they are found to exceed the speed limit. Aeron Thomas (2005) noted that the strongest evidence came from a study that had signs at the entrance to the monitored area but not at the camera site itself. It is assumed that making the cameras covert motives the behavioural change in drivers to travel at the speed limit everywhere however the validity of this assumption has not been demonstrated adequately to date.

An associated issue with a weak association between the unsafe act and the consequence is its effect on driver attitudes. Speed enforcement is generally supported by the community, at least in principle, but this support is tempered by a view, unfortunately shared by more than half of the community that speed enforcement is revenue raising (Austroads, 2013). Clearly the belief that speed enforcement does not have a road safety objective is likely to be a significant impediment to drivers complying with speed limits.

This issue that drivers perceive that speed enforcement does not have a road safety objective, is discussed in a paper by Belin et al (2010). They compare speed camera programs in Sweden and Victoria. They state that the "*approach adopted in Victoria is based on the concept that speeding is a deliberate offence in which a rational individual wants to drive as fast as possible and is prepared to calculate the costs and benefits of* their *behaviour. Therefore, the underlying aim of the intervention is to increase the perceived cost of committing an offence whilst at the same time decrease the perceived benefits, so that the former outweigh the latter. The Swedish approach, on the other hand, appears to be based on a belief that road safety is an important priority for the road users and one of the reasons to why road users drive too fast is lack of information and social support."* The Swedish approach is to assist the driver with making a safe speed choice and thus bring about a general cultural behavioural change. On the other hand, in Victoria the system is punitive and treats the offending driver as intentionally carrying out a criminal act. In Sweden however, it is accepted that drivers need to be assisted with making the right speed choice. The approach is engineering based where the choice in what system is used to achieve a particular road safety target can be either through the use of speed cameras or through upgrading the road system.

The relative benefits of the Victorian or Swedish approaches are still to be formally evaluated. There is evidence, however, that the covert approach adopted by Victoria resulted in significant proportions of drivers believing that camera technology was being used for revenue raising (Smith and Senserrick, 2004) and the approach also involves a weak link between the unsafe behaviour that we wish to change (speeding) and the punishment that is intended to change that behaviour. There is evidence that the Victorian approach has produced some benefits of reduced speeding and crashes (Cameron et al, 2003). However, it is unclear what aspects of the approach produced these effects given that it included covert cameras, greater enforcement, increase media and lower speed limits. It is likely, however, that the benefits could be greater if elements of the Swedish approach were included. For example, the underlying premise of the Victorian approach that drivers make deliberate decisions to speed so making them believe that they must always drive slower than the speed limit as they could be caught anywhere and anytime has not been rigorously evaluated. Exceeding the speed limit can occur when drivers are not focussing on their speed due to other activities including driving-related activities. This means that drivers can inadvertently exceed the speed limit even when they did not intend to do so. Current statistics on speed camera infringements in Victoria show that only a smaller percentage of all drivers (around 30%) are caught speeding by speed cameras, but this corresponds to over one million drivers each year. If only a proportion of these drivers, e.g. half did not intend to speed, this may have an impact on community attitudes to speed cameras, which is likely to be negative particularly if they were not immediately aware that they had actually committed the infringement.

Delaney et al (2005) highlight the various controversies which they suggest need to be considered in any speed camera enforcement program. The examples they listed are that speed cameras are seen by some as: revenue raising; unfair in that they do not identify offenders on the spot; not timely in terms of issuing the infringement notices; placed in locations where speed is perceived to be safe because it is felt that the speed limits are too low; lack reliability in terms of instrument measurement; not addressing road safety, i.e. speeding may not be perceived as a road safety problem; intruding into the Privacy of individuals, i.e. big brother is watching. They noted in the case of Victoria: '*Public opinion surveys conducted in Victoria identified the controversies associated with camera use. In the initial years few controversial issues arose, thought to be a result of carefully planned strategies of camera implementation. These strategies included independent technical testing and quality assurance of equipment and procedures, identification of safety (not revenue) as the primary objective, winning public support even though the level of fines was high, and subjecting the program to independent evaluation research to establish its road safety potential.'* Nevertheless, they found that despite Victoria deploying covert cameras across the road network without warning signs, and taking an aggressive approach of reducing the speeding threshold tolerance to 3 km/h, the camera program was widely supported by the public. They advised that any jurisdiction planning to introduce a speed camera program should at a minimum: *'involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important. Finally, it is essential that the equipment and operating procedures used are reliable.'*

The evaluation of the point-to-point cameras in Italy by Montella et al (2012) also clearly show they are effective for reducing speed in the location where the camera system is installed. However, compared to other speed enforcement approaches, point-to-point systems are relatively expensive (Austroads 2012). Nevertheless the cost-benefit ratios appear high and compliance extends over longer distances. A four year evaluation of speed cameras of all types in Britain (Austroads 2012), showed that all types of cameras produced reductions in speeds at the camera site. In all, fixed cameras produced the greatest reductions, followed by point-to-point cameras and mobile speed cameras. However, it should be noted that fixed cameras also produce their effects over the shortest distances.

4.2 Review of community attitudes to speeding

The introduction of mobile and red light cameras occurred fairly close in time: 1999 and 2000. This means that individual effects of each camera are likely to be difficult to disentangle. Nevertheless, a number of changes were found that were associated with the introduction of safety cameras in the ACT. First, initial introduction of mobile and red light cameras was associated with increased perception that enforcement had increased so ACT residents noticed the additional enforcement. Aligned with this finding was the increased reporting of being booked for speeding over the last two years in the two years following the introduction of mobile and red light cameras, although this effect trended down between 2006 and 2008. Furthermore, more

ACT respondents reported decreasing their own driving speed in the period following the introduction of mobile and red light cameras. Combined, these findings suggest that the initial implementation of the safety camera programme with mobile and red light cameras may have influenced the amount and impact of speed enforcement and even had effects on driver behaviour through reducing their driving speed. The data shows that around this time serious injury crashes dramatically fell by around 40% from around mid-2002 and was maintained until 2004 after which the trend began to steadily rise.

The introduction of fixed cameras in 2007 was not associated with increased perception of increased enforcement, even though more respondents reported being booked for speeding over the past two years and six months in 2009 and 2011 following the introduction of fixed cameras. Alternatively, the lack of reported change in perception of enforcement may reflect an insensitivity of the question (lack of detailed questioning) which has only a few available responses compared with the question on being booked. In addition, the personal experience of being booked is memorable whereas the amount of enforcement years earlier may not be.

Interestingly, there was a relationship between increased reporting of being booked for speeding between 2002 and 2005 and a clear drop in the percentage of ACT respondents who supported no tolerance for speeding in 60 and 100kph zones, especially after 2002. It may be that the more widespread experience of being booked made ACT respondents review their attitude to speed limits so fewer supported a tougher 'no tolerance' approach.

Many attitudes to speeding in the ACT seem to have changed little since 1995, although there are a few exceptions. Since the introduction of safety cameras, far fewer ACT respondents agree with the idea of safe speeding. Similarly, support for increasing levels of enforcement and even severity of penalties has increased or at least stayed the same following introduction of safety cameras. The initial introduction of safety cameras in the ACT was also associated with a marked increase in support for lowering residential speed limits. While there may not have been a direct causal relationship between the effect of safety cameras and views in the ACT about speed limits, the presence of cameras clearly did not have a significant influence on attitudes about speed limits as in 2003 over 90 percent of respondents supported lower speeds.

On the other hand, around half of respondents in the ACT agree with the view that speeding fines are for revenue raising. Unfortunately, support for this view increased in the two years immediately following the introduction of fixed cameras. Although this effect dropped in the most recent survey, to the same levels as before the introduction of fixed cameras.

These findings suggest some clear targets for further consideration in order to enhance community support for speed management in the ACT. There seem to have been some very clear benefits for community perceptions and attitudes from the first introduction of safety cameras in the ACT. People noticed their effect and at least reported reducing their driving speed but they maintained support for establishing lower speed limits, increased enforcement and stricter penalties for speeding. Factors that challenge these encouraging findings include the suggestion from this research that being booked may have an effect of reducing support for stricter enforcement of limits and potentially general support for speed management. Also, the commonly held view that speeding fines are revenue-raising is clearly not supportive of programmes that include speeding fines. Further understanding is needed of both of these factors, in order to encourage more supportive community attitudes towards speed management programmes in general.

This analysis of changes in community attitudes also suggests that the implementation of fixed cameras may not have been as successful as the introduction of the mobile and red light cameras. It is possible that the difference is related to a general reduction in effectiveness of the whole safety camera programme, since a number of other studies have demonstrated that most benefits of camera programmes occur immediately after implementation. Even so, the introduction of fixed cameras did not produce the same initial changes in enforcement perception, and self-reported speed behaviour as the mobile and red light cameras. Furthermore, fixed cameras were associated with a temporary increase in community perceptions of the revenue-raising nature of speeding fines. Based on these patterns of community attitude change, it would be worthwhile to review communications strategies that articulate the rationale for speed cameras and how they are being used, and also simultaneously review the operation of fixed cameras in the ACT in order to determine whether there are specific aspects of their operation that may have had negative effects on community support for the safety camera programme.

4.3 Speed survey and road crash data study

The infringements data indicate that the rate of fixed camera infringements (per vehicle checked) has been very low, where after the first year the rate remained below 0.2%. The rate of mobile camera infringements decreased consistently for approximately three years following the introduction of cameras in late 1999. After approximately late 2002, the rate of mobile camera infringements levelled off to a long-term rate of around 0.6%. Several issues may have been influencing these rates, including; drivers were not infringed at the same rate, drivers may not have been communicated to via various media outlets adequately and consistently that their speeding could result in a ticket, location of the camera, and the tolerance levels used by the cameras (i.e. the speed above the speed limit at which an infringement is issued – however camera tolerance levels are not publicly available information). During this approximately three year period of reducing infringement rates, vehicle speeds were also reducing. This indicates that drivers were getting used to the cameras and adjusting their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding.

However, following 2004, mean vehicle speeds began increasing back to the same levels when cameras were first introduced. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. Possibly when they found that they were not being caught very much or at all, or they found the penalty was not severe, or drivers have learnt how to speed and yet avoid detection, their speed started to return to customary levels. In other words, the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Alternatively, it could be other factors like initial bursts of enforcement and the relevant new publicity, which were not able to sustain mean speed reduction over longer periods. Evaluation of these possible accounts through further research is recommended. Moreover, it is recommend that the ACT examine how to make all aspect of mobile cameras less predictable in terms of location, time and vehicle used, and whether this is effective in reducing speeds and hence serious injury crashes.

It is notable that vehicle mean speeds on control streets decreased substantially immediately prior to the introduction of cameras in late 1999, which indicates that the publicity about their presence and likely effects was possibly having the desired effect of getting drivers to slow down. The introduction of cameras possibly increased the perception that drivers were likely to be caught if they exceeded the speed limit because cameras will photograph all who infringe. The effect will of course diminish when drivers find that this is not actually the case. It could be expected that speeds decrease where cameras are first introduced (and as above, even before) due to the community expectations about their effects. But then it would be expected for drivers mean speed to return to levels previous to their mention and introduction on control streets, because there are no cameras, but on camera streets the speeds would be expected to reduce as a result of the cameras photographing infringing drivers who are speeding and a ticket being issued. This effect was found initially for case streets although the effect dissipated over time.

The longer term mean and 85th percentile speed data indicated that vehicle speeds on control streets remained relatively constant, indeed annual trends remained below 1% for the full period from 1999 to 2012. These results indicate that mobile speed camera operations likely had minimal effect on speeds on streets in which cameras were not introduced.

Meanwhile, case streets saw an increase in speeds followed by a decrease in speeds before and after Intervention 2, indicating that after increases in speeds, speeds levelled off and decreased slightly with long-term mobile camera operations. Changes that occurred around Intervention 2 were small in magnitude and insignificant, indicating little effect on speeds from the drop in mobile camera operations that occurred at this time. As noted in the discussion of the literature review, many studies have shown that the effect of cameras on mean speeds is typically small in magnitude. Nevertheless, these small values can have a significant effect on casualty crashes as demonstrated in Figure 2 by Nilsson (2004). With a very small percentage of people speeding (which is known from the infringement rates), the mean speed will not decrease much but will actually reflect a significant effect on the number of speeding drivers.

It is noted that prior to the introduction of mobile cameras, speeds in case streets were higher than those in control streets. This is likely related to the fact that streets with known speed problems and/or speed-related crash problems were targeted for mobile camera operations. The drop in speeds on camera streets could be related to RTM and, as a consequence may overestimate camera effects when comparing pre and post camera introduction. However, the opposite effect might be expected due to spillover since control streets will have also been influenced by the general community awareness of cameras, which is likely to have an effect of underestimating camera effects if differences between camera and control sites is looked at.

Serious injury crashes (injury or fatality) generally decreased on streets following the introduction of mobile cameras although there was a continuing smaller trend that was evident for the five years prior to their introduction. There was a large drop in mid-2002, i.e. around two and half years after the introduction of cameras. Careful inspection of the both the number of mobile operations and serious injury crashes shows an alignment of the sudden fall of serious injury crashes with the camera operation rise over a 12 month period from around 400 to around 600 (30% increase). Fatal crashes also appeared to generally decrease after the introduction of cameras commencing around 2001. This appears to align with the period when casualty crashes started to drop. Further analysis of the nature of the serious crashes would be helpful in understanding the circumstances surrounding this sudden fall in mid-2002. Additionally, it appears the trends in serious crashes do not align well with trends in vehicle speeds. While speeds increased slightly from 2004 to 2007, they then decreased slightly until present, meanwhile serious crash counts increased steadily albeit interspersed with sudden oscillations of large increases and large decreases. Further analysis of the nature of crashes would be useful to attempt to understand these changes. If the causes of crashes varied across the study period, it may be possible to understand whether speed indeed played a role consistently across the period and whether speed cameras were likely the likely source of the casualty crashes.

Nevertheless, this two-fold increase (normalised to vehicle registrations) in serious crashes over the most recent ten years is a major road safety concern for the ACT. It was noted earlier that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. Whilst the serious crashes were normalised to vehicle registrations, the road network may not have changed significantly. In other words, vehicle density is likely rising and as a result traffic conflicts have risen. This increase in exposure may be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Further research is recommended to understand these changes in injury crashes, and develop countermeasures and prevention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties. It is possible that changes in police-reported injury crash rates might be related to changes in how police identify individuals as ‘injured’, thus linkage to hospital records provides a more accurate assessment of crash casualties (and allows assessments of individual injuries and injury severity).

Considering all road crashes (property damage, minor injury, serious injury or fatality), before and after the introduction of cameras there was a relatively consistent decreasing trend in all crash counts for both streets with and without mobile cameras. Increases in crashes around the time of the introduction of cameras were evident on both streets with and without mobile cameras, and were more pronounced on streets with cameras, likely because this was the basis for choosing camera streets. It is noted that the magnitudes of crash counts were substantially higher for the case streets compared with the control streets (by an average of 5.4 times), which is likely a result of the fact that mobile camera operations were more likely to be located on streets with high crash counts and/or traffic volumes. It could be argued that both of these effects may be at least partly due to RTM.

The results of the analyses of all intersection crashes (property damage, injury or fatality) indicated that the introduction of fixed red light and speed cameras increased the frequency of crashes followed by a decline to a level slightly lower than baseline levels, while serious intersection crashes decreased slightly along with non-rear-end crashes/right angle collision/right turn crashes. This initial increase in intersection crashes resulted directly from an increase in rear-end crashes at intersections where the cameras were installed but then declined to baseline levels. This trend that did not occur at intersections where fixed cameras were not installed, i.e. rear end crashes continued to rise on control streets. As noted in the literature review, many studies have noted a similar result (Erke 2009, Hoyos 2013, Vanlaar et al 2014, Pulugurtha and Otturu 2014). It is clear that the road safety benefit is confounded, because it is more crashes in the initial stages of camera installation albeit in this study the crashes reduced to levels slightly below baseline levels. Some authors have argued that road safety might tolerate a trade-off of reducing serious speed-related side-impact crashes for increased lower severity rear-end crashes (Kloeden et al 2009). However, this needs to be further researched.

4.4 Evaluation scope and detailed requirements

Appendix E details the evaluation scope and detailed statement of requirements. They are as follows:

The evaluation is to assess the impact of the ACT's Road Safety Camera Program, which includes mobile, fixed mid-block, point to point and red light/speed cameras, on the road safety objectives of:

- *(a) reducing crashes;*
- *(b) reducing speeding (and thereby reducing crash risk).*

Part (a) is presented in Sections 3.6 to 3.10 and Part (b) is presented in Section 3.4. Discussions concerning Parts (a) and (b) are presented in Section 4.3. Conclusions regarding the reduction of speeds and crashes are presented in the Executive Summary under the header 'Results' and in Section 6.

The evaluation is to utilise:

- *(c) available ACT data, including crash data, speed surveys, and infringement data;*
- *(d) relevant research and findings of other jurisdictions' evaluations of the effectiveness of road safety cameras and road safety camera programs; and*
- *(e) any other relevant data, studies, evaluations or information.*

Part (c) is addressed in the Executive Summary under the header 'Methods' and Section 2.3 (Speed survey and road crash data) and hence subsections 2.3.1 to 2.3.5.

Parts (d) and (e) is addressed in Section 1.2, Section 2.1, Section 3.1 which includes subsections 3.1.1 to 3.1.5, and Section 4.1.

The evaluation is to, as far as possible, having regard to the available data and information:

- *(f) assess the impact of the ACT Road Safety Camera Program as a whole;*
- *(g) assess the contribution and impact of the various types of cameras used as part of the ACT Road Safety Camera Program; and*
- *(h) assess the governance arrangements for the ACT Road Safety Camera Program.*

Part (f) has been addressed in Section 3.2 including subsections 3.2.1 to 3.2.4, Section 3.3 including subsections 3.4 which considers the community attitudes to speeding and community perceived effects. Sections 4.2 also discuss the overall effects of the ACT Road Safety Camera program both from a community attitude perspective and Section 4.3 discuses the overall effects from the speed survey and road crash data.

Part (g) has been addressed in so far that the effects of mobile cameras on speeds and crashes respectively have been presented in Sections 3.4, 3.5, 3.6, 3.7, and 3.8, and for fixed cameras at intersections in Sections 3.9 and 3.10. Section 4.3 also discusses the effects of the mobile and fixed intersection cameras. Figure 11 also provides information concerning the infringement rates for the two camera types. Summary results for both mobile and fixed camera types are also presented in the Executive summary dot points and conclusions as well as in Section 6.

In regards to the red light cameras, these had to be evaluated as a 'job lot' rather than individually. The main reason is that the before-after analysis require a minimum amount of crash data, otherwise the statistical evaluation is meaningless. Due to the low crash counts, the fixed intersection cameras had to be aggregated. Even when aggregated, serious crash counts were too low to make meaningful interpretations (see Figure 30 and Table 22). When each camera was assessed individually, no conclusions could be drawn from the data.

There was no information that could be extracted concerning the point-to-point cameras. Point-to-point cameras were only recently installed in 2012, thus insufficient data were available to assess these cameras in this study.

Moreover, because a rigorous evaluation methodology was adopted, road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period analysed in Section 2.3 and 3.3, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. Furthermore, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

Nevertheless, since 2011 mid-block crashes can be located. However, there is insufficient data, essentially two years of data at best. Hence any issues concerning evaluating the effectiveness of safety cameras, in particular, the two factors commonly cited as potential threats to the validity of safety camera evaluations being Regression to the Mean (RTM) and spillover effects, cannot be addressed with such a small amount of data. The impact of the introduction of a camera requires at least several years of data both prior to and after the installation (absolute minimum of 2 years either side) or a large number of crashes at baseline. Since mid-block crash data are only available from 2011, mid-block camera installations prior to 2013 cannot be assessed with a before-after analysis with these data. Table 29 summarises the evaluations.

Camera type	Evaluation details
Mobile cameras	Sections 3.4, 3.5, 3.6, 3.7, and 3.8
Fixed intersection cameras	Sections 3.9 and 3.10 – However crash counts were generally low and data had to be aggregated for this camera type.
Fixed mid-block cameras	Prior to 2011 mid-block crash locations could not be accurately identified, therefore crashes occurring in the vicinity of the mid-block cameras could not be identified. Since mid-block crash data is only available from 2011, mid-block camera installations prior to 2013 cannot be assessed with a before-after analysis with these

	data.
Point-to-point	Only installed in 2012 which does not provide sufficient data for before-after analyses.

Table 29: Details of which cameras could be evaluated and what could not be evaluated.

In regards to Part (h) the various holding agencies and governance arrangements for the ACT Road Safety Camera Program for the data are shown in Table 30. It is important to realise that the effectiveness of the enforcement system must be considered as a whole system. It is essential the planning and coordination of data collection be effective and timely. All data (speed, infringements, and crash data that include injury severity, i.e. hospitalisations, deaths, etc.) needs to flow freely to a single data analysis office staffed by one or two highly skilled biostatisticians, where the various regression analyses and trends can be easily compiled with a standard format that readily feeds into a statistical program and the data models generated and critically assessed as presented in this report. Alternatively data could be outsourced, again though in a standard format readily analysed by a statistical package, every 12 months to a facility similar to TARS. However it is essential that the biostatisticians need to be at a high level of competency and fully articulate is statistical modelling. For example, the team assemble at TARS has Australia's leading researchers in the field.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 30: Holding agencies for the data available

Timely regular monitoring and evaluation is essential to the success of any enforcement program by decision makers. The output generated from the statistical reports need to be presented and analysed in regular review meetings (possibly every 6 or 12 months) held between the analysts, and the experts and senior staff within the various holding and governance agencies to assess the trends, develop a strategy for the ACT road network and plan enforcement strategies. These high level strategy meetings among the decision makers could be run by Justice and Community Safety Directorate in collaboration with the other stakeholders such as ACT Police and Territory and Municipal Services Directorate. Ideal governance arrangements (most of which are occurring in the ACT, which has relevant committees, data monitoring, sound relevant strategy, and as the commissioning of this report shows, a commitment to evaluation) would include:

1. Regular monitoring and analysis of relevant intermediate and final outcome variables, including:
    a. crashes and casualties involving speeding (though these should be treated as an under-estimate of the problem- see below);

   b. Speeding behaviour by drivers (not at speed camera locations as well as at speed camera locations);
   c. Attitudes and beliefs, especially in relation to the perceived risk of being caught and enforcement avoidance behaviours;
   d. Enforcement rates at cameras, and by police.
2. Close working relationships with relevant partners (especially Police) including informal meetings as well as formal committees;
3. Reporting arrangements for committees and organisations to ensure that concerns are elevated to the appropriate decision making levels of the relevant organisations;
4. Mechanisms for consultation with NGOs and the community as well as for obtaining appropriate support and advocacy for sound road safety management of speed;
5. Resources, capacity, policy, and strategy for evolving enforcement, communications, advertising, speed limit reviews, and legislation, as necessary in response to identified issues and monitoring data;
6. Specific accountabilities and responsibilities (organisations and people) assigned for the above governance functions, with these included in job descriptions and performance contracts.

It essential that a team culture focussed on addressing road casualties via successful safe systems approaches is encouraged. Speed management (to reduce both crash risk and the forces to which people are exposed in the event of a crash) is a core element of safe systems. Strong enforcement combined with good community credible communication providing reasons why it is essential speeds must be reduced has been shown to be highly successful.

As mentioned earlier Delaney et al (2005) highlight a speed camera program should at a minimum: *'involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important.'* Enforcement and communication and <u>strong detection</u> go hand in hand and do result in average speed reduction and associated crash reductions as was clearly evident in Figure 24 in around 2002/2003.

The evaluation is to identify:

(i) potential opportunities to gain improved road safety effectiveness from the existing resources of the ACT Road Safety Camera Program;

(j) future opportunities to maximise the road safety effectiveness of the ACT Road Safety Camera Program, in relation to both network resources and governance; and

(k) an appropriate ongoing evaluation framework to support an effective ACT Road Safety Camera Program.

In regards to Part (i), the rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006. Hence it is clear operation needs to increase back to the similar levels per 2006. However this needs to be carried out hand in hand with strong communication via various media outlets and timely notices.

Better data gathering on speed surveys that is regular and consistent and allows analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also essential.

Formatting of all data gathered needs to be compatible with the statistical analysis programs (whichever one used) such that little effort is required in converting the collected data.

Strategy meetings between analysts and decision makers need to be held and a camera strategy that is effective for the entire road network needs to be developed and maintain with adequate resources. It is important a network approach in terms strategic placement of the mobile operations and fixed cameras and operation of the point-to-point cameras throughout the road network is considered.

Appropriate staffing and financial resources to support that scheme are essential, i.e. highly skilled data analysts that can communicate results to decision makers, sufficiently resourced enforcement agencies for increased mobile operations, sufficient resources for timely processing of infringement notices, and sufficient financial resources for community communication and media advertising with an appropriate communication strategy that takes the community along with the increased enforcement program that demonstrates obvious safety benefits.

It is also strongly recommended that further research on injury crashes during this period is performed, i.e. a linked data analysis between crashes and hospitalisations in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

In regards to Part (j) mix, density and manner of deployment of various camera types as well a supporting measures to improve effectiveness (e.g. community engagement and timely notification of infringement) is essential. Regular (yearly) strategy plans with all stakeholders needs to be developed based on the feedback from the survey, crash and speed data analysis. Any strategy must include both enforcement and public awareness and that this must be maintained.

A rational basis for fixed camera use that is maintained and again enforced effectively and included in the public awareness campaign is critical. The rational for their placement in the road network is usually based on black spots as this is where they are likely most effective. Other approaches could be also be explored such as using powerful network optimisation analysis programs, for example artificial intelligence that considers harm minimisation.

History (evidence base) has proven time and again that the presence of a mix of safety camera types (fixed, mobile of both overt and covert, and point-to-point) and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication and consistent enforcement that are perceived to be wide spread in different forms are a key part of any enforcement program. Returning the number of mobile operations to the same levels prior to 2006 and including point-to-point cameras in the mobile camera programme would be a first step.

It is important that communications and advertising are related to enforcement, not simply to speeding. Experience and evaluations of the greatest successes in road safety via behaviour change have all been achieved through the close association of strong media promotion of enforcement and the enforcement itself. Local examples include the very large media campaigns associated with the introduction of RBT in NSW (Job et al., 1997), and the large campaigns which occurred with the re-introduction of mobile speed cameras in NSW (Job, 2013). The immediate effects of these campaigns, which started at or even before the enforcement started, attest to the key role of the communications in these successes. Many communication messages do not alter behaviour because messages are not aligned and based on the threat of enforcement.

Non-enforcement messages are legitimate for other purposes such as setting the agenda (e.g., gaining community acceptance of stronger enforcement).

Opportunity also exists in working with Police to improve the recording of speeding as a factor in crashes. It is clear that the role of speeding is significantly under-estimated in Police crash recording processes globally. Evidence for this includes:

1. It is understandable that speeding is omitted as a factor when the Police have no way of knowing what caused a cash with no witnesses etc., or the driver swears they were not speeding and the other party involved (a pedestrian) is not alive to tell their side of the story;
2. Estimates of the role of speeding have often been below the benefits in serious crash reduction occurring when speed is better managed (e.g. by speed cameras). Thus the role of speeding must have been under-estimated since the cameras only manage speeding, and not even completely;
3. Many countries and states have data which indicate the patent absurdity that speeding is safe behaviour. For example, some countries report data such as over half of all vehicles are speeding in on-road surveys and only 25% of crashes involve speeding.

If police could be moved from a fairly legalistic approach to crash records to a probabilistic estimate of speed involvement, separately from their approach to legal processes, this may help.

In regards to Part (k), an evaluation program that continues to <u>add data each year to the current data</u> set presented in this report would be essential to the development of a successful camera program strategy that improves on the current status. It is critical for decision makers to receive timely feedback from surveys, speed data and crash data and this should be done in a round table mode so that it promotes a culture of team work, focusing on reducing casualties and receiving valuable input from a number of experienced participants at senior level. The data coming from the different camera types and in particular the mid-block crashes since 2011 and from the point-to-point from 2012 can be streamlined to input directly to a statistical software program and every 6 or 12 months updated. Point-to-point cameras should be included in the mobile camera programme (if possible) and hence in the evaluation analysis.

In terms of evaluating the effectiveness of mobile cameras on mid-block crashes and point-to-point cameras, this cannot realistically be started until around 2016 because of the reasons of RTM and spillover effects.

Better data gathering on speed surveys that is regular and consistent and allows for regular analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also important.

The need to monitor and refine the program according to the data is critical. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix. For example if motorists are speeding more at non-enforcement sites than at fixed cameras this indicates the cameras are working as black spot treatments but not for general suppression of speeding. If speeding is more common at mobile camera locations when there is no mobile camera present versus when the camera is there, then this indicates that the mobile cameras are being predicted and thus motorists feel that can speed and slow down for the cameras. This destroys general deterrence. This would suggest the need for more covert operations, and/or the need for less predictable locations for enforcement. Monitoring of attitudes and beliefs can also be informative on these issues. This should also include determining if the penalties are sufficient to deter speeding and the possibility of revising these.

Again appropriate staffing to support these proposed improvements is important.

5. Limitations

It should be noted that trends in mean vehicle speeds may have been influenced by other factors not considered in this study. However, driving speeds are, in the main, a very deliberate action by the vehicle operator, and are likely to be influenced directly by enforcement operations that monitor vehicle speeds and penalise operators when they exceed limits, or indirectly by drivers' perceptions of the operation of cameras and related enforcement. Even inadvertent speeding can be influenced by cameras through creating more care to avoid speeding.

The crash study considered nearly two decades of data, over which time many changes may have occurred in the ACT with regards to roadway infrastructure, roadway design, safety devices, vehicle designs, road user type (cyclist, motorcyclists) and road user behaviours (including speeding, alcohol and drug use, protective device use, etc.) in addition to the introduction of speed cameras. There have also been many road safety initiatives in the ACT addressing particular road user groups and behaviours. These factors may have affected crash frequencies, however were not considered in the present study.

As mentioned in the methodology, it should also be considered that the control streets identified for the analyses do not represent a true 'control area'. The issue of spillover effects in evaluation studies of safety cameras has been discussed at length in the literature (Retting, Ferguson & Hakkert 2003; Aeron-Thomas 2005; Erke 2009; Hoyos 2013; Ko, Geedipally, Walden 2013; Porter, Johnson, Bland 2014; McCartt, Hu 2014; Pulugurtha, Otturu 2014; Vanlaar, Robertson, Marcoux 2014). It is acknowledged that in evaluations such as this study, spillover effects may result in an underestimation of the effects of cameras although they may indicate that the public awareness aspect of the camera introduction has been effective.

Another limitation of the study is that road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations considered could not be directly assessed in this study. Moreover, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

The speed survey data used in the present study was derived from surveys on particular streets that were undertaken at irregular intervals. As a result, for any given month all speed survey results were averaged (aggregated separately by case and control streets). Thus the monthly speed survey results used in the statistical models were discrete time data, which may limit the specificity and applicability of the results. It is preferable that each street location had continuous data, such that the statistical models could be stratified by location, such as was the case for the monthly crash counts. However, such data were not available for the speed surveys. It is recommended that subsets of streets with and without cameras are identified, and future surveys be performed on these streets in a regular manner (with the period being defined by resource limitations). This would provide more meaningful results in future speed meta-assessments. It is also noted that assessments of several speeding-related indicators could not be assessed in the present study, including proportion of vehicles speeding, proportion more than 20km/h over the speed limit, etc. More detailed information on the speed surveys performed might have provided further insights into driver speeding. These data are stored on an old computer system from which it was not possible to extract bulk data (i.e. for the 1,758 speed surveys assessed in the present study). Consequently, the present study used data from the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

6. Final brief conclusions

Along with the conclusions listed at the front of this report, the following summary conclusions are provided for completeness of the report.

Mobile cameras seem to have been effective initially as seen by reductions in serious crashes in the period 2002-2006 and the pre/post analysis for cases but not for controls. The serious injury crashes increased in case streets following 2006 and seemed to coincide with decreasing and less consistent enforcement which is what would be expected if the cameras were located in the high risk streets compared to controls.

Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. The increase in speeds would explain the increase in serious crashes. Avoidance mechanisms could be based on prediction of location and/or time/ and or/day and/or the vehicles being used, or provision of information from various sources.

Fixed cameras did not seem to be as effective in regards to all crashes as they showed increases on case locations compared to controls which then returned to baseline levels. However, this may have been the result of changes in rear-end crashes which may have been because drivers became aware of where the fixed cameras were. This in turn may have had an effect on rear end crashes mostly. The continuing increase in traffic demand could also have played a role. Nevertheless, there appeared to be a fall in serious injury crashes.

These results suggest that more work needs to be done to understand why serious crashes have increased since 2007 and what can be done to improve the effectiveness of cameras since the initial introduction and the research literature demonstrates that they can be effective. In the ACT it would be beneficial for road safety to develop a more sustained programme of re-implementation and evaluation of safety cameras and road safety public awareness campaigns.

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Appendix A: Case and control streets and intersections

STREETS

CASES	CONTROLS
Anthill St	A'Beckett St
Athllon Drv	Archibald St
Barry Drv	Ballumbir St
Barton Hwy	Boldrewood St
Bateman St	Brigalow St
Beasley St	Canopus Cr
Belconnen Way	Chrisholm St
Canberra Ave	Condamine St
Carruthers St	Cowper St
Chuculba Cr	Culgoa Cct
Clift Cr	Dalrymple St
Clive steele Ave	Davenport St
Darwinia Ter	De Burgh St
David St	Emu Bank
Drakeford Drv	Fincham Cr
Dryandra St	Flemington Rd
Ellerston Ave	Forbes St
Federal Hwy	Foveaux St
Florey Drv	Goodwin St
Gilmore St	Grey St
Ginninderra Drv	Hawdon St
Gladstone St	Hopetoun St
Goyder St	Knox St
Groom St	Krefft St
Gungahlin Drv	Langdon Ave
Heyson St	Mackennal St
Hindmarsh Dr	Macpherson St
Kent St	McCaughey St
Kitchener St	McCulloch St
La perouse St	Melba St
Lady Denman Drv	Miller St
Launceston St	Moore St
Learmonth Drv	Mortimer Lewis
Livingston Ave	Murranji St
Macgregor St	Palmer St
Melrose Drv	Paul Coe Cr
Monaro Hwy	Ratcliffe Cr
Namatjira Drv	Scrivener St
Northbourne Ave	Spalding St
Novar St	Vanisttart Cr
Officer Cr	Verbrugghen St
Petterd St	Victoria St
Phillip Ave	Watson St
Ross smith Cr	Wattle St
Theodore St	William Slim Dr
Tillyard Drv	Windeyer St
Tuggeranong Pkwy	Wisdom St
Williamson St	

INTERSECTIONS

CASES	CONTROLS
Northbourne Ave and London Circuit	Northbourne and Swinden
Northbourne Ave and Barry Drive	Northbourne, Eloura and Gould
Drakeford Drive and Marconi Cres	Drakeford, Sulwood and Tuggeranong
Northbourne Ave and Antill Street	Northbourne, Girrahween and Masson
Ginninderra Drive and Aikman Drive	Ginninderra and Kingsford Smith
Hindmarsh Dr and Tuggeranong Pkwy	Hindmarsh and Monaro
Ginninderra Drive and Coulter Drive	Ginninderra and Lance Hill
Barry Drive and Marcus Clarke Street	Barry and McCaughey
Hindmarsh Drive and Yamba Drive	Hindmarsh and Streeton
Hindmarsh Drive and Ball Street	Hindmarsh and Jerrabomberra
Hindmarsh Drive, Newcastle St and Canberra Ave	Hindmarsh and Larakia
Canberra Ave, Captain Cook Cres and Manuka Circle	Canberra and Dalby
Gungahlin Drive and Gundaroo Drive	Gungahlin and Sanford

Appendix B: Results of literature searches

Table B1: Results of review of peer-reviewed scientific published literature for each search engine

Database	Search Term	# Retrievals	Repeats	Remaining	Final	Search Strategy
Web of Science	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "topic")	7				Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	25				Search in "Topic"
	Red light camera + Enforcement + Evaluation	14				Search in "Topic"
	Speed (search in "title") + Camera (search in "title") + Enforcement (search in "topic")	27				
Subtotal		**73**	**19**	**54**	**51**	
PsycINFO	Speed + Camera + Evaluation	3	22			Search in "Abstract", Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	0				Search in "Abstract"
	Red light camera + Enforcement + Evaluation	1				Search in "Abstract"
	Speed (search in "abstract") + Camera (search in "abstract") + Enforcement (search in "all fields")	16				
Subtotal		**20**	**3**	**17**	**8**	
Scopus	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "abstract")	5	12			Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	27				Search in "Article title, abstract, keywords"
	Red light camera + Enforcement + Evaluation	19		The		Search in "Article title, abstract, keywords"
	Speed + Camera + Enforcement	12				Search in "Article title"
Subtotal		**63**	**14**	**49**	**14**	
PAIS International	Speed + Camera + Evaluation	0	49			Search in "Anywhere"
	Speed enforcement camera* + Evaluat*	1				Search in "Anywhere"
	Red light camera + Enforcement + Evaluation	1				Search in "Anywhere"
	Speed + Camera + Enforcement	7				Search in "Anywhere"
Subtotal		**9**	**1**	**8**	**6**	
Final repeats			**49**			
Total		**165**	**86**	**128**	**79**	

Table B2: Australian government road safety authority websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
NSW - Roads & Traffic Authority	1	0	0	1	0	0	0	1
NSW - Transport for NSW - Centre for Road Safety	1	1	1	1	0	0	0	1
VIC - VicRoads	0	0	0	0	0	0	0	0
VIC - Cameras Save Lives	1	0	0	0	0	0	0	0
WA - Department of Transport	0	0	0	0	0	0	0	0
QLD - Department of Transport and Main Roads	1	1	1	1	1	0	0	0
SA - Department of Planning, Transport and Infrastructure	1	1	1	1	1	1	1	0
SA - Government of South Australia	0	0	0	0	0	0	0	0
NT - Northern Territory Transport Group	0	0	0	0	0	0	0	0
TAS - Department of Infrastructure, Energy & Resources - Transport	0	0	0	0	0	0	0	0
AU - Department of Infrastructure and Transport	1	1	0	0	0	0	0	1

Table B3: Individual Road Safety organisation websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
US - National Highway Traffic Safety Administration (NHTSA)	0	0	0	0	0	0	0	0
US - Liberty Mutual Research Institute for Safety	0	0	0	0	0	0	0	0
CA - Transport Canada	1	1	0	0	0	0	0	0
UK - Department for Transport (DfT)	1	1	1	1	1	0	0	1
EU - Eurosafe (European Association for Injury Prevention and Safety Promotion)	0	0	0	0	0	0	0	0
EU - European Agency for Safety and Health at Work	0	0	0	0	0	0	0	0
AU - Australian Transport Safety Bureau (ATSB)	0	0	0	0	0	0	0	0
AU - Austroads	1	1	1	1	1	0	0	1
AU - Roadwise	0	0	0	0	0	0	0	0
AU - Standing Council on Transport and Infrastructure (SCOTI, formerly Australian Transport Council)	1	0	0	1	1	0	0	0
AU - Australian Bureau of Statistics (ABS)	1	0	1	1	0	0	0	0
AU - Australiasian College of Road Safety (ACRS)	1	0	1	1	0	0	0	1
AU - RACV	1	1	1	1	1	0	0	0
AU - Queensland Travelsafe Committee	1	1	1	1	0	0	0	1
AU - NSW Bureau of Crime Statistics	0	0	0	0	0	0	0	0
AU - NRMA	0	0	0	0	0	0	0	0
AU - NRMA - ACT Road Safety Trust	0	0	0	0	0	0	0	0
AU - NSW StaySafe Committee	0	0	0	0	0	0	0	0
AU - NSW Motor Accidents Authority	0	0	0	0	0	0	0	0
AU - Transport Accident Commission (TAC) in Victoria	0	0	0	0	0	0	0	0
AU - The State Attorney-General's Departments	0	0	0	0	0	0	0	0

NZ - Transport Agency	1	1	0	0	1	0	0	1
NZ - Ministry of Transport	0	0	0	0	0	0	0	0
SW – Swedish Transport Administration (Trafikverket)	1	0	1	0	0	0	0	1
Ireland – Road Safety Authority	1	0	1	0	0	0	0	0
The Netherlands – EuroRAP	0	0	0	0	0	0	0	0
France – Institut National De Recherche Sur Les Transports Et Leur Securite (INRETS)	0	0	0	0	0	0	0	0

Table B4: Research centre websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
QLD - Queensland University of Technology - CARRS-Q	1	0	1	1	0	0	0	1
VIC - Monash University - MUARC	1	1	1	0	1	0	0	1
SA - University of Adelaide - Centre for Automotive Safety Research	1	1	0	1	0	0	0	1
NSW - Sydney University - Institute of Transport and Logistics Studies	0	0	0	0	0	0	0	0
NSW - UNSW - TARS	1	1	1	1	0	0	0	1
AU - Australian Road Research Board	1	1		1	0	0	0	0
US - Research and Innovative Technology Administration: National Transportation Library	1	1	1	1	0	1	0	1
US - Transportation Research Board	0	0	0	0	0	0	0	0
US - American Transportation Research Institute	0	0	0	0	0	0	0	0
UK - Transport Research Laboratory	1	1	0	1	0	0	0	1

Appendix C: Results of ACT community attitudes to speeding surveys

"In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"

Year	Increased (%)	Same (%)	Decreased (%)	Don't Know (%)
2011	64	27	5	4
2009	65	26	4	6
2008	63	27	8	2
2006	69	22	4	5
2005	72	21	3	3
2004	71	15	8	7
2003	77	15	5	3
2002	62	22	7	8
2001	74	13	7	5
2000	69	29	7	4
1999	58	30	6	5
1998	56	34	8	2
1997	55	33	7	5
1996	54	26	8	13
1995	59	28	4	9

"Have you personally been booked for speeding in the last two years?"
…and, if so, "Have you personally been booked for speeding in the last six months?"

Year	Last 2 years (%)	Last 6 months (%)
2011	20	9
2009	19	9
2008	15	6
2006	17	6
2005	24	9
2004	21	3
2003	28	8
2002	21	9
2001	17	8
2000	16	4
1999	11	3
1998	13	5
1997	25	11
1996	20	10
1995		9

"Thinking about 60km/h speed zones in urban areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	64	31	64	20
2009	65	34	64	22
2008	64	36	65	21
2006	64	32	64	15
2005	64	33	64	12
2004	65	28	65	13
2003	64.2	33	65.4	10
2002		51	64.9	15
2001		44		
2000		38		
1999		49		
1998		49		
1997		49		
1996		42		
1995		34		

"Thinking about 100km/h speed zones in rural areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	106	25	106	21
2009	110	23	107.9	15
2008	105.5	28	108	14
2006	107	18	107	5
2005	109	20	109	7
2004	110	23	109	8
2003	106.8	22	108.7	6
2002		35	109.2	10
2001		26		
2000		25		
1999		28		
1998		36		
1997		23		
1996		27		

Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:

- Fines for speeding are mainly intended to raise revenue
- I think it is okay to exceed the speed limit if you are driving safely
- Speed limits are generally set at reasonable levels
- If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
- An accident at 70km/h will be a lot more severe than an accident at 60km/h

Year	Speeding fines mainly intended to raise revenue (%)	OK to speed if driving safely (%)	Speed limits generally reasonable (%)	More likely to be involved in accident if increase speed by 10km/h (%)	Accident at 70m/h more severe than 60km/h (%)	TOTAL: Cautious / Conservative attitude to speeding / speed limit enforcement (%)
2011	51	29	85	62	92	26
2009	59	21	86	73	92	25
2008	55	38	85	65	94	22
2006	50	29	88	71	96	26
2005	51	28	87	67	91	28
2004	51	34	87	66	93	
2003	49	33	86	70	91	
2002	48	34	89	63	95	
2001	51	34	87	71	95	
2000	48	38	85	67	89	
1999	53	39	94	69	89	

"Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?" … and then,
"Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"

Year	Level of enforcement			Severity of penalties		
	Should increase (%)	Should decrease (%)	Stay the same (%)	Should increase (%)	Should decrease (%)	Stay the same (%)
2011	44	8	44	27	6	63
2009	46	7	43	24	9	61
2008	45	5	48	23	6	63
2006	37	7	54	23	8	62
2005	37	10	52	20	8	68
2004	47			25		
2003	34			17		

"Do you think that 50km/h in residential area is too low or too high, or about right?" and
"Do you think that limits below 60km/h should be set on more streets, fewer streets, or is it about right as is?"

Year	50km/h speed limit in residential areas are:			Speed limits below 60km/h should be set on:		
	Too low (%)	Too high (%)	About right (%)	Increase the number of <60km/h streets	Decrease the number of <60km/h streets	About right
2009	13	7	80	20	6	74
2008	11	4	86	20	7	73
2006	20	3	77	16	18	66
2005	20	2	78	22	13	65
2004	20	<1	80	24	19	57

"Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways"

They were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"

Year	Approve strongly (%)	Approve somewhat (%)	Total approve (%)	Not care either way (%)	Disapprove somewhat (%)	Disapprove strongly (%)	Don't Know (%)
2003			91				
2002	42	34	77	4	10	10	0
2001	45	27	72	6	15	6	1
2000	28	27	55	8	13	22	1
1999	27	33	60	4	15	20	2
1998	39	18	58	13	12	18	0
1997	17	24	41	13	26	20	1
1996	38	20	58	3	19	20	0
1995	17	28	45	9	26	18	2

"How often do you drive at 10km/h or more over the speed limit?"

Year	%
2011	5
2009	11
2008	5
2006	9
2005	8
2004	9

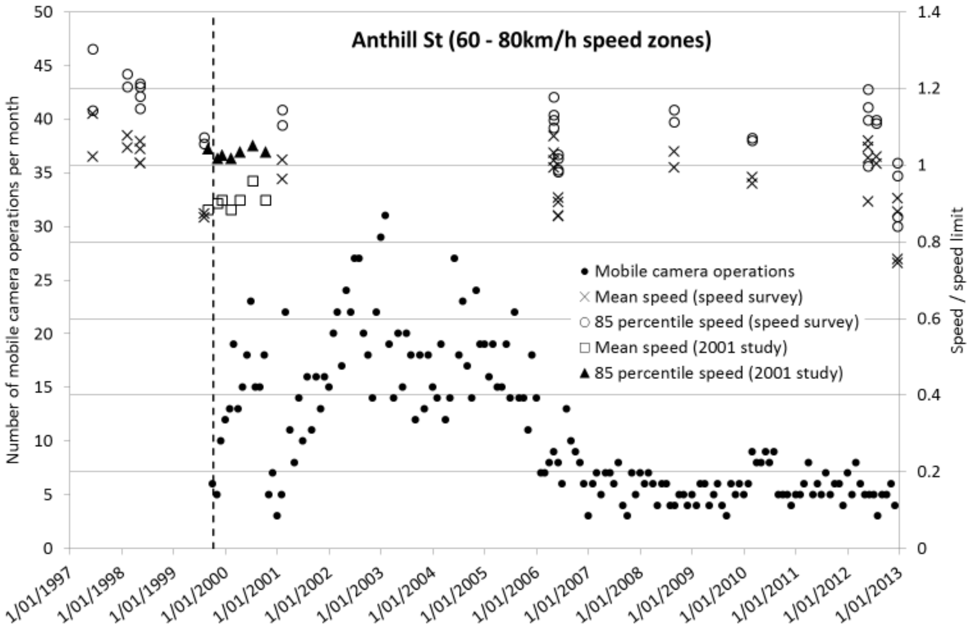
"In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

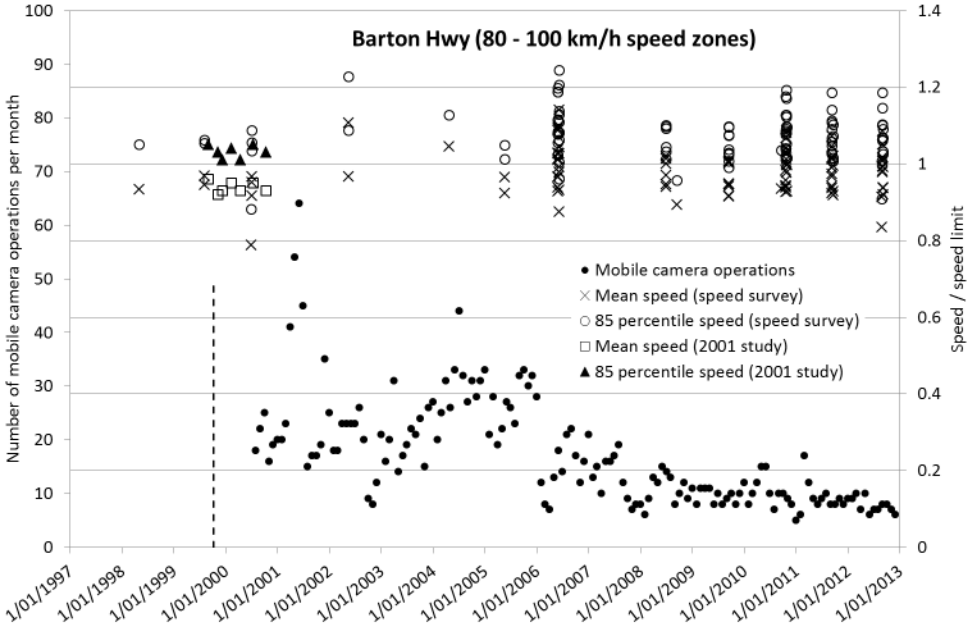
Year	Increased (%)	Stayed the same (%)	Decreased (%)
2011	1	76	23
2009	4	73	23
2008	4	73	23
2006	7	68	25
2005	2	69	29
2004	5	65	28
2003	6	67	25
2002	5	66	28
2001	5	62	32
2000	4	61	33
1999	6	70	21
1998	4	73	23
1997	6	62	32
1996	7	52	41
1995	11	62	26

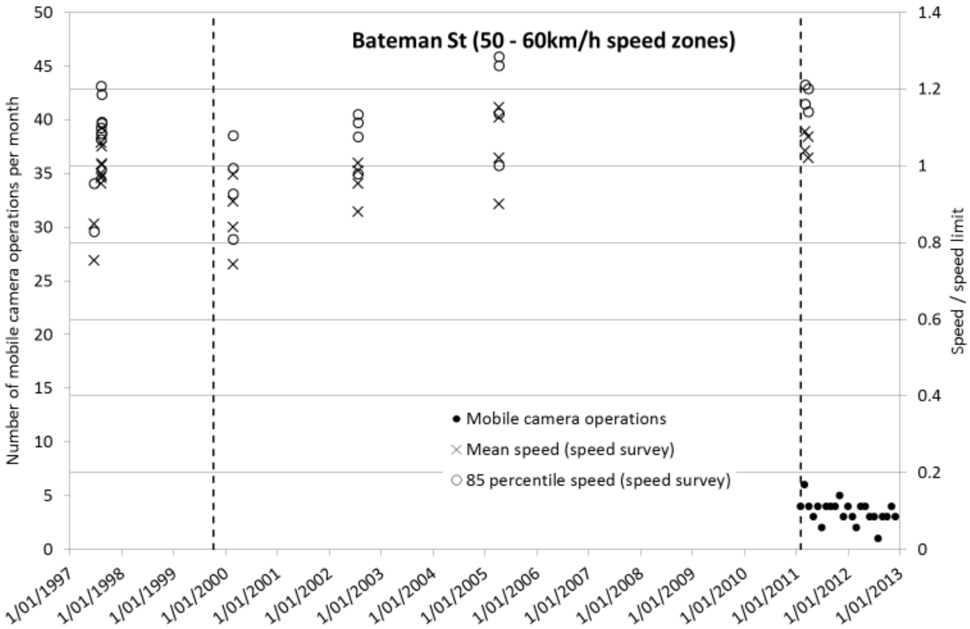
Appendix D: Individual speed survey results for case and control streets

This appendix contains plots for most of the case and control street locations used in this study (a few streets were excluded due to plotting issues). The available speed surveys provided by the Territory and Municipal Services Directorate are plotted for all streets, where mean and 85th percentile speeds are normalised to the speed zone in which the survey was undertaken (in some cases surveys were undertaken on sections of the same street with different speed limits). Additional speed surveys undertaken by ARRB in the 18 months following the introduction of cameras in October 1999 are also plotted where available (Edgar, A., 2001. Evaluation of the Effectiveness of Speed Cameras in the ACT, Final Report 1. NRMA-ACT Trust Project Evaluation Reports, ARRB Transport Research). The start date of October 1999 is identified on all plots. For case streets the number of mobile operations undertaken per month along that particular street are also plotted.

CASE STREETS




Barton Hwy (80 - 100 km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Bateman St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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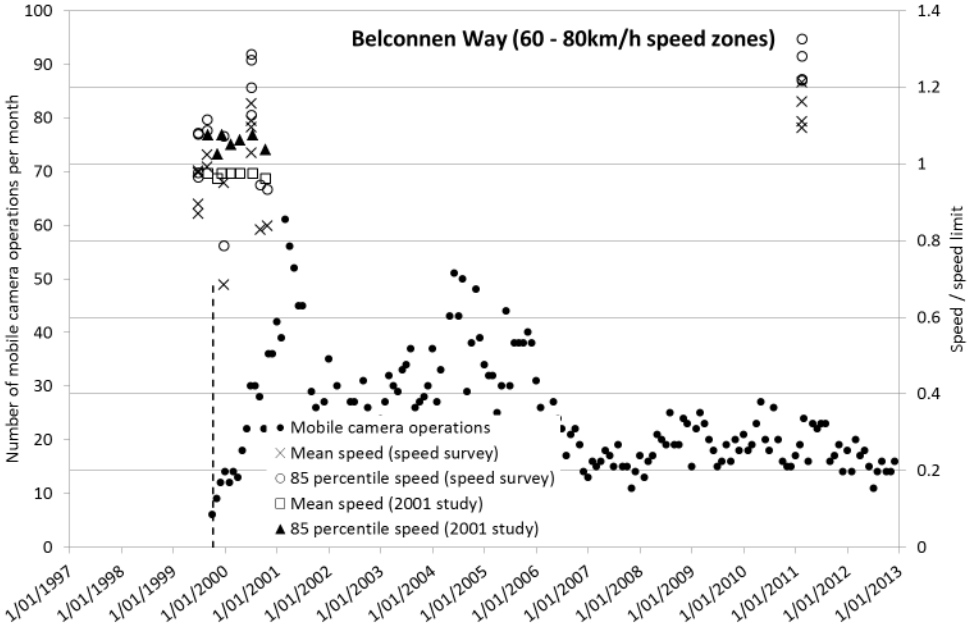
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Belconnen Way (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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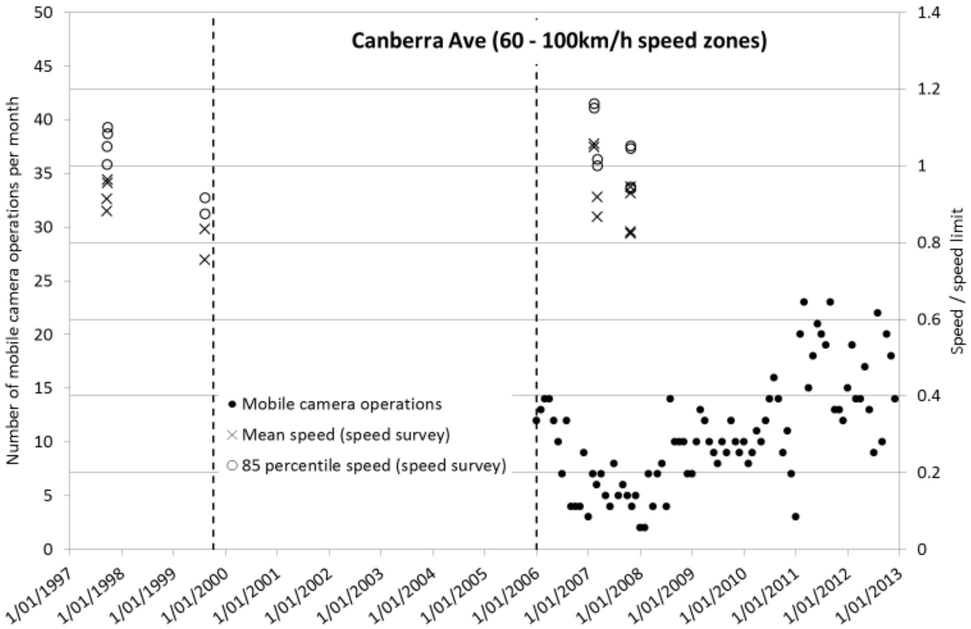
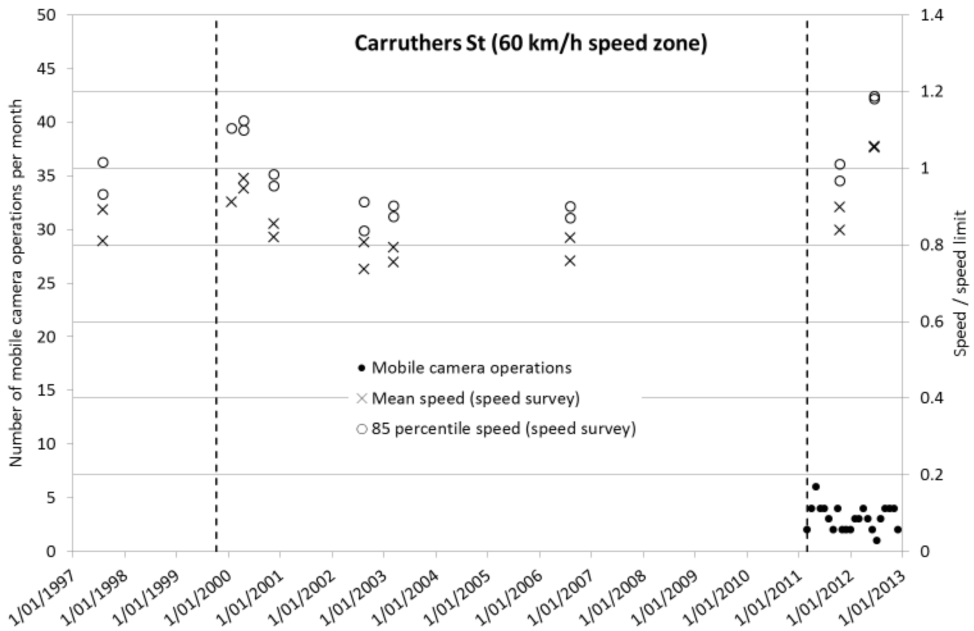
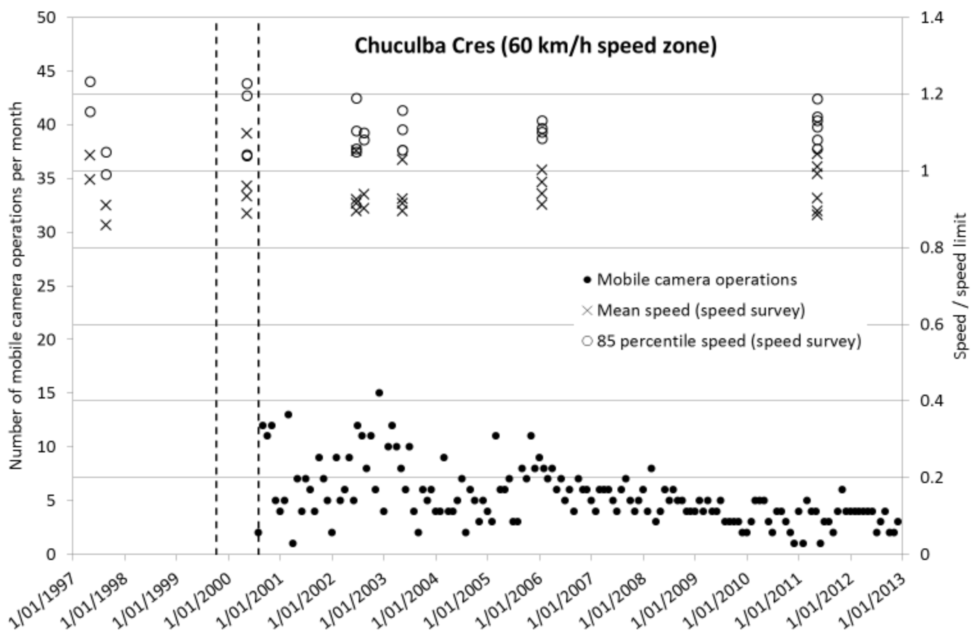
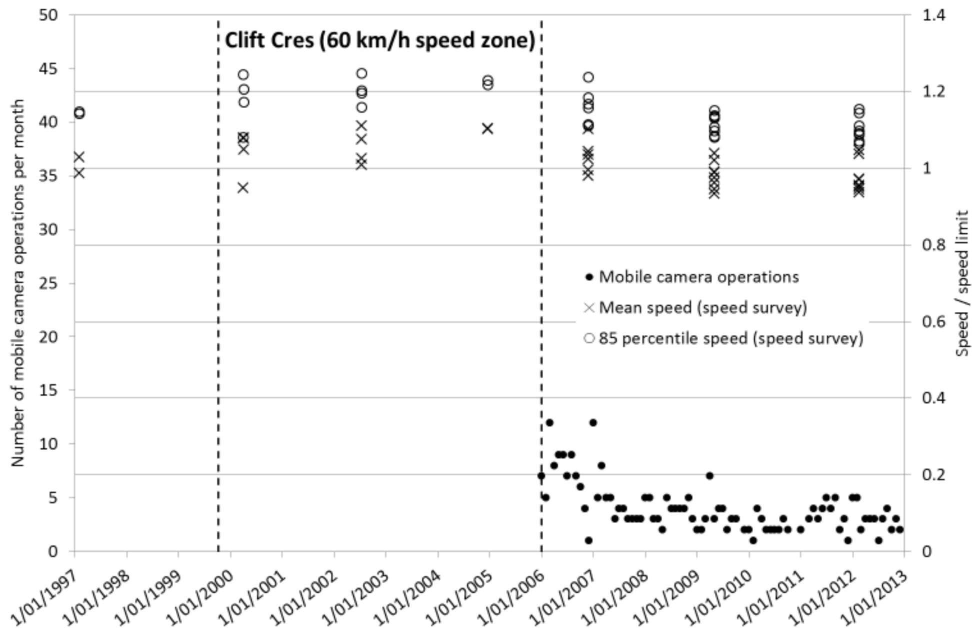
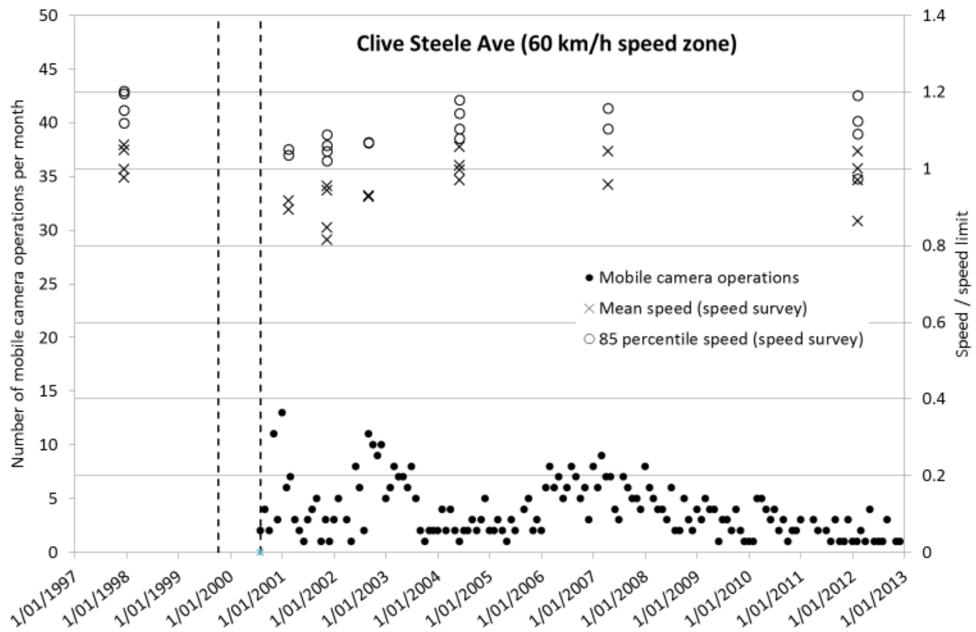
1/01/2011
1/01/2012
1/01/2013

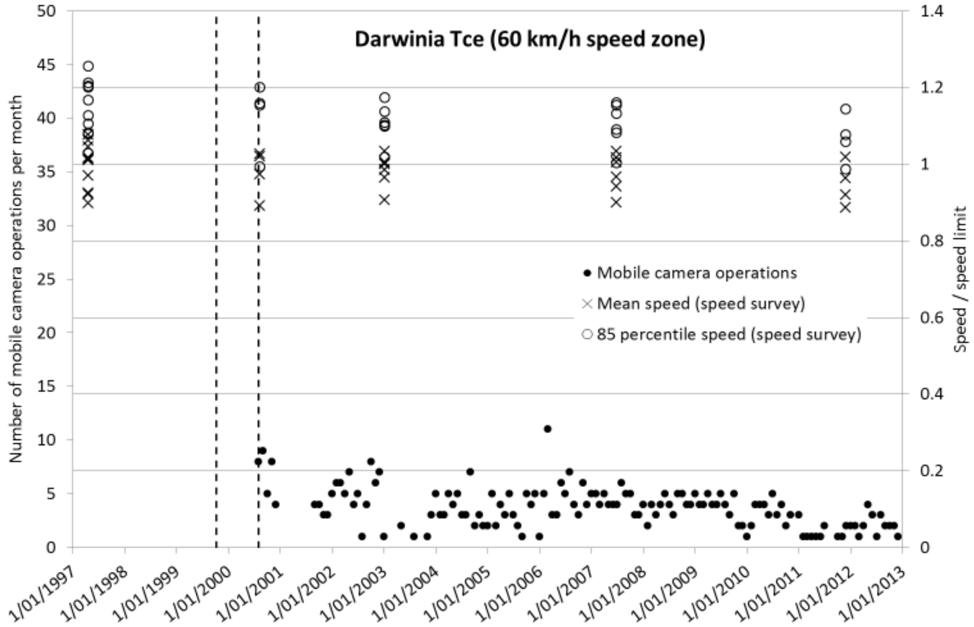

Canberra Ave (60 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

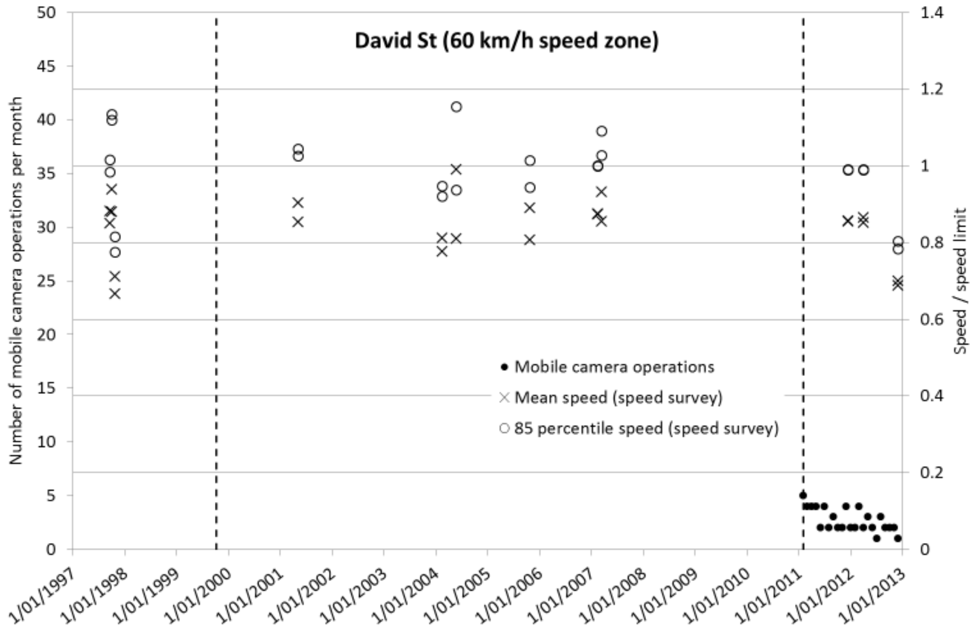

Carruthers St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Chuculba Cres (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Clift Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)


Clive Steele Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)


Darwinia Tce (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


David St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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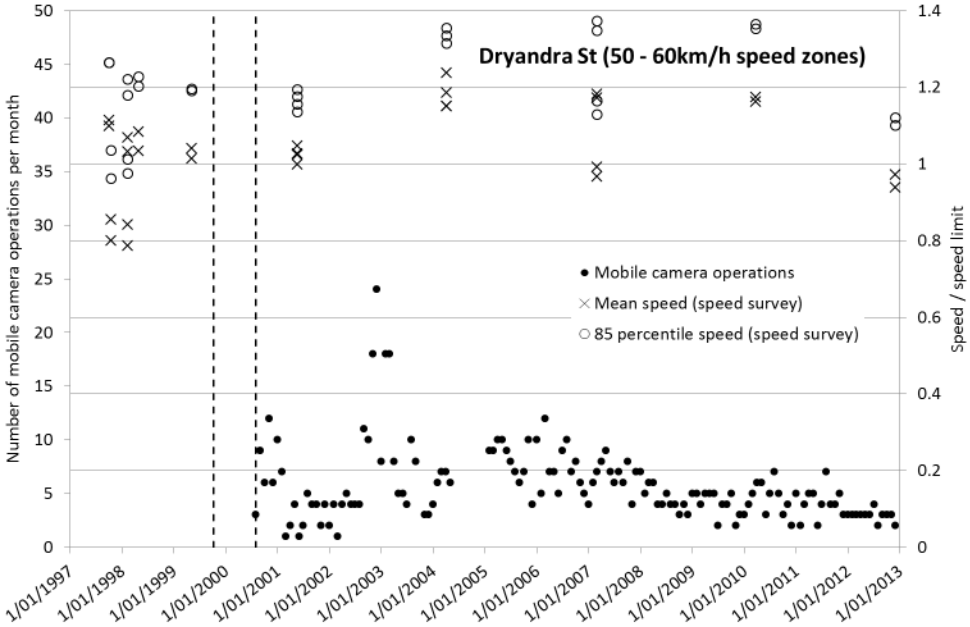
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Dryandra St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
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20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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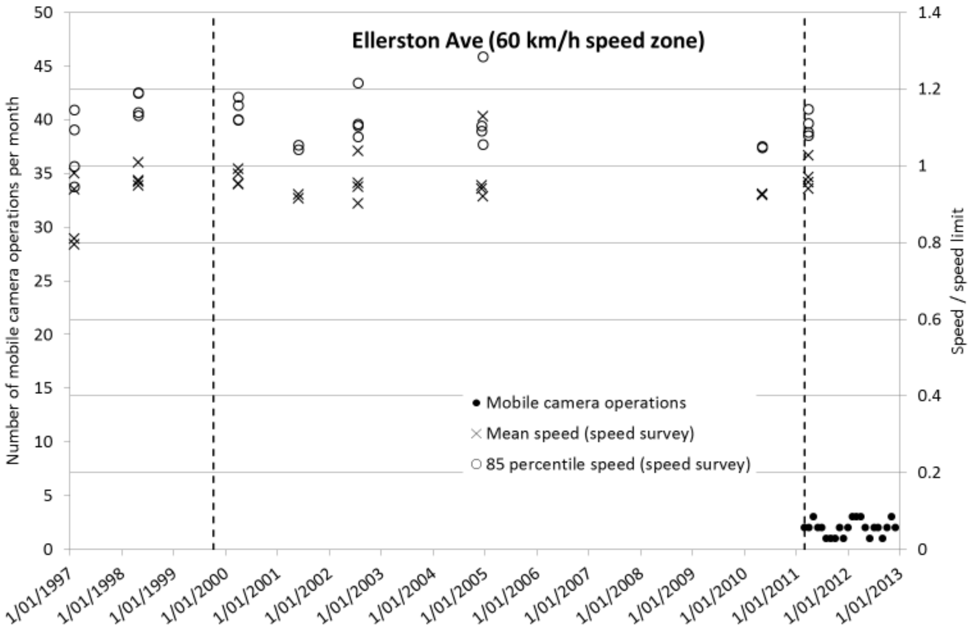
1/01/2012
1/01/2013


Ellerston Ave (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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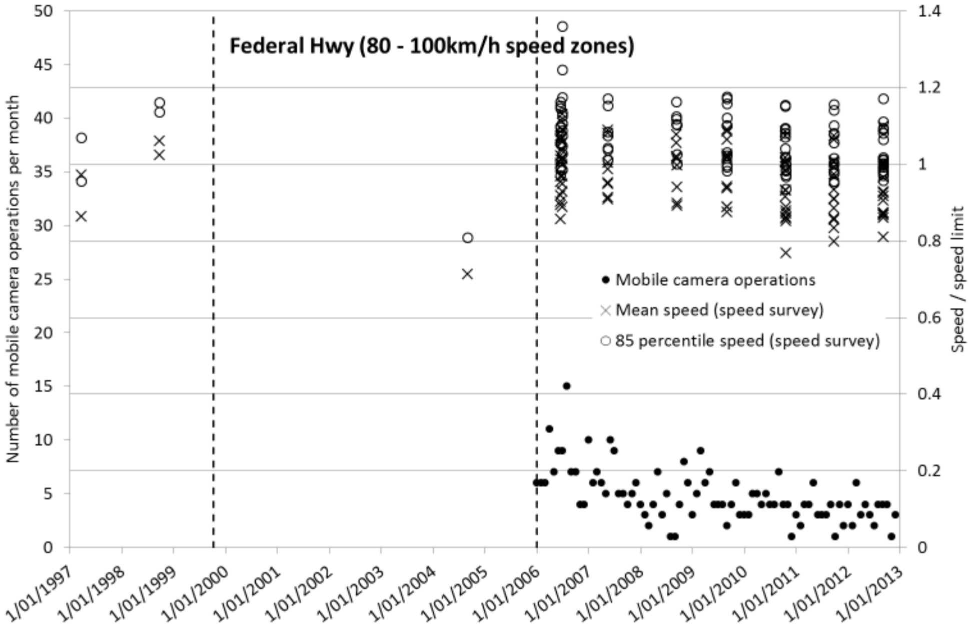
1/01/2012
1/01/2013


Federal Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
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25
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35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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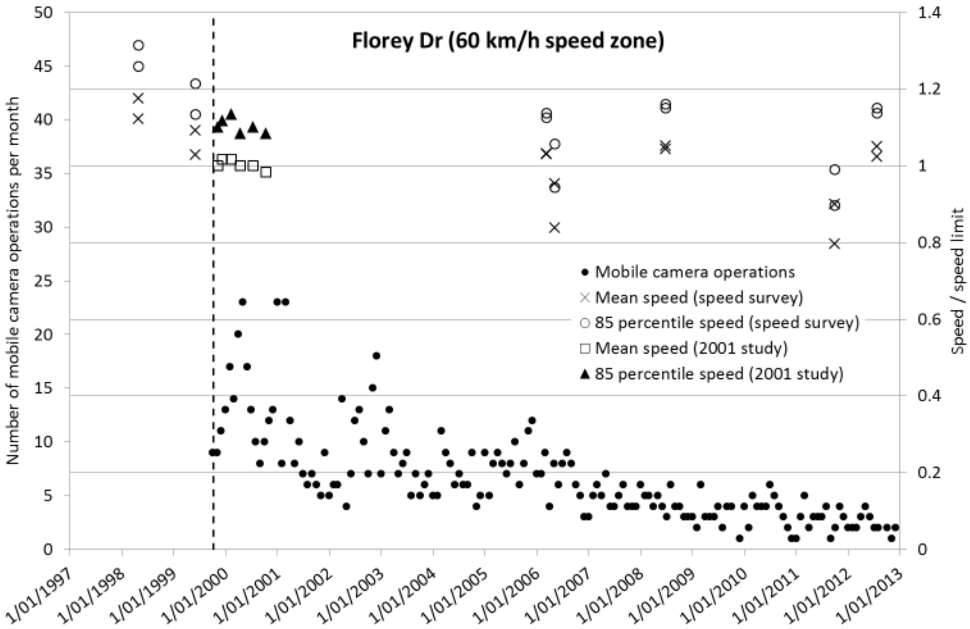
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Florey Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
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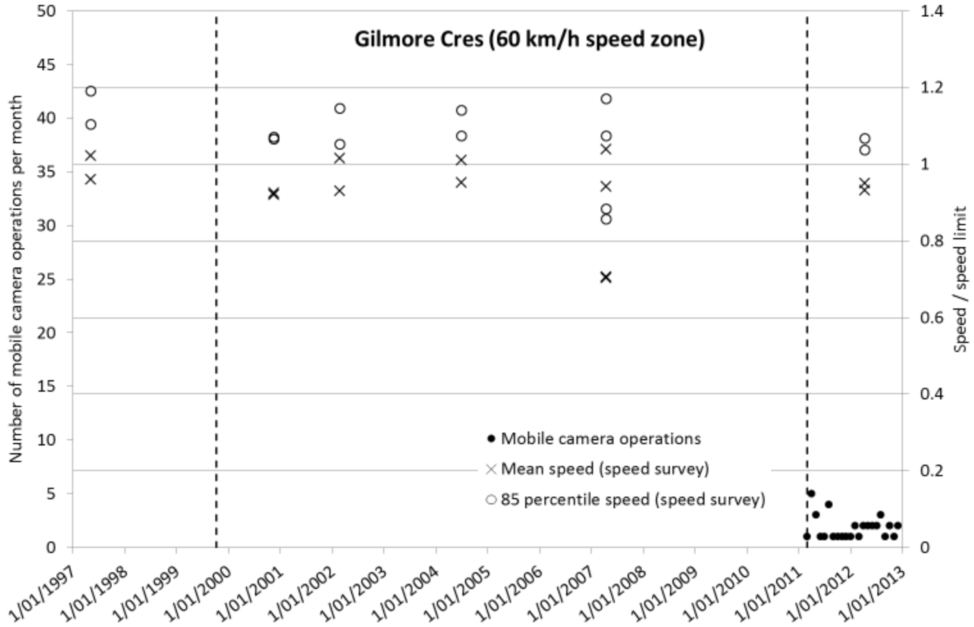
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Gilmore Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
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25
20
15
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5
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1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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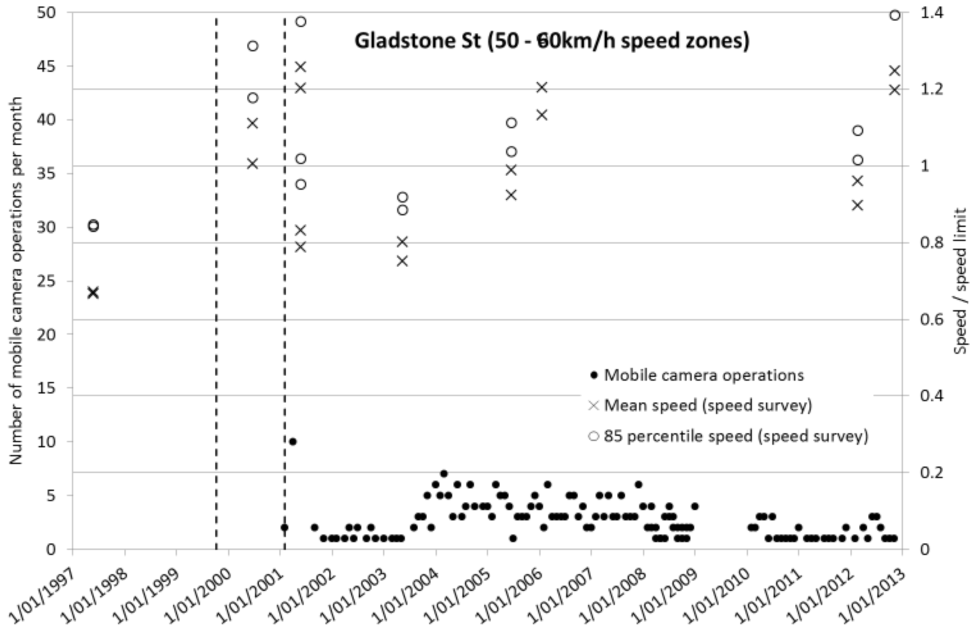
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Gladstone St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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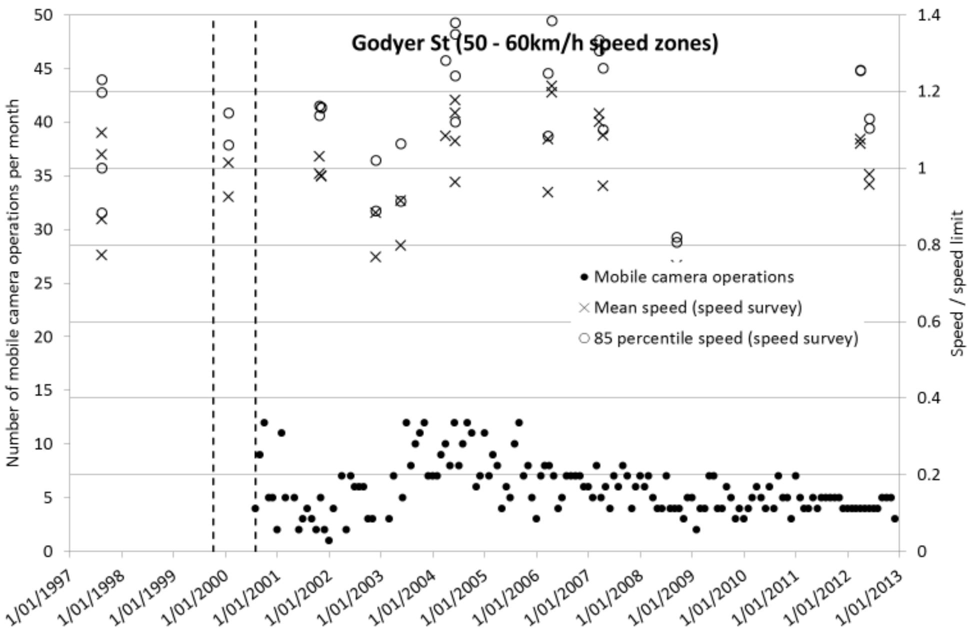
1/01/2012
1/01/2013


Godyer St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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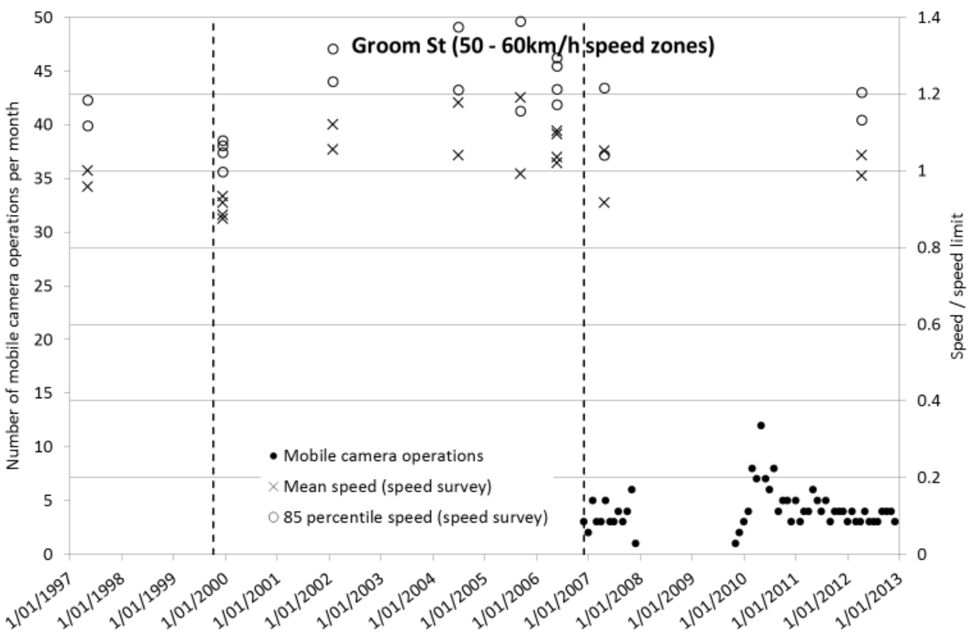
1/01/2012
1/01/2013


Groom St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
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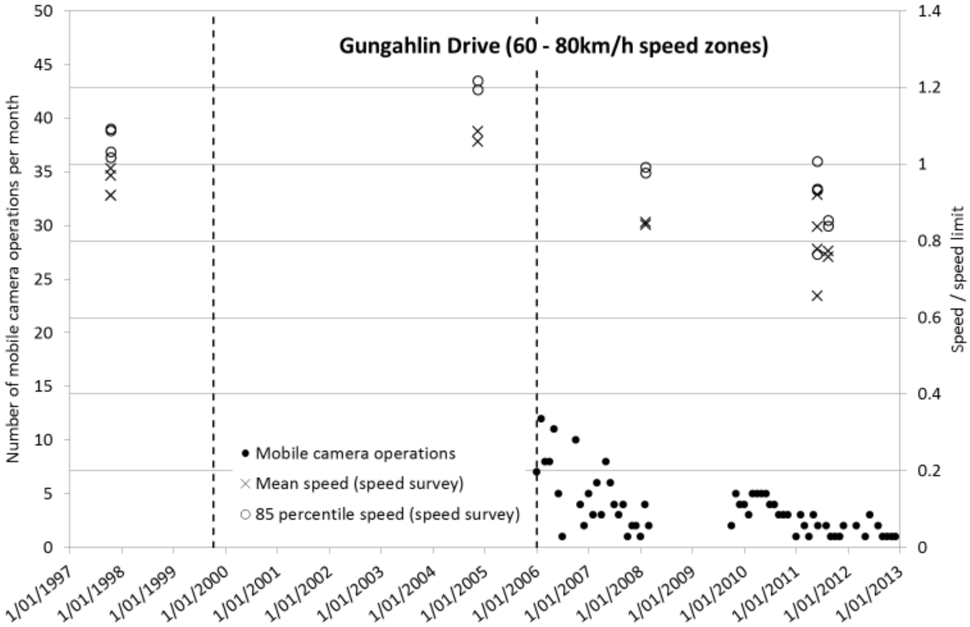
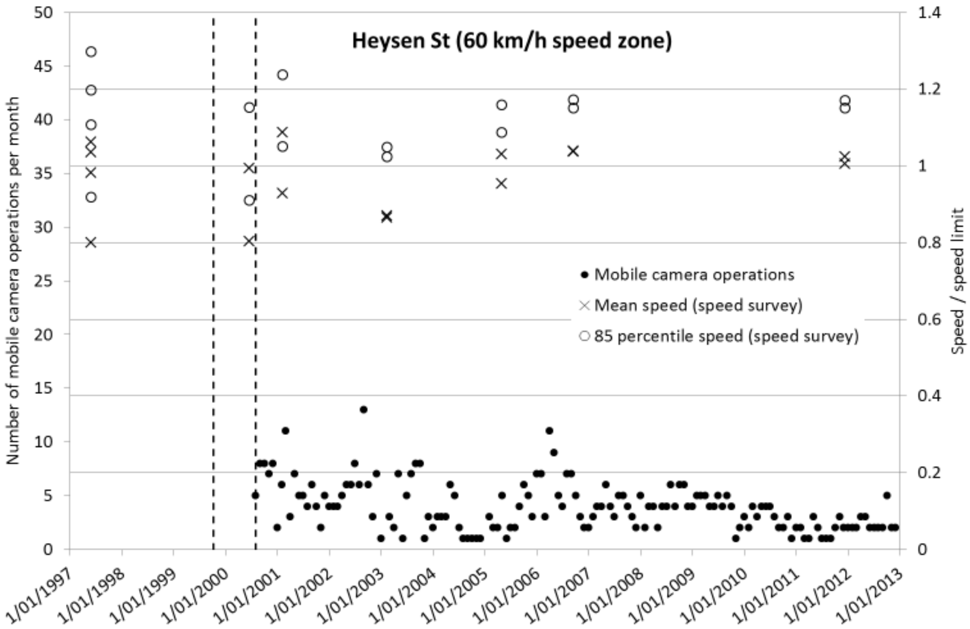
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Gungahlin Drive (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Heysen St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
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1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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1/01/2005
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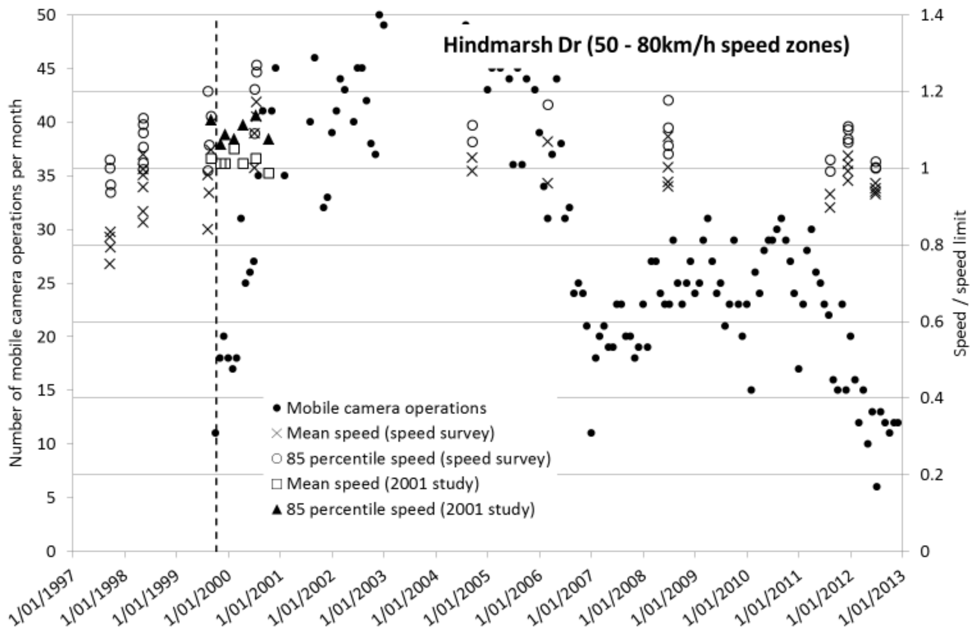
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hindmarsh Dr (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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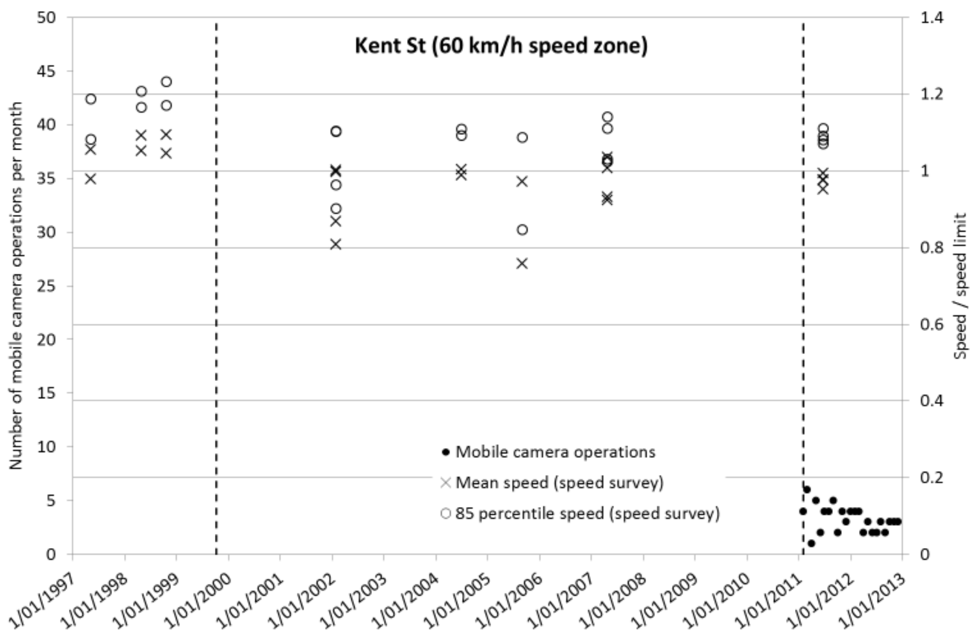
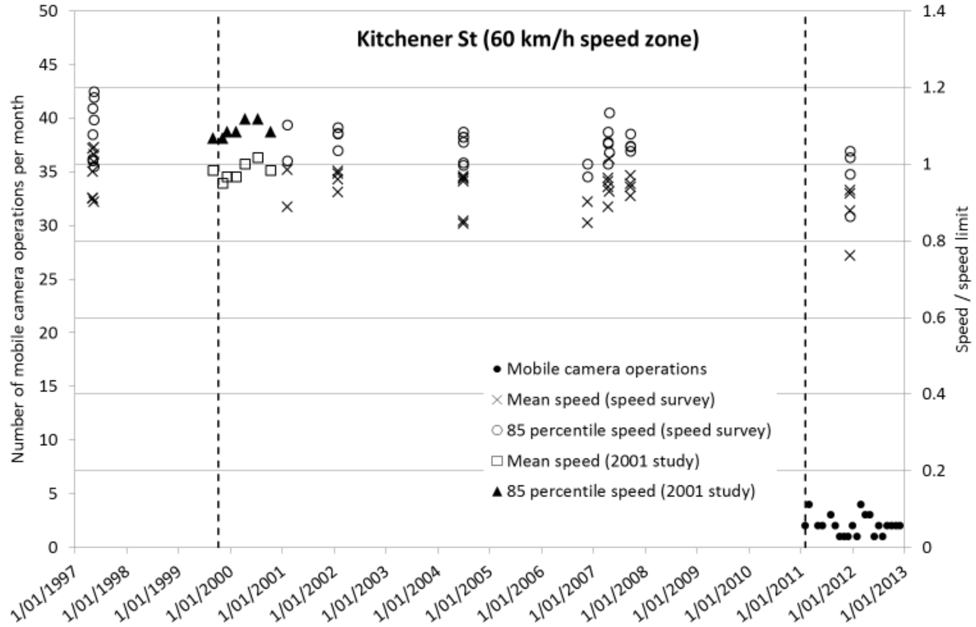
1/01/2012
1/01/2013


Kent St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Kitchener St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2010
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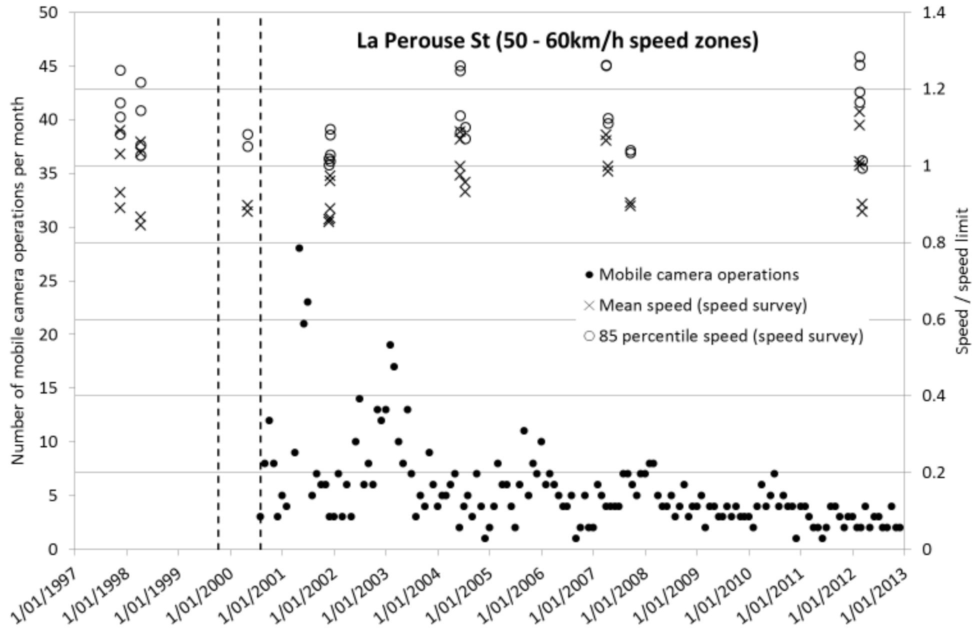
1/01/2012
1/01/2013


La Perouse St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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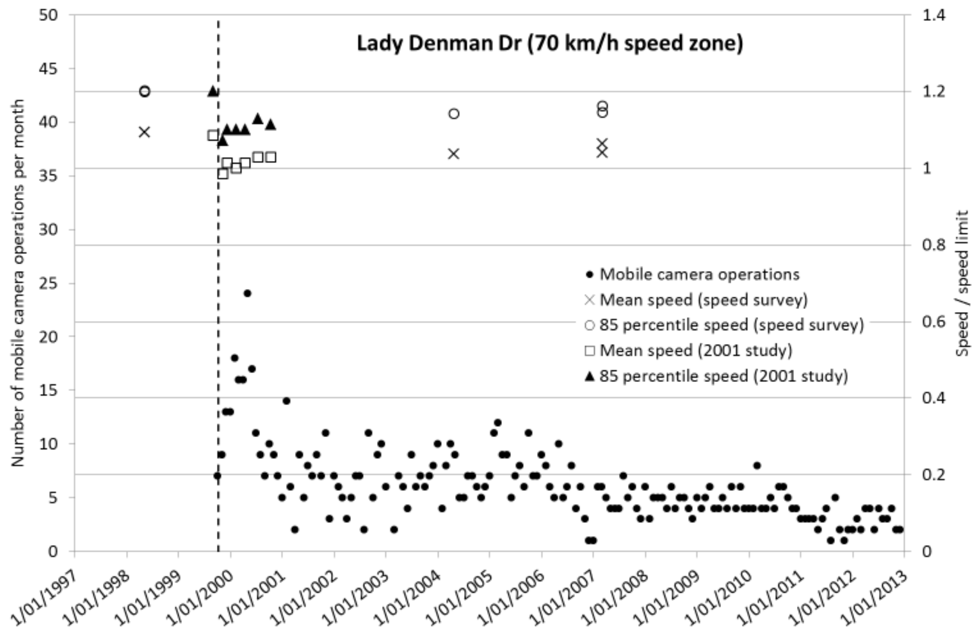
1/01/2012
1/01/2013


Lady Denman Dr (70 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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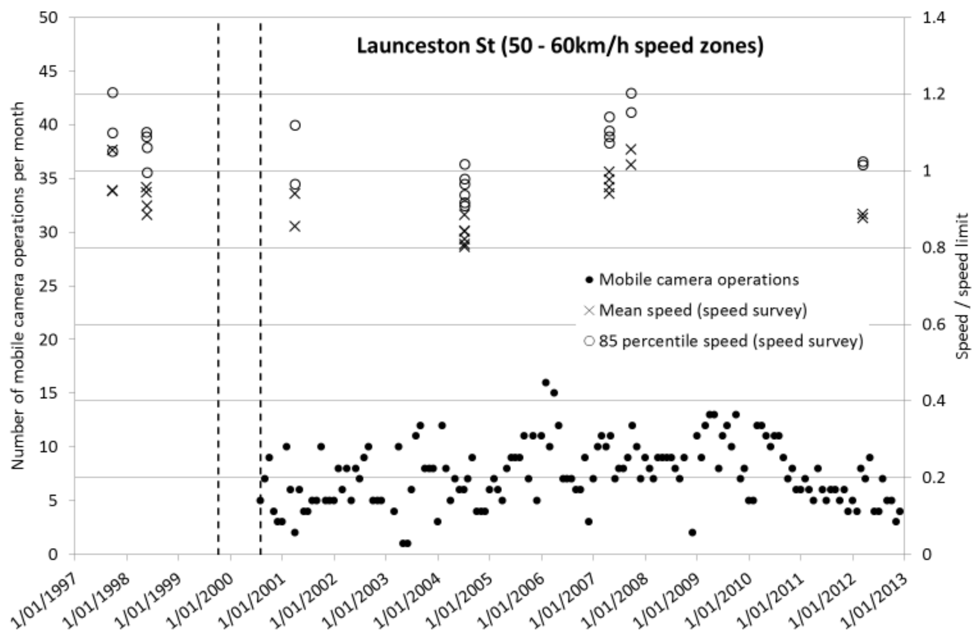
1/01/2012
1/01/2013


Launceston St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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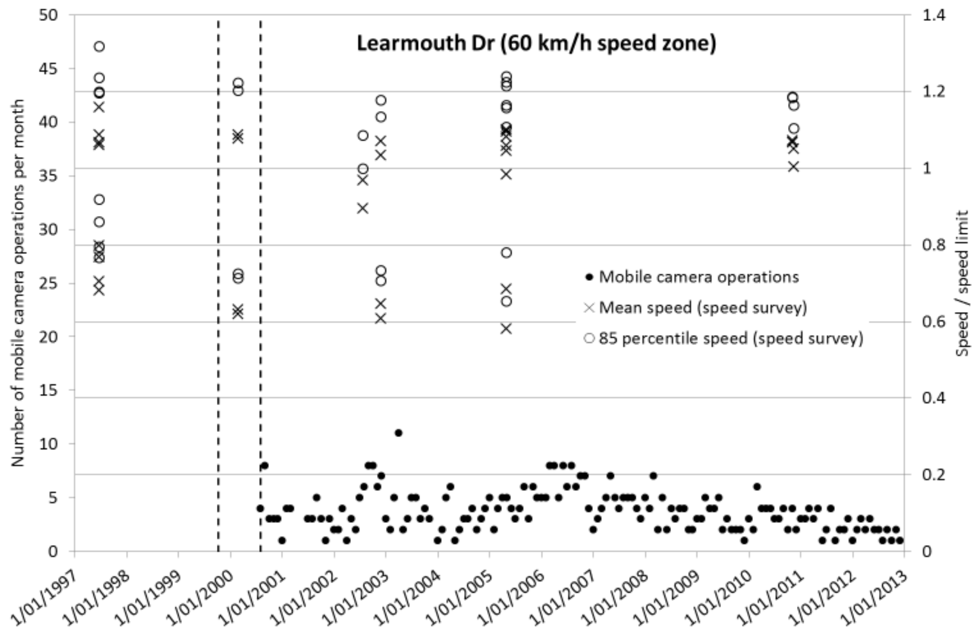
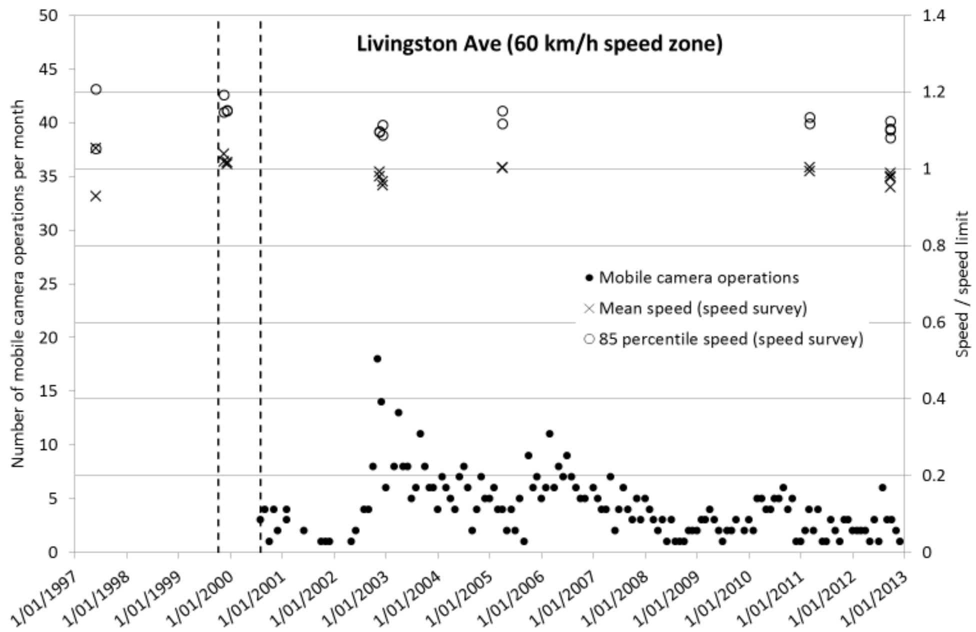
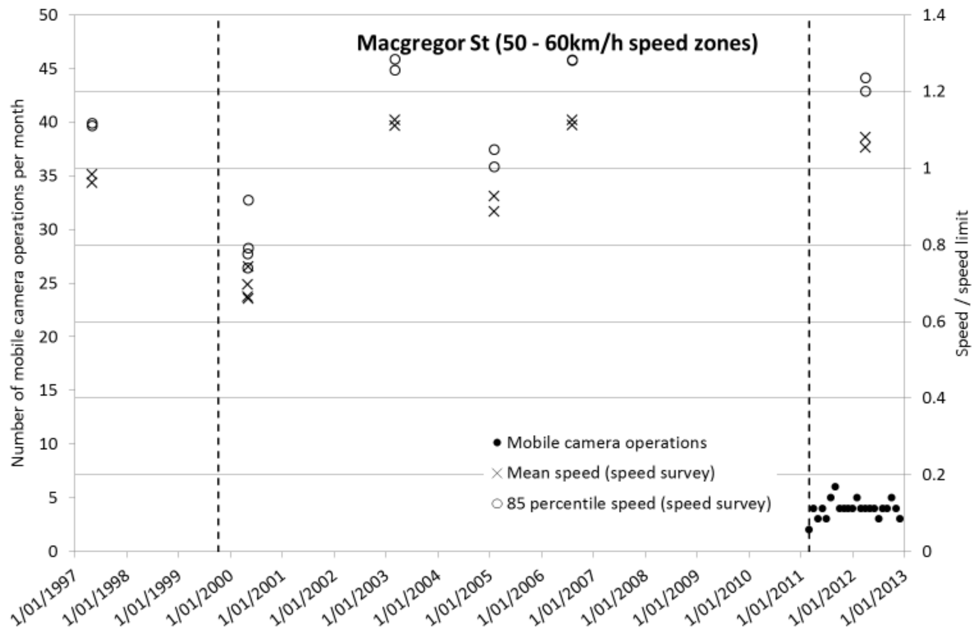
1/01/2012
1/01/2013


Learmouth Dr (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit


Livingston Ave (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit


Macgregor St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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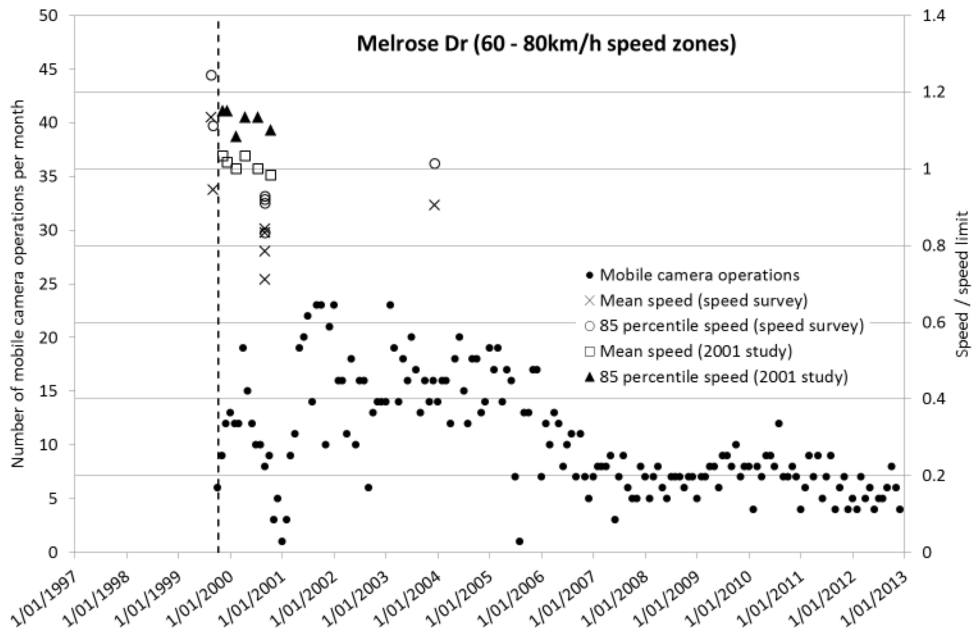
1/01/2012
1/01/2013


Melrose Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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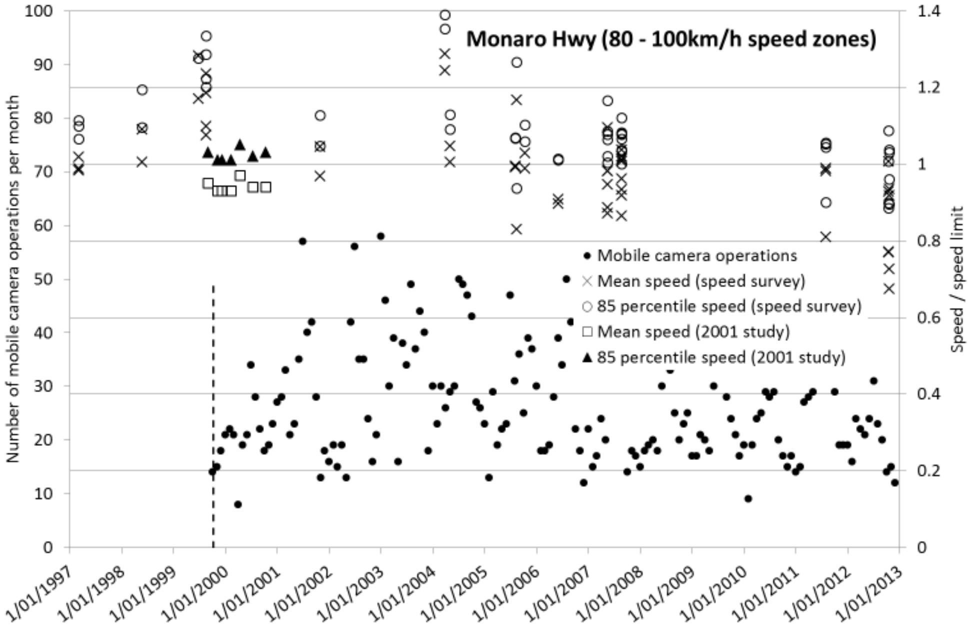
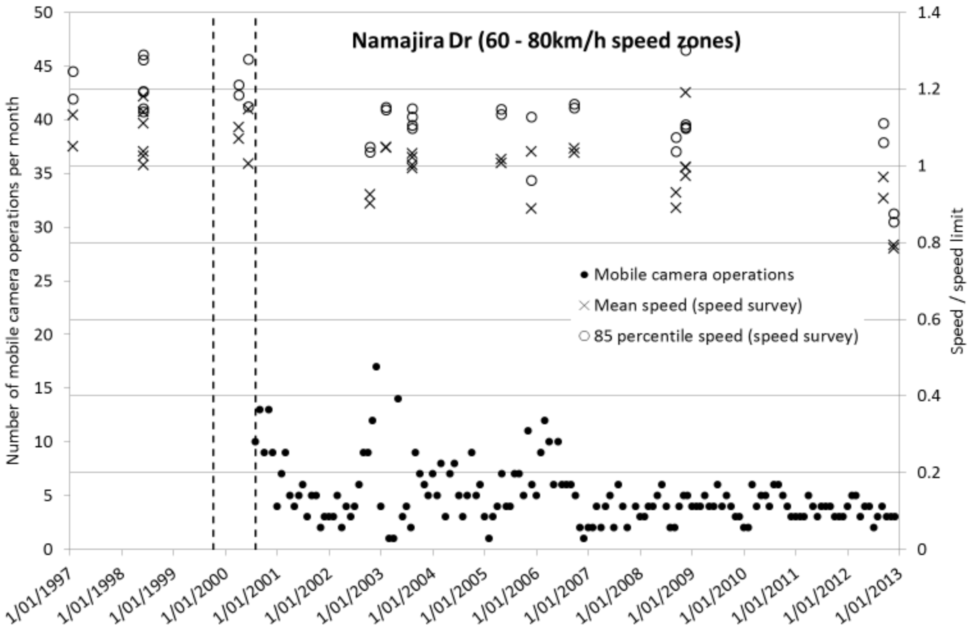
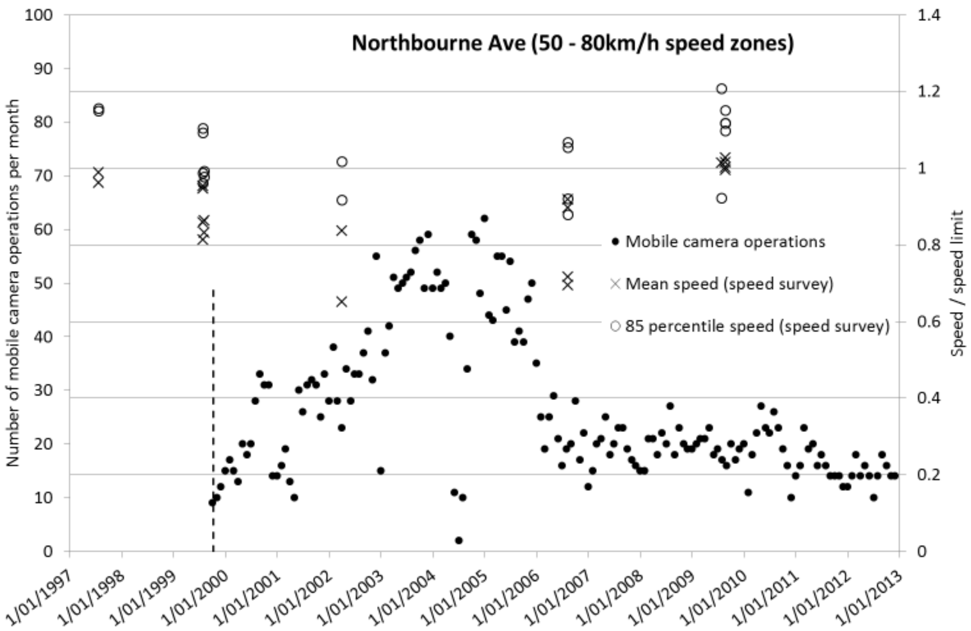
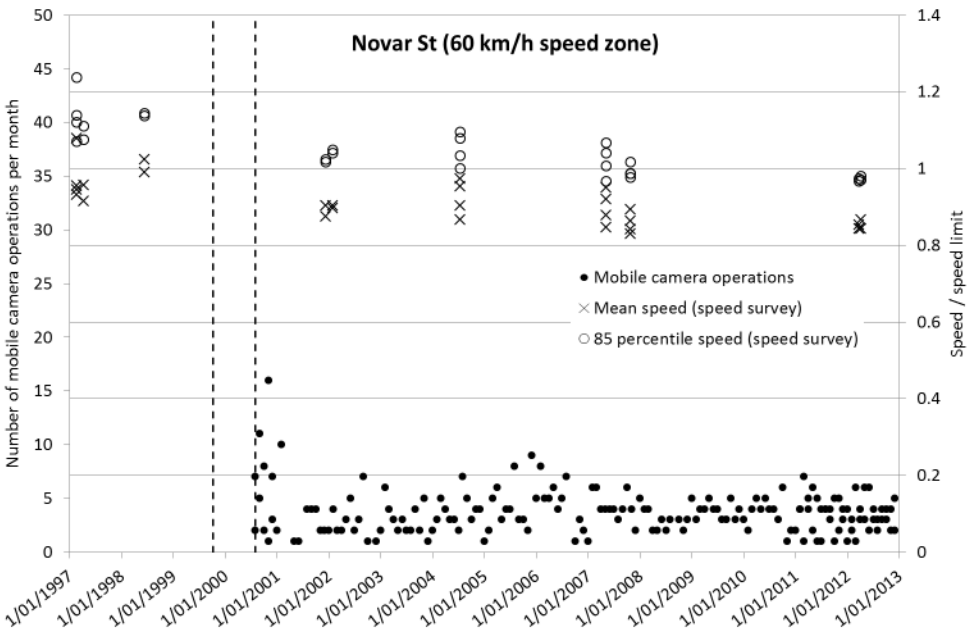
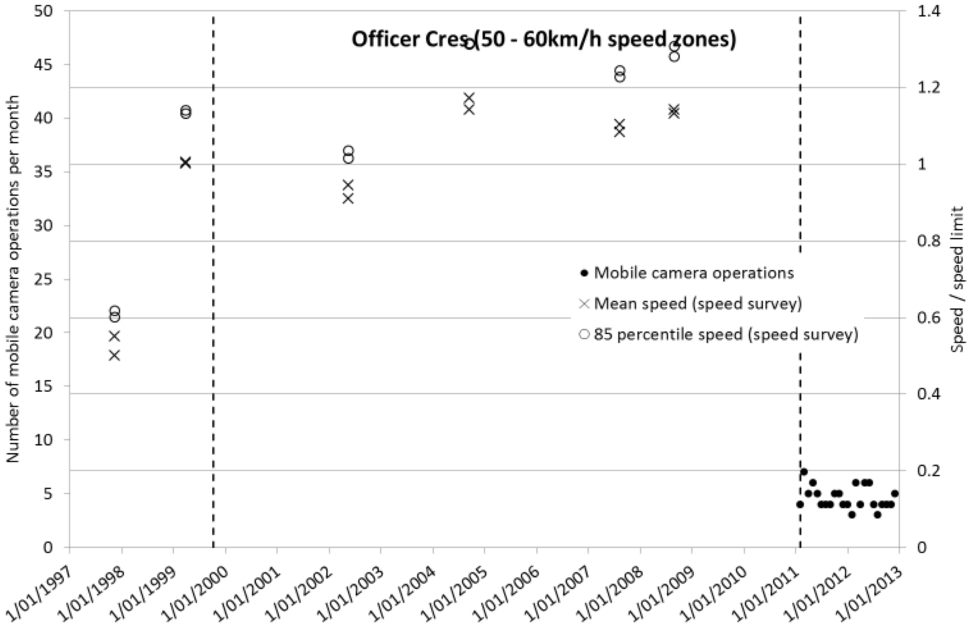
1/01/2012
1/01/2013

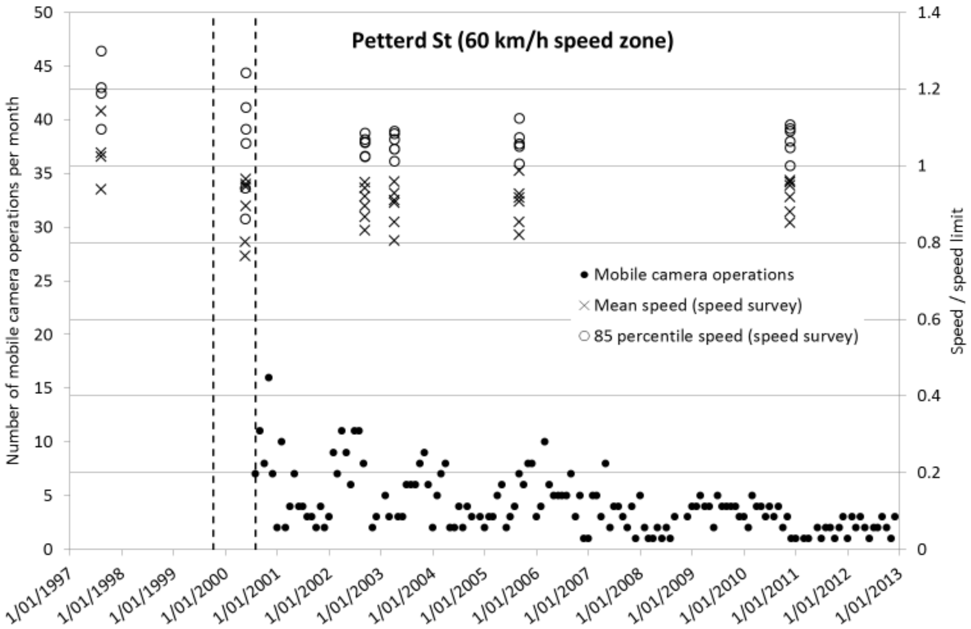

Monaro Hwy (80 - 100km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
Number of mobile camera operations per month
Speed / speed limit
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Namajira Dr (60 - 80km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Northbourne Ave (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Novar St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Officer Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Petterd St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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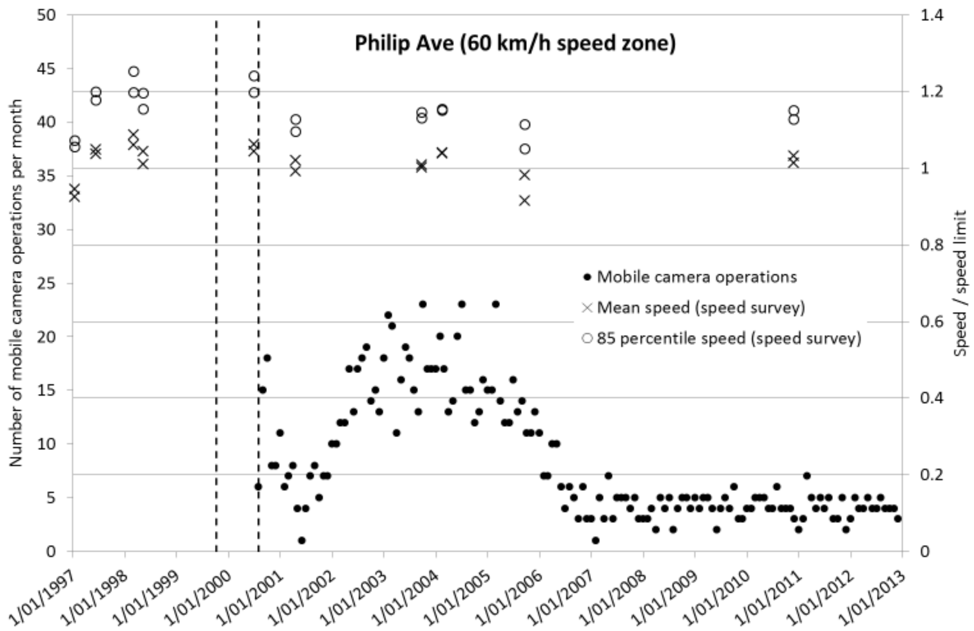
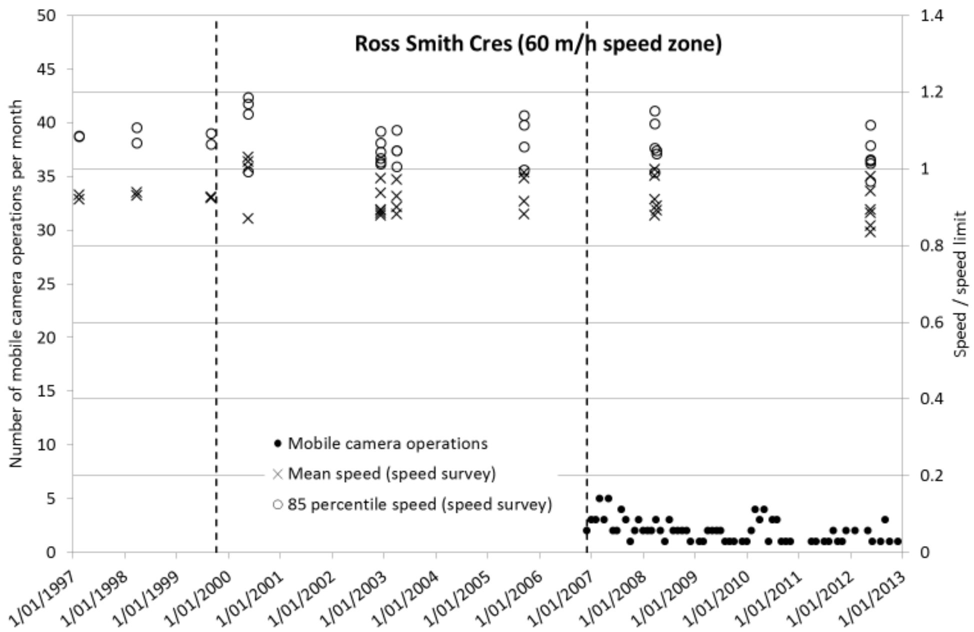
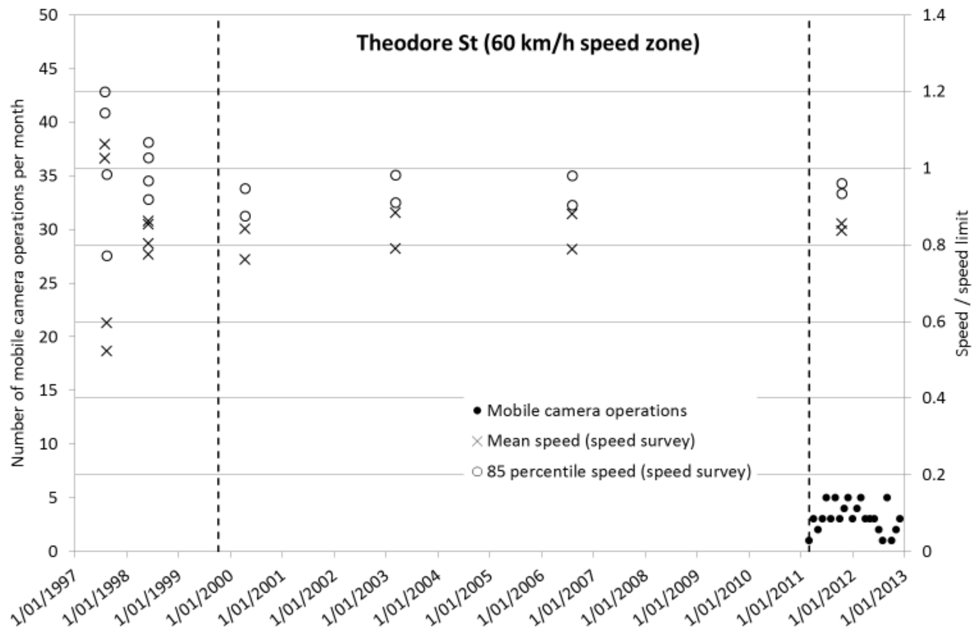
1/01/2012
1/01/2013



Philip Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)



Ross Smith Cres (60 m/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)


Theodore St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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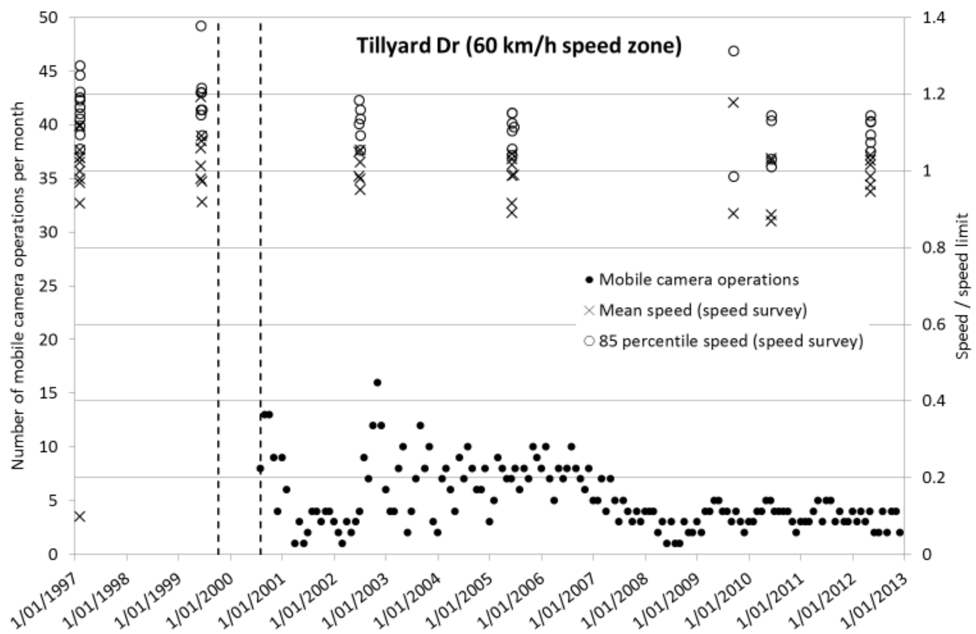
1/01/2011
1/01/2012
1/01/2013


Tillyard Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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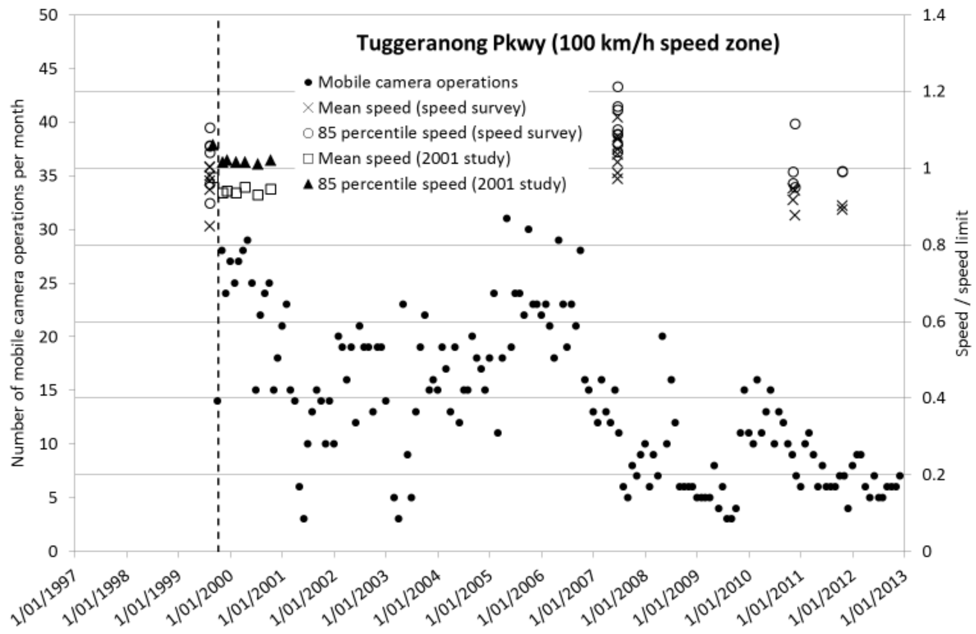
1/01/2012
1/01/2013


Tuggeranong Pkwy (100 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2009
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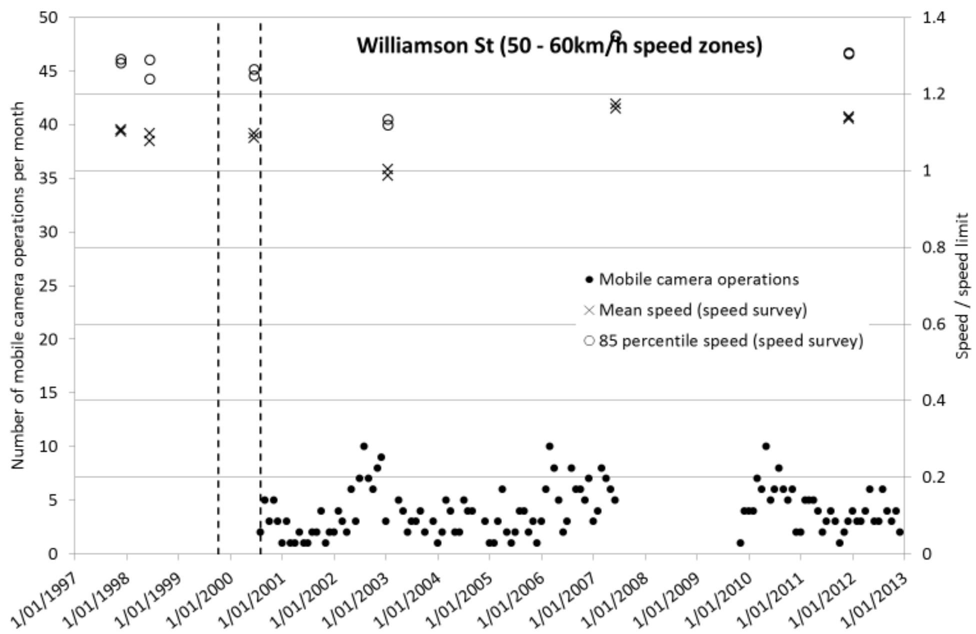
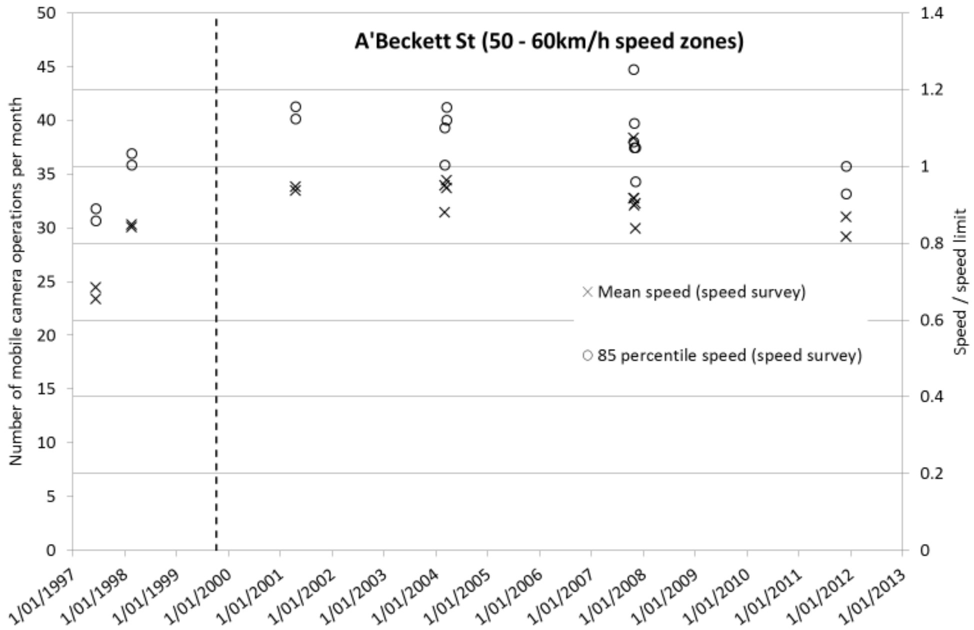
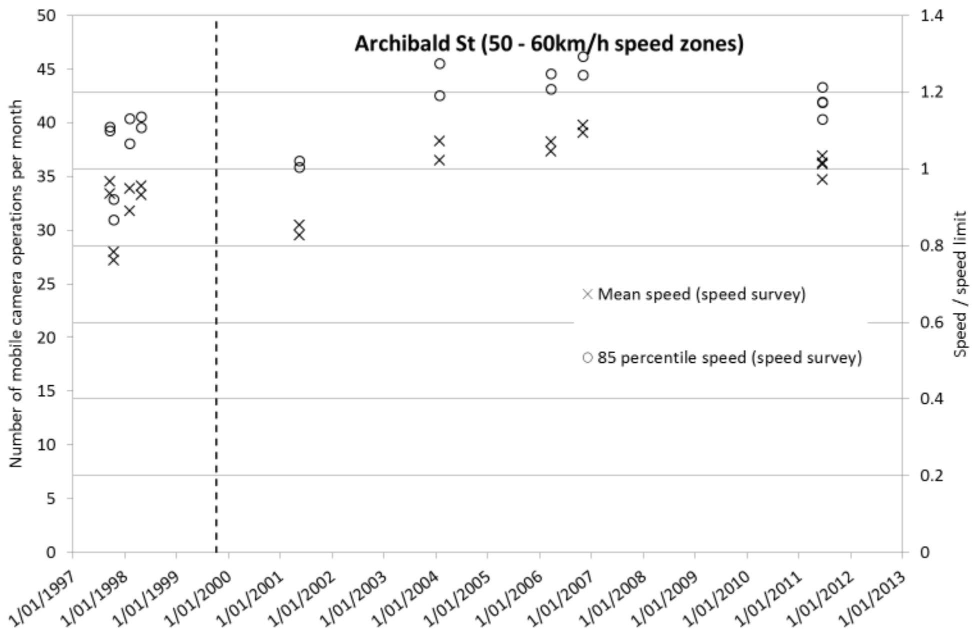
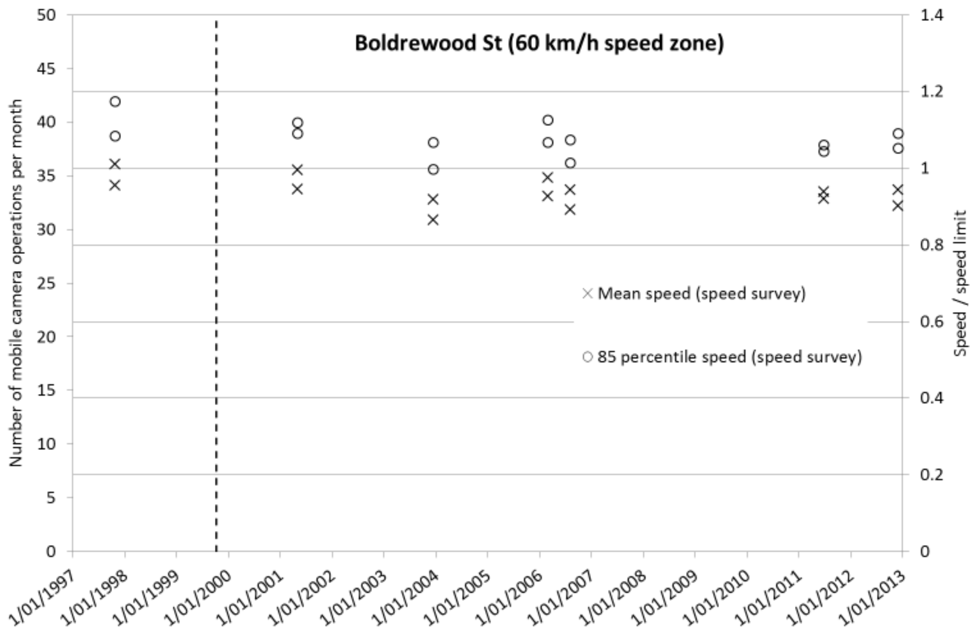
1/01/2011
1/01/2012
1/01/2013


Williamson St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

CONTROL STREETS






Boldrewood St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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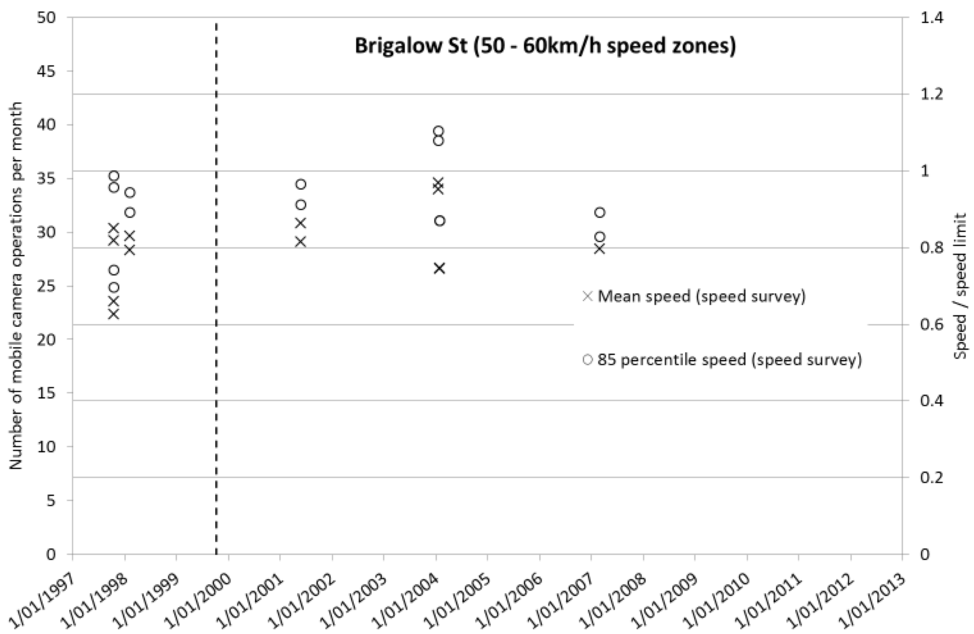
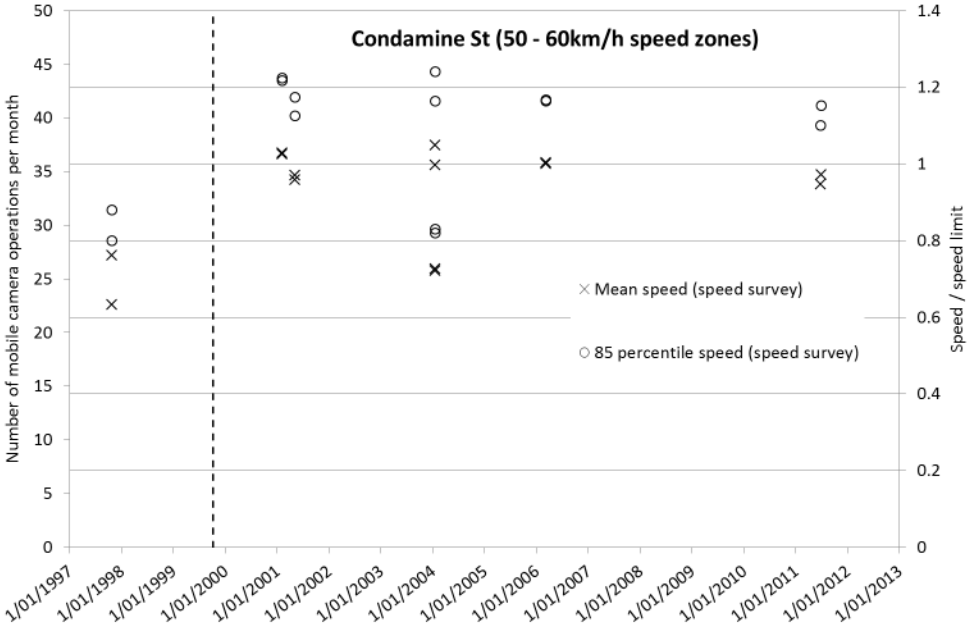
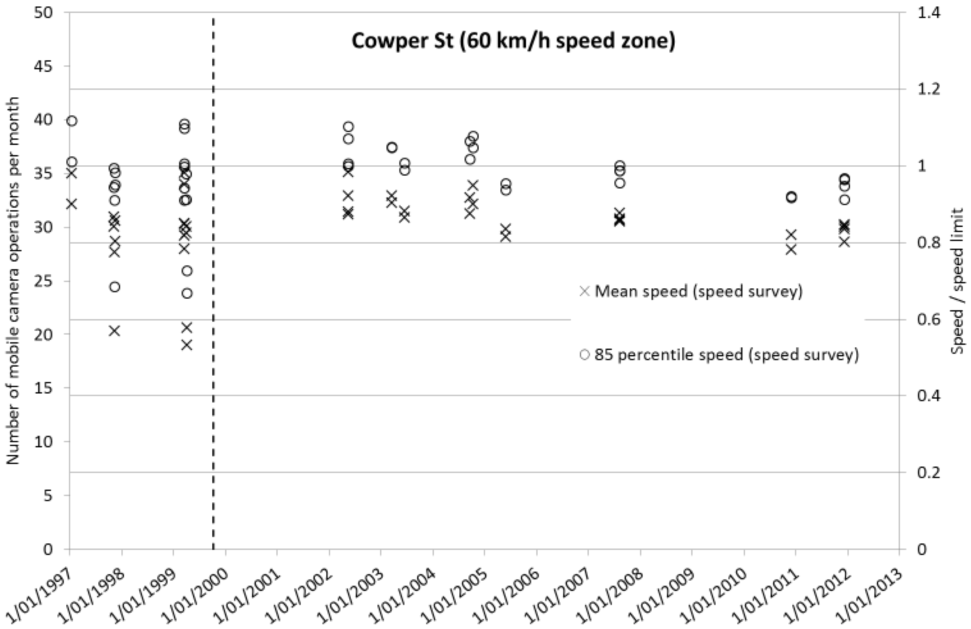
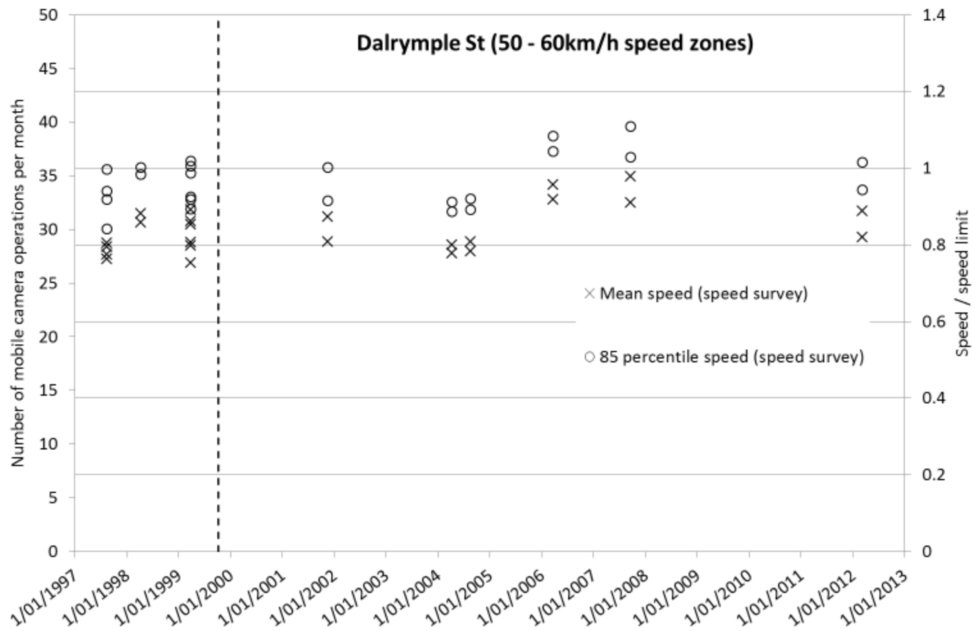
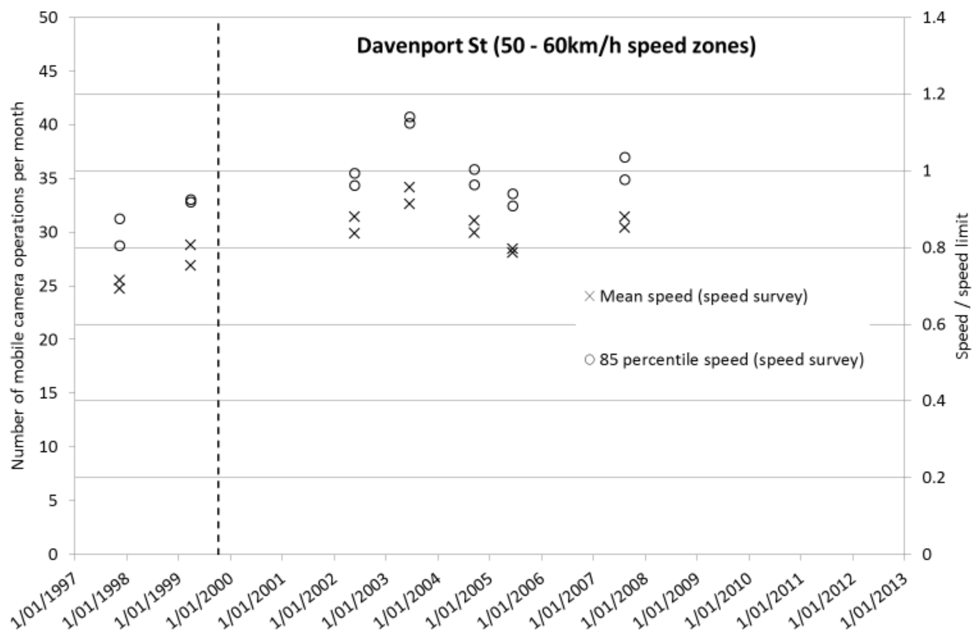
1/01/2011
1/01/2012
1/01/2013

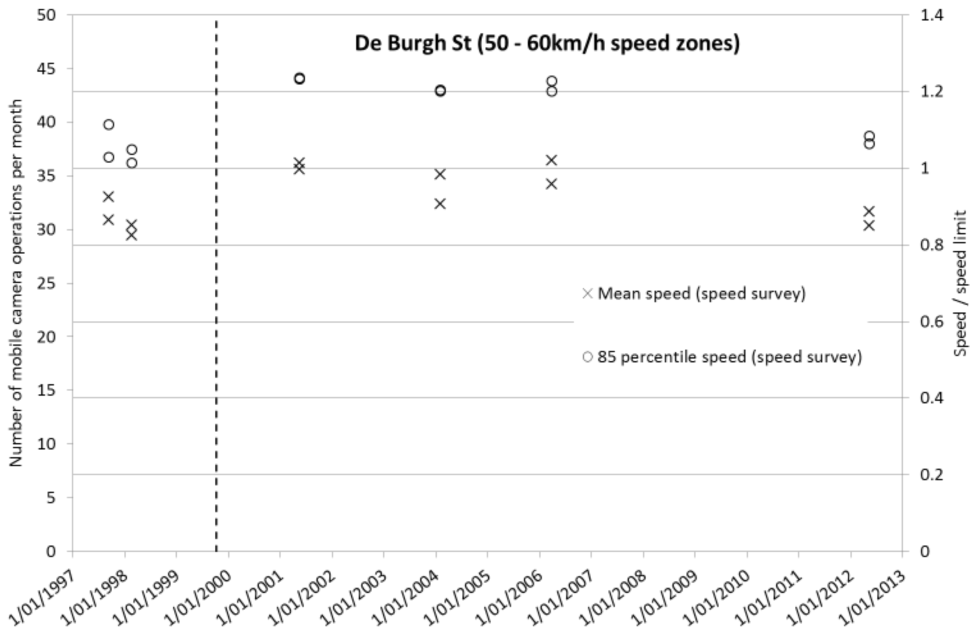

Brigalow St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

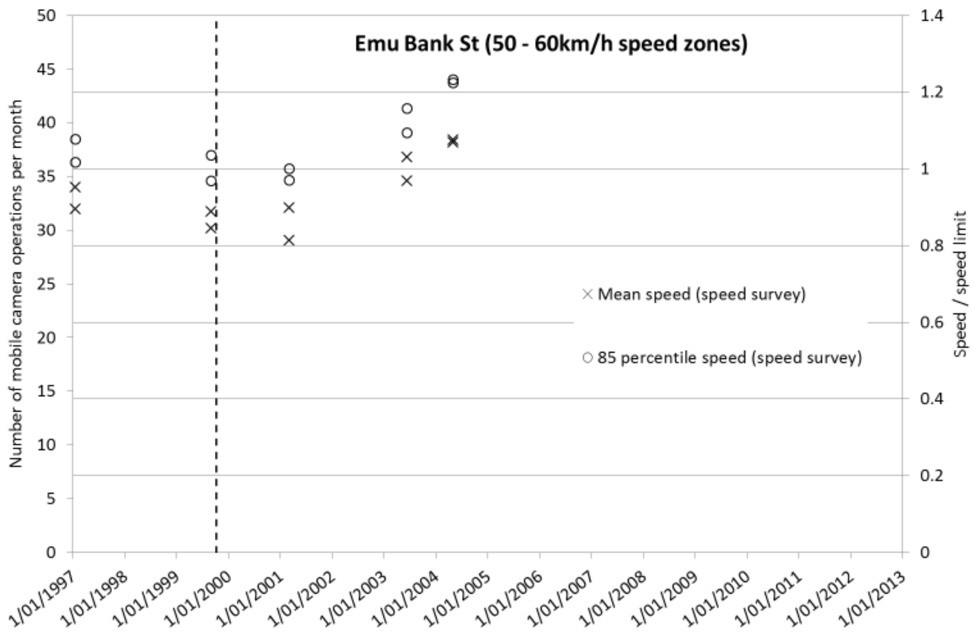

Condamine St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Cowper St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Dalrymple St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Davenport St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


De Burgh St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Emu Bank St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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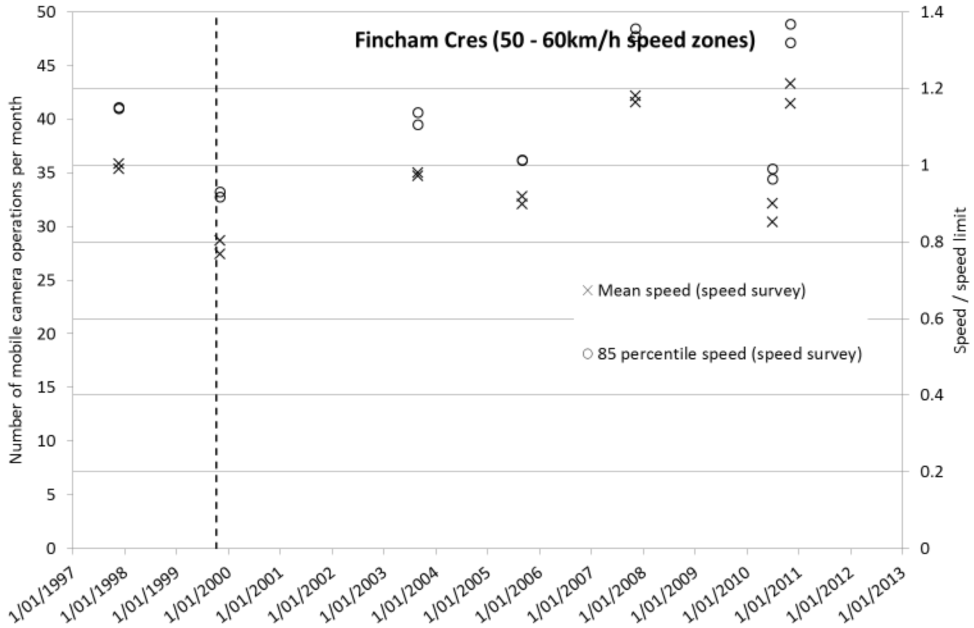
1/01/2012
1/01/2013



Fincham Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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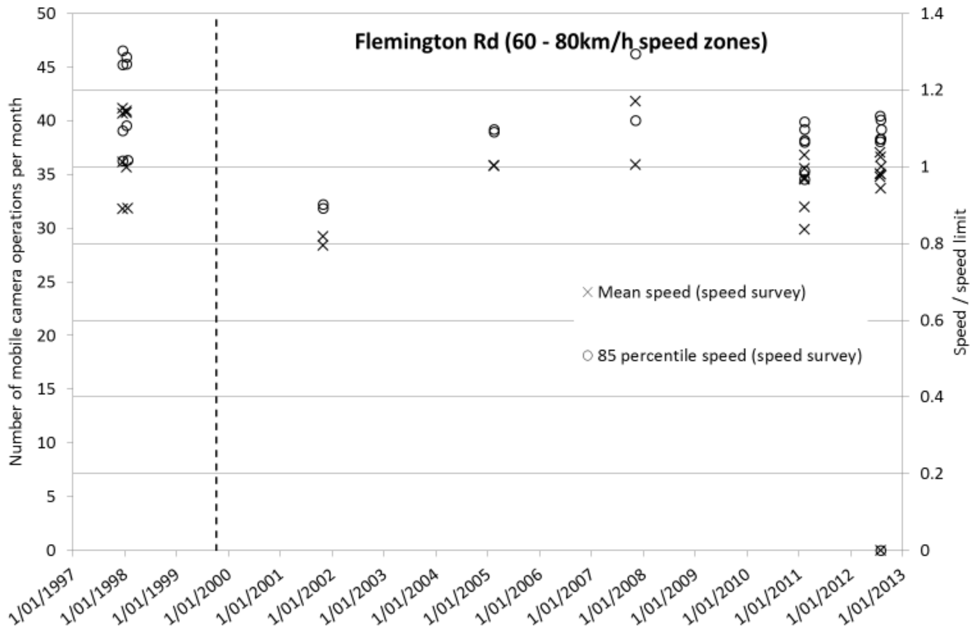
1/01/2012
1/01/2013



Flemington Rd (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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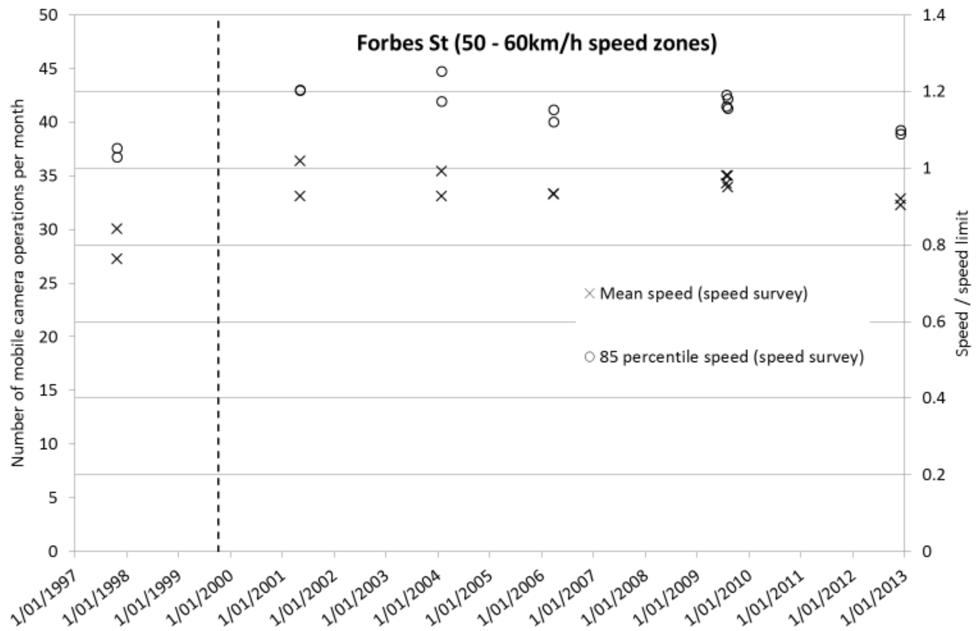
1/01/2012
1/01/2013


Forbes St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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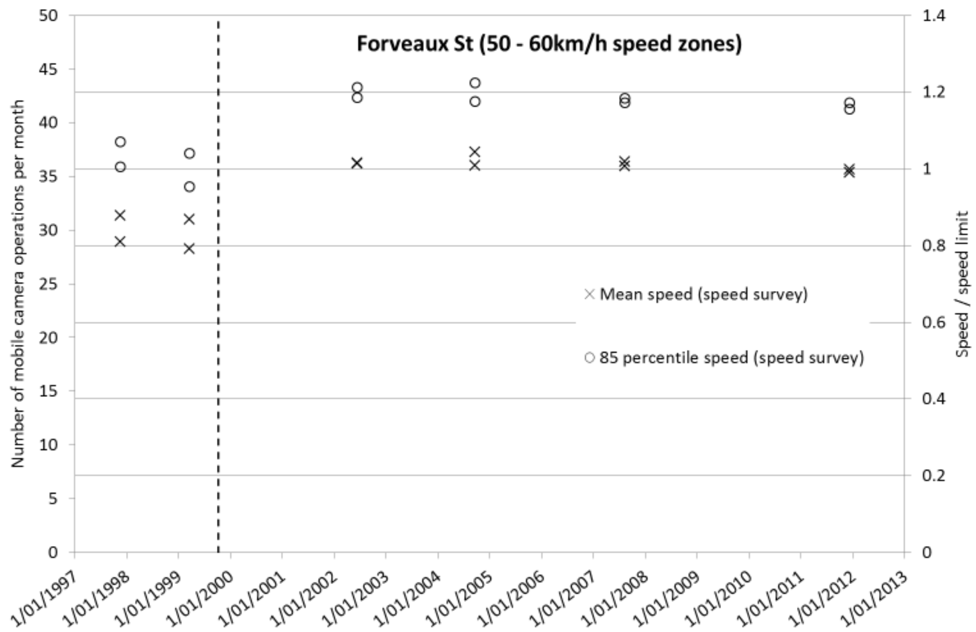
1/01/2012
1/01/2013


Forveaux St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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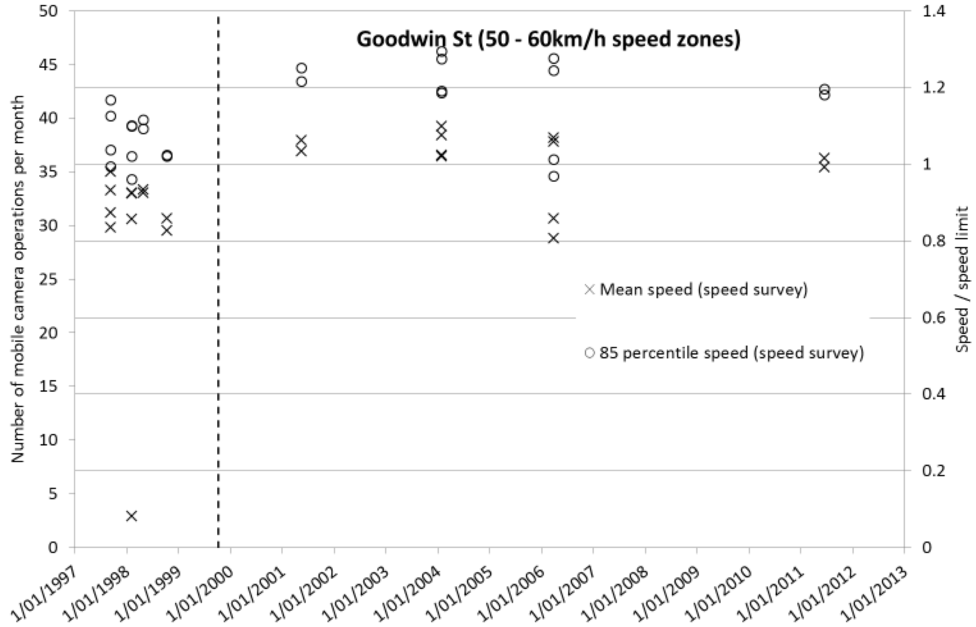
1/01/2011
1/01/2012
1/01/2013


Goodwin St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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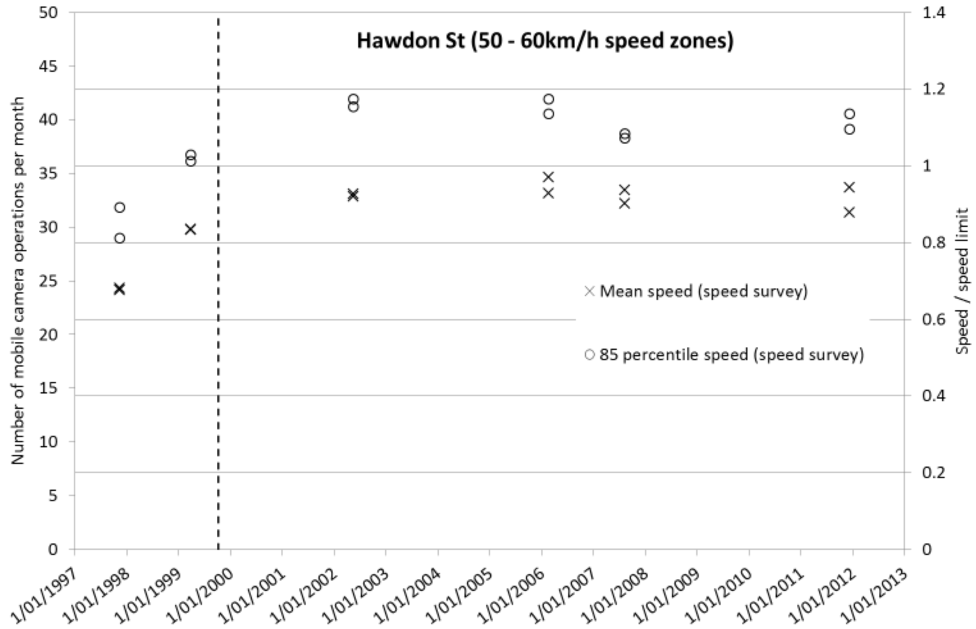
1/01/2011
1/01/2012
1/01/2013


Hawdon St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
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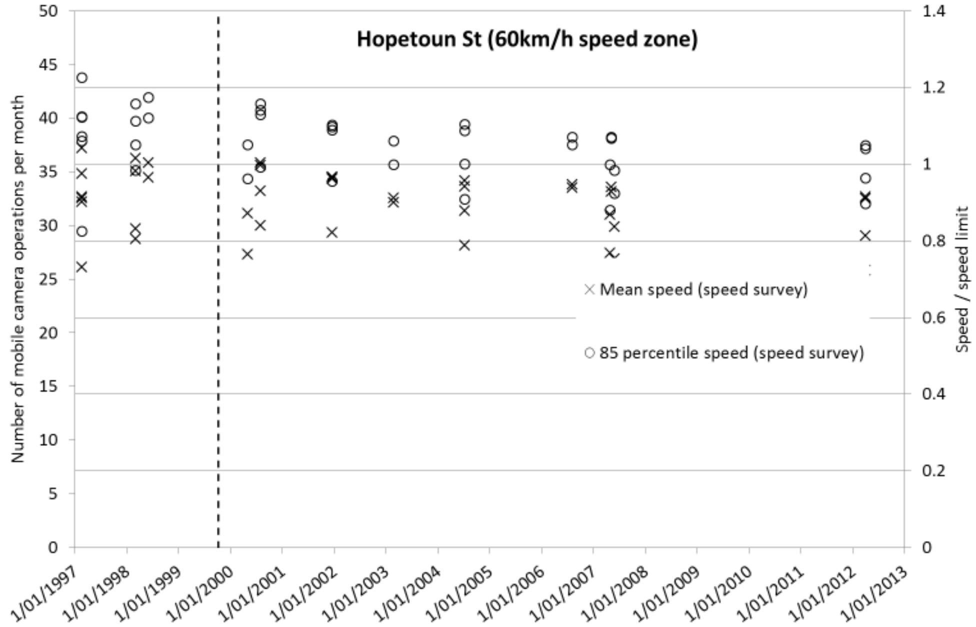
Hopetoun St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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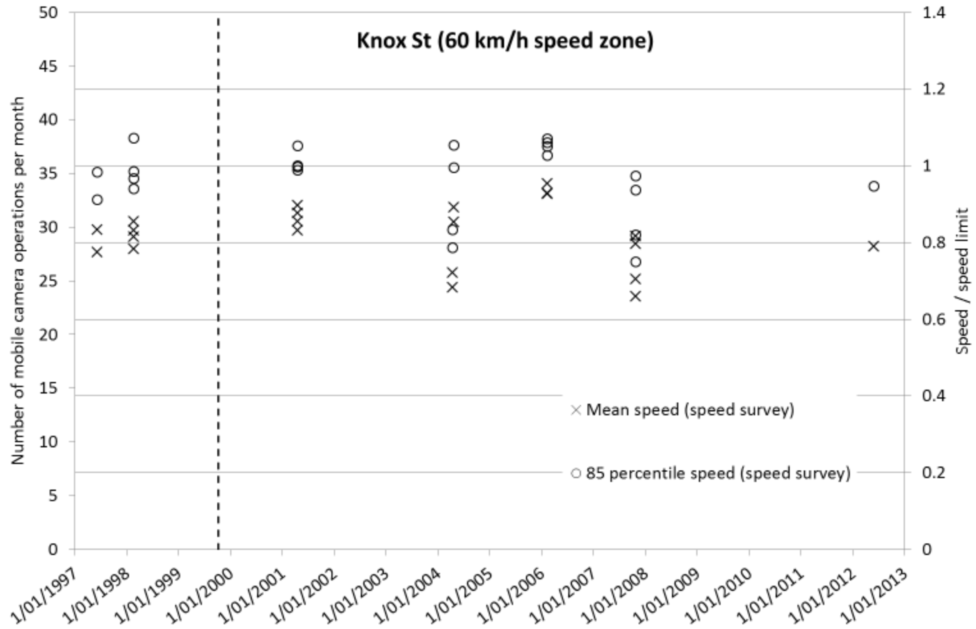
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Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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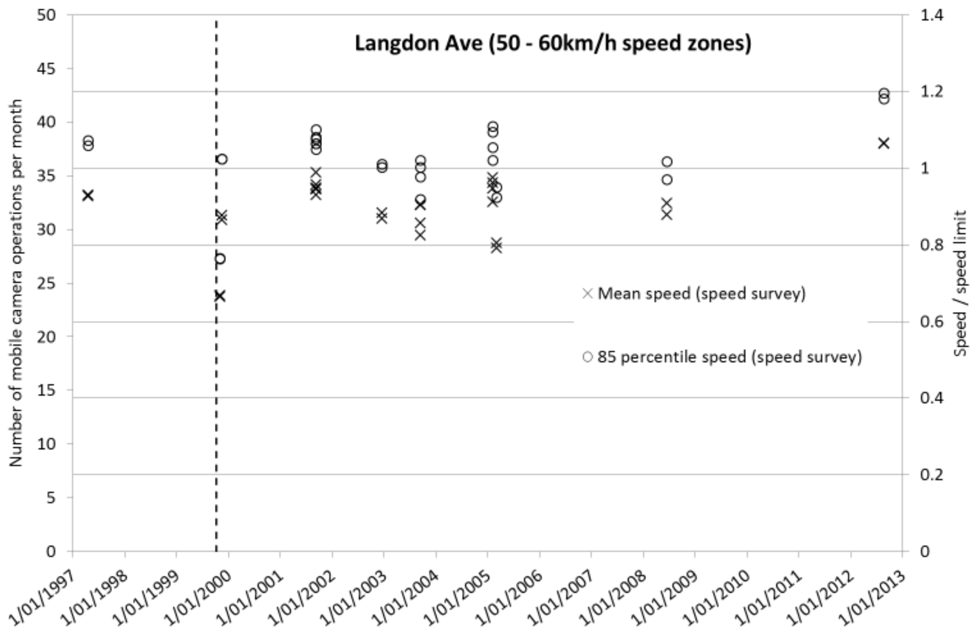
Langdon Ave (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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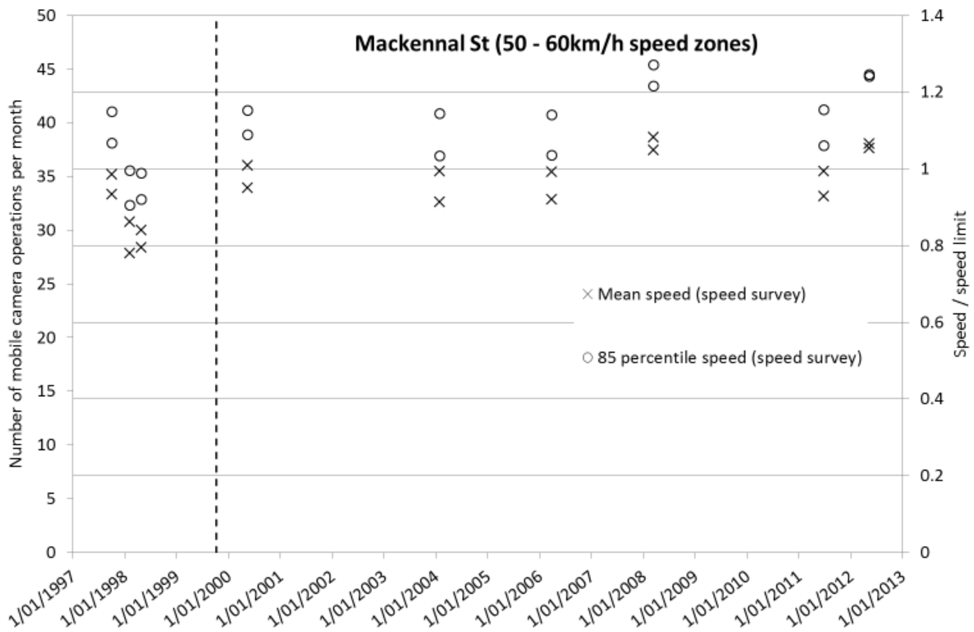
Mackennal St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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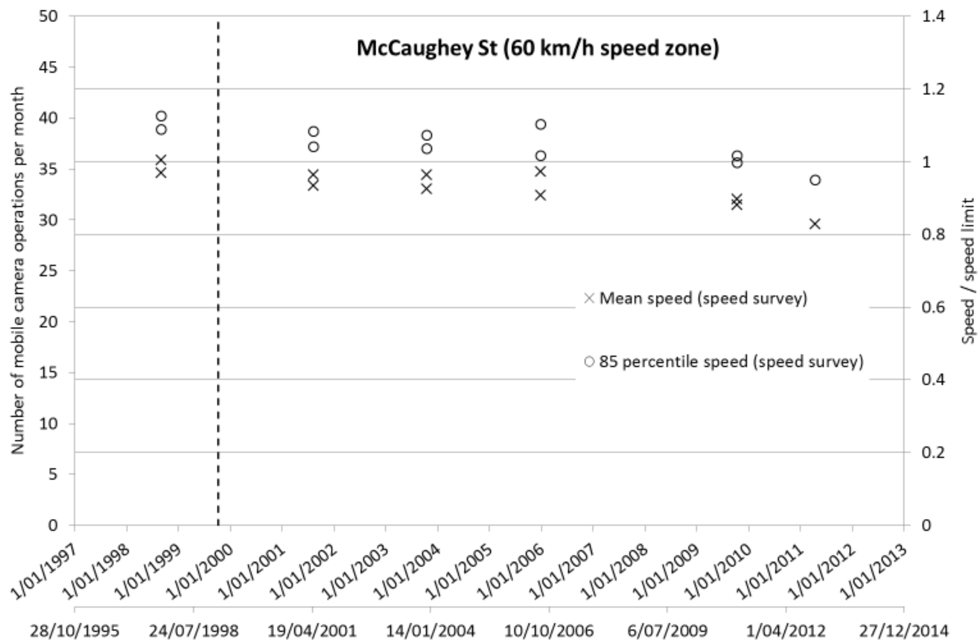
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Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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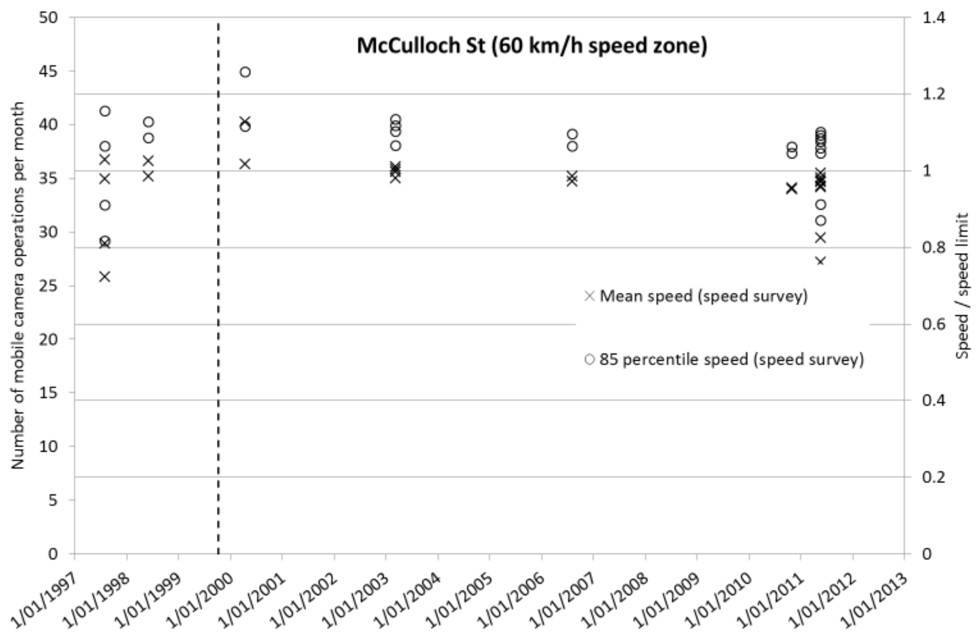
McCulloch St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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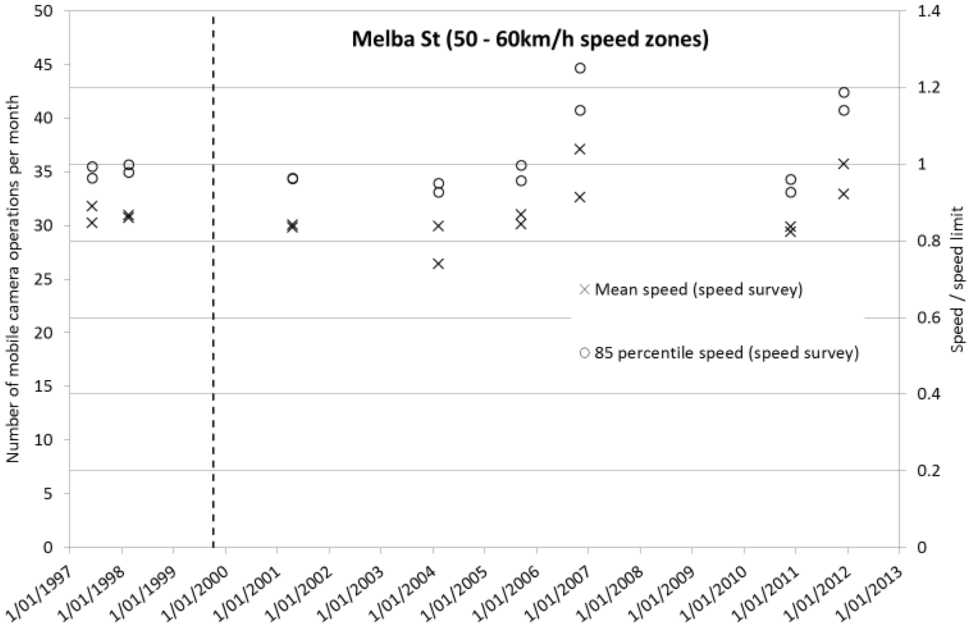
Melba St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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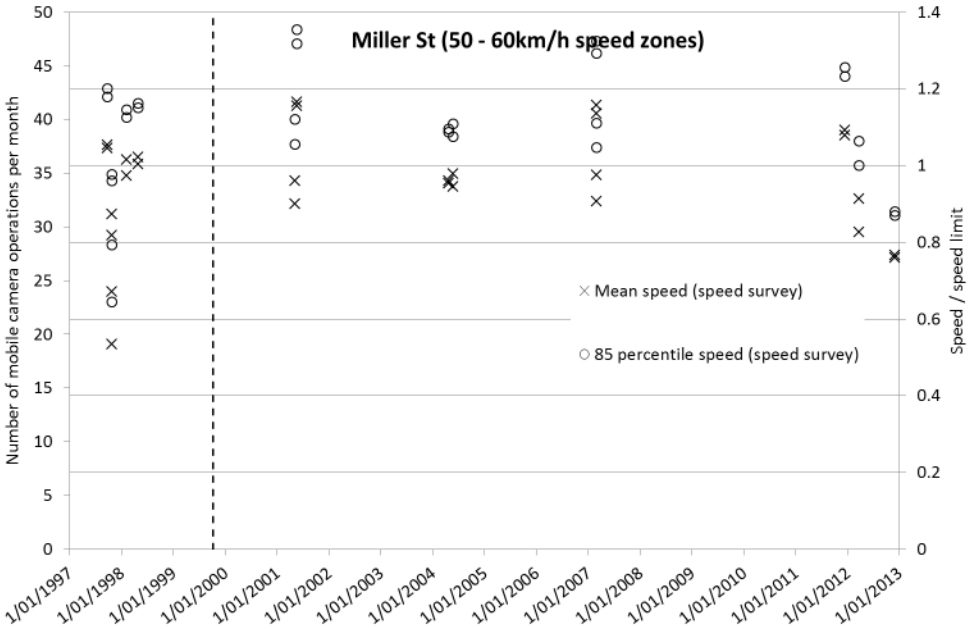
Miller St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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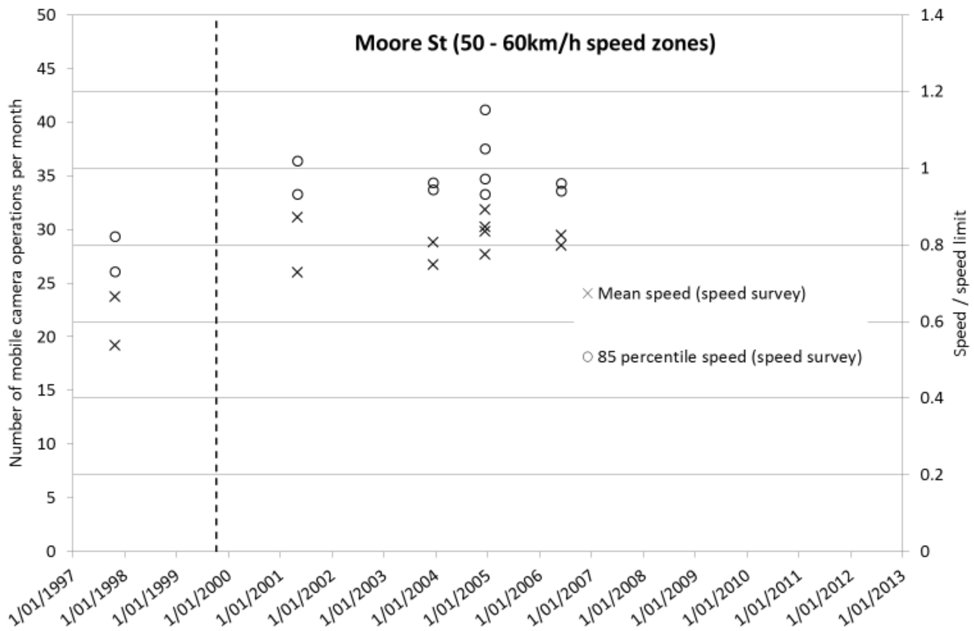
Moore St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
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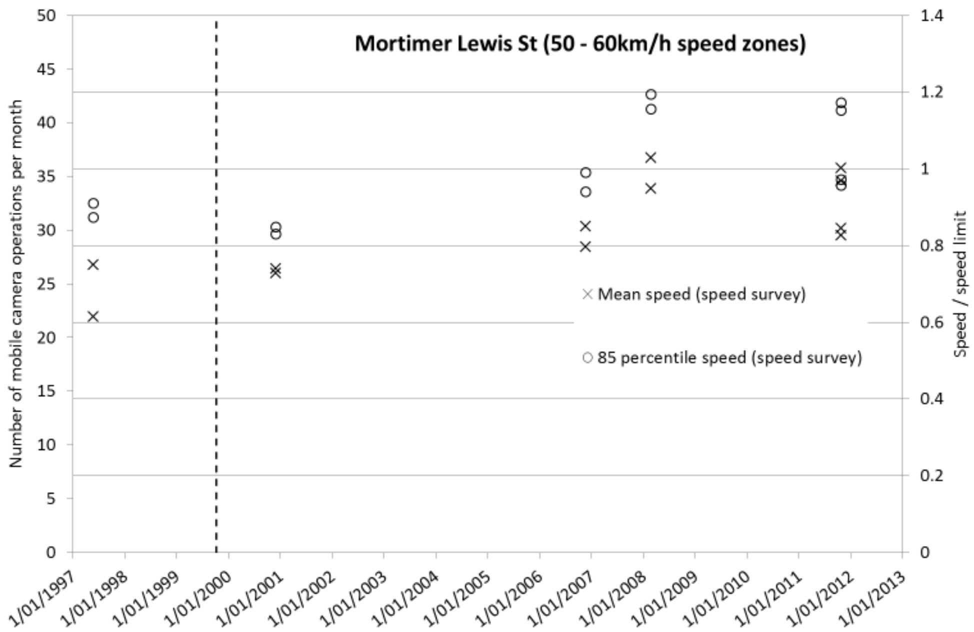
Mortimer Lewis St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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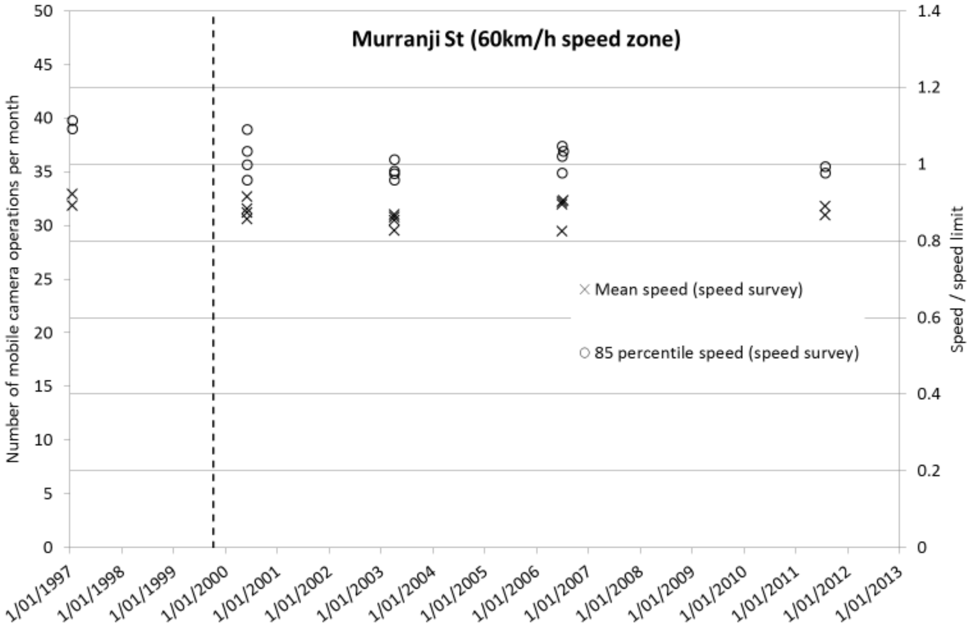
Murranji St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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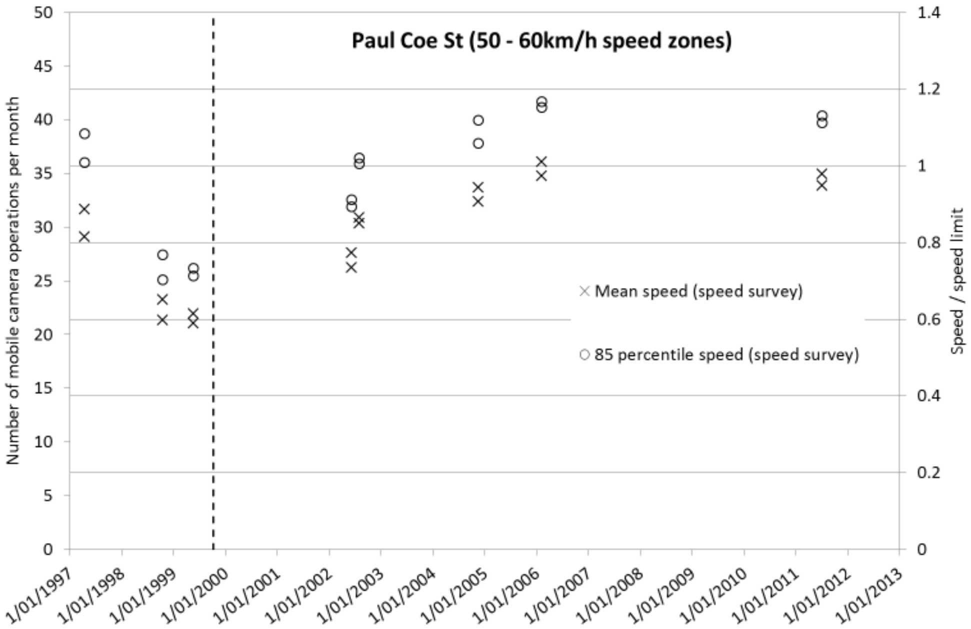
Paul Coe St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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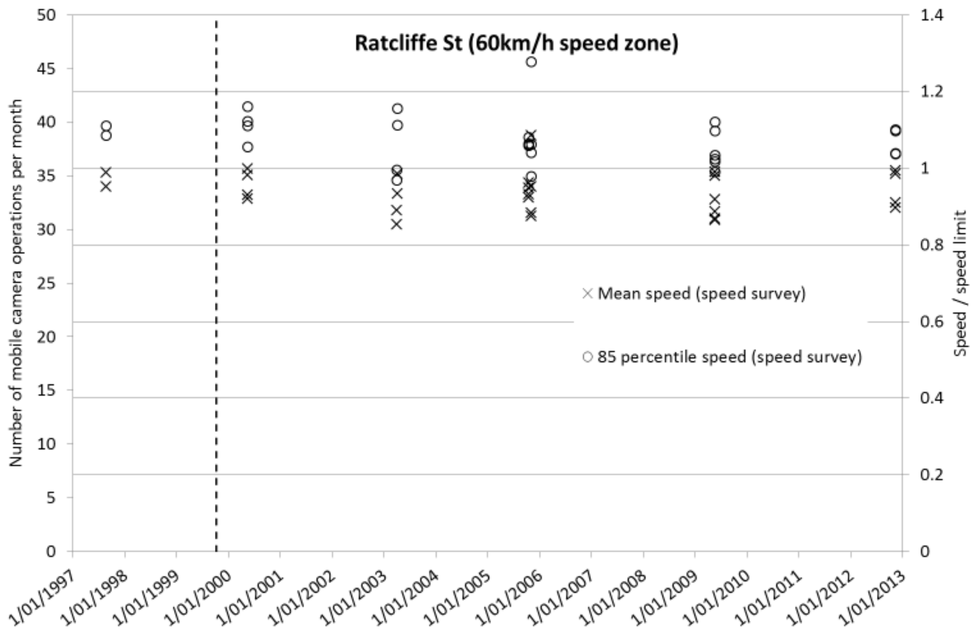
Ratcliffe St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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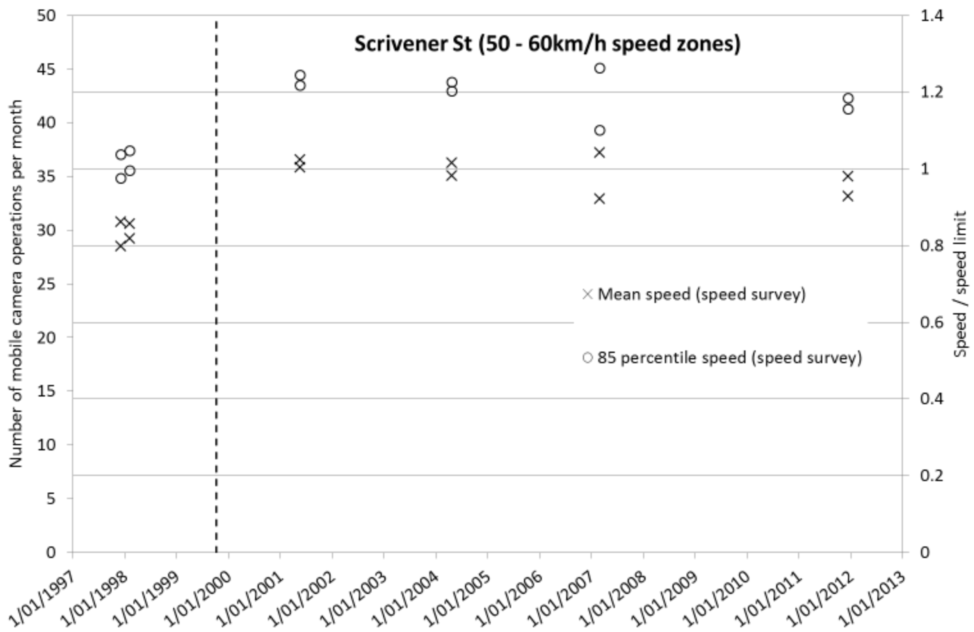
Scrivener St (50 - 60km/h speed zones)
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Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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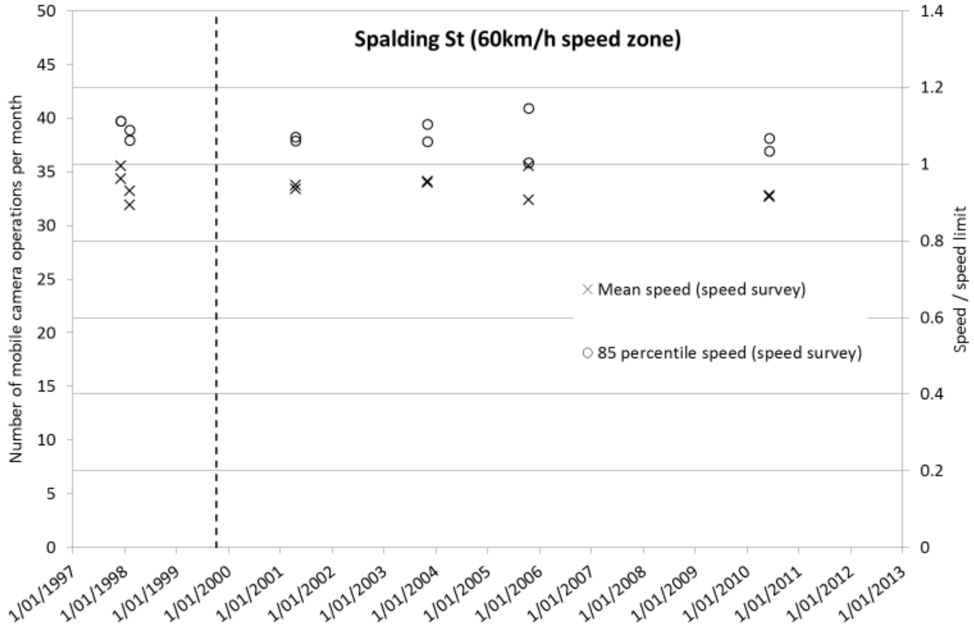
Spalding St (60km/h speed zone)
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Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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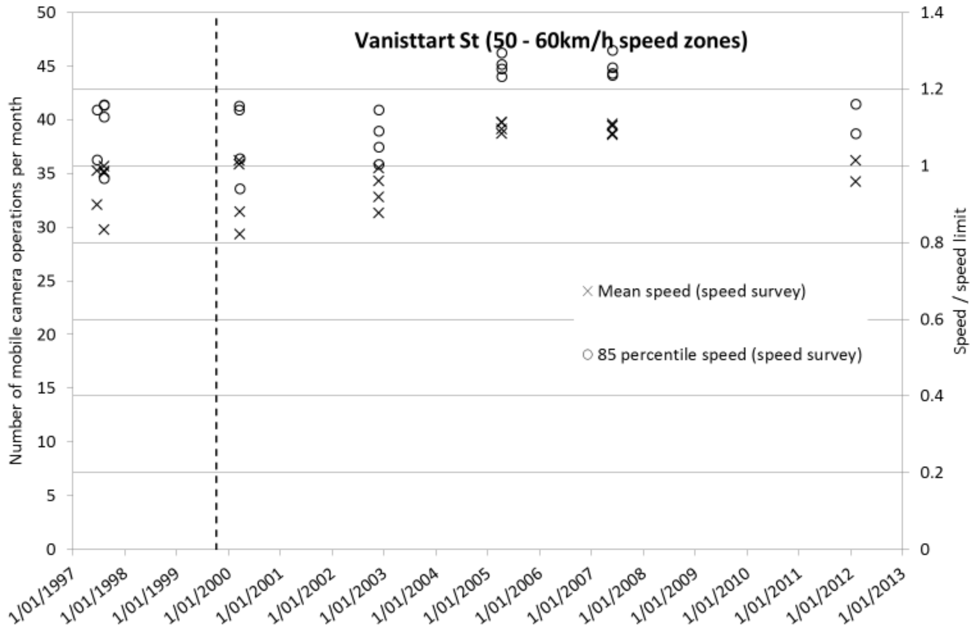
Vanisttart St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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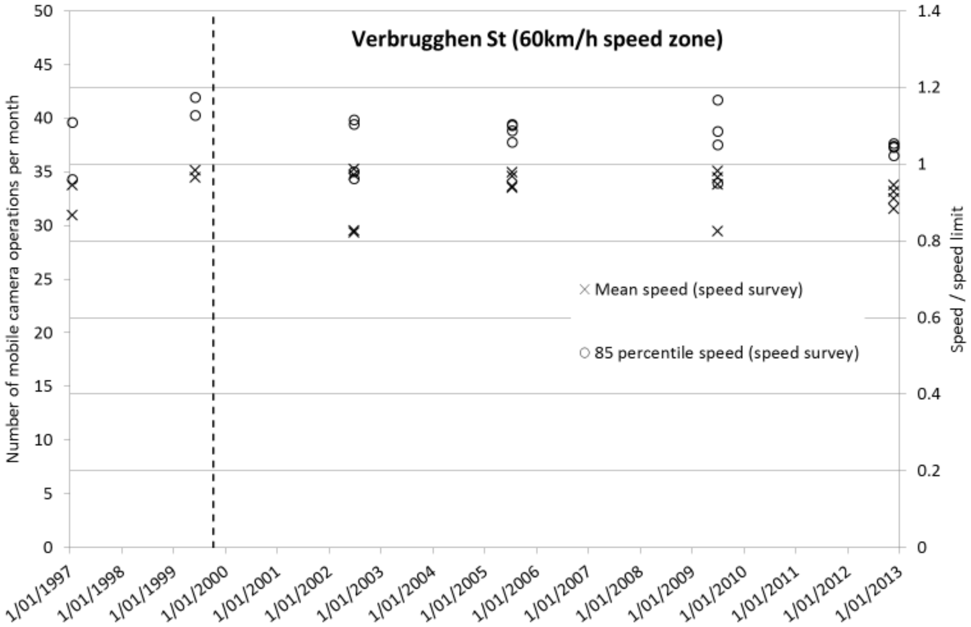
Verbrugghen St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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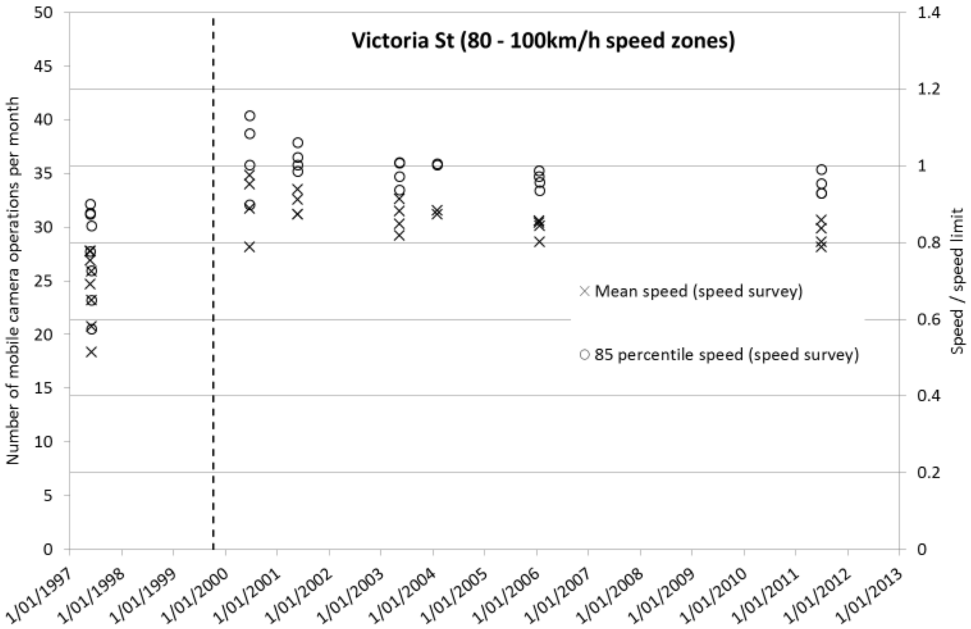
Victoria St (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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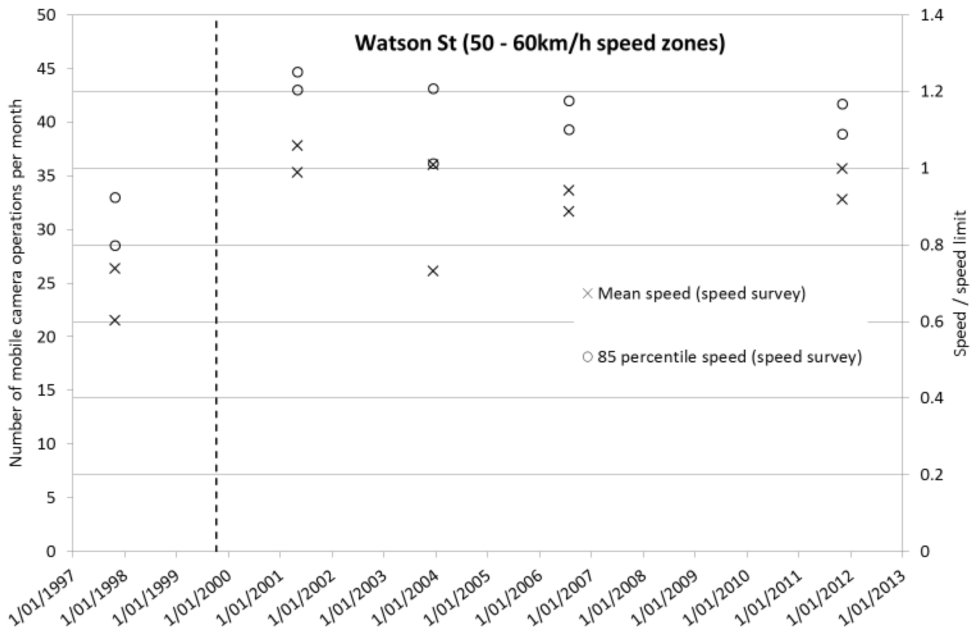
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Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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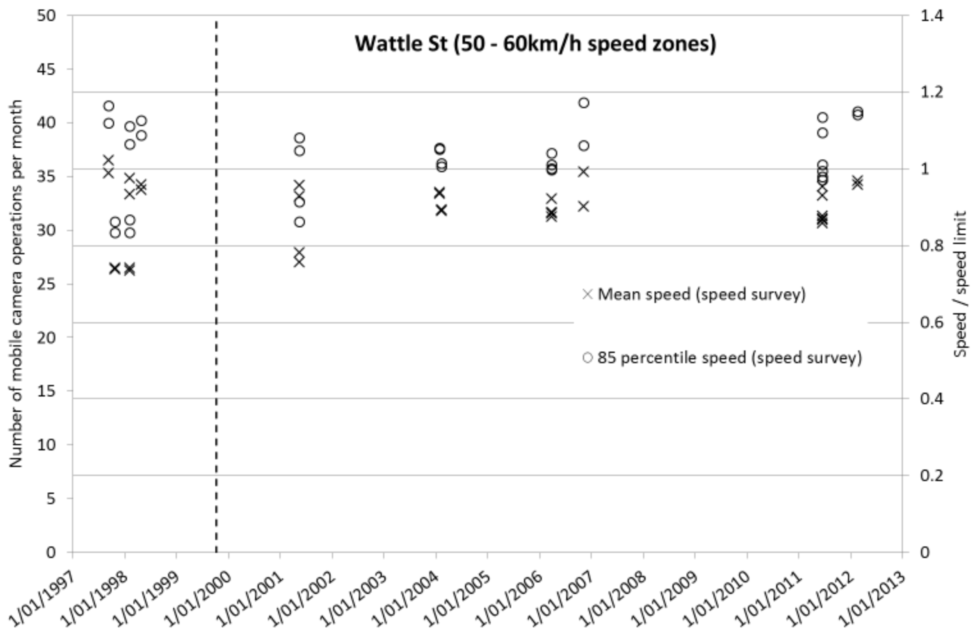
Wattle St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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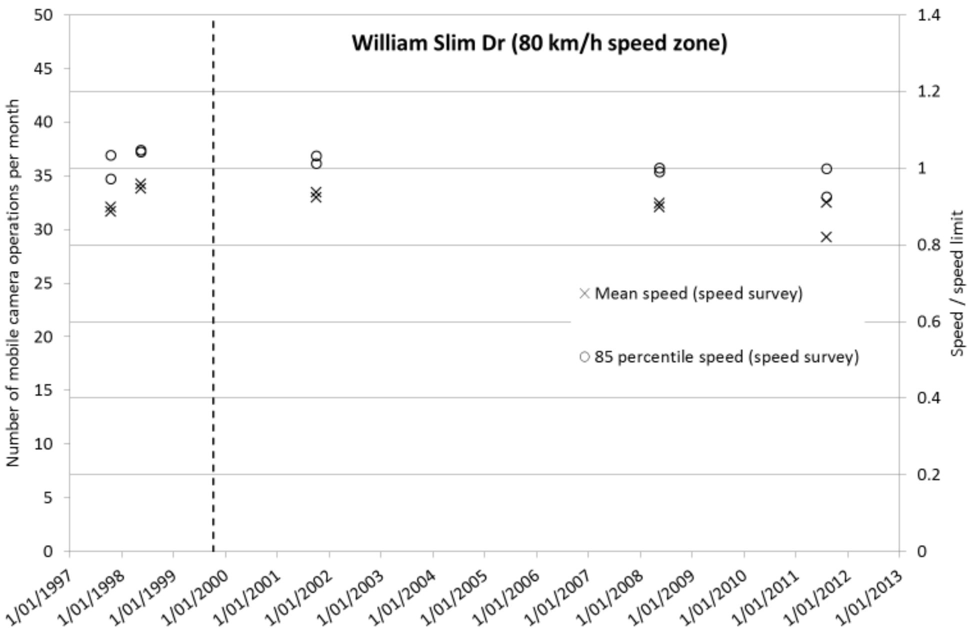
William Slim Dr (80 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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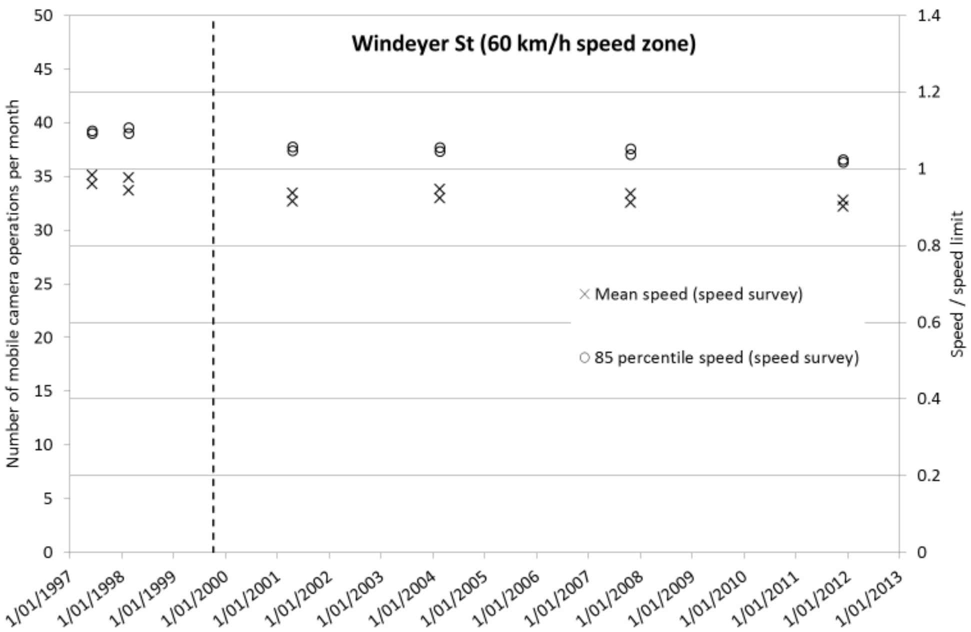
Windeyer St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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Appendix E: Detailed statement of requirements

Evaluation scope

The evaluation is to assess the impact of the ACT's Road Safety Camera Program, which includes mobile, fixed mid-block, point to point and red light/speed cameras, on the road safety objectives of:

(a) reducing crashes;

(b) reducing speeding (and thereby reducing crash risk).

The evaluation is to utilise:

(c) available ACT data, including crash data, speed surveys, and infringement data;

(d) relevant research and findings of other jurisdictions' evaluations of the effectiveness of road safety cameras and road safety camera programs; and

(e) any other relevant data, studies, evaluations or information.

The evaluation is to, as far as possible, having regard to the available data and information:

(f) assess the impact of the ACT Road Safety Camera Program as a whole;

(g) assess the contribution and impact of the various types of cameras used as part of the ACT Road Safety Camera Program; and

(h) assess the governance arrangements for the ACT Road Safety Camera Program.

The evaluation is to identify:

(i) potential opportunities to gain improved road safety effectiveness from the existing resources of the ACT Road Safety Camera Program;

(j) future opportunities to maximise the road safety effectiveness of the ACT Road Safety Camera Program, in relation to both network resources and governance; and

(k) an appropriate ongoing evaluation framework to support an effective ACT Road Safety Camera Program.

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Draft Report:

Evaluation of the ACT Road Safety Camera Program

A TARS Research report for the ACT Government Justice and Community Safety Directorate

June 2014

TRANSPORT AND ROAD SAFETY
(TARS) RESEARCH

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Definitions

Road crash – police-reported road crash that occurred on a public ACT roadway, resulting in property damage, injury or fatality
Serious road crash – police-reported road crash that occurred on a public ACT roadway, resulting in injury or fatality
Casualty crash – fatal and serious injury crashes
Case streets – ACT streets on which road safety cameras were installed/operated
Control streets – ACT streets on which road safety cameras were not installed/operated
Driver – Vehicle driver including light and heavy drivers and motorcycle riders
Intervention 1 – Introduction of the ACT Road Safety Camera Program, on the 6th October 1999
Intervention 2 – Reduction of mobile camera operations on ACT streets, around October 2006
Begin-date – Date of the introduction of cameras on a particular street/intersection
CL_L – Lower 95% confidence limit
CL_U – Upper 95% confidence limit
Statistically significant – a statistical result with a *p* value less than 0.05
Mean speed – the mean of all vehicle speeds measured during a speed survey
85th percentile speed – the speed below which 85% of vehicles were travelling during a speed survey (conversely, the speed 15% of vehicles were exceeding)
RTM – Regression to the mean
Spillover effect – when the effects of a fixed camera extend further along a roadway from the camera location

Executive Summary

Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, in order to guide improvement of the Program. This report delivers that independent evaluation.

Aim

The aim of this study was to investigate the performance of the ACT Road Safety Camera Program as a whole, including its impact on speeding and road crashes, and identify opportunities for improvement.

Whilst the above aim has been addressed in this report, emphasis in terms of evaluation of the camera program's effectiveness has been placed on whether the program has reduced serious and fatal injury crashes. This emphasis was implemented based on the National Road Safety Strategy (ATC, 2011) vision that no person should be killed or seriously injured on Australia's roads, where the strategy presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. In this context the following statements from that strategy document are particularly relevant: '*Crashes will continue to occur on our roads because humans will always make mistakes no matter how informed and compliant they are. But we do not have to accept a transport system that allows people to be killed or severely injured as a consequence….. This means we must manage the combined effects of the speeds at which we travel, the safety of the vehicles we use, and the level of protection provided by our roads — not only to minimise the number of crashes, but to ensure that when crashes do occur they do not result in death or serious injury.*'

<u>Thus a key question in this evaluation the Authors decided to further consider is whether casualty crashes in the ACT have reduced as a result of the introduction of the ACT Road Safety Camera Program.</u>

Methods

Speed surveys and road crash data were assessed for the period from 1994 to 2012 (inclusive). A sample of 95 ACT streets and 26 ACT intersections were assessed, including 48 case streets (with mobile cameras), 47 control streets (without mobile cameras), 13 case intersections (with fixed cameras) and 13 control intersections (without fixed cameras). It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

Data were collected for a total of 57,809 road crashes, 3,325 serious road crashes, 100 fatal road crashes, 4,261 intersection crashes, 1,758 speed surveys and 87,687 mobile camera operations. The sample represents 40% of the total number of ACT road crashes that occurred in the period.

Statistical models were developed to assess speed and crash trends, effects of interventions (introduction of cameras) and perform case-control analyses. Additionally, 66 assessments of road safety camera programs in the scientific literature were summarised, as were surveys of community attitudes to speeding collected from 1995 to 2011 (inclusive).

Results

- The number of mobile camera operations undertaken in the ACT increased following their introduction until late 2006, after which they decreased (around 30%) due to resource limitations;
- Mobile camera infringement rates decreased from approximately 6% to 0.6% of vehicles passing cameras during the first three years of operations, and remained thereafter steady at this low rate;
- Mean percentile speeds reduced by 6% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- mean 85th percentile speeds reduced by 8% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- Over the next two years, speeds on streets with mobile camera operations returned to levels similar to those before their introduction (mid-2004 to mid-2006);
- Mean and 85th percentile speeds then reduced by 7% and 9%, respectively, on streets with mobile cameras (mid-2006 to 2012);
- Mean and 85th percentile speeds on streets without mobile cameras were generally constant in the long term, and were lower in magnitude than speeds on streets with cameras reflecting the original reasons for the selection of some streets for camera enforcement;
- 85th percentile speeds were higher in magnitude than mean speeds, and although reduced by the cameras remained above the speed limit during the study period;
- Fatal crashes on streets with cameras generally decreased over the study period;
- Serious injury crashes at intersections were generally lower following the introduction of fixed cameras;
- Crashes at intersections with fixed cameras increased after their installation due to an increase in rear-end crashes which was then followed by a decline to levels slightly below baseline levels;
- Crashes at intersections without fixed cameras remained relatively constant although trending slightly upwards, and were lower in magnitude than crashes at intersections with fixed cameras reflecting the original reasons for the selection of some intersections for camera enforcement;
- There was a decreasing trend in serious crashes around the time of the introduction of mobile cameras, on both streets in which mobile cameras were operating and not;
- There was a large decrease in serious injury crashes in mid-2002 on streets with mobile cameras when mobile camera operations increased from around 400 per month to over 600 per month;

- The large decrease (around 40%) in serious injury crashes commencing in mid-2002 was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend steadily increasing up to 2013 to the same levels when cameras were first introduced;
- The rising trend in serious injury crashes starting from around 2004 through to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period;
- The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006;
- The large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras occurred in the year immediately following the period when more than two-thirds of survey participants reported that enforcement had increased in 2001;
- In the surveys conducted between 1999 and 2001 and in 2001 the percentage of people reporting no change in enforcement clearly fell to its lowest level in the survey period. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years up to 2006, perception of increased speed enforcement remained high. This increased awareness of speed enforcement coincides with the large 40% decrease in serious injury crashes commencing in mid-2002 until the end of 2004;
- More ACT residents reported decreasing their own driving speed in 2000 up until around 2005, being the period following the introduction of mobile and red light cameras and the period when there was a large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras. However, since 2008 around three quarters of drivers reported no change to their speed coinciding with the period of steady increase in serious injury crashes;
- More ACT residents reported supporting lowering residential speed limits following the introduction of mobile and red light cameras;
- Since the introduction of cameras in, the proportion of residents that agree that safe speeding is 'OK' has decreased, however around one half agree with the view that speeding fines are for revenue raising;
- Evaluations of red light cameras in the literature have identified mixed effects: benefits include reduced red light running and right-angle crashes; detriments include increased rear-end crashes (a less severe crash type) during the initial phase when introduced however, right angle crashes are on average more severe than the rear end crashes;
- Evaluations of fixed speed cameras in the literature have identified benefits such as reduced speeds in the vicinity of the camera and reductions in injury and fatal crashes;
- Evaluations of mobile speed cameras in the literature have identified benefits such as reductions in speeds and speeding, and reductions in crashes;
- Evaluations of point-to-point cameras in the literature have identified benefits such as reductions in crashes

Conclusions

Beginning at the start of 2000, mobile cameras reduced speeds by around 6%-8% in the short-term (late-1999 to mid-2002), and remained at the lower speed until 2004 (a total period of four to five years). Speeds then began to rise back to pre-camera levels over a period of approximately four years (mid-2004 to mid-2007). The 6%-8% fall in speed reached by mid-2002 coincided with a 25% to 30% reduction in serious injury crashes on streets where cameras were present. This reduction in serious injury crashes was sustained until mid-2005. If this fall in serious injury crashes is attributed to the average speed reduction it would be consistent with the Nilsson power model where a 6% to 8% reduction in speed is estimated to result in around 20% serious and fatal (casualty) crashes. This short-term effect of speed cameras is consistent with camera evaluations in other jurisdictions and countries.

It is noted that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. This increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Coinciding with this 25% to 30% fall in serious injury crashes from mid-2002 to the end of 2004 period, the survey of community attitudes to speeding indicated a marked increase in survey participants' awareness from 2001 to 2004 that speed enforcement had increased. This indicates that drivers (includes motorcycle riders) likely adjusted their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. When they found that they were not being caught as often as they thought they would be, their speed started to return to customary levels. Associated with this rise in average speed was a rise in serious injury crashes to the same rates as those when cameras operations started in 1999. Alternatively, it could be other factors like initial bursts of enforcement, which slowed drivers (and riders) down.

The introduction of cameras had a short-term effect on vehicle mean and 85th percentile speeds. This short term effect coincided with driver's awareness that enforcement of speeds had increased. As a result serious crashes fell around mid-2002. However, serious crashes and speeds started to trend upwards since around 2005-2006, finally reaching the same levels of serious injury crashes as when cameras were first introduced. Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. Further speculating, the loss of this benefit may be reflecting an unrelated background trend such as an increase in traffic activity. It could also be due to drivers realising the low risk of detection and possibly weak penalties. When a driver receives an infringement and little changes with respect to penalty fees and to loss of their license, then the impact of detection is weakened. For example, in NSW when the law was introduced that any speeding by a P1 driver would cause them to lose their licence, the speed related fatalities dropped by over on third (Job, 2013). However, it appears that the main cause may have been the drop in mobile camera hours from a peak of 700 operations per month to an average of around 500 per month (around 30% reduction) in 2007. This pattern of data over time, with the decreases in severe crashes and decreases in speeding and then increases in both serious crashes and speed, reinforce the key role of speed in road trauma. Regardless, this increase in serious crashes over the last five to six years presents a substantial road safety challenge to the ACT.

Intersection cameras produced reductions in right angle crashes and small decrease in serious crashes offset by increases in rear end crashes. Concurrently rear-end crashes were on an upward slope at control intersections. Thus, the initial increase in rear-end crashes followed by a steady return to baseline rates at case intersections resulted in a net reduction in serious crashes. On average, whilst the number of injuries resulting from rear end crashes can be substantial in terms of number of lower severity injury claims, and can have long term chronic effects related to whiplash injuries, they are often significantly less severe than side impact crashes, mainly as a result of the crashworthiness crush and occupant protection characteristics of the struck vehicle.

Recommendations

The results strongly suggest that the cameras had a positive effect on reducing speeds and thus serious injury crashes when first introduced, but that this effect began to dissipate starting around the mid-2000's. The reasons for the increases in speeding and in crashing are not clear, but factors that may have played a role were a distinct reduction in the number and consistency of mobile camera operations in approximately late 2006, and avoidance mechanisms by drivers. Simply the threat or even presence of cameras is unlikely to have an effect of reducing speeds unless there is a clear consequence of doing so. A review is recommended of the information sources available for avoidance and improved management of camera operations to create true unpredictability (along with strong publicity warning that these changes are occurring)

Other factors that may have played a role could include less media and community awareness raising of the presence of cameras and the importance of speed as a factor in road safety around 2006 to 2007. The survey data indicates an increase of survey participants reporting no change in enforcement around then. It is therefore recommended that the ACT government re-engages with the community regarding the benefits of reducing speeds for road safety and the role of cameras in reducing speeds.

Alternative accounts of the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Evaluation of these possible accounts through further research is recommended.

Serious crashes have been increasing in the ACT since around mid-2005. It is also worth noting that the total ACT vehicle fleet has increased 25% over the period 2004–2013, and transport modelling of car trips during the morning peak period suggests the total number increase by 7% from 2006 to 2011 and by 13.5 % from 2001 over a ten year period. Given the infrastructure remains relatively constant (approximately the same road area and intersections) this increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes. It is therefore recommended that further research on injury crashes during this period is performed, in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

1. Introduction

1.2 Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, as well as the governance of the program. The key reason for conducting this evaluation is to identify opportunities for improvement. This report delivers that independent evaluation.

1.2 General

Camera technology has been adopted widely as a means of encouraging drivers to reduce their driving speed. Lack of control of speed is a major challenge to road safety, and is a large contributor to road crashes, especially more severe crashes. The use of photographic or camera enforcement automates and extends the reach of enforcement in an effort to encourage drivers to comply with speed limits.

Red light cameras are used to encourage compliance with traffic signals and by doing so promote lower driving speeds around signalised intersections. Fixed speed cameras being located at specific points in the road network are used to encourage lower speeds usually in areas of higher traffic risk, often regarded as traffic 'black spots'. As fixed cameras become a standard fixture they can be expected to have local effects on driving speeds. On the other hand, mobile speed cameras can be placed at any position in the road network and this position can be varied so drivers will not expect their presence. Mobile cameras therefore would be expected to have a more general effect on driving speeds as drivers cannot predict their presence around the road network. Some jurisdictions, including the ACT, operate mobile cameras overtly and provide information to drivers about the presence of mobile cameras. Others operate mobile cameras covertly, providing only general information to drivers that cameras may be operating 'anywhere, anytime'. Different outcomes might therefore be expected from overt and covert operation of mobile cameras. Overt operations that make the need to reduce speeds clear to drivers might be expected to have effects in their immediate vicinity. The general deterrence effect might be expected to be stronger in situations where mobile cameras are used covertly although this effect is likely to be much weaker as the effect will require drivers to reduce speeds 'just in case' there are cameras in their vicinity, and many other factors are likely to influence this effect including driver attitudes towards road safety and enforcement.

Evaluation of the effectiveness of safety camera programmes requires well-designed studies. Evaluation studies that only include measurement before and after cameras are implemented only provide weak evidence. At the least, study design needs to include appropriately chosen controls where measures are taken at the same time as the camera measures in order to be able to show that any changes seen after the cameras are in place are not simply due to changes in driver behaviour over time. An ideal study design would also include randomisation of locations for cameras and controls to ensure that choice of location does not bias measures of effectiveness of the cameras. In road safety, however, interventions like safety cameras are almost never randomly assigned; rather they are implemented in locations where they are likely to achieve the best improvements in road safety. Nevertheless, evaluation studies should still involve the best design possible and at least a before-after design with control groups.

In evaluating the effectiveness of safety cameras in particular, two other factors commonly cited as potential threats to the validity of safety camera evaluations are Regression to the Mean (RTM) and spillover effects. Non-random assignment of cameras to locations makes these types of evaluations vulnerable to RTM effects. Cameras are almost always implemented at sites that have high demonstrated crash risk and crash risk will be significantly lower after cameras are implemented if they operate as expected. It is possible, however, that the high initial crash risk is due to natural variation in crashing that occurs potentially in any location in the road network, in which case crash risk will decrease for the same reason, rather than due to the presence of cameras. RTM effects can lead to overestimation of the effects of safety cameras and so should be avoided if we want to reveal the effect of the presence of safety cameras. Best study designs for avoiding RTM effects include using long periods for before and after measurement so natural variation can be captured in the study and using statistical means such as empirical Bayes methodology (Hallmark et al, 2010).

It is argued that spillover effects, sometimes also referred to as halo effects, threaten the validity of the evaluation of safety cameras in studies where the chosen control sites may be influenced by the presence of the safety camera such as a similar location in the next section of road. In such locations, it is argued that driver speed may still be low due to a lasting effect of the camera. Spillover effects will underestimate the effectiveness of safety cameras and again invalidate the evaluation of the effect of the camera. It should be recognised, however, that spillover effects are also likely to occur due to general community awareness of speeding and speed-related enforcement that usually occurs around the introduction of safety cameras. Where this is the case, the finding of improvements in road safety outcomes at comparison locations with no camera should be viewed as another outcome of the road safety intervention rather than a nuisance factor in the evaluation. The comparison between camera and no camera sites will then be showing the additional effect of cameras to a road safety program rather than necessarily the whole program itself. Spillover effects of cameras may be less likely for some types of safety cameras. In particular, where camera locations are known and expected, such as fixed location cameras (red light and fixed speed), people come to anticipate their presence and so would be expected to produce less spillover effect as drivers respond to the particular sites that they know are enforced. Overall, to evaluate the effect of a safety camera program in its entirety would ideally ensure that control sites are in areas that will not be influenced by any facets of the program, not just the presence of cameras.

Finally, good evaluation designs should include measures relevant to the outcome expected to change as a result of the intervention. The objective of introducing safety cameras is to reduce driving speeds and as a result to reduce crashes and casualties. As shown in Figure 1, it is expected that the presence of safety cameras and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication is a key part of any enforcement program. The relationship between speed and casualty crashes is well known and has been modelled by many researchers. For example, Figure 2 shows the often cited Nilsson (2004) power model showing the relationship between the change in mean speed and fatal and serious injury crashes. It shows that a 7% reduction in mean speed will result in around 20% fall in Fatal and Serious injury crashes.

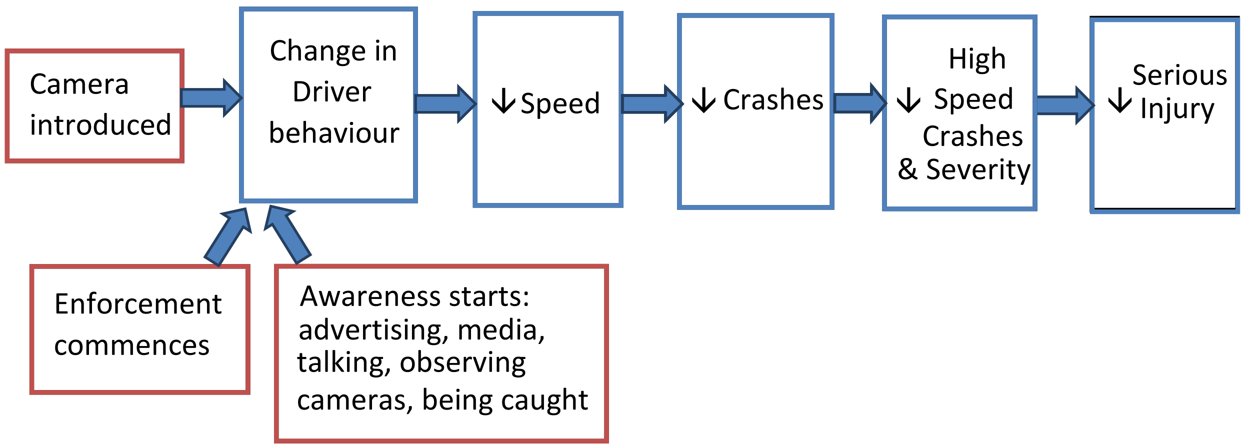

Figure 1: Schematic of the expected effects of safety cameras on road safety outcomes.

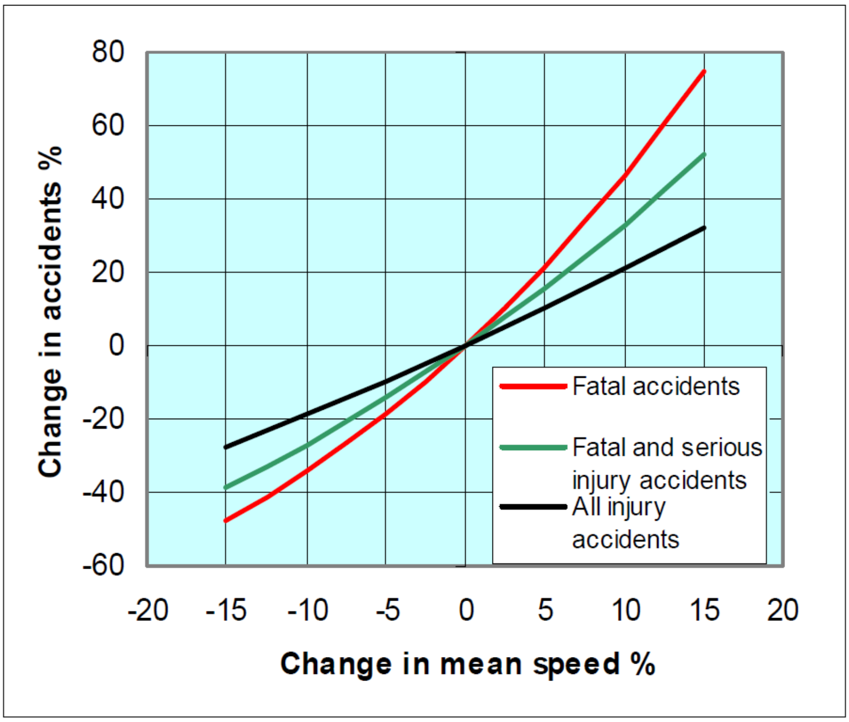

Figure 2: Nilsson (2004) power model showing relationship between casualty crashes and mean speed.

It must not be overlooked that the effect of safety cameras is also through punishment or enforcement of speed limits which also encourages changes in driver behaviour to produce lower speeds, crashes and injury. In this way, simply the presence of safety cameras can have a general deterrence effect on driver behaviour due to the fear of being caught, whereas the use of enforcement together with communication tends to have a specific effect on individual driver behaviour, mainly influencing speeding drivers who are caught.

These three effects of cameras, communication and enforcement are also likely to produce different changes in behaviour in parts of the road network in which cameras are introduced or not. The strongest effects naturally should occur in the safety camera locations where the presence of cameras combined with enforcement and communication provides the greatest encouragement for drivers to comply. It would be expected, that cameras will also influence driver behaviour in areas where some drivers might suspect that cameras are operating and so modify their behaviour accordingly. In most settings, the introduction of safety cameras is publicised and justified through media and other means of dissemination. This will also raise awareness amongst the community of the general presence of safety cameras which would be expected to add incentives for some drivers to change their behaviour and reduce speed because they want to avoid penalties and because they believe that compliance is safer.

The presence of enforcement and consequent speeding infringements for drivers who violate the speed limit, is likely to create further incentive for drivers to reduce their speed in locations where the enforcement occurs. Following the introduction of safety cameras it would be expected that infringements may be initially high, but will reduce as drivers learn about the presence of cameras and enforcement either through their own experience or the publicised experiences of others. With time, infringement rates would be expected to reduce as driver speed is reduced because of the cameras having an effect.

Safety camera evaluations should therefore include measures of changes in driver behaviour, especially speed around speed cameras and speed and red light running around red light cameras. As the ultimate outcome of camera programmes is to reduce injury crashes, these measures should also be included. Measures of enforcement should also be included in camera evaluations because enforcement is an integral aspect of the road safety intervention. Numbers of infringements are not a direct outcome of camera programmes. However, they would be expected to influence driver behaviour both independently and in combination with the presence of cameras. In the present study, efforts have been made to include all the relevant measures (infringement rates, speed, injury and crash data), while minimising the potential confounders (RTM and spillover effect).

2. Method

2.1 Literature review

The review of existing scientific literature on the impact and effectiveness of road safety cameras looked at published studies in the international peer-reviewed literature and unpublished reports from English-speaking countries including all Australian jurisdictions, Canada, UK, NZ and USA and from the top road safety performing countries in the OECD where their websites are translated into English (e.g., Sweden, Netherlands, France). The objective of these literature searches was to identify evidence of best practice in implementation of road safety cameras in order to evaluate the impact of different types of cameras, identify any issues that need to be taken into account in implementing safety camera programs and to determine whether there are new opportunities to improve the effectiveness of the current program in the ACT.

A search of the available published scientific literature was conducted using four major search engines including Web of Science, PsycINFO, Scopus and PAIS International. The key words used included speed, camera, red light camera, evaluation and enforcement in different combinations. A search of reports of evaluations of safety camera effectiveness was also conducted. This involved a website search of the main websites of road authorities in the different jurisdictions of Australia, Canada, UK, NZ and USA as well as Sweden, Netherlands, France (where their website is in English). The purpose of this search was to identify any grey literature that was not located from the conventional literature search.

2.2 Review of community attitudes to speeding

This review used existing literature to understand changes in community attitudes to speeding in the ACT following the introduction of different types of speed cameras, including the results of the series of community attitude surveys conducted for the Department of Infrastructure and Development and related entities over nearly 25 years. Changes in respondent's views of speeding were linked to the introduction of the different types of cameras in the ACT (i.e., mobile cameras from 1999, fixed red light/speed cameras from 2000, fixed speed cameras from 2007). As community attitudes are an important component of compliance with speed limits, this analysis may provide some other insights into the comparative effectiveness of the road safety camera program.

A series of community attitude surveys have been conducted for the Australian government's transport portfolio, currently the Department of Infrastructure and Regional Development. A total of 22 surveys have been conducted on a regular basis since the late 1980's. Questions about speeding were included in all surveys but since 1995 there has been a standard series of questions about speeding included in each survey. Answers to many of these questions are also available by jurisdiction so that it is possible to track changes in the perceptions and attitudes of ACT residents about speeding over the 15 years between 1995 and 2011. This data also allows investigation of the influence of the introduction of safety camera's on community attitudes towards speed and speeding over the period. With the staggered introduction of different types of cameras in the ACT, it was possible to look at the relative impact of each type of camera on community attitudes. This will allow examination of the general deterrence effect of mobile cameras which were introduced from 1999, the effects of fixed red light cameras operating in specific locations which were introduced from 2000 and fixed speed cameras from 2007.

Each of the 22 Community Attitude surveys conducted by the federal transport authority between 1995 and 2011 were reviewed to establish the series of questions on speeding that had remained the same across each survey.

The questions included were:

- "In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"
- "Have you personally been booked for speeding in the last two years?" And, if so "Have you personally been booked for speeding in the last six months?"
- "Thinking about 60km/h speed zones in urban areas:
  1. How fast should people be allowed to drive without being booked for speeding? (i.e. the 'acceptable' speed tolerance)
  2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"
- "Thinking about 100km/h speed zones in rural areas,
  1. How fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance)
  2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

- Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:
  1. Fines for speeding are mainly intended to raise revenue
  2. I think it is okay to exceed the speed limit if you are driving safely
  3. Speed limits are generally set at reasonable levels
  4. If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
  5. An accident at 70km/h will be a lot more severe than an accident at 60km/h
- "Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?"
- "Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"
- "Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways", they were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"
- "In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

Each survey looked at a national sample of residents 15 years and over. Survey was by telephone with a letter in advance advising the household about the survey. Sampling of all states and territories was stratified by regional probability sampling, but from 1999 the sampling strategy was modified to ensure at least 150 interviews in each jurisdiction. Sample size for the 1995 to 1998 surveys was around 100 interviews in each survey.

2.3 Speed survey and road crash data study

2.3.1 Data collections

The data collections that were accessed for the data study are summarised in Table 1.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 1: Data collections used for the study

Speed survey data was available from 1997 to 2012 (inclusive), and consisted of the annual summaries indicating the site location, speed limit, survey date, 24 hours traffic volume, mean and 85^{th} percentile speeds of the survey. The road crash data consisted of all police-reported crashes that occurred on public ACT roadways, resulting in either property damage, injury or fatality. In order to have five years of crash data prior to the start of the camera program, crash data was extracted from 1994 to 2012 (inclusive). Enforcement data for both fixed and mobile cameras consisted of the number of vehicles checked by the camera, and the number of infringements issued, and was available from the implementation of each camera.

2.3.2 Selection of case and control mobile camera locations

The present study considered two types of roadway locations; streets in which mobile cameras were implemented anytime during the period 1999 to 2012, and streets in which they were not. Streets with mobile camera operations are hereafter termed 'case' streets, while those without cameras are termed 'control' streets. It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

During the implementation of the mobile camera program since 1999, a total of 177 ACT streets were approved for mobile camera operations. Road crash data was available for all public ACT streets on a continuous basis. Speed survey data was available for selected ACT streets on a discontinuous basis, since surveys have been performed in a non-systematic way since 1997. In order to select locations for the present study of mobile camera operations, the speed survey data was deemed to be the limiting data collection and was therefore used.

Initially, streets on which mobile camera operations were introduced were identified in the speed surveys undertaken in 1997. This allowed for as much pre-camera data as possible. These streets were then tracked temporally and the number of years in which at least one survey was undertaken up to 2012 (inclusive) was established. Streets were then ranked according to the total number of years available, resulting in a total of 48 streets with five or more survey years. Streets on which mobile camera operations were not introduced were then selected in the same manner, resulting in a total of 47 streets with five or more survey years available. These analyses were performed manually using the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

This resulted in a total of 95 streets for the mobile camera analysis. The full list of case and control streets is provided in Appendix A. Crash data located anywhere along these streets was then provided by the ACT Territory and Municipal Services Directorate. Each street was then treated as a single location, a location number was assigned to it, and any crash or speed survey located at any position along the full length of that street, was assigned to that location number.

2.3.3 Selection of case and control fixed camera locations

There are three different types of fixed cameras operating in the ACT; combined red light and speed cameras located at intersections, speed cameras located along mid-block sections and point-to-point cameras. Point-to-point cameras were recently installed in 2012, thus insufficient data was available to assess these two cameras in this study. Road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. However, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis.

Intersection crashes are identified specifically in the road crash data collection, thus particular intersections were easily identified, and an assessment of the association of the introduction of fixed intersection cameras with crash outcomes could be assessed. Case and control intersections were identified in a similar manner to the mobile cameras, where case intersections were those on which fixed red light and speed cameras were installed. Since there was a relatively small number of these (thirteen), all fixed camera intersection locations were selected. Thirteen control intersections were then identified by randomly selecting other intersections located on the same street as each of the case intersections. This resulted in a total of 26 intersections for the fixed intersection camera analysis. The full list of case and control intersections is provided in Appendix A.

2.3.4 Time periods

The ACT road safety camera program began on the 6th October 1999 with the introduction of mobile camera operations on 22 streets. Fixed cameras began to be introduced shortly thereafter in 2000. There was a reduction in mobile operations in 2006, where due to various resource limitations mobile camera vans performed fewer operations. In order to assess associations with the overall camera program, the two key dates of the introduction (October 1999) and the change (October 2006) were identified, and are hereafter termed Intervention 1 and Intervention 2, respectively.

For each case street, the date on which mobile camera operations began in that street was established, and is hereafter termed the ‘begin-date’. Begin-dates for the selected streets ranged between October 1999 and March 2011. In order to perform the case-control analyses, each control street was matched to a case street, based upon traffic volume and speed zone. Since every case and control street had a speed survey performed in 1997, the traffic volume in 1997 was used to establish matched street pairs. Each control street was matched to a unique case street, and the begin-date of the case street was then allocated to the matched control street.

For each case intersection, the date of the installation of the fixed red light and speed camera was established as the begin-date for that street, and ranged between June 2000 and August 2007. Begin-dates were then assigned to control intersections, as the date corresponding to the begin-date of the matched case intersection.

2.3.5 Statistical analysis

The statistical analyses were divided into two categories, assessing the association of the camera program with changes in; vehicle speeds and road crashes. Vehicle speeds were assessed using speed survey mean and 85th percentile values. Road crashes were aggregated into intersection and non-intersection crashes. Intersection crashes were aggregated into serious (injury or fatality), rear-end, non-rear-end and right angle/right turn into oncoming vehicle crashes. Non-intersection crashes were aggregated into fatal, serious and all crashes. Within these categories the analyses were divided into two further categories, assessing associations with regards to; the implementation of the overall camera program and the implementation of cameras at particular streets/intersections. A total of 32 models were developed, as outlined in Table 2. All outcomes of vehicle speeds and crash counts were aggregated into monthly counts.

The aim of assessing the implementation of the overall camera program was to identify the effect of the camera program on the network generally. For this purpose the case and control streets were aggregated and assessed individually, in order to assess the effect of the camera program on streets that had, or did not have, camera operations. These analyses were relative to the start date of the camera program (Intervention 1) and the change date of mobile operations (Intervention 2).

Model #	Outcome	Type	Intervention	Intervention dates
1	Speed surveys – mean	cases	Overall program	Interventions 1 and 2
2	Speed surveys – mean	controls	Overall program	Interventions 1 and 2
3	Speed surveys – mean	cases	Individual mobile cameras	Begin-date of cameras on each street
4	Speed surveys – mean	controls	Individual mobile cameras	Begin-date of cameras on each street
5	Speed surveys – mean	case-control	Individual mobile cameras	Begin-date of cameras on each street
6	Speed surveys – 85th percentile	cases	Overall program	Interventions 1 and 2
7	Speed surveys – 85th percentile	controls	Overall program	Interventions 1 and 2
8	Speed surveys – 85th percentile	cases	Individual mobile cameras	Begin-date of cameras on each street
9	Speed surveys – 85th percentile	controls	Individual mobile cameras	Begin-date of cameras on each street
10	Speed surveys – 85th percentile	case-control	Individual mobile cameras	Begin-date of cameras on each street
11	Serious road crashes	cases	Overall program	Interventions 1 and 2
12	Serious road crashes	controls	Overall program	Interventions 1 and 2
13	Serious road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
14	Serious road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
15	Serious road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
16	Road crashes	cases	Overall program	Interventions 1 and 2
17	Road crashes	controls	Overall program	Interventions 1 and 2
18	Road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
19	Road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
20	Road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
21	Serious intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
22	Serious intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
23	Serious intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
24	Intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
25	Intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
26	Intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
27	Intersection crashes-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
28	Intersection crashes-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
29	Intersection crashes-non-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
30	Intersection crashes-non-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
31	Intersection crashes-right A/T	cases	Individual fixed cameras	Begin-date of cameras on each street
32	Intersection crashes-right A/T	controls	Individual fixed cameras	Begin-date of cameras on each street

Table 2: Statistical models

The aim of assessing the implementation of cameras on particular streets/intersections was to identify the local effect of introducing individual cameras or camera operations. These analyses were relative to the begin-date for case streets/intersections, or the assigned begin-date for control streets/intersections (i.e. the begin-date of the matched case street/intersection). Case and control streets/intersections were first aggregated and assessed individually, then aggregated and assessed in a case-control study. The latter analysis provides statistical measures of the difference between the implementation of cameras on case and control streets/intersections. However, this comes with the caveat concerning the limitations outlined earlier regarding the selection of the control streets and the spillover effects that may be occurring.

Poisson regression was used for all models, and Pearson deviance was used to correct for over-dispersion. Poisson regression fits a log-linear model to the data, and is therefore most appropriate when the data approximates a log-linear trend. Before-and-after studies typically use the same temporal length both before and after, however are not bound by this. For the assessment of the implementation of camera operations on each individual street/intersection, this seemed a rational approach and the temporal period was set by the minimum amount of pre-data available (60 months for the crash data and 33 months for the speed survey data). For the assessment of the implementation of the overall camera program, the raw data was first assessed. For the crash data a relatively linear trend was observed between Intervention 1 and Intervention

2, therefore a single model was fit for this period. For the speed survey data a bilinear trend was observed during this period, therefore two models were fit. The first model used the same temporal length as the pre-camera speed survey data (33 months), while the second model used the remaining period up to Intervention 2. Accordingly, the crash data model was continuous between Intervention 1 and Intervention 2, while the speed survey model was not.

The outcome (COUNT) for the models was either monthly speed survey results (Models 1 – 10) or monthly crash counts (Models 11 – 32). The former were expressed as the measured speed divided by the speed limit (speed rate). Since speed surveys were not continuous over time, for each month all the speed rates for case streets were averaged, as were all the rates for control streets. Monthly crash counts were normalised to monthly vehicle registrations in the ACT (where monthly values were linear interpolations of annual values), for models considering the overall camera program (1994 to 2012). For all statistical models the following two covariates were assessed; TIME and CAMERA. The variable TIME represents monthly intervals and was a continuous covariate centred on the intervention date being considered. CAMERA was a binary variable which had the value zero prior to the intervention, and one following the intervention. For all models of crash counts, the locations (i.e. individual streets) were treated as subjects, where responses from different subjects were assumed to be statistically independent, while responses within subjects were assumed to be correlated. These models took the form of Equation 1. For the case-control models (Models 5, 10, 15, 20, 23, and 26), the identification of the location as a case or control street was included as an additional binary variable CASE. These models took the form of Equation 2. Interactions between variables were also considered. It should be noted that in all 32 statistical models the outcome considered was based on a period of one month, however in many results figures plotted in the following sections the raw crash counts are plotted with respect to three months, purely for clarity in the figures. SAS version 9.3 was used for all statistical analyses. Statistical significance was measured at the 0.05 level.

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,(\text{TIME} \times \text{CAMERA}) \tag{1}$$

$$\log(\text{COUNT}) = \beta_0 + \beta_1\,\text{TIME} + \beta_2\,\text{CAMERA} + \beta_3\,\text{CASE} + \beta_4\,(\text{TIME} \times \text{CAMERA}) + \beta_5\,(\text{TIME} \times \text{CASE}) + \beta_6\,(\text{CAMERA} \times \text{CASE}) + \beta_7\,(\text{TIME x CAMERA} \times \text{CASE}) \tag{2}$$

3. Results

3.1 Literature review

3.1.1 Evaluations of red light cameras

Appendix B provides a summary of the papers and reports identified in the literature search. Four existing reviews of literature on the effectiveness of red light cameras were identified (Table 3a). The first was a critical review of international literature (Retting, Ferguson and Hakkert, 2003) looking at outcomes of violations and crashes, however no information was provided about how studies were chosen for inclusion in the review, except that they were all controlled evaluations of before and after effects. Only some of the studies included in this review accounted for RTM and spillover effects. The second was a Cochrane Collaboration meta-analysis review (Aeron-Thomas et al, 2005) of violations and different crash types from studies selected based on searches of electronic databases that fulfilled established criteria for inclusion. This review included only studies with controlled before-after designs and controls for regression to the mean (RTM) and spillover effects. The third was a meta-analysis of studies investigating intersection crashes that were identified from searches of electronic databases (Erke, 2009). This review included all designs including uncontrolled before-after studies and only some of the studies included controls for RTM and spillover effects. The fourth was an update and extension of the third review and again involving studies of intersection crashes that were identified from electronic searches, but with no restrictions on design or whether or not RTM and spillover was accounted for (Hoyos 2013). As might be expected there was a significant degree of overlap between the four reviews. Of the 10 papers included in the Cochrane review, 60 percent were shared with the Retting et al (2003) review and all were included in the two most recent reviews which included 14 and 11 new studies respectively. The Retting et al (2003) review included seven studies that were not included in any of the recent reviews.

In addition, the search in the current review of literature found four more recent evaluation studies of red light cameras (Table 3b). Two of these studies were well-designed before-after evaluations of the installation of red cameras (Ko, Geedipally and Walton, 2013; McCartt and Hu, 2014) and the other two involved studies comparing before and after the removal of red light cameras (Porter, Johnson and Bland, 2014; and Pulugurtha and Otturu, 2014). All studies involved controls of some type and all took steps to control for RTM and spillover effects.

The review also identified four evaluation studies of safety cameras that incorporated red light and speed cameras (Table 4). These were included in this review as they were the only evaluations found specifically of safety cameras which combine the two types. Three of these studies involved before and after with control designs (Vanlaar, Robertson and Marcoux, 2014; Kloeden, Edwards and McClean, 2009; Budd, Scully and Newstead, 2011) and one involved description of the change after cameras were introduced and did not include before measures or controls (McKenzie, Kloeden and Hutchinson, 2012). Only two of these studies accounted for RTM effects (Vanlaar et al, 2014; Budd et al, 2011) and only one accounted for spillover effects (Vanlaar et al., 2014)

Overall, each of the reviews concluded that the presence of red light cameras decreased injury crashes especially right angle crashes, however, the extent of the decrease varied between reviews and the extent to which the reviewers took into account RTM and spillover effects. Both

Retting et al (2003) and the Cochrane review concluded that injury crashes were reduced by 25-30%. It is notable however that the conclusion from the Cochrane review was based on a single well-designed study with appropriate controls. In contrast, the most recent reviews concluded either that there was no statistically significant change in casualty crashes (Hoyos, 2013) or a 13 percent increase in such crashes (Erke, 2009). While these reviews were the most comprehensive, including the largest number of studies, unlike the Cochrane review approach, they included all studies regardless of design flaws. Lund et al (2009) criticised the Erke (2009) review and cautioned against accepting its conclusions on the basis that it included a number of poorly designed studies. In response, Hoyos (2013) conducted a revised review that included extensive analysis of the role of potential moderator variables. Hoyos (2013) concluded that when RTM is controlled there is no evidence of significant effects of red light cameras on overall injury crashes, but the presence of red light cameras reduced right angle casualty crashes by 33 percent. The earlier review by Erke (2009) also found a significant, but smaller reduction of 10 percent in right angle crashes once RTM and spillover effects were accounted for. Two recent evaluation studies of the presence of red light cameras (Ko et al, 2013; Pulugurtha and Othuru, 2014) also showed a 24 and 69 percent decrease respectively in right angle crashes. Similarly the three recent A-B/control evaluation studies of red light and speed camera combinations (Vanlaar, et al, 2014; Kloeden et al, 2009; Budd, et al, 2011) all found significant decreases in right angle crashes of over 40 percent. The Cochrane review found no significant effect on right angle crashes but this was based on only two studies with partial control of moderator variables and the Retting et al (2003) review did not look at specific types of crashes. The evidence therefore leads to the conclusion that the presence of red light cameras have a significant benefit of reducing right angle crashes. This conclusion is supported by the nature of the crash that shows the most benefit. We would expect that red light cameras should reduce right angle crashes the most, and the evidence suggests that they do.

On the other hand, almost all of the reviews and studies that included measures of rear-end crashes made the opposite conclusion: rear-end crashes increased by around 40 percent after the introduction of red light cameras (Erke, 2009; Hoyos, 2013; Vanlaar et al, 2014; Pulugurtha and Otturu, 2014) and by around 19 percent for injury crashes (Hoyos, 2013). The exceptions were the Cochrane study which found no significant change across three studies, and two of the red light/speed camera combination evaluations (Kloeden et al, 2009; Budd et al, 2011), none of which accounted for the effects of all moderator variables.

In combination, the above studies indicate that red-light cameras reduce right angle crashes and increase rear-end crashes. While both crash types can be severe, on average right angle crashes are significantly more severe than rear-end crashes mainly as a result of the vehicle's structure and hence occupant protection crashworthiness. For example, in a side impact, the crush distance is small and hence there is little opportunity for ride-down to reduce the severity of the impact. On the other hand, in rear-end impacts, the crush distances are much larger (both the front end of the impacting vehicle and the rear end of the struck vehicle), and with current improved seat back and head rest anti-whiplash design, the severity of the crash would be substantially reduce compared to a side impact.

Red light cameras would also be expected to influence violations in the form of reductions in red light running. The Retting et al (2003) review concluded that these cameras reduced violations by 40 to 50 percent and two recent studies (Ko et al, 2013; McCartt and Hu, 2014) made similar conclusions, with McCartt and Hu (2014) finding that violations involving making very late decisions to run the red light (up to 1.5 seconds after red) were almost eliminated. Again, the

Study	Study design	RTM	Spill over	Outcome	Conclusions
a) Reviews of evaluations: Red light cameras					
Retting, Ferguson & Hakkert (2003)	Review but no detail on study selection	N	Y	Violations (7 studies)	↓ camera sites (22-78%), but ↓ noncamera sites (27-69%) (4 studies) = for control sites (3 studies)
	A-B + controls (15 studies)	some (4)	some (1)	Crashes/injury (8 studies)	↓ camera sites: noncamera (10-39%) (7 studies)
Aeron-Thomas (2005)	Cochrane review A-B+controls (10 studies)	Y	Y	Injury crashes, (5 studies)	↓ camera sites: noncamera/controls (29%)* 1 study ↓ camera sites: noncamera (13%)* (3 studies)
				right-angle (2 studies)	not significant
				rear-end (3 studies)	not significant
				Violations (1 study)	not significant
Erke (2009)	Meta-analysis varied designs (21 studies)	Y	Y	All crashes	↑ camera sites (if control RTM & Spillover effects) (+15%) ↓ camera sites (if no/some controls) (-16-19%)
				Injury crashes	↑ camera sites (if control RTM & Spillover effects) (+13%) ↓ camera sites (if no/some controls) (- 17-25%)
				Right angle	↓ camera sites (if control RTM & Spillover effects) (-10%) ↓ camera sites (if no/some controls) (- 14-49%)
				Rear end	↑ camera sites (if control RTM & Spillover effects) (+43%) ↓ camera sites (if no/some controls) (- 4- +17%)
Hoyos (2013)	Meta-analysis (28 studies)	Y	Y	All crashes	not significant (+6%)
				Injury crashes	not significant (+13%)
				Right angle	↓ camera sites (non-injury: -13%; injury: - 33%)
				Rear end	↑ camera sites (non-injury: +39%; injury: +19%)

Table 3: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
b) Recent evaluations: Red light cameras					
Ko, Geedipally, Walden (2013)	A-B +empirical Bayes (245 cameras, 66 no cameras)	Y	Y	Red light running Right angle Rear end	↓ camera sites (-20%) ↓ camera sites (-24%) ↑ camera sites (+37%)
Porter, Johnson, Bland (2014)	A-B + controls: Cameras removed (4 cameras, 2 local no cameras, 2 outside no cameras)	Y	Y	Red light running	Change 3.1% with cameras to 11.3% after removal Non-treated - 14%
McCartt, Hu (2014)	A-B +controls (4 camera, 4 local no camera, 4 outside no cameras	Y	Y	Violations 1 yr after ticketing commenced	↓ camera sites (-39% for 0.5secs after red) ↓ camera sites (-86% for 1.5secs after red)
Pulugurtha, Otturu (2014)	A-B -C: Cameras removed, empirical Bayes (32 cameras)	Y	Y	intersections with reduced crashes intersections with reduced rear end/ sideswipe crashes	↓ camera sites (-50% for before - after cameras) ↓ camera sites (-16% for before - termination of cameras) ↑ camera sites (+>50%)

Table 3 cont'd: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
Vanlaar, Robertson, Marcoux (2014)	A-B +controls Time series (4 cameras, 4 local no cameras), no cameras comparison)	Y	Y	Right angle Rear end Speed	↓ camera sites (-46%) ↑ camera sites (+42%) No change
McKenzie , Kloeden, Hutchinson, 2012)	Change after cameras introduced (21 cameras)	N	N	Red light Violations Speed violations	↓ over 12 months (slow change) ↓ over 12 months (rapid change, especially higher range speeding)
Kloeden, Edwards, McClean (2009)	A-B +controls (1988: 8 cameras, all no camera sites in Adelaide) (2001: 24 cameras, all no camera sites)	?	N	Casualty crashes Right angle Rear end	1988 study: ↓ camera sites (-21%) 2001 study: no change 1988 study: ↓ camera sites (-491%) 2001 study: no change No change
Budd, Scully, Newstead (2011)	A-B+controls (76 camera sites: Camera activated, camera not activated)	Y	N	Casualty crashes Right angle/right turn Rear end	↓ camera sites (-47% direction of travel monitored by camera; -26% for all) ↓ camera sites (-44%) No change

Table 4: Summary of literature on red light and speed camera evaluations

Cochrane review failed to find evidence of changes in violations due to red light cameras, but only one study included this measure. One study (Porter et al, 2014) studied the effect of removing red light cameras and found an increase in violations of around 8 percent after they were removed.

3.1.2 Evaluations of speed cameras

The literature search identified three reviews of speed cameras generally (fixed and mobile). This included a meta-analysis by Pilkington and Kinra (2005), which reviewed 14 controlled trials and observational studies and a systematic, narrative review by Thomas, Srinivasan, Decina and Stapin (2008) containing 13 studies chosen because of their methodological strengths. The most recent review was a Cochrane Collaboration review by Wilson, Willis, Hendrika, Brocque and Bellamy (2010), which examined the use of speed cameras for the prevention of road injuries and fatalities. The three reviews overlapped considerably. The Pilkington and Kinra (2005) and Thomas et al. (2008) reviews shared seven studies and the Cochrane review contained all of the studies in the Thomas review and 64.3 percent of those in the Pilkington and Kinra review as well as 20 additional studies, most of which were more recent. The Cochrane review was therefore the most comprehensive and became the basis of the current review.

Overall, the Cochrane review concluded that in the presence of speed cameras, average speed reduced by between 1 and 15 percent and the proportion of vehicles speeding by 14 to 65 percent compared to controls. They also concluded that in the vicinity of cameras, all crashes reduced by 8 to 49 percent and fatal and serious injury crashes by 11 to 44 percent, leading to an overall improvement of between 8 to 50 percent compared to control sites. This provides a good appraisal of the existing well-designed evaluations of speed cameras, however the review did not distinguish fixed and mobile cameras. As the action of these two types of cameras is quite different, the current review included the studies in the Wilson et al review but separated them into those looking at each type of camera in order to determine the separate effects of each type. Additional studies published since the Cochrane review were also included in this analysis.

3.1.3 Evaluation of fixed speed cameras

The Cochrane review (Wilson et al., 2010) included 17 studies of the effectiveness of fixed speeding cameras which were judged to have adequate study designs. In addition to those included in the Cochrane review, the electronic searches for this review identified two additional more recent studies so the review for this report included 19 studies of fixed speed cameras (Table 5).

The studies included in the review involved study designs with pre/post camera implementation measures and control or comparison sites (78.9%) or interrupted time series analysis (21.1%). Using the Cochrane collaboration criteria which require random assignment of treatment and controls, these studies designs would be classified as only of moderate methodological quality. Around half addressed the problem of potential bias due to RTM (52.6%). None of the studies formally addressed spillover effects, although it could be argued that the inclusion of appropriate control or comparison groups provided an opportunity to assess these effects by showing the extent of additional change due to the presence of the camera itself. Around half of the studies looked at the effect of cameras on both speeding and crashes (52.6%), with half of the remainder looking at effects only on speed (21.1%) or crashes (26.3%). The studies were conducted in a

broad range of countries including Australia, Canada, Germany, Spain, Finland, UK, Hong Kong, Netherlands, New Zealand and USA.

All studies showed benefits of fixed speed cameras for reducing speed in the location of the cameras. Overall, the studies showed reductions in mean speed in the vicinity of cameras of 3 to 10 percent or 2 to 8kph reductions in mean speed. Studies that included control of RTM effects showed similar reductions in speed. Of the five studies that looked at the proportion of speeding vehicles in the vicinity of fixed cameras, all showed reductions but there was a very large variation between studies, ranging from 10 to 70%, although the two studies that controlled for RTM showed similar reductions of around 30 percent. Twelve studies measured injury crashes and all found reductions following implementation of fixed cameras ranging from 7 to 32 percent. In studies that controlled for RTM effects, the reductions tended to be greater (20-56%). Only five studies measured fatal crashes specifically, and again all showed reductions after implementation of fixed cameras ranging from 11 to 89 percent.

The greatest effects of fixed cameras are likely to be in their immediate vicinity. In some studies, the effects of cameras may have been underestimated as the effects were measured 2km from the treatment area (Chen et al, 2002; Makinen, 2001) although studies that directly measured distance halo effects showed decreases in road safety benefit with increased distance from the fixed camera site (Mountain, et al., 2004; Hess and Polack, 2003; De Pauw et al, 2013). Figure 3 shows the 85th percentile speeds around a speed camera in NSW and shows that speeding drivers slow for the cameras and speed up again after the camera, i.e. deliberate slowing for the camera (Job 2014).

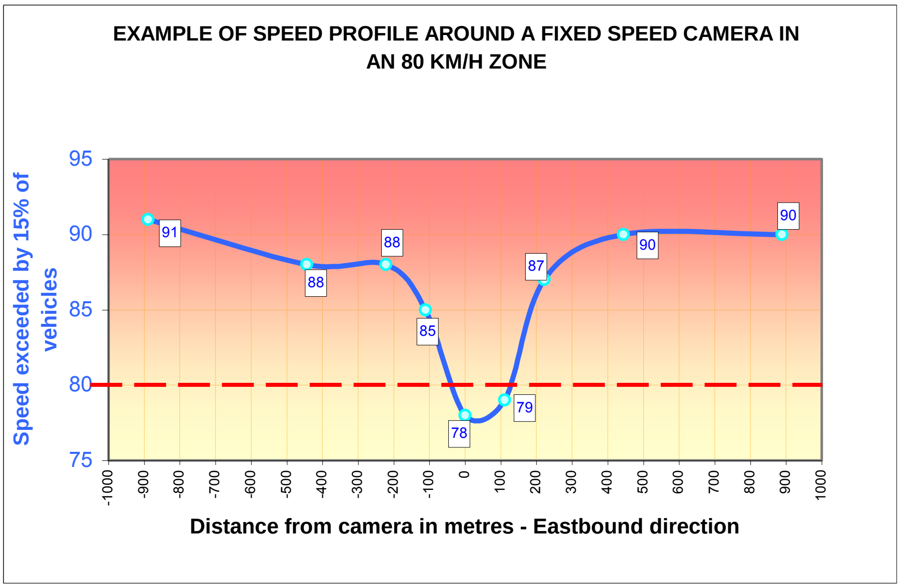

Figure 3: 85th percentile speeds recorded on approach and departure around a sign-posted speed camera in in an 80km/h speed limit in New South Wales

The duration of the benefit of fixed cameras over time was examined in some studies, with findings of fatal crash reductions for up to two years (ARRB, 2005; Perez et al, 2007; Makinen, 2001), but Retting, Kyrychenko and McCartt (2008) showed that positive speed reductions diminished when the enforcement period ended.

Study	Design	RTM	Spillover	Outcome	Conclusions
ARRB Group Project Team (2005)	A-B+Control	N	N	Speed fatal crashes injury crashes	↓ 6.3 km/h mean speeds, 5.8kh/h at 2 years ↓ 70% exceeding speed limit, maintained at 2 years ↓ 86% exceeding speed limits by at least 10 km/h, 88% at 2 yrs. ↓ 22.8% all fatal and injury crashes ↓ 89.8% fatal crashes ↓ 20.1% injury crashes at 1 yr
Diamantopoulou, Corben (2002) (2 reports)	A-B+Control.	N	N	Speed reduction	↓ 3.4% speed reduction ↓66% drivers exceeding the 80km/h posted speed limit ↓ 79% drivers speeding over 90km/h ↓ 76% drivers speeding over 110km/h ↓ 13% fatal crashes ↓ 10% serious injury ↓ 7% overall injuries
Chen, Meckle, Wilson (2002)	A-B+Control	Y	N	crashes Mean speed	↓2.8km/h mean speed at monitoring site 2km from treatment area ↓14% expected crashes at photo-radar locations ↓ 19% at non-Photo-Radar locations ↓ 16% along the study corridor as a whole
Lamm, Kloeckne (1984)	A-B+Control	N	N	Median speed crashes (injury and fatal)	↓ 30kph median speed ↓ 42kph 85th percentile speed ↓ 18 times in injury crash frequency ↓ fatal crashes
Perez, Mari-Dell'Olmo, Borrell (2007)	Interrupted time series	N.	N	crashes injured	RR= 0.69 (95% CI = 0.54 - 0.89) crash 2 years post implementation RR= 0.70 (95% CI = 0.53-0.92) injury = comparison sites.
Makinen (2001)	A-B+Control	N	N	speeding crashes	↓ 8% speeding at 80kph limit in year one, further ↓2% in year two. ↓ 5% speeding at 100km/h in year one, further ↓2% in year two. Distance halo of 3km upstream and 2km downstream. no change in crashes compared to controls

Mountain, Hirst, Maher (2004)	A-B+Control	Empirical Bayes	N	speeds	↓4.4mph mean speeds ↓5.9 mph 85th percentile speeds ↓35% percentage exceeding the speed limit. ↓ 25% personal injury crashes, 11% fatal and serious at 500m post camera ↓ 24% personal injury crashes, 13% fatal and serious at 1km post camera
Hess (2003) (2 reports)	Interrupted time series	Y	N	Injury crashes	↓ 45.74% weighted injury crashes in 250m from camera sites ↓ 20.86% injury crashes in 2000m from the camera.
Gains, Heydecker, Shrewsbury, Robertson (2004) (3 reports)	A-B+Control	empirical Bayes	N	speed Fatal/serious injury injury crashes	↓ 6% mean speed ↓7% 85th percentile speed ↓ 30% exceeding speed limit ↓43% exceeding speed limit > 15 mph ↓42% fatal/serious injury ↓ 24% injury crashes
Highways Agency's London Network and Customer Services (LNCS) (1997)	A-B+Control	N	N	crashes (fatal, serious, and injury)	↓ 12.4% all crashes. ↓69.4% fatal crashes pre/post and 55.7% relative to controls. ↓ 25% serious injuries ↓ 31% fatal/serious crashes combined.
Hung-Leung (2000)	A-B+Control	N	N	speeding cars injury, fatal crashes	↓ 65% speed > 15 km/h over limit. ↓ 23% injury crashes pre/post; ↑32% in the control group. ↓66% fatal crashes.
Oei (1996) (2 reports)	A-B+Control	N	N	speed crashes	↓3 - 5kph mean speed ↓3-8kph 85 percentile speed ↓ 10% to 27% drivers speeding over limit ↓ 35% crashes pre/post and control
Elvik (1997)	A-B+Control	Y	N	injury crashes	↓20% injury crashes
Tay (2000)	A-B+Control	N	N	crashes speed	↓ 9.17% all crashes ↓ 32.4% serious injury = speed, pre/post
Shin, Washington, van Schalkwyk (2009)	A-B+Control	Y	N	crashes	↓44 to 55% crashes ↓ 46-56% injury crashes = rear-end crashes

Retting, Kyrychenko, McCartt (2008)	A-B+Control	N	N	speed	↓ 5mph mean speeds pre/post no change control site ↓ 13% exceeding speed limit after speed camera enforcement suspended both increased.
Retting, Farmer, McCartt (2008)	A-B+Control	N	N	speed	↓10% mean speed ↓ 70% > 10 mph above the speed limits (with warnings and camera enforcement), ↓ 39% > 10 mph above the speed limits (with warning signs only) ↓ 16% on 40 mph residential streets (no warnings or speed cameras).
De Pauw, Daniels, Brijs, Hermans, Wets (2013)	A-B	N	N	injury crashes	↓ 29% serious/fatal injuries in 500m of camera
Novoa, Perez, Santamarina-Rubio, Mari-Dell'Olmo, Tobias	Time series analyses	N	N	Crashes injuries	↓ 30% and 26% on enforced and non-enforced arterial road respectively.

Table 5: Summary of literature on fixed speed camera evaluations

Only eight of the studies mentioned the speed limit at the fixed camera sites. In five studies the cameras were on high speed roads (80+ kph) and the remainder were in the 50-80 kph regions. There were no obvious patterns of effects on speeding or crashes on different speed limit areas. Novoa et al (2010) found benefits of fixed speed cameras on a high speed beltway, but not on lower speed arterial roads, suggesting that there may be influences of speed limit on the effectiveness of fixed cameras.

3.1.4 Evaluation of mobile cameras

A total of 19 of the studies included in the Cochrane review (Willis, et al., 2010) involved an evaluation of mobile cameras. The electronic searches found one further evaluation study (Moon and Hummer, 2010) so the current review involved 20 studies in total (Table 6).

As for the fixed camera evaluations, the majority of studies included involve a pre/post implementation with control design (80%) with the remainder an interrupted time series design. Few studies (25%) included control for RTM effects although this may not be as great a concern for mobile cameras which by definition are moved around so they may not necessarily be located only in locations of high concern for road safety. Spillover effects were also managed indirectly by inclusion of control locations in all studies. Most of the evaluations looked at either speed (40%) or crash (35%) outcomes and only 25% looked at both. Evaluations were from a broad range of countries including Australia, Canada, Denmark, UK, Norway, New Zealand and the USA.

Across evaluation studies, consistent benefits were found for mobile speed cameras. Seven studies cited reductions of mean speeds in the location of mobile cameras with effects ranging from around 1 to 6kph. There was a very large range in the proportion of vehicles exceeding the speed limit, from 10 to 70 percent across five studies. Similarly, the reductions in injury crashes also varied considerably between the six studies that included this measure, from 21 to 71.3 percent although reductions in fatal crashes were more consistent (31-44% across three studies).

As might be expected, there is evidence that the effect of mobile cameras extend well-beyond the immediate vicinity of the camera. Cairney (1988) found effects of reduced speed for up to 14 km downstream of mobile cameras. The study by Newstead and Cameron (2003) measured crashes within 2 kms, 2-4kms and 4-6kms of camera sites and found a decreasing effect on crashes with increasing distance away from cameras, although even at the greatest distance, there were still 10.7 percent reductions in all severity crashes.

A number of studies looked at the time halo or duration of the effect of mobile cameras. Time halo effects ranged from at least two days of continued lower proportion of speeding vehicles (Armour, 1984), three days of lower mean speeds after a single day of enforcement (Hauer and Ahlin 1982) to up to eight weeks of lower mean speeds (Vaa, 1997). On the other hand, Legget (1988) found no time halo effect on mean speed.

The effects of speed cameras may vary with the speed limit of roads, however most studies (55%) failed to mention the speed limit on which the cameras were placed. In seven studies (35%) mobile cameras were sited on higher speed roads of 80kph or greater. Only two studies involved mobile cameras on roads of 60kph or lower.

In the majority of studies, mobile cameras were marked with warning signs to alert drivers to their presence. Two studies looked at the effect of covert or overt placement of mobile cameras. Diamantopoulou and Cameron (2002) compared the two strategies of camera use and concluded that the best effect on injury crashes occurred when a mix of overt and covert cameras were in

Study	Design	RTM	Spillover	Outcome	Conclusions
Amour (1984)	A-B +Control	N	N	speeders	↓ 70% proportion vehicles exceeding the speed limit with camera Time halo effect ≥ two days
Cairney (1988)	A-B +Control	N	N	Mean speed	↓ 2-3kph mean speed at camera and control sites. Distance halo up to 14km downstream with aerial surveillance
Kearns & Webster (1988)	A-B +Control	N	N	crashes	↓ 23% crashes at camera sites during the day, ↓ 21% at other times, compared to controls
Newstead, Cameron, Leggett (2001)	A-B with comparison group	N	N	fatal crashes	↓ 31% fatal crashes. ↓ 11% total crashes outside of metropolitan Brisbane.
Newstead, Cameron (2003) (2 reports)	A-B +Control	N	N	No. of crashes (fatal and injury)	↓ 45% fatal crashes in 2km of camera sites ↓ 31% hospitalisation crashes in 2km of camera sites ↓ 39% medically-treated crashes in 2km of camera sites ↓ 19% other injury crashes in 2km of camera sites ↓ 21% non-injury crashes in 2km of camera sites All crashes: ↓ 17.5% all severity crashes in 2km of camera sites ↓ 11.4% all severity crashes in 2 - 4km of camera sites ↓ 10.7% all severity crashes in 4 - 6km of camera sites
Cairney, Fackrell (1993) (2 reports)	A-B +Control	N	N	Median traffic speed	↓ 5kph median speeds reduced sharply by 5 km/h on camera roads but then little change despite intensified enforcement, control sites no change
Leggett (1988)	A-B +Control	N	N	Mean speed No. of crashes (injury or fatal)	↓ 3-6kph mean speeds compared to pre, only during enforcement no time halo effect. ↓ 58% serious injury crashes. ↑ 33% serious injury during non-enforced times of day
Cameron, Cavallo, Gilbert (1992) (2 reports)	Interrupted time series	N	N	No. of injury crashes	↓ 30% injury crash on 60km/h city roads with camera over12mths ↓ 20% injury crash on rural 60km/h zones with camera over 12 mths ↓ 14% injury crash on rural 100km/h zones with camera over 12 mths
Diamantopoulou, Cameron (2002) (3 reports)	A-B +Control	N	N	No. of injury crashes	↓ 71.3% injury crashes within 4 days of presence of enforcement ↓73.9% injury crashes with mix of overt/covert enforcement in use.
Chen, Wilson, Meckle, Cooper (2000)	A-B +Control	Y	N	No. of speeding vehicles No. of crashes	↓ 31% speeding vehicles pre/post cameras ↓ 12% speeding at control sites ↓ 17% reduction in daytime crash fatalities

Hauer, Ahlin (1982)	A-B +Control	N	N	Average speed	time halo for three days with1 day enforcement, for six days after five days enforcement
Agustsson (2001)	A-B +Control.	N	N	Mean speed % drivers exceeding spee limit by 10km/hr No. of injury crashes	↓ 2.4 km/ h mean speed ↓ 10.4% exceeding speed limit ↓ 4.5% exceeding the speed limit by 10km. ↓ 22% injury crashes in first year, ↓ 20% in second year post intervention compared to pre
Jones, Sauerzapf, Haynes (2008)	A-B +Control	Y	N	No. of crashes	↓ 19% all crashes at camera sites ↓ 44% for fatal and serious crashes at camera sites .
Christie, Lyons, Dunstan, Jones (2003)	A-B +Control	N	N	No. of injury crashes	↓ 50% injury crashes sustained for two years at camera sites
Goldenbeld, van Schagen (2005)	A-B +Control	Y	N	speeds speeders over the targeted speed limit	↓ 12% speeders at camera sites, ↓ 5% speeders at controls ↓ 21% injury crashes for enforcement period compared to pre
Vaa (1997)	A-B +Control	N	N	Average speed No. Speeding drivers	↓ 0.9 to 4.8kph mean speeds time halo effect of up to eight weeks ↓ 10% speeding drivers
Keall, Povey, Frith (2002) (2 reports)	Interrupted time series	N	N	Mean speed 85th percentile speed No. of injury crashes	↓1.3kph mean speed over 2 years ↓ 4.3kph 85th percentile speeds on open roads ↓ 11% all crashes compared to control areas ↓ 19% injury crashes additional effect for covert cameras period compared to overt cameras ↓ 17% for crashes at camera sites compared to controls ↓ 31% for injury crashes
Cunningham, Hummer, Moon (2005)	A-B +Control	Y	N	crashes, speeds	↓ 12% total crashes in camera corridors compared to expected ↓0.91 miles/hr mean speeds at camera sites, control sites no change ↓ 0.99mph in 85th percentile speeds, controls no change.
Retting, Farmer (2003)	A-B +Control	N	N	Mean speed Proportion of vehicles exceeding the speed limit by more than 10mph	↓ 14% mean speeds at camera sites compared to control sites. ↓ 82% exceeding the speed limit by more than 10mph
Moon, Hummer (2010)	A-B with comparison sites.	Y	N	No. of crashes	↓ crashes in camera sites pre/post.

Table 6: Summary of literature on mobile speed camera evaluations

place, although the additional reductions in injury crashes were not pronounced. A study by Keall, Povey and Frith (2002) compared the effect on injury crashes of a period of overt camera use with a period where camera use was covert and found an additional 19 percent reduction in injury crashes with covert use of cameras. It should be noted however that covert camera use occurred following overt use so some of the effect may be due to the fact that drivers were aware the cameras were in operation.

3.1.5 Point-to-point cameras

The literature for this camera system type is sparse. There are three articles discussing the benefits of point-to-point in terms of reduced speeds and crash reduction. However, only one study by Montella et al (2012) was adequate in its design in terms of providing a rigorous statistical evaluation of a system installed in Italy (Table 7). The system is composed of steel gantries at the section entrance and exit, with one camera and inductive loop detectors for each lane. Data were collected and processed by police at a central monitoring station.

The study analysis period was over 9 years, with a before period of 6.5 years and an after period of 2.5 years. The number of crashes per kilometre in the before period was 4.2, which decreased to 2.2 during the after period. A reduction in crashes per kilometre was observed for all crash types.

The authors used an empirical Bayes methodology evaluation which accounted for regression to the mean, changes over time not due to the treatment being evaluated and overcoming exposure crash rates in normalising volume differences.

The evaluation of the point-to-point cameras revealed a total crash reduction of 31.2%. The greatest crash reductions were observed for 55.6% severe crashes and 43.3% crashes at curves. However they noted an effectiveness decrease over time, i.e. 39.4% total crashes for the first semester and 18.7% in the fifth semester after activation. The authors suggest that the decrease system effectiveness over time may have been due to a reduction in speed enforcement and driver adaptation. They suggest that higher compliance to the speed limits might be achieved by a better strategy of communication and information to the road users and a speed limit management strategy synergic between the highway agency and the Police who actually manage the commitments of fines.

Study	Design	RTM	Spillover	Outcome	Conclusions
Montella, Persaud, D'Apuzzo, Imbriani (2012)	Empirical Bayes observational before-and-after study. Crash data disability lasting at least 15 days.	Y	N	No. of crashes	↓ 31.2% total crash The greatest crash reductions were observed for ↓ 55.6% severe crashes and 43.3% crashes at curves, effectiveness decreased over time ↓ 39.4% total crashes - first semester ; ↓ 18.7% - fifth semester after activation.

Table 7: Summary of literature on point-to-point speed camera evaluations

3.2 Review of community attitudes to speeding

This section summarises the results of the Community Attitude surveys for ACT residents over 1995 to 2011. The detailed collated results are shown in Appendix C.

3.2.1 Perceptions of changes in enforcement

The year following the introduction of mobile speed cameras was associated with an increase in the percentage of ACT residents who perceived that the amount of speed enforcement had changed over the past two years (Figure 4). In the surveys conducted between 1999 and 2001 more than two-thirds of survey participants reported that enforcement had increased and in 2001 there was a clear fall in the percentage reporting no change in enforcement. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years, perception of increased speed enforcement remained high. Interestingly, the introduction of fixed speed cameras in 2007 was not associated with increased perception of more enforcement activity. However, this question only has a few broad options to choose from and may likely have been too coarse to determine accurate perceptions of change in enforcement.

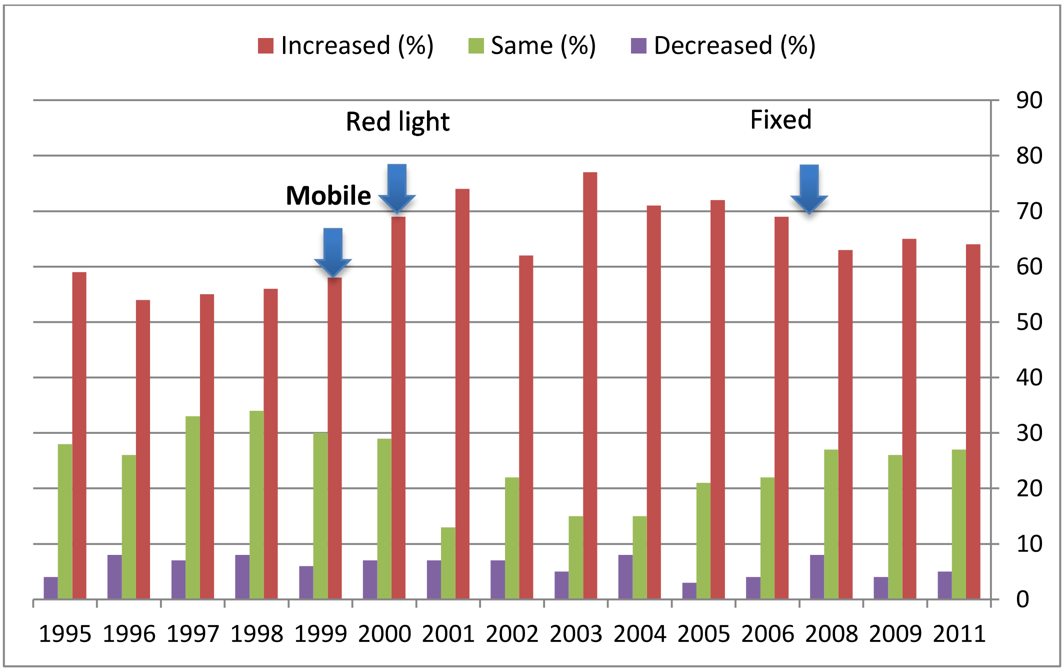

Figure 4: Perceptions of whether the amount of speed limit enforcement has changed over the last two years

The reported likelihood of being booked for speeding varied considerably across the survey years (Figure 5). Reports of being booked in the last two years were lowest in 1999 when mobile cameras were introduced, but between 1999 and 2003 the percentage of survey participants reporting being booked for speeding increased more than two-fold to more than one in four participants. Reports of speeding infringements decreased again to 2008, but following the introduction of fixed speed cameras, there was some increase in reported infringements to 2011. Reports for the last 6 months showed similar patterns. Notably, reports of being booked in the last 6 months were lowest in 2004 compared to all other years, and were lowest compared to other jurisdictions as well.

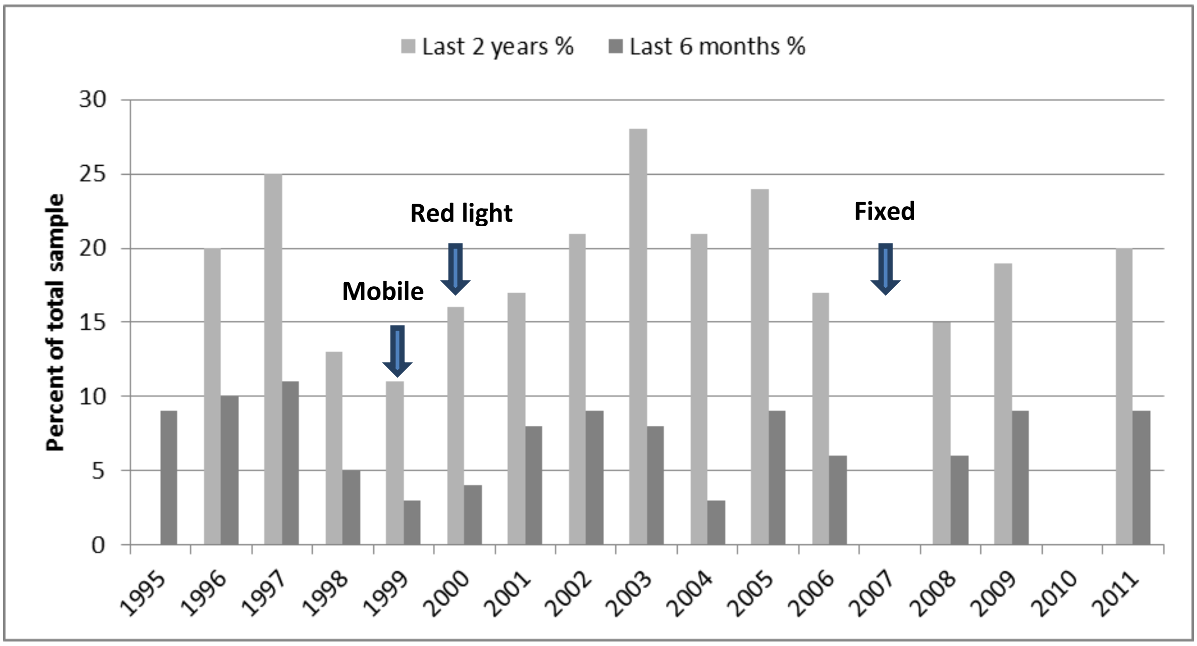

Figure 5: Incidence of being booked for speeding in the last 2 years and the last 6 months

3.2.2 Perceptions of acceptable and actual speed tolerances

ACT residents believe that the median acceptable speed in 60kph urban zones should be around 65 km/h (Table 8). Interestingly, this is almost identical to the median of their reported actual speed. Neither of these judgements showed much variation across the seven surveys in which these questions were asked. Around one-third of Survey participants across all surveys between 2003 and 2011 agreed that there should be no tolerance of speeding in 60kph zones. However in surveys before 2003 nearly half of respondents felt that there should be no tolerance for speeding in 60kph zones. This was coincident with the introduction of the first mobile and red light cameras. It is possible that the strong community response for no tolerance for speeding in 60kph zones that preceded the introduction of cameras may have played a role in their introduction. However, community acceptance of no tolerance for speeding clearly decreased a few years after the first wave of the introduction of cameras so by 2003 and subsequent years, there has been considerably lower support for no tolerance of speeding in these zones.

For 100kph zones, acceptable speeds for respondents were between 105 and 110kph and actual reported speeds were very similar, or higher (Table 9). There were no consistent patterns for judgements of acceptance of no tolerance for speeding with between one in four and one in three respondents supporting no tolerance. In contrast, between 2002 and 2011 there has been notable change in ACT residents perceptions of no tolerance of actual speeding. Where in 2006 almost no ACT respondent perceived no tolerance for speeding over 100kph and this was lower than all other jurisdictions, by 2011 the situation had reversed. Over one in five respondents felt that there was no tolerance for speeding in 100kph zones in the ACT which was significantly higher than other jurisdictions.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1995		34		
1996		42		
1997		49		
1998		49		
1999 **Mobile**		49		
2000 **Red light**		38		
2001		44		
2002		51	64.9	15
2003	64.2	33	65.4	10
2004	65	28	65	13
2005	64	33	64	12
2006	64	32	64	15
2008 **Fixed**	64	36	65	21
2009	65	34	64	22
2011	64	31	64	20

Table 8: Perceived acceptable and actual speed in 60kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1996		27		
1997		23		
1998		36		
1999 **Mobile**		28		
2000 **Red light**		25		
2001		26		
2002		35	109.2	10
2003	106.8	22	108.7	6
2004	110	23	109	8
2005	109	20	109	7
2006	107	18	107	5
2008 **Fixed**	105.5	28	108	14
2009	110	23	107.9	15
2011	106	25	106	21

Table 9: Perceived acceptable and actual speed in 100kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

3.2.3 Attitudes to speeding, speed enforcement and penalties

ACT survey respondents attitudes to speed-related issues did not change greatly across the 1999 to 2011 period for most questions. The majority of respondents (>85% in all years) viewed speed limits as generally reasonable. Similarly, almost all respondents (>89% in all years) agreed that an accident at 70kph would be more severe than one at 60kph. Notably, fewer felt that they would be more likely to be in an accident if they increased their speed by 10kph, but there was no pattern of change across the survey years on this question.

Two questions showed some evidence of attitudinal changes between 1999 and 2011 that may be associated with safety camera use in the ACT. Associated with the introduction of the mobile and red light cameras in 1999 and 2000 there has been a decrease in respondents agreeing that exceeding the speed limit is okay if you are driving safely. The percentage increased again for the 2008 survey following the introduction of fixed cameras, but decreased to the lowest level in 2009 and remained fairly low in 2011. In contrast, there was no change in the percentage of respondents viewing speeding fines as revenue raising associated with mobile or red light cameras, but 2008 and 2009 following the introduction of fixed cameras saw the highest percentage of respondents viewing speed fines as revenue raising (Figure 6).

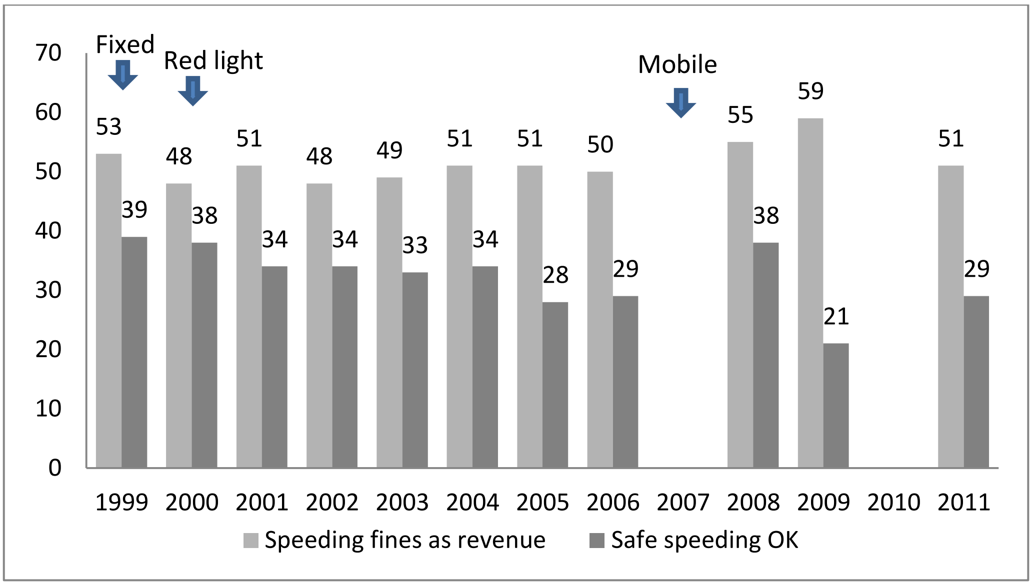

Figure 6: Percentage of ACT resident agreeing with the statements 'Fines for speeding are mainly intended to raise revenue' and 'I think it is okay to exceed the speed limit if you are driving safely'

Questions were asked about their views of the level of enforcement and severity of penalties from the 2003 survey (Figures 7 and 8). Increasing percentages of ACT residents believed the level of enforcement and severity of penalties should increase for 2003 and 2004, but this decreased in the next two years. In the survey following the introduction of fixed speed cameras the percentage of respondents who felt enforcement should increase grew to nearly half and this remained high to the most recent survey in 2011. For severity of penalties, there was not much change before and after the introduction of fixed cameras, although the most recent survey had the highest percentage of respondents reporting that they should be increased.

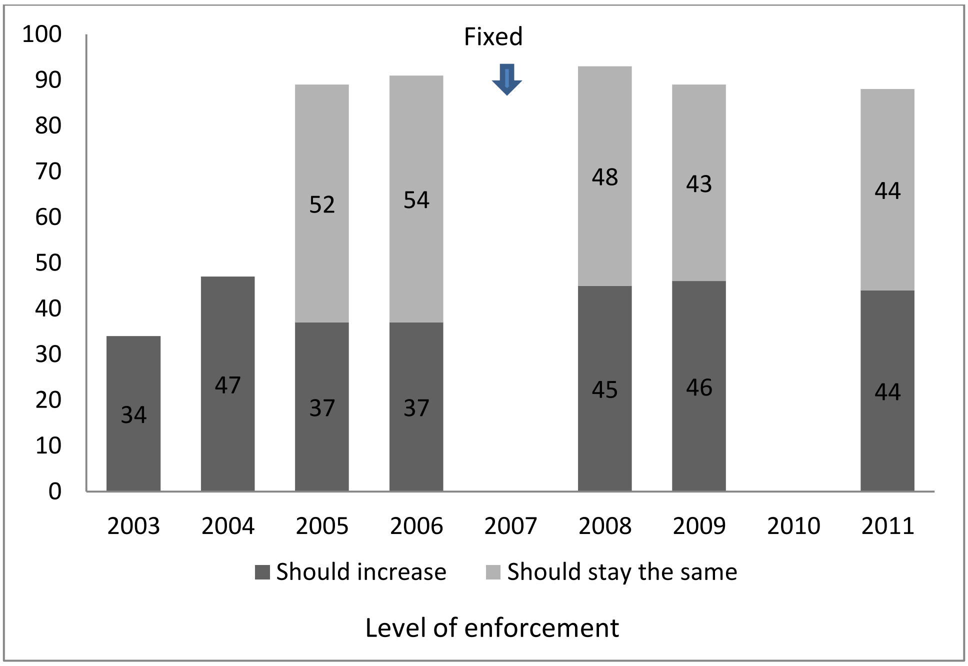

Figure 7: Percentage of ACT residents responding that the level of enforcement should increase or stay the same

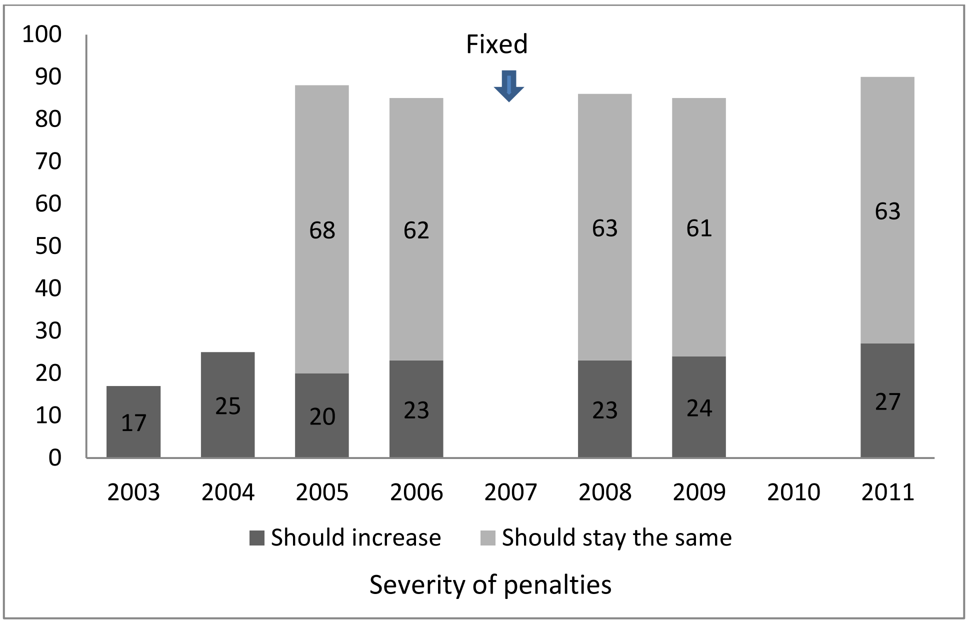

Figure 8: Percentage of ACT residents responding that the severity of penalties should increase or stay the same

The patterns of approval for lowering residential speed limits from 60 to 50 kph show an association with the introduction of mobile and red light cameras (Figure 9). Since 2000 when both types of cameras were in operation, there has been a clear increase in the percentage of survey respondents who showed approval for such a change so that by 2003 the greater majority of respondents were in agreement.

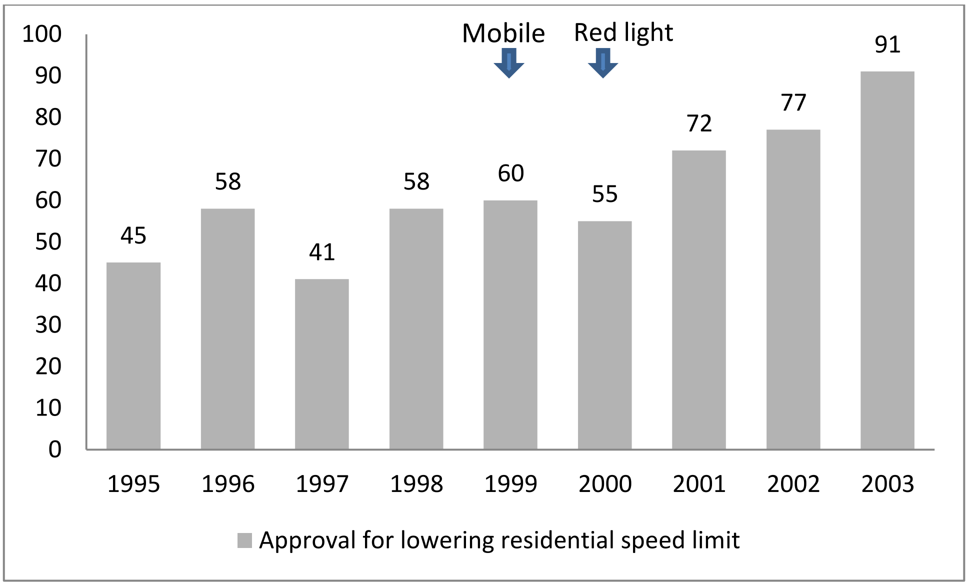

Figure 9: Percentage of ACT residents approving (somewhat and strongly) a potential decision to lower the speed limit in residential areas to 50kph

3.2.4 Changes in self-reported driving speed

Following the introduction of mobile and red light cameras a larger percentage of ACT respondents reported that their driving speed had decreased over the past two years, however since 2008 this effect has decreased somewhat with around three-quarters of drivers reporting no change to their speed (Figure 10).

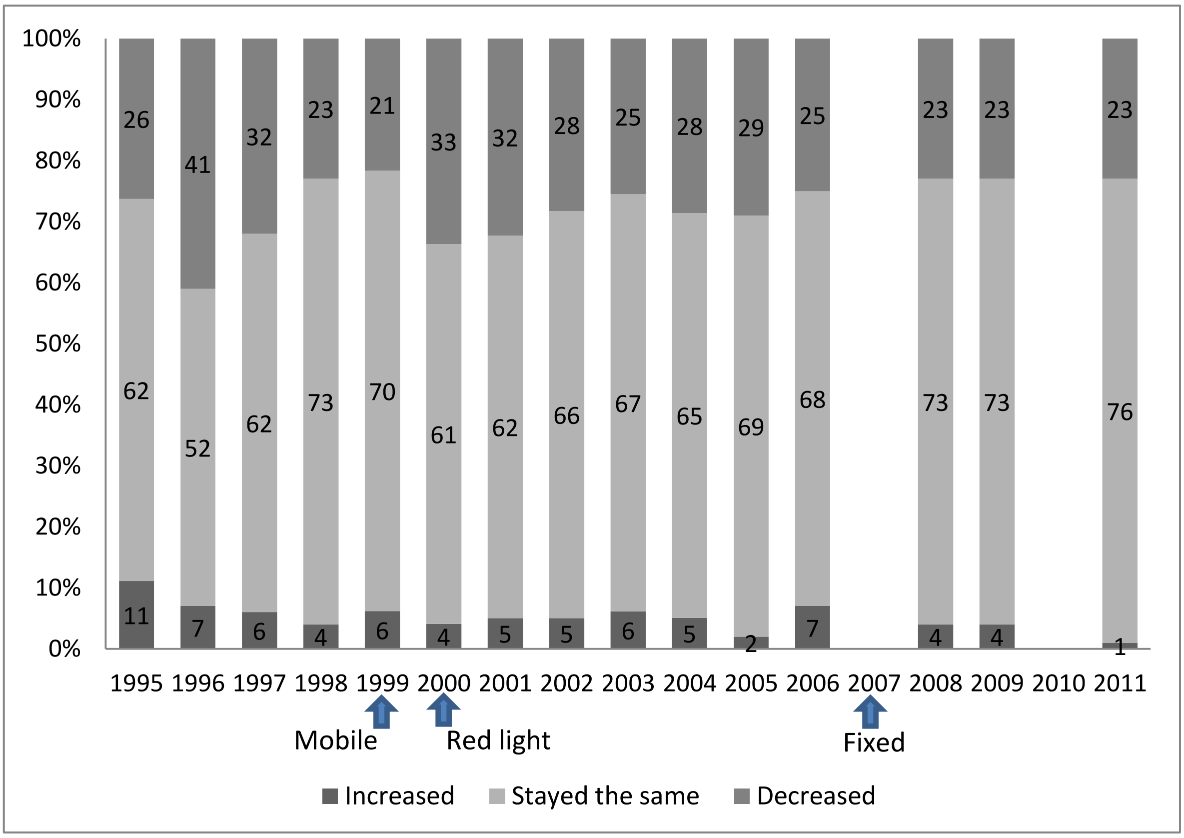

Figure 10: Reported changes in driving speed over the last two years

3.3 Infringements data

The infringements data are expressed as the proportion of infringements issued to vehicles checked, and data were available for the 14 year period from 1999 to 2012 (inclusive). It is noted that all fixed and mobile camera operations data were included, not only those related to the case and control streets/intersections selected for this study. Infringement rates for fixed and mobile cameras over the period are plotted in Figure 11. For the mobile cameras, mean infringement rates were up to 10% initially, however dropped to an average long-term value of approximately 0.6% during a period extending to approximately late 2002. For the fixed intersection cameras, mean infringement rates reduced rapidly to less than 0.2%. It is noted that due to data issues, the fixed camera infringement rates are not plotted beyond 2008 in Figure 11.

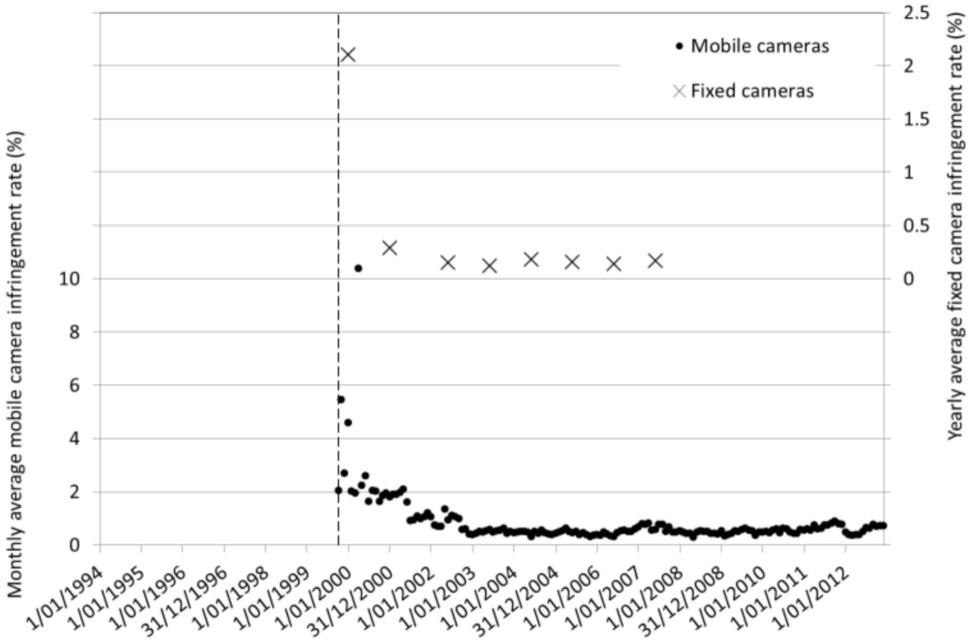

Figure 11: Infringement rates for fixed and mobile cameras

3.4 Speed survey analyses – effects of mobile cameras on mean vehicle speeds (Models 1 to 5)

Speed surveys were assessed for the 95 street locations for the 16 year period from 1997 to 2012 (inclusive). A total of 1,758 speed surveys were identified in the period, including 1,032 that were undertaken on case streets and 726 on control streets. The speed survey results are plotted for case and control streets, and compared with mobile camera operations on each individual street, in Appendix D. Considering an outcome of monthly averaged values of the mean survey speed divided by the speed limit, the statistical models are tabulated in Tables 10 to 12. Models 1 to 4 are plotted in Figures 12 to 14. In Models 1 and 3, trends in mean speeds for case streets showed increases in the pre-intervention period (however in Model 3 the value was very small), and decreases in the post-intervention periods, where the intervention was Intervention 1 (Model 1) or the camera begin-date (Model 3). Trends in mean speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 1). Mean speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 2 and 4). CAMERA

estimates were generally not statistically significant, indicating changes that occurred in mean speeds at the intervention times were not generally significant (Tables 10 and 11).

Annual trend magnitudes for case streets were an increase of 0.7% and decrease of 3.2% prior to and following Intervention 1, and an increase of 1.7% and decrease of 0.9% prior to and following Intervention 2. An increase of 0.1% and decrease of 1.8% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 2.4% and decrease of 0.8% prior to and following Intervention 1, and an increase of 0.1% and decrease of 0.2% prior to and following Intervention 2. A decrease of 3.9% and decrease of 3.8% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 12. The estimate for the CASE variable was highly significant, likely a result of the fact that mean speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The speed survey results for case streets are compared with the mobile camera infringement rates in Figure 15, where the change from a decreasing trend in speeds to an increasing trend approximately corresponds to the beginning of the long-term infringement rate of 0.6%. The regression models for case and control streets (Models 1 and 2) are compared in Figure 16. Mean speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The mean speeds on all streets were predominantly below the speed limit for the full time period.

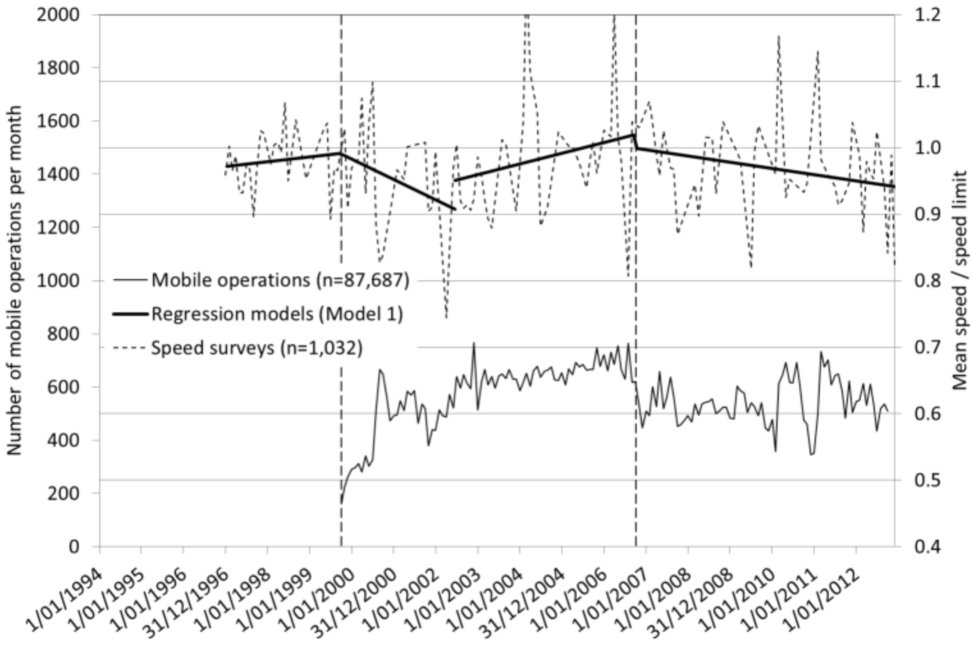

Figure 12: Mean speed survey data relative to the overall camera program – case streets

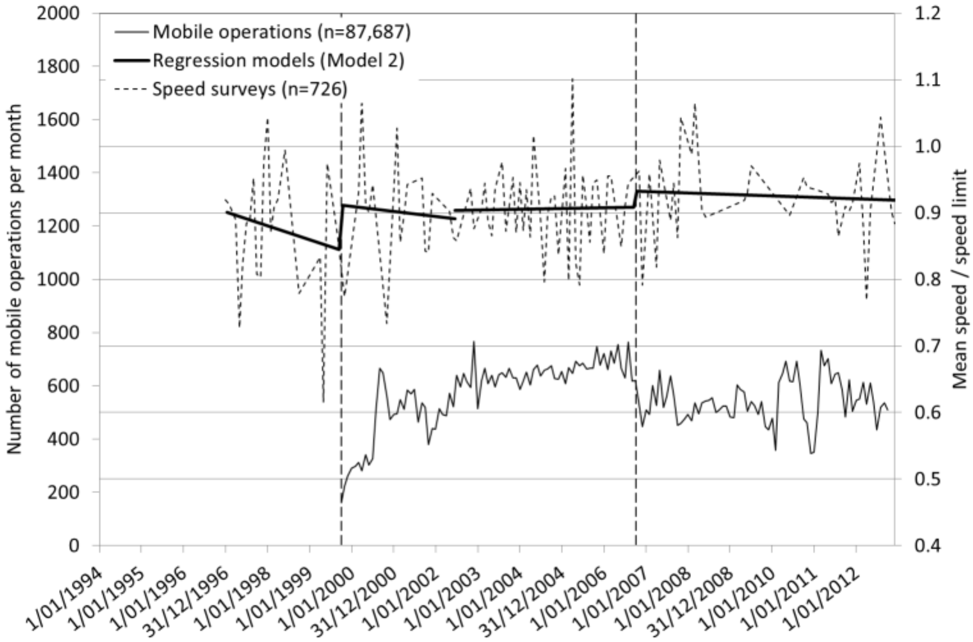

Figure 13: Mean speed survey data relative to the overall camera program – control streets

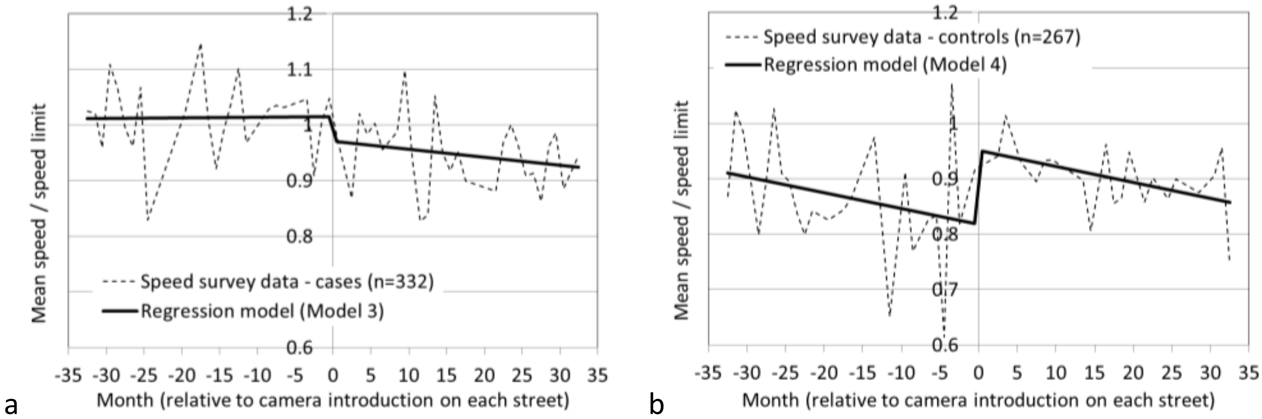

Figure 14: Mean speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

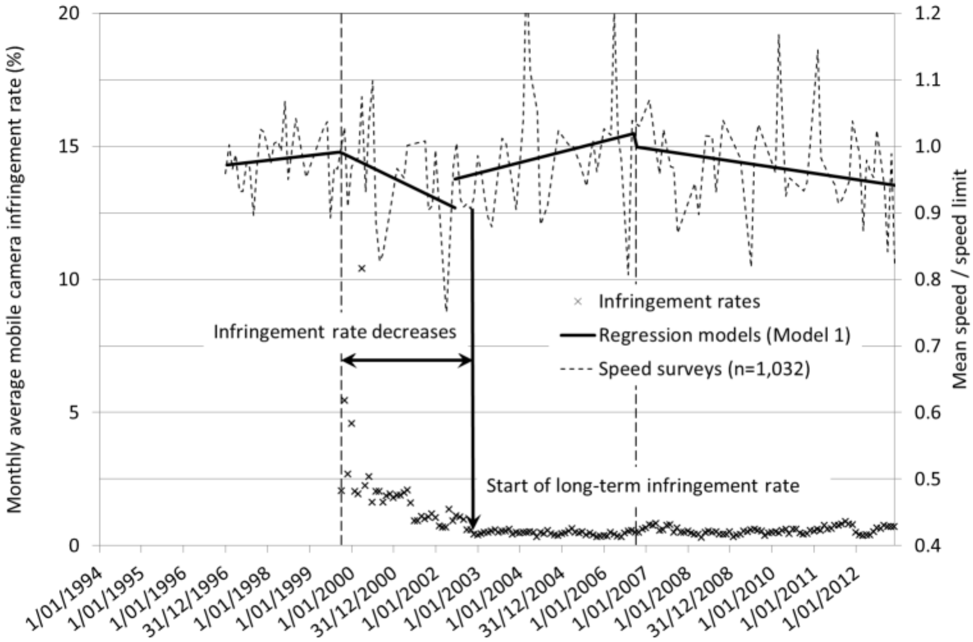

Figure 15: Mean speed survey data relative to the overall camera program – case streets

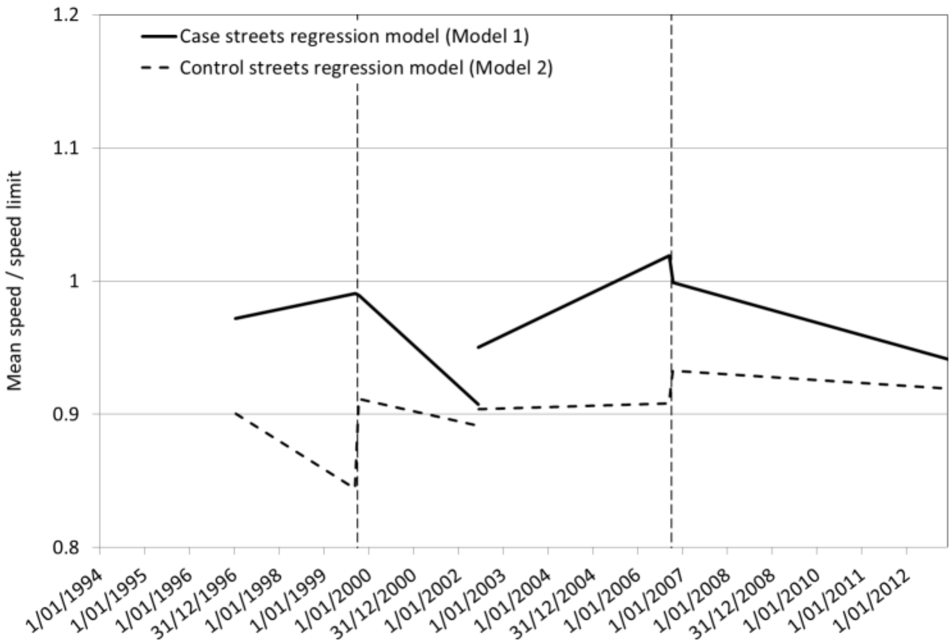

Figure 16: Comparison of the regression models of mean speeds for case and control streets

	MODEL 1 Cases (streets with cameras)								**MODEL 2** Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.009	-0.065	0.047	0.754	0.020	-0.031	0.070	0.442	-0.170	-0.268	-0.073	0.001	-0.096	-0.142	-0.050	<.0001
Time (T)	0.001	-0.002	0.003	0.666	0.001	0.000	0.003	0.087	-0.002	-0.007	0.003	0.386	0.000	-0.002	0.002	0.901
Camera (C)	0.000	-0.079	0.078	0.992	-0.021	-0.090	0.049	0.560	0.078	-0.064	0.220	0.282	0.027	-0.037	0.090	0.408
T x C	-0.003	-0.007	0.001	0.116	-0.002	-0.004	0.000	0.027	0.001	-0.006	0.008	0.711	0.000	-0.002	0.002	0.743

Table 10: Mean speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 3 Cases (streets with cameras)				**MODEL 4** Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.015	-0.037	0.067	0.577	-0.201	-0.280	-0.122	<.0001
Time (T)	0.000	-0.003	0.003	0.977	-0.003	-0.007	0.001	0.087
Camera (C)	-0.044	-0.118	0.029	0.236	0.151	0.031	0.271	0.014
T x C	-0.002	-0.005	0.002	0.409	0.000	-0.006	0.006	0.963

Table 11: Mean speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 5			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.201	-0.270	-0.133	<.0001
Time (T)	-0.003	-0.007	0.000	0.049
Camera (C1)	0.151	0.047	0.256	0.004
Case (C2)	0.216	0.124	0.308	<.0001
T x C1	0.000	-0.005	0.005	0.958
T x C2	0.003	-0.001	0.008	0.145
C1 x C2	-0.196	-0.331	-0.060	0.005
T x C1 x C2	-0.002	-0.009	0.005	0.619

Table 12: Mean speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.5 Speed survey analyses – effects of mobile cameras on 85th percentile vehicle speeds (Models 6 to 10)

Considering an outcome of monthly averaged values of the 85th percentile speed divided by the speed limit, the statistical models are tabulated in Tables 13 to 15. Models 6 to 9 are plotted in Figures 17 to 19. In Models 6 and 8, trends in 85th percentile speeds for case streets were relatively constant in the pre-intervention periods, and decreased in the post-intervention periods, where the intervention was Intervention 1 (Model 6) or the camera begin-date (Model 8). Trends in 85th percentile speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 6). 85th percentile speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 7 and 9). CAMERA estimates were generally not statistically significant, indicating changes that occurred in 85th percentile speeds at the intervention times were not generally significant (Tables 13 and 14).

Annual trend magnitudes for case streets were an increase of 0.1% and decrease of 1.8% prior to and following Intervention 1, and an increase of 1.4% and decrease of 1.1% prior to and following Intervention 2. A decrease of 0.8% and decrease of 1.7% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 3.6% and decrease of 0.7% prior to and following Intervention 1, and an increase of 0.2% and decrease of 0.4% prior to and following Intervention 2. A decrease of 4.6% and decrease of 5.2% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 15. The estimate for the CASE variable was highly significant, likely a result of the fact that 85th percentile speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The regression models for case and control streets (Models 6 and 7) are compared in Figure 20. 85th percentile speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The 85th percentile speeds on all streets were predominantly above the speed limit for the full time period.

Comparison of the mean and 85th percentile speeds indicates that trends were very similar between the two, however the magnitudes of the 85th percentile speeds were higher than the mean speeds. This is also evident in the speed survey results plotted in Appendix D, where mean and 85th percentile speeds are plotted on the same graphs.

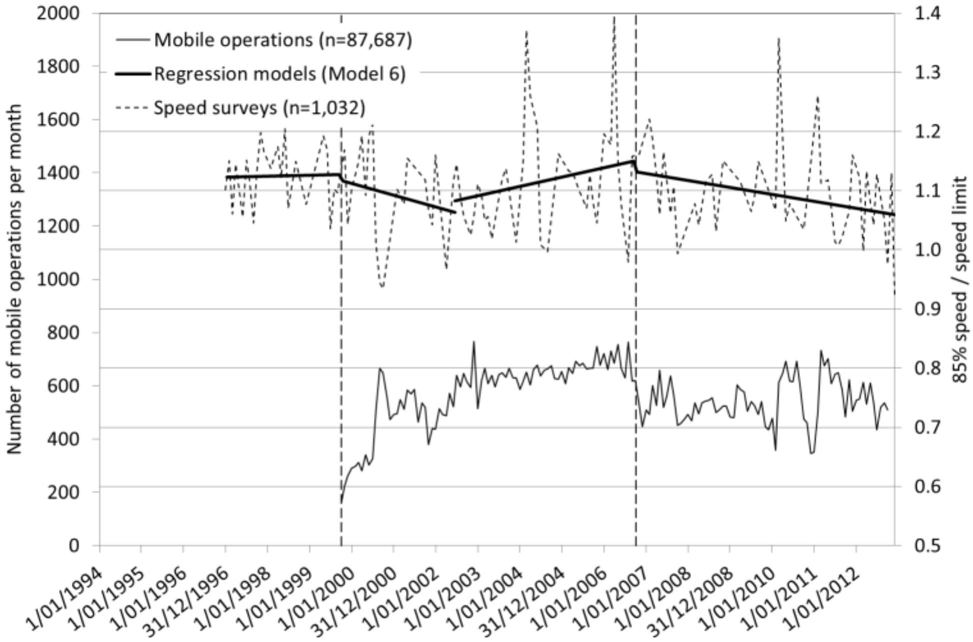

Figure 17: 85th percentile speed survey data relative to the overall camera program – case streets

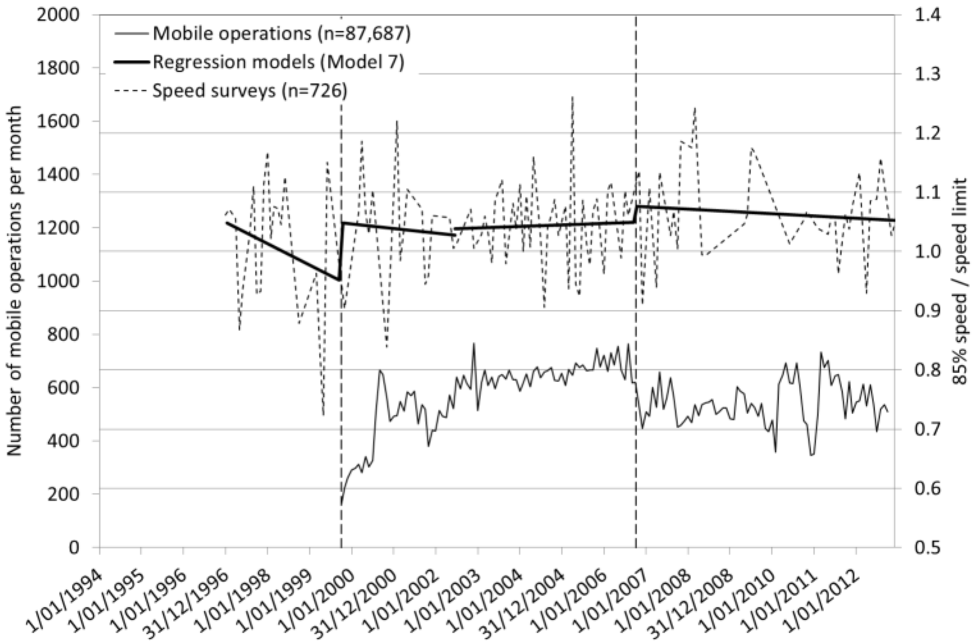

Figure 18: 85th percentile speed survey data relative to the overall camera program – control streets

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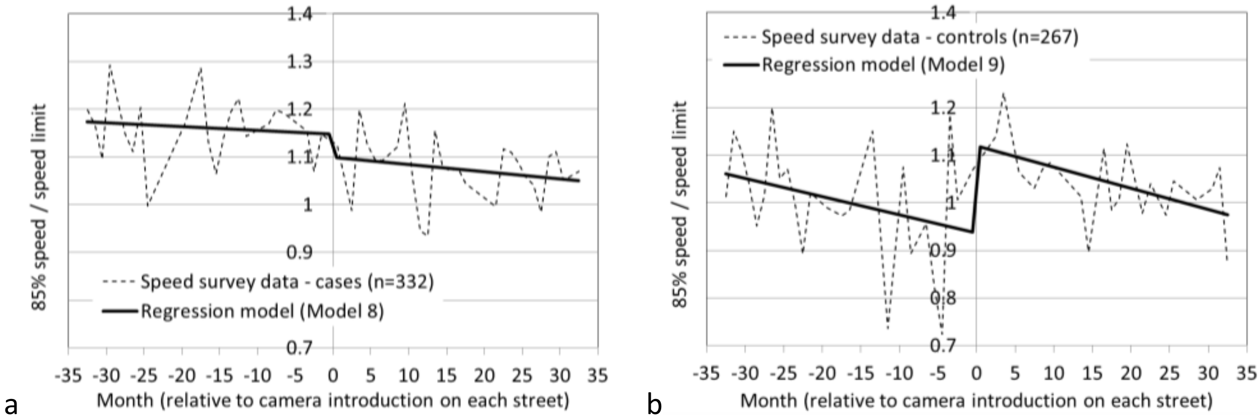

Figure 19: 85th percentile speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

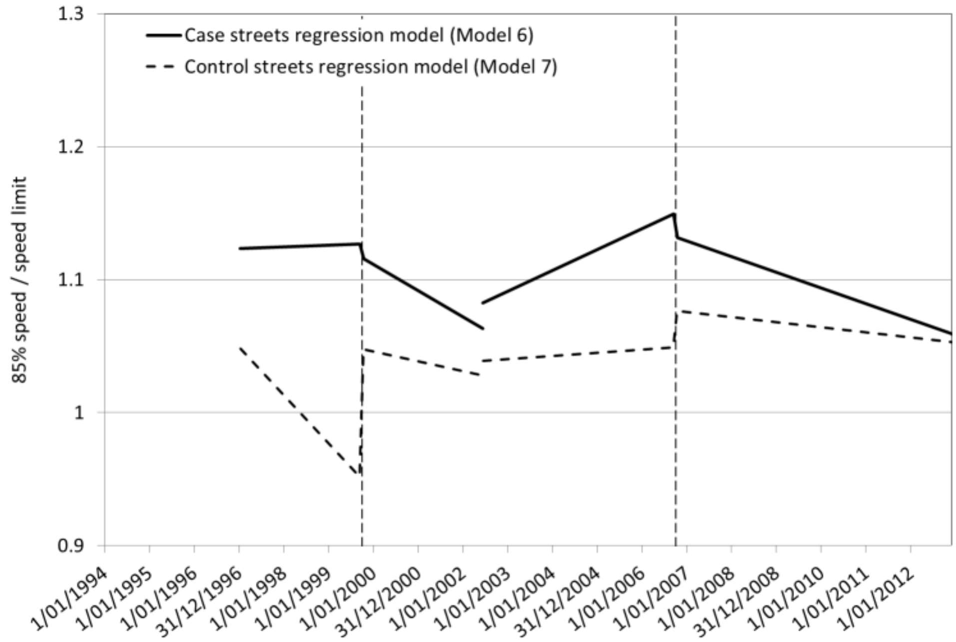

Figure 20: Comparison of the regression models of 85th percentile speeds for case and control streets

	MODEL 6 Cases (streets with cameras)								**MODEL 7** Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.120	0.070	0.169	<.0001	0.140	0.093	0.187	<.0001	-0.051	-0.150	0.048	0.315	0.048	0.002	0.094	0.040
Time (T)	0.000	-0.002	0.003	0.908	0.001	0.000	0.003	0.120	-0.003	-0.008	0.002	0.208	0.000	-0.001	0.002	0.820
Camera (C)	-0.009	-0.079	0.061	0.797	-0.016	-0.081	0.049	0.636	0.098	-0.046	0.241	0.182	0.026	-0.037	0.089	0.426
T x C	-0.002	-0.005	0.002	0.390	-0.002	-0.004	0.000	0.026	0.002	-0.005	0.010	0.508	-0.001	-0.002	0.001	0.618

Table 13: 85th percentile speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 8 Cases (streets with cameras)				**MODEL 9** Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.138	0.092	0.184	<.0001	-0.065	-0.146	0.017	0.120
Time (T)	-0.001	-0.003	0.002	0.578	-0.004	-0.008	0.000	0.060
Camera (C)	-0.043	-0.108	0.022	0.197	0.179	0.055	0.302	0.005
T x C	-0.001	-0.004	0.003	0.697	-0.001	-0.007	0.006	0.867

Table 14: 85th percentile speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 10			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.065	-0.132	0.002	0.059
Time (T)	-0.004	-0.007	-0.001	0.022
Camera (C1)	0.179	0.077	0.280	0.001
Case (C2)	0.202	0.112	0.293	<.0001
T x C1	-0.001	-0.006	0.005	0.839
T x C2	0.003	-0.001	0.008	0.167
C1 x C2	-0.222	-0.354	-0.089	0.001
T x C1 x C2	0.000	-0.007	0.007	0.967

Table 15: 85th percentile speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.6 Road crash analyses – effects of mobile cameras on fatal crashes

Fatal crashes for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 100 fatal crashes were identified in the period, including 91 that occurred on case streets and 9 that occurred on control streets. Fatal crash counts are plotted in Figures 21 to 22. Due to small crash counts statistical models were not fitted to these data, however it is clear from visual inspection of Figure 21 that fatal crashes on case streets generally decreased over the study period.

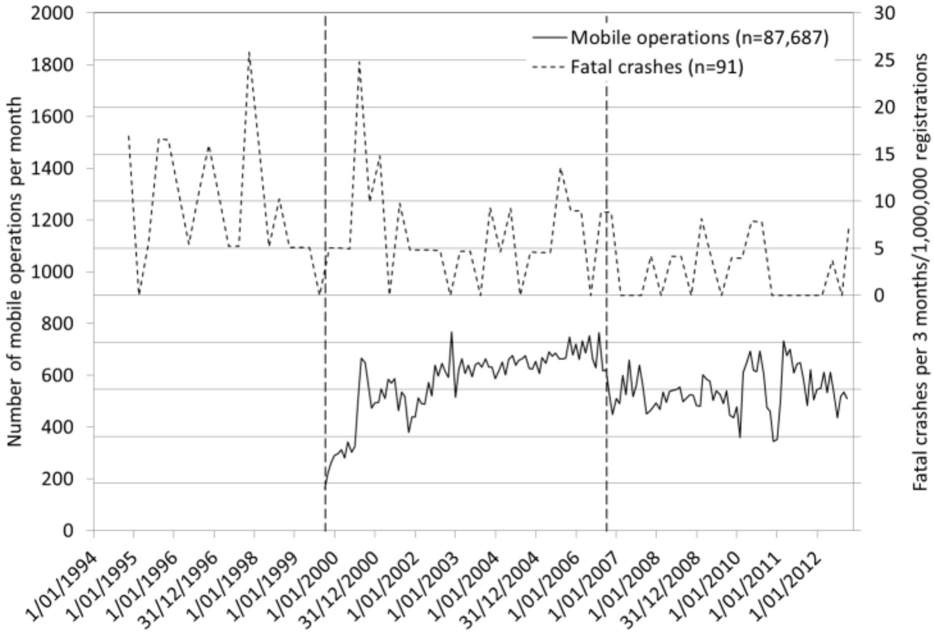

Figure 21: Fatal crash data relative to the overall camera program – case streets

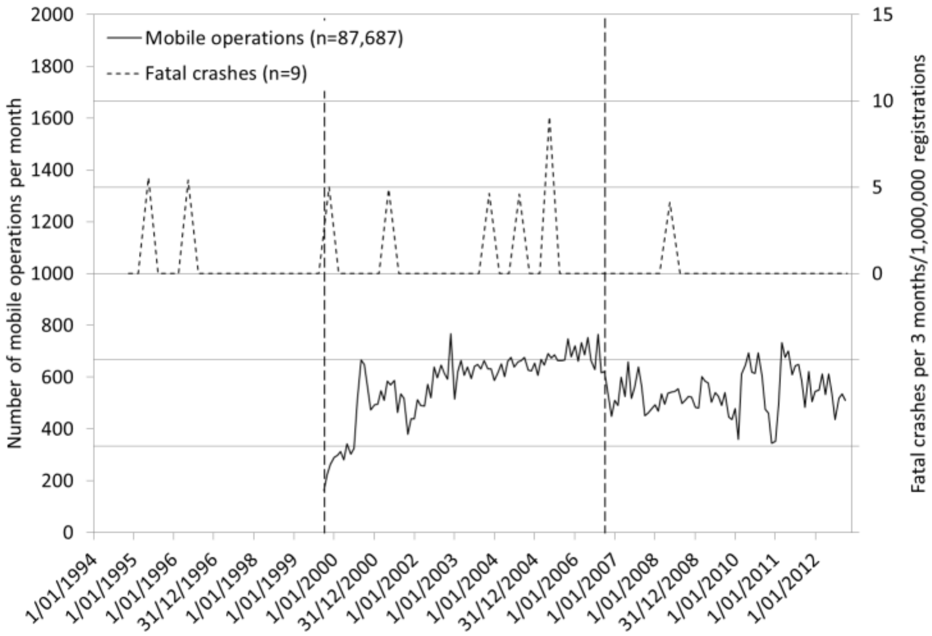

Figure 22: Fatal crash data relative to the overall camera program – control streets

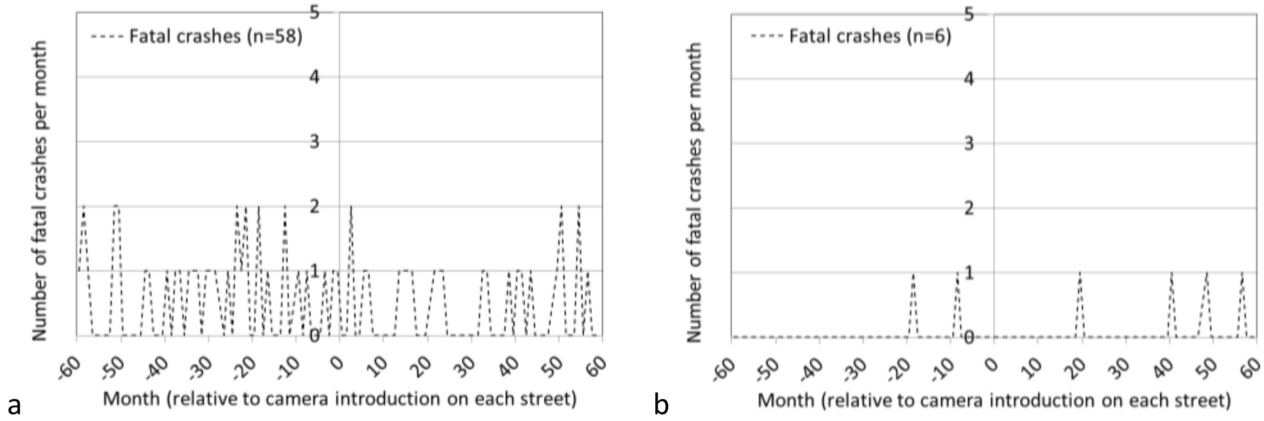

Figure 23: Fatal crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

3.7 Road crash analyses – effects of mobile cameras on serious crashes (Models 11 to 15)

Serious crashes (injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 3,325 serious crashes were identified in the period, including 2,788 that occurred on case streets and 537 that occurred on control streets. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 16 to 18. Models 11 to 14 are plotted in Figures 24 to 26. In Models 11 and 13, trends in serious crash counts for case streets showed decreases post-intervention, where the intervention was Intervention 1 (Model 11) or the camera begin-date (Model 13). A substantial drop occurred in mid-2002 (around 40% in raw numbers) and was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend following Intervention 2 (Model 11) steadily increasing up to 2013 to the same levels when cameras were first introduced. It should be noted that this rising trend in serious injury crashes from around 2004 to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period.

Serious crash counts for control streets were at much lower levels at around one quarter that of the case streets. Trends for control streets (Models 12 and 14) were similar, however the drop in 2002 was much less pronounced. Negative estimates for CAMERA in Models 11 to 14 indicates that crash counts were generally lower following Intervention 1/begin-date, while positive estimates following Intervention 2 indicates crash counts were higher. CAMERA estimates were generally not significant, however this may have been influenced by the relatively small serious crash counts.

Annual trend magnitudes for case streets were a decrease of 3.2% prior to Intervention 1, decrease of 3.7% between Intervention 1 and 2, and increase of 7.1% following Intervention 2. An increase of 1.1% prior to the begin-date and decrease of 10.3% following the begin-date were evident. Trend magnitudes for control streets were an increase of 4.7% prior to Intervention 1, a decrease of 24.5% between Intervention 1 and 2, and an increase of 1.4% following Intervention 2.

Decreases of 6.1% prior to the begin-date and 2.5% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 18. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, however this may reflect the relatively small serious crash counts.

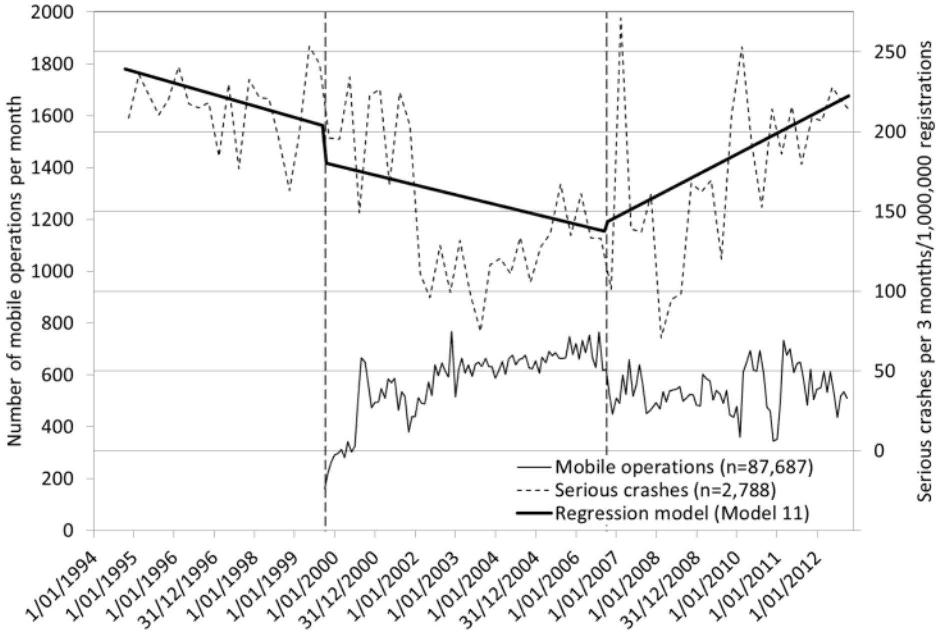

Figure 24: Serious crash data relative to the overall camera program – case streets

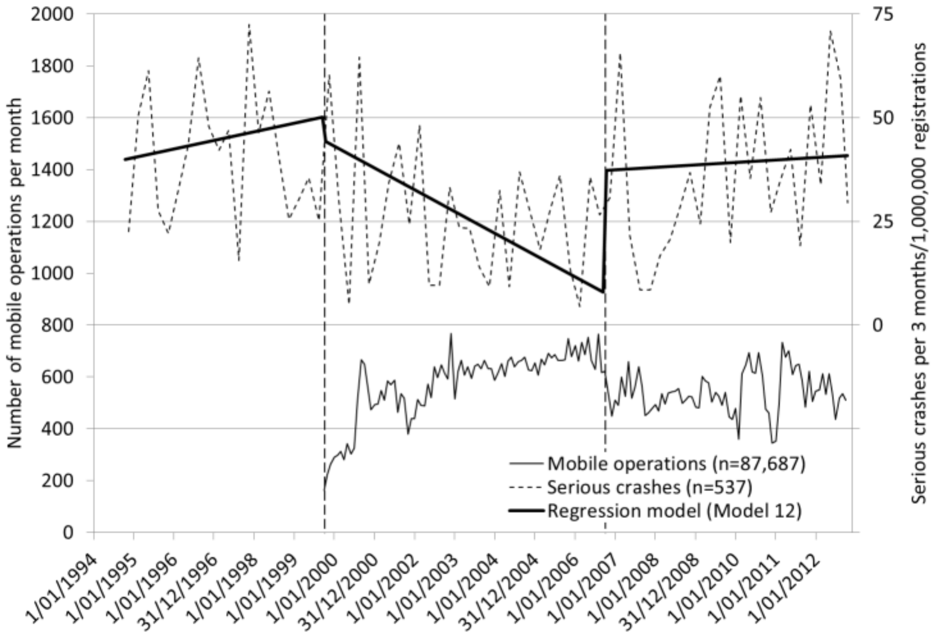

Figure 25: Serious crash data relative to the overall camera program – control streets

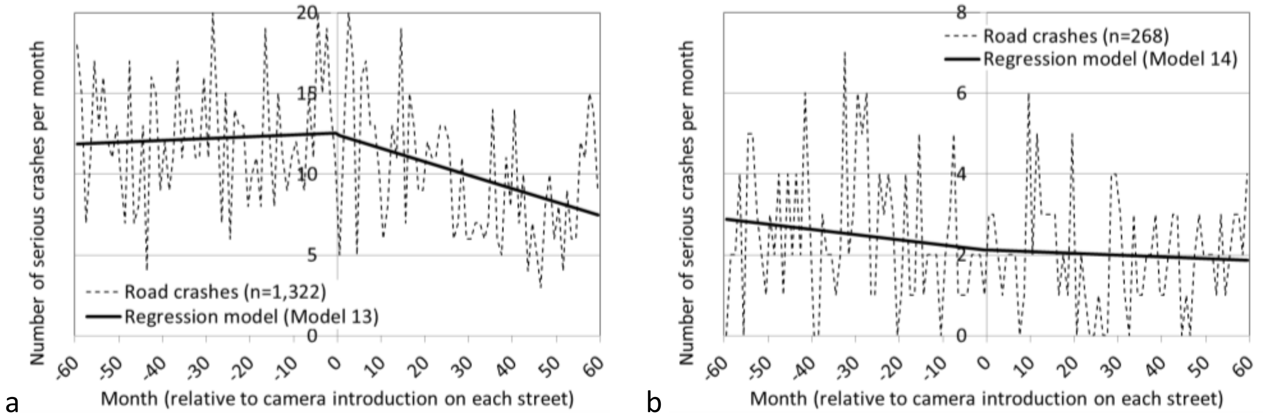

Figure 26: Serious crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

Variable	**MODEL 11** Cases (streets with mobile cameras) (a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012				**MODEL 12** Controls (streets without mobile cameras) (a) 10/1994 – 10/1999 – 10/2006				(b) 10/1999 – 10/2006 – 10/2012			
	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-13.381	-13.873	-12.889	<.0001	-13.776	-14.238	-13.314	<.0001	-14.634	-15.092	-14.176	<.0001	-16.482	-17.397	-15.567	<.0001
Time (T)	-0.003	-0.009	0.003	0.353	-0.003	-0.009	0.002	0.265	0.004	-0.010	0.018	0.596	-0.021	-0.036	-0.005	0.011
Camera (C)	-0.122	-0.533	0.289	0.561	0.043	-0.266	0.353	0.785	-0.119	-0.824	0.586	0.742	1.550	0.678	2.423	0.001
T x C	0.000	-0.008	0.007	0.916	0.009	0.002	0.016	0.016	-0.024	-0.042	-0.007	0.007	0.022	-0.002	0.045	0.068

Table 16: Serious crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	**MODEL 13** Cases (streets with mobile cameras)				**MODEL 14** Controls (streets without mobile cameras)			
	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.998	-1.460	-0.536	<.0001	-2.886	-3.189	-2.583	<.0001
Time (T)	0.001	-0.004	0.006	0.720	-0.005	-0.011	0.001	0.108
Camera (C)	-0.007	-0.247	0.233	0.955	-0.002	-0.377	0.373	0.991
T x C	-0.010	-0.017	-0.002	0.010	0.003	-0.007	0.013	0.566

Table 17: Serious crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

Variable	**MODEL 15** Estimate	CL_U	CL_L	*p*-value
Intercept	-2.885	-3.188	-2.582	<.0001
Time (T)	-0.005	-0.011	0.001	0.108
Camera (C1)	-0.002	-0.376	0.372	0.991
Case (C2)	1.889	1.337	2.441	<.0001
T x C1	0.003	-0.007	0.013	0.566
T x C2	0.006	-0.002	0.014	0.135
C1 x C2	-0.005	-0.449	0.440	0.983
T x C1 x C2	-0.013	-0.025	0.000	0.050

Table 18: Serious crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.8 Road crash analyses – effects of mobile cameras on all crashes (Models 16 to 20)

All road crashes (property damage, injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 57,809 road crashes were identified in the period, including 48,733 that occurred on case streets and 9,076 that occurred on control streets. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 19 to 21. Models 16 to 19 are plotted in Figures 27 to 29. In Models 16 and 18, trends in crash counts for case streets showed decreases in both the pre- and post-intervention periods, where the intervention was Intervention 1 (Model 16) or the camera begin-date (Model 18), and following Intervention 2 (Model 16). Large positive CAMERA estimates were evident for case streets at Intervention 1/begin-date, which were statistically significant, which indicates a significant increase in crash counts at this time. Crash counts for control streets indicated very similar trends (Models 17 and 19), however the changes that occurred at the time of the interventions was less pronounced.

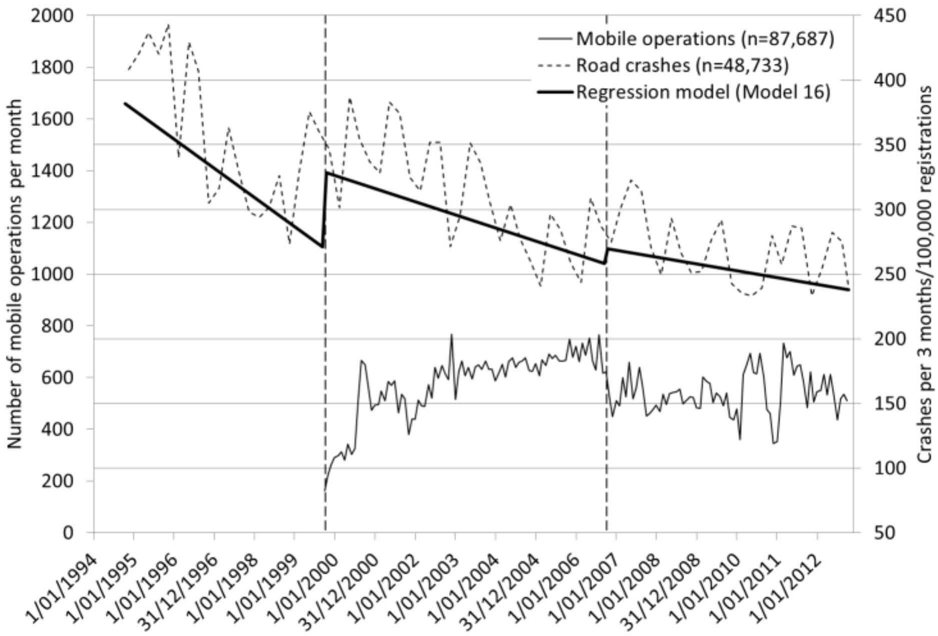

Figure 27: All crash data relative to the overall camera program – case streets

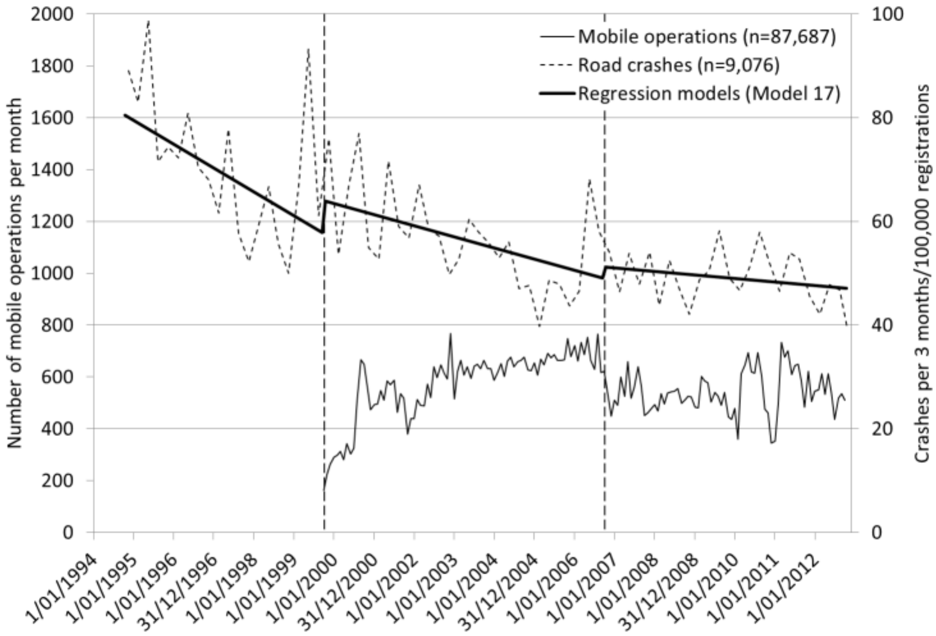

Figure 28: All crash data relative to the overall camera program – control streets

Annual trend magnitudes for case streets were decreases of 6.9% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 2.0% following Intervention 2. Decreases of 3.6% prior to the begin-date and 1.7% following the begin-date were evident. Trend magnitudes for control streets were decreases of 6.7% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 1.0% following Intervention 2. Decreases of 2.9% prior to the begin-date and 3.6% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 21. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, indicating that the effect of the intervention (begin-date) was not significantly different between case and control streets. However, another explanation may be that limitation concerning the selection of control streets, i.e. that the control streets identified for the analyses do not represent a true 'control area'.

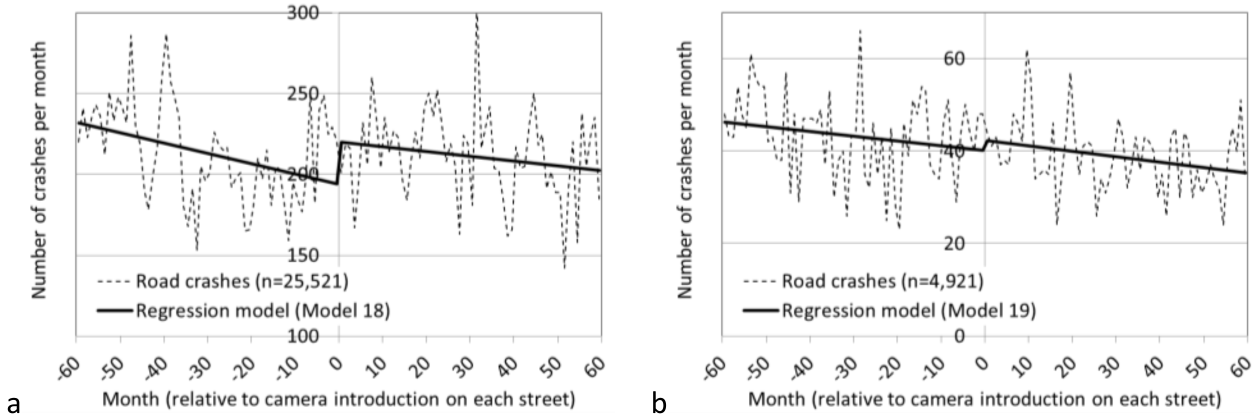

Figure 29: All crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

Variable	MODEL 16 Cases (streets with mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value	MODEL 17 Controls (streets without mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	-10.796	-11.240	-10.351	<.0001	-10.844	-11.276	-10.413	<.0001	-12.245	-12.669	-11.821	<.0001	-12.409	-12.858	-11.960	<.0001
Time (T)	-0.006	-0.007	-0.004	<.0001	-0.004	-0.005	-0.002	<.0001	-0.006	-0.008	-0.004	<.0001	-0.004	-0.006	-0.001	0.006
Camera (C)	0.196	0.136	0.255	<.0001	0.047	-0.024	0.117	0.193	0.104	0.014	0.194	0.024	0.044	-0.093	0.181	0.532
T x C	0.002	-0.001	0.005	0.119	0.002	0.000	0.004	0.104	0.002	-0.002	0.006	0.262	0.002	-0.001	0.005	0.102

Table 19: All crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	MODEL 18 Cases (streets with mobile cameras) Estimate	CL_U	CL_L	*p*-value	MODEL 19 Controls (streets without mobile cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	1.741	1.300	2.182	<.0001	0.004	-0.413	0.420	0.986
Time (T)	-0.003	-0.005	-0.001	0.000	-0.002	-0.005	0.000	0.063
Camera (C)	0.127	0.081	0.173	<.0001	0.052	-0.053	0.157	0.331
T x C	0.002	-0.002	0.005	0.371	-0.001	-0.005	0.004	0.788

Table 20: All crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

Variable	MODEL 20 Estimate	CL_U	CL_L	*p*-value
Intercept	0.001	-0.415	0.417	0.997
Time (T)	-0.002	-0.005	0.000	0.063
Camera (C1)	0.052	-0.053	0.157	0.332
Case (C2)	1.742	1.136	2.348	<.0001
T x C1	-0.001	-0.005	0.004	0.789
T x C2	-0.001	-0.004	0.002	0.698
C1 x C2	0.075	-0.040	0.190	0.201
T x C1 x C2	0.002	-0.003	0.008	0.446

Table 21: All crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.9 Road crash analyses – effects of fixed cameras on serious intersection crashes (Models 21 to 23)

A total of 152 serious (injury or fatality) intersection crashes were identified in the period for the 26 intersection locations, including 78 that occurred at case intersections and 74 that occurred at control intersections. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 22 and 23, and Models 21 and 22 are plotted in Figure 30. The negative estimates for CAMERA indicates that serious intersection crash counts for case and control intersections were generally lower following the introduction of fixed cameras, and the similar magnitudes indicates that the drop was similar at case and control locations. Model results were not significant, including those for the case-control Model 23, likely a result of the small crash counts.

Annual trend magnitudes for case intersections were a decrease of 5.2% prior to the begin-date and an increase of 0.4% following the begin-date. Trend magnitudes for control intersections were a decrease of 5.0% prior to the begin-date and an increase of 8.2% following the begin-date. All trend magnitudes are per year.

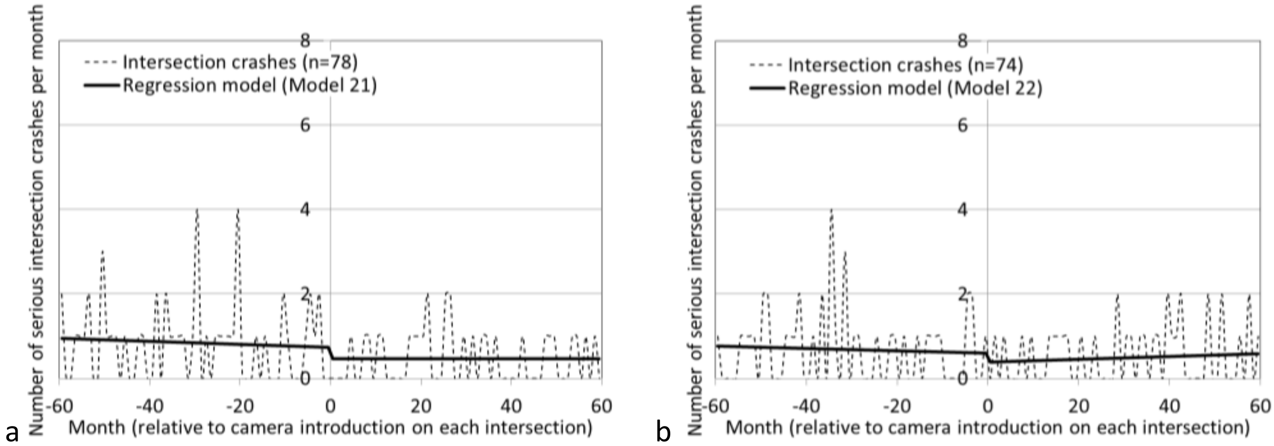

Figure 30: Serious intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

	MODEL 21	Cases (with fixed cameras)			MODEL 22	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.315	-0.891	0.261	0.283	-0.509	-1.167	0.149	0.130
Time (T)	-0.004	-0.020	0.012	0.598	-0.004	-0.023	0.014	0.656
Camera (C)	-0.454	-1.396	0.488	0.345	-0.430	-1.438	0.578	0.403
T x C	0.005	-0.022	0.031	0.738	0.017	-0.011	0.044	0.230

Table 22: Serious intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 23 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.509	-1.156	0.138	0.123
Time (T)	-0.004	-0.022	0.014	0.650
Camera (C1)	-0.430	-1.421	0.561	0.395
Case (C2)	0.194	-0.679	1.067	0.664
T x C1	0.017	-0.010	0.044	0.222
T x C2	0.000	-0.025	0.024	0.991
C1 x C2	-0.024	-1.403	1.355	0.973
T x C1 x C2	-0.012	-0.051	0.026	0.534

Table 23: Serious intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

3.10 Road crash analyses – effects of fixed cameras on all intersection crashes (Models 24 to 32)

A total of 4,261 intersection crashes (property damage, injury or fatality) were identified in the period for the 26 intersection locations, including 2,826 that occurred at case intersections and 1,435 that occurred at control intersections. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 24 to 28 and are plotted in Figures 31 to 33. Trends in crash counts for case intersections showed an increase in crashes following the introduction of the fixed cameras followed by a decline to rates slightly lower than baseline levels. On the other hand, crash counts for control intersections were relatively consistent before and after. The positive estimate for CAMERA in Model 24 indicates that case intersection crash counts were generally higher following the introduction of fixed cameras, and this result was significant. Disaggregating intersection crashes by rear-end crashes indicates that, at intersections where fixed cameras were introduced, this increase resulted from an increase in rear-end crashes which then returned to levels slightly below baseline levels. This is evidenced in the estimates for CAMERA, where a large positive value was estimated for rear-end crashes (0.277, Model 27), and this result was significant. Conversely, a small value was estimated for non-rear-end crashes (0.007, Model 29).

Comparison with the generally consistent frequency of rear-end crashes before and after at intersections without fixed cameras (small negative value for CAMERA estimate in Model 28), indicates that the initial increase in rear-end crashes at intersections with fixed cameras was likely a result of the introduction of these cameras. This is further evidenced by the statistical results for the case-control analysis in Model 26, where the estimate for CAMERA × CASE was highly significant, indicating that the effect of the introduction of fixed intersection cameras was significantly different between case and control streets.

Negative estimates for CAMERA in the models for right angle collision/right turn into oncoming vehicle intersection crashes indicate that crash counts were generally lower following the introduction of fixed cameras, at both case and control intersections.

Annual trend magnitudes for case intersections were decreases of 3.4% prior to the begin-date and 6.2% following the begin-date. This included decreases of 0.5% prior to the begin-date and 6.5% following the begin-date for rear-end crashes, decreases of 8.9% prior to the begin-date and 5.5% following the begin-date for non-rear-end crashes, and decreases of 1.6% prior to the begin-date and 2.2% following the begin-date for right angle collision/right turn into oncoming vehicle

crashes. Trend magnitudes for control intersections were a decrease of 1.6% prior to the begin-date and an increase of 2.2% following the begin-date. This included an increase of 1.2% prior to the begin-date and an increase of 2.2% following the begin-date for rear-end crashes, a decrease of 6.0% prior to the begin-date and an increase of 0.7% following the begin-date for non-rear-end crashes, and a decrease of 13.6% prior to the begin-date and an increase of 3.0% following the begin-date for right angle collision/right turn into oncoming vehicle crashes. All trend magnitudes are per year.

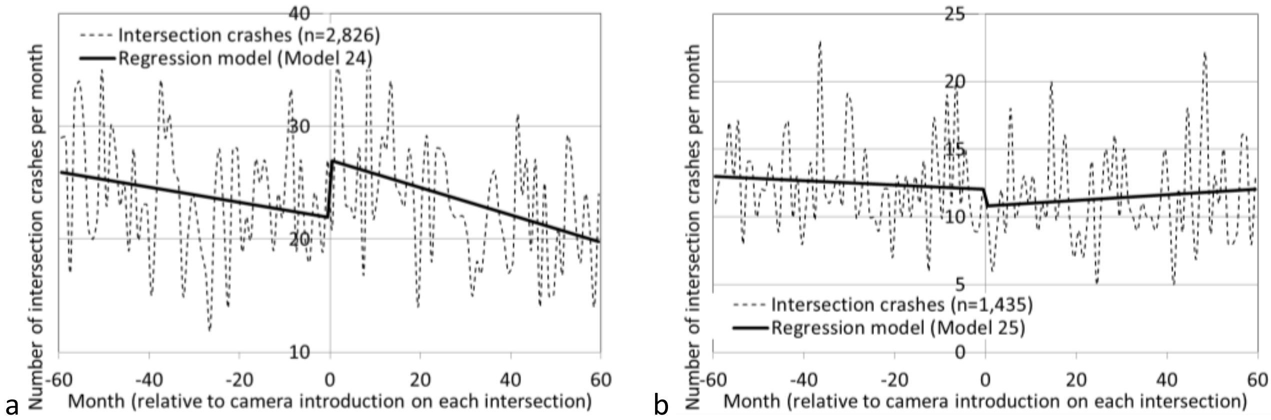

Figure 31: Intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

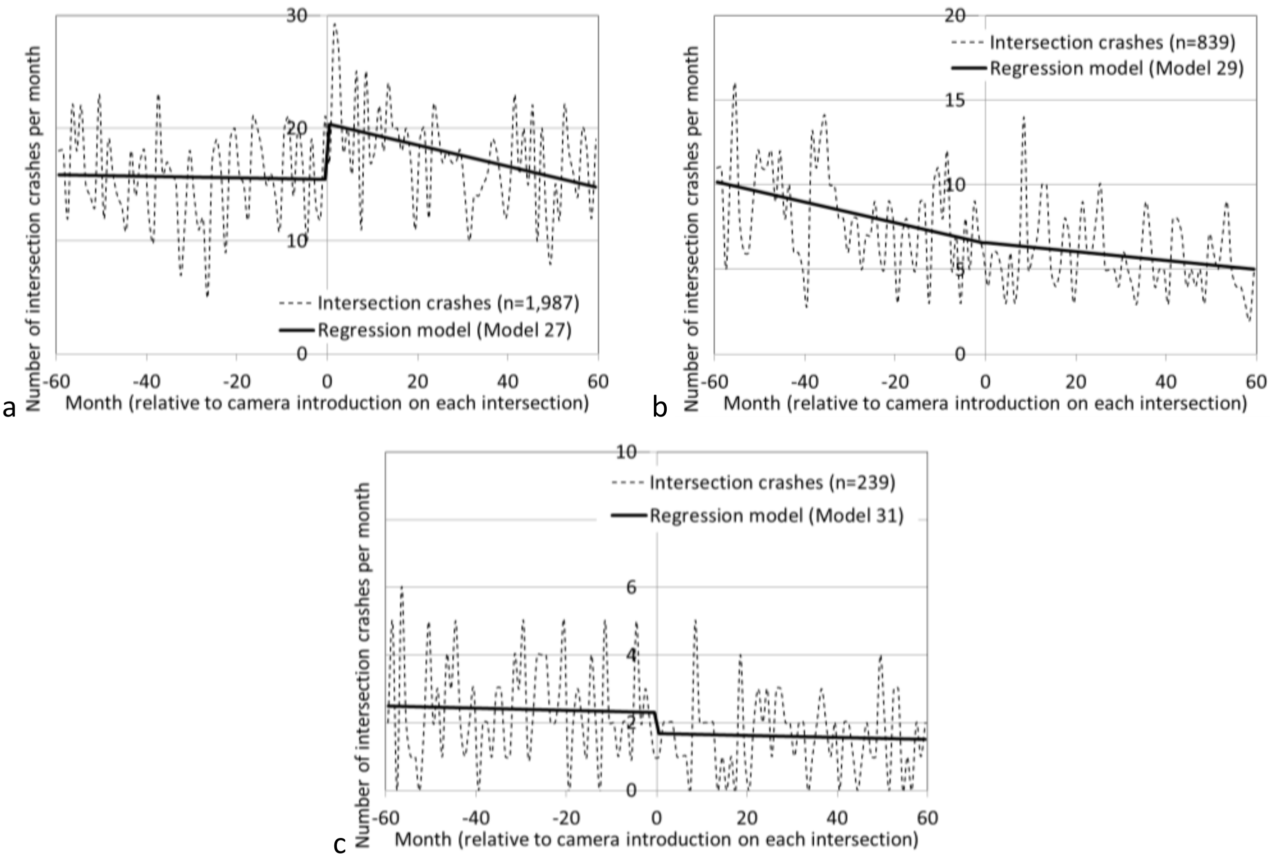

Figure 32: Case intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

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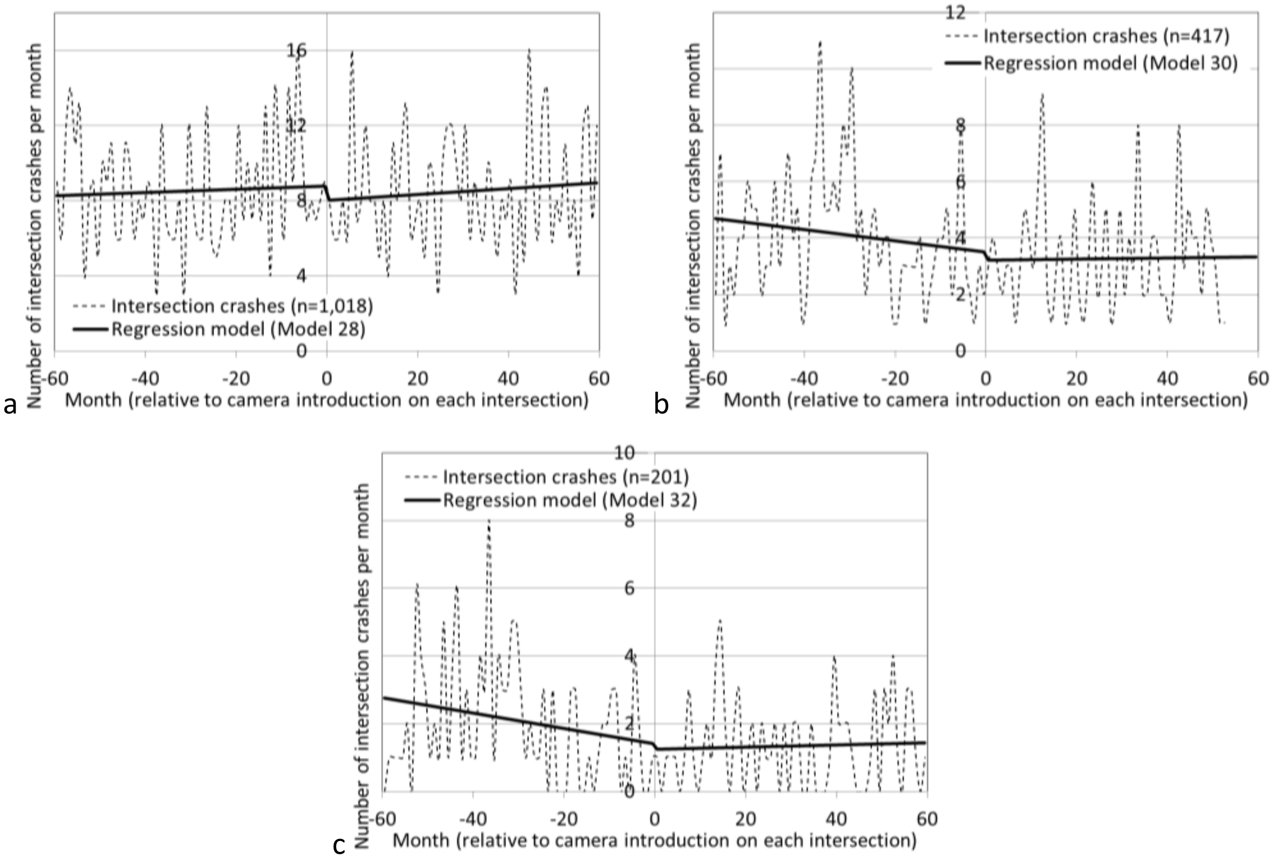

Figure 33: Control intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

	MODEL 24	Cases (with fixed cameras)			**MODEL 25**	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	3.089	2.977	3.200	<.0001	2.487	2.346	2.628	<.0001
Time (T)	-0.003	-0.006	0.000	0.082	-0.001	-0.005	0.003	0.520
Camera (C)	0.207	0.053	0.362	0.009	-0.107	-0.312	0.097	0.303
T x C	-0.002	-0.007	0.002	0.298	0.003	-0.003	0.009	0.297

Table 24: Intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 26			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	2.487	2.340	2.634	<.0001
Time (T)	-0.001	-0.006	0.003	0.537
Camera (C1)	-0.107	-0.321	0.106	0.323
Case (C2)	0.601	0.420	0.783	<.0001
T x C1	0.003	-0.003	0.009	0.318
T x C2	-0.002	-0.007	0.004	0.575
C1 x C2	0.315	0.055	0.575	0.018
T x C1 x C2	-0.006	-0.013	0.002	0.149

Table 25: Intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 27 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 28 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	2.740	2.611	2.868	<.0001	2.171	1.995	2.348	<.0001
Time (T)	0.000	-0.004	0.003	0.834	0.001	-0.004	0.006	0.690
Camera (C)	0.277	0.103	0.451	0.002	-0.090	-0.342	0.163	0.487
T x C	-0.005	-0.010	0.000	0.056	0.001	-0.007	0.008	0.839

Table 26: Rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 29 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 30 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	1.878	1.706	2.050	<.0001	1.250	0.975	1.525	<.0001
Time (T)	-0.007	-0.012	-0.003	0.002	-0.005	-0.013	0.003	0.193
Camera (C)	0.007	-0.249	0.262	0.959	-0.085	-0.498	0.327	0.686
T x C	0.003	-0.005	0.010	0.458	0.006	-0.006	0.017	0.344

Table 27: Non-rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 31 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 32 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	0.836	0.498	1.173	<.0001	0.343	-0.147	0.833	0.170
Time (T)	-0.001	-0.011	0.008	0.789	-0.011	-0.024	0.002	0.090
Camera (C)	-0.322	-0.850	0.205	0.231	-0.130	-0.875	0.615	0.733
T x C	-0.001	-0.016	0.015	0.950	0.014	-0.007	0.034	0.190

Table 28: Right angle collision/right turn into oncoming vehicle intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

4. Discussion

The views of drivers about speeding and enforcement of speed limits is likely to influence their on-road behaviour. For this reason, in evaluating the effects of road safety initiatives like safety cameras, it is useful to take into account changes in driver and community views about speed and enforcement. The community attitude surveys conducted between 1992 and 2012 provide some insights into changes in attitudes over the period of introduction of safety cameras in the ACT.

Drivers choose the speed of travel from moment to moment based on a range of factors that might be loosely grouped into the driving environment and their preferred driving style. The driving environment includes the physical conditions that can have a large impact on the driver's chosen speed and the regulatory speed limits. Driving style also undoubtedly plays a considerable role in speed choice with the behavioural style of individual drivers influencing their perception of speed and of the importance of regulating speed according to the environment. The majority of drivers make considerable effort to conform to speed limits. Compliance with speed limits and, as a consequence, to general driving conditions is encouraged primarily through enforcement such as the use of speed cameras, but drivers differ in their reactions to such enforcement measures. Driver experience of enforcement may also differ depending on the type of camera in use which will also affect whether and how drivers respond to the presence of speed cameras.

The following is a discussion of what was found to be available in the wide literature in terms of evidence base concerning the effectiveness or otherwise of the different camera types, a discussion of the review of community attitudes to speeding, and a discussion of the speed survey and road crash data study. It is hoped that this discussion and the conclusions (placed at the front of report for convenience) will provide insight into some of the questions raised.

4.1 Literature review

Evaluations of red light cameras clearly yield mixed effects. There is good evidence that they have the effect that we expect and hope for: reduce red light running in the form of violations and most importantly produce reductions in right angle crashes. These effects are clearly road safety benefits.

On the other hand, there is consistent evidence that they also increase rear-end crashes, which is clearly not a benefit for road safety, but again might be expected if drivers are responding rapidly to the onset of red lights when cameras are present. It has been argued that the difference in likely severity of crashes offsets the increase in rear-end crashes. Kloeden et al (2009), for example argued that the damage caused in side impact crashes are often much more extreme than that produced in rear-end crashes, so the trade-off for road safety by the presence of red light cameras is in the positive direction. However, it should be noted that whiplash injury, which is often associated with rear-end crashes, may have long term chronic effects which result in both pain and suffering. Whiplash injuries can also result in a substantial financial burden, where a recent study of road-crash related personal injury insurance claims noted that the average injury claim made for the treatment of whiplash injuries was $90,700 (Bambach et al 2013). Clearly, good road safety practice needs to also consider how to reduce increased rear-end crashes even if the severity of the crash is much less extreme than for example a side impact crash resulting in serious injuries. One way may be to consider light phases at intersections.

The available research provides some guidance on the best approaches to implementation of red light cameras. Some focus on the length of phase sequences. Yang, Han and Cherry (2013) reviewed the evidence for modifying signal sequences as a method of sustaining red light camera operations in order to balance safety benefit with revenue raised. They concluded that safety benefits would be obtained by lengthening the all-red clearance phase and from shortening overall cycle length, whereas shortened yellow light sequences increased the likelihood of rear-end crashes. It seems that providing greater opportunity for drivers to make the decision to stop may be effective in reducing red light running. Further, providing an all-red clearance period at intersections reduces red light violations (Schattler, Datta and Hill, 2003) by requiring drivers to pause between the change in direction of traffic flow. However, it needs to be noted that the ACT already has an all-red phase and the other phasing features noted above.

Evaluations of fixed cameras also clearly show they are effective for reducing speeds and crashes in the location where the camera is installed. The results also show a large variation. There are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

Critical to any evaluation is the choice of a control comparison site. Even if a Random Location Control (RLC) non-camera site is chosen some distance away in order to avoid distance or time halo effects, the site is likely to be influenced by the information about the general presence of cameras in the area by the community. The level of enforcement is also likely to increase driver awareness as people are 'caught' when they are speeding at the camera site and then drive through control sites elsewhere. Drivers tend to watch what they are doing through signalised intersections and drivers have warnings of the presence of the camera in the general vicinity.

Another factor that may account for the large variation is the issue of the effectiveness of enforcement using camera technology. For enforcement to be effective, just as for any behaviour change, the punishment and the infringement need to be linked closely; the consequence and the act must be clearly tied. Since cameras produce automatic enforcement, when drivers receive fines or notification of demerit points some considerable time after they have committed the violation, this presents a problem. The link between committing the violation and being made aware of it and/or the consequence is weakened by the length of time between them. Drivers need to know that they have been caught as close as possible to committing the offence. Information available from red camera sites can provide this in the form of camera flashes or feedback to drivers from mobile camera units.

Evaluations of mobile cameras also clearly show they are effective for reducing speed and crash outcomes. The results similarly show some variation between the different studies. Again there are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

The same issue exists for this camera type as for fixed cameras in terms of timeliness of issuing the infringement notice and demerit points in relation to the time the violation was committed. Evaluations of this camera type (and for the fixed camera type) likely have not considered this factor in any analysis. A related issue is the extent to which drivers are even aware that they have been detected violating speed limits. The question is whether drivers should be warned they are about to pass a mobile camera or whether no warning should be provided. For example in Victoria, the policy for mobile cameras is that they remain covert. In Victoria the flash of a camera has been removed, and as a result the link between committing the violation and its consequence is significantly weakened. If drivers are not warned that there are cameras in a particular location or even in a general location, the arrival of an infringement notice may be the first time they learn about it. The strategy behind this approach is to impart to the driver the notion that they can be photographed 'any time anywhere' if they are found to exceed the speed limit. Aeron Thomas (2005) noted that the strongest evidence came from a study that had signs at the entrance to the monitored area but not at the camera site itself. It is assumed that making the cameras covert motives the behavioural change in drivers to travel at the speed limit everywhere however the validity of this assumption has not been demonstrated adequately to date.

An associated issue with a weak association between the unsafe act and the consequence is its effect on driver attitudes. Speed enforcement is generally supported by the community, at least in principle, but this support is tempered by a view, unfortunately shared by more than half of the community that speed enforcement is revenue raising (Austroads, 2013). Clearly the belief that speed enforcement does not have a road safety objective is likely to be a significant impediment to drivers complying with speed limits.

This issue that drivers perceive that speed enforcement does not have a road safety objective, is discussed in a paper by Belin et al (2010). They compare speed camera programs in Sweden and Victoria. They state that the "*approach adopted in Victoria is based on the concept that speeding is a deliberate offence in which a rational individual wants to drive as fast as possible and is prepared to calculate the costs and benefits of* their *behaviour. Therefore, the underlying aim of the intervention is to increase the perceived cost of committing an offence whilst at the same time decrease the perceived benefits, so that the former outweigh the latter. The Swedish approach, on the other hand, appears to be based on a belief that road safety is an important priority for the road users and one of the reasons to why road users drive too fast is lack of information and social support."* The Swedish approach is to assist the driver with making a safe speed choice and thus bring about a general cultural behavioural change. On the other hand, in Victoria the system is punitive and treats the offending driver as intentionally carrying out a criminal act. In Sweden however, it is accepted that drivers need to be assisted with making the right speed choice. The approach is engineering based where the choice in what system is used to achieve a particular road safety target can be either through the use of speed cameras or through upgrading the road system.

The relative benefits of the Victorian or Swedish approaches are still to be formally evaluated. There is evidence, however, that the covert approach adopted by Victoria resulted in significant proportions of drivers believing that camera technology was being used for revenue raising (Smith and Senserrick, 2004) and the approach also involves a weak link between the unsafe behaviour that we wish to change (speeding) and the punishment that is intended to change that behaviour. There is evidence that the Victorian approach has produced some benefits of reduced speeding and crashes (Cameron et al, 2003). However, it is unclear what aspects of the approach produced these effects given that it included covert cameras, greater enforcement, increase media and lower speed limits. It is likely, however, that the benefits could be greater if elements of the Swedish approach were included. For example, the underlying premise of the Victorian approach that drivers make deliberate decisions to speed so making them believe that they must always drive slower than the speed limit as they could be caught anywhere and anytime has not been rigorously evaluated. Exceeding the speed limit can occur when drivers are not focussing on their speed due to other activities including driving-related activities. This means that drivers can inadvertently exceed the speed limit even when they did not intend to do so. Current statistics on speed camera infringements in Victoria show that only a smaller percentage of all drivers (around 30%) are caught speeding by speed cameras, but this corresponds to over one million drivers each year. If only a proportion of these drivers, e.g. half did not intend to speed, this may have an impact on community attitudes to speed cameras, which is likely to be negative particularly if they were not immediately aware that they had actually committed the infringement.

Delaney et al (2005) highlight the various controversies which they suggest need to be considered in any speed camera enforcement program. The examples they listed are that speed cameras are seen by some as: revenue raising; unfair in that they do not identify offenders on the spot; not timely in terms of issuing the infringement notices; placed in locations where speed is perceived to be safe because it is felt that the speed limits are too low; lack reliability in terms of instrument measurement; not addressing road safety, i.e. speeding may not be perceived as a road safety problem; intruding into the Privacy of individuals, i.e. big brother is watching. They noted in the case of Victoria: '*Public opinion surveys conducted in Victoria identified the controversies associated with camera use. In the initial years few controversial issues arose, thought to be a result of carefully planned strategies of camera implementation. These strategies included independent technical testing and quality assurance of equipment and procedures, identification of safety (not revenue) as the primary objective, winning public support even though the level of fines was high, and subjecting the program to independent evaluation research to establish its road safety potential.'* Nevertheless, they found that despite Victoria deploying covert cameras across the road network without warning signs, and taking an aggressive approach of reducing the speeding threshold tolerance to 3 km/h, the camera program was widely supported by the public. They advised that any jurisdiction planning to introduce a speed camera program should at a minimum: *'involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important. Finally, it is essential that the equipment and operating procedures used are reliable.'*

The evaluation of the point-to-point cameras in Italy by Montella et al (2012) also clearly show they are effective for reducing speed in the location where the camera system is installed. However, compared to other speed enforcement approaches, point-to-point systems are relatively expensive (Austroads 2012). Nevertheless the cost-benefit ratios appear high and compliance extends over longer distances. A four year evaluation of speed cameras of all types in Britain (Austroads 2012), showed that all types of cameras produced reductions in speeds at the camera site. In all, fixed cameras produced the greatest reductions, followed by point-to-point cameras and mobile speed cameras. However, it should be noted that fixed cameras also produce their effects over the shortest distances.

4.2 Review of community attitudes to speeding

The introduction of mobile and red light cameras occurred fairly close in time: 1999 and 2000. This means that individual effects of each camera are likely to be difficult to disentangle. Nevertheless, a number of changes were found that were associated with the introduction of safety cameras in the ACT. First, initial introduction of mobile and red light cameras was associated with increased perception that enforcement had increased so ACT residents noticed the additional enforcement. Aligned with this finding was the increased reporting of being booked for speeding over the last two years in the two years following the introduction of mobile and red light cameras, although this effect trended down between 2006 and 2008. Furthermore, more ACT respondents reported decreasing their own driving speed in the period following the introduction of mobile and red light cameras. Combined, these findings suggest that the initial implementation of the safety camera programme with mobile and red light cameras may have influenced the amount and impact of speed enforcement and even had effects on driver behaviour through reducing their driving speed. The data shows that around this time serious injury crashes dramatically fell by around 40% from around mid-2002 and was maintained until 2004 after which the trend began to steadily rise.

The introduction of fixed cameras in 2007 was not associated with increased perception of increased enforcement, even though more respondents reported being booked for speeding over the past two years and six months in 2009 and 2011 following the introduction of fixed cameras. Alternatively, the lack of reported change in perception of enforcement may reflect an insensitivity of the question (lack of detailed questioning) which has only a few available responses compared with the question on being booked. In addition, the personal experience of being booked is memorable whereas the amount of enforcement years earlier may not be.

Interestingly, there was a relationship between increased reporting of being booked for speeding between 2002 and 2005 and a clear drop in the percentage of ACT respondents who supported no tolerance for speeding in 60 and 100kph zones, especially after 2002. It may be that the more widespread experience of being booked made ACT respondents review their attitude to speed limits so fewer supported a tougher 'no tolerance' approach.

Many attitudes to speeding in the ACT seem to have changed little since 1995, although there are a few exceptions. Since the introduction of safety cameras, far fewer ACT respondents agree with the idea of safe speeding. Similarly, support for increasing levels of enforcement and even severity of penalties has increased or at least stayed the same following introduction of safety cameras. The initial introduction of safety cameras in the ACT was also associated with a marked increase in support for lowering residential speed limits. While there may not have been a direct causal relationship between the effect of safety cameras and views in the ACT about speed limits, the presence of cameras clearly did not have a significant influence on attitudes about speed limits as in 2003 over 90 percent of respondents supported lower speeds.

On the other hand, around half of respondents in the ACT agree with the view that speeding fines are for revenue raising. Unfortunately, support for this view increased in the two years immediately following the introduction of fixed cameras. Although this effect dropped in the most recent survey, to the same levels as before the introduction of fixed cameras.

These findings suggest some clear targets for further consideration in order to enhance community support for speed management in the ACT. There seem to have been some very clear benefits for community perceptions and attitudes from the first introduction of safety cameras in the ACT. People noticed their effect and at least reported reducing their driving speed but they maintained support for establishing lower speed limits, increased enforcement and stricter penalties for speeding. Factors that challenge these encouraging findings include the suggestion from this research that being booked may have an effect of reducing support for stricter enforcement of limits and potentially general support for speed management. Also, the commonly held view that speeding fines are revenue-raising is clearly not supportive of programmes that include speeding fines. Further understanding is needed of both of these factors, in order to encourage more supportive community attitudes towards speed management programmes in general.

This analysis of changes in community attitudes also suggests that the implementation of fixed cameras may not have been as successful as the introduction of the mobile and red light cameras. It is possible that the difference is related to a general reduction in effectiveness of the whole safety camera programme, since a number of other studies have demonstrated that most benefits of camera programmes occur immediately after implementation. Even so, the introduction of fixed cameras did not produce the same initial changes in enforcement perception, and self-reported speed behaviour as the mobile and red light cameras. Furthermore, fixed cameras were associated with a temporary increase in community perceptions of the revenue-raising nature of speeding fines. Based on these patterns of community attitude change, it would be worthwhile to review communications strategies that articulate the rationale for speed cameras and how they are being used, and also simultaneously review the operation of fixed cameras in the ACT in order to determine whether there are specific aspects of their operation that may have had negative effects on community support for the safety camera programme.

4.3 Speed survey and road crash data study

The infringements data indicate that the rate of fixed camera infringements (per vehicle checked) has been very low, where after the first year the rate remained below 0.2%. The rate of mobile camera infringements decreased consistently for approximately three years following the introduction of cameras in late 1999. After approximately late 2002, the rate of mobile camera infringements levelled off to a long-term rate of around 0.6%. Several issues may have been influencing these rates, including; drivers were not infringed at the same rate, drivers may not have been communicated to via various media outlets adequately and consistently that their speeding could result in a ticket, location of the camera, and the tolerance levels used by the cameras (i.e. the speed above the speed limit at which an infringement is issued – however camera tolerance levels are not publicly available information). During this approximately three year period of reducing infringement rates, vehicle speeds were also reducing. This indicates that drivers were getting used to the cameras and adjusting their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding.

However, following 2004, mean vehicle speeds began increasing back to the same levels when cameras were first introduced. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. Possibly when they found that they were not being caught very much or at all, or they found the penalty was not severe, or drivers have learnt how to speed and yet avoid detection, their speed started to return to customary levels. In other words, the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Alternatively, it could be other factors like initial bursts of enforcement and the relevant new publicity, which were not able to sustain mean speed reduction over longer periods. Evaluation of these possible accounts through further research is recommended. Moreover, it is recommend that the ACT examine how to make all aspect of mobile cameras less predictable in terms of location, time and vehicle used, and whether this is effective in reducing speeds and hence serious injury crashes.

It is notable that vehicle mean speeds on control streets decreased substantially immediately prior to the introduction of cameras in late 1999, which indicates that the publicity about their presence and likely effects was possibly having the desired effect of getting drivers to slow down. The introduction of cameras possibly increased the perception that drivers were likely to be caught if they exceeded the speed limit because cameras will photograph all who infringe. The effect will of course diminish when drivers find that this is not actually the case. It could be expected that speeds decrease where cameras are first introduced (and as above, even before) due to the community expectations about their effects. But then it would be expected for drivers mean speed to return to levels previous to their mention and introduction on control streets, because there are no cameras, but on camera streets the speeds would be expected to reduce as a result of the cameras photographing infringing drivers who are speeding and a ticket being issued. This effect was found initially for case streets although the effect dissipated over time.

The longer term mean and 85th percentile speed data indicated that vehicle speeds on control streets remained relatively constant, indeed annual trends remained below 1% for the full period from 1999 to 2012. These results indicate that mobile speed camera operations likely had minimal effect on speeds on streets in which cameras were not introduced.

Meanwhile, case streets saw an increase in speeds followed by a decrease in speeds before and after Intervention 2, indicating that after increases in speeds, speeds levelled off and decreased slightly with long-term mobile camera operations. Changes that occurred around Intervention 2 were small in magnitude and insignificant, indicating little effect on speeds from the drop in mobile camera operations that occurred at this time. As noted in the discussion of the literature review, many studies have shown that the effect of cameras on mean speeds is typically small in magnitude. Nevertheless, these small values can have a significant effect on casualty crashes as demonstrated in Figure 2 by Nilsson (2004). With a very small percentage of people speeding (which is known from the infringement rates), the mean speed will not decrease much but will actually reflect a significant effect on the number of speeding drivers.

It is noted that prior to the introduction of mobile cameras, speeds in case streets were higher than those in control streets. This is likely related to the fact that streets with known speed problems and/or speed-related crash problems were targeted for mobile camera operations. The drop in speeds on camera streets could be related to RTM and, as a consequence may overestimate camera effects when comparing pre and post camera introduction. However, the opposite effect might be expected due to spillover since control streets will have also been influenced by the general community awareness of cameras, which is likely to have an effect of underestimating camera effects if differences between camera and control sites is looked at.

Serious injury crashes (injury or fatality) generally decreased on streets following the introduction of mobile cameras although there was a continuing smaller trend that was evident for the five years prior to their introduction. There was a large drop in mid-2002, i.e. around two and half years after the introduction of cameras. Careful inspection of the both the number of mobile operations and serious injury crashes shows an alignment of the sudden fall of serious injury crashes with the camera operation rise over a 12 month period from around 400 to around 600 (30% increase). Fatal crashes also appeared to generally decrease after the introduction of cameras commencing around 2001. This appears to align with the period when casualty crashes started to drop. Further analysis of the nature of the serious crashes would be helpful in understanding the circumstances surrounding this sudden fall in mid-2002. Additionally, it appears the trends in serious crashes do not align well with trends in vehicle speeds. While speeds increased slightly from 2004 to 2007, they then decreased slightly until present, meanwhile serious crash counts increased steadily albeit interspersed with sudden oscillations of large increases and large decreases. Further analysis of the nature of crashes would be useful to attempt to understand these changes. If the causes of crashes varied across the study period, it may be possible to understand whether speed indeed played a role consistently across the period and whether speed cameras were likely the likely source of the casualty crashes.

Nevertheless, this two-fold increase (normalised to vehicle registrations) in serious crashes over the most recent ten years is a major road safety concern for the ACT. It was noted earlier that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. Whilst the serious crashes were normalised to vehicle registrations, the road network may not have changed significantly. In other words, vehicle density is likely rising and as a result traffic conflicts have risen. This increase in exposure may be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Further research is recommended to understand these changes in injury crashes, and develop countermeasures and prevention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties. It is possible that changes in police-reported injury crash rates might be related to changes in how police identify individuals as ‘injured’, thus linkage to hospital records provides a more accurate assessment of crash casualties (and allows assessments of individual injuries and injury severity).

Considering all road crashes (property damage, minor injury, serious injury or fatality), before and after the introduction of cameras there was a relatively consistent decreasing trend in all crash counts for both streets with and without mobile cameras. Increases in crashes around the time of the introduction of cameras were evident on both streets with and without mobile cameras, and were more pronounced on streets with cameras, likely because this was the basis for choosing camera streets. It is noted that the magnitudes of crash counts were substantially higher for the case streets compared with the control streets (by an average of 5.4 times), which is likely a result of the fact that mobile camera operations were more likely to be located on streets with high crash counts and/or traffic volumes. It could be argued that both of these effects may be at least partly due to RTM.

The results of the analyses of all intersection crashes (property damage, injury or fatality) indicated that the introduction of fixed red light and speed cameras increased the frequency of crashes followed by a decline to a level slightly lower than baseline levels, while serious intersection crashes decreased slightly along with non-rear-end crashes/right angle collision/right turn crashes. This initial increase in intersection crashes resulted directly from an increase in rear-end crashes at intersections where the cameras were installed but then declined to baseline levels. This trend that did not occur at intersections where fixed cameras were not installed, i.e. rear end crashes continued to rise on control streets. As noted in the literature review, many studies have noted a similar result (Erke 2009, Hoyos 2013, Vanlaar et al 2014, Pulugurtha and Otturu 2014). It is clear that the road safety benefit is confounded, because it is more crashes in the initial stages of camera installation albeit in this study the crashes reduced to levels slightly below baseline levels. Some authors have argued that road safety might tolerate a trade-off of reducing serious speed-related side-impact crashes for increased lower severity rear-end crashes (Kloeden et al 2009). However, this needs to be further researched.

5. Limitations

It should be noted that trends in mean vehicle speeds may have been influenced by other factors not considered in this study. However, driving speeds are, in the main, a very deliberate action by the vehicle operator, and are likely to be influenced directly by enforcement operations that monitor vehicle speeds and penalise operators when they exceed limits, or indirectly by drivers' perceptions of the operation of cameras and related enforcement. Even inadvertent speeding can be influenced by cameras through creating more care to avoid speeding.

The crash study considered nearly two decades of data, over which time many changes may have occurred in the ACT with regards to roadway infrastructure, roadway design, safety devices, vehicle designs, road user type (cyclist, motorcyclists) and road user behaviours (including speeding, alcohol and drug use, protective device use, etc.) in addition to the introduction of speed cameras. There have also been many road safety initiatives in the ACT addressing particular road user groups and behaviours. These factors may have affected crash frequencies, however were not considered in the present study.

As mentioned in the methodology, it should also be considered that the control streets identified for the analyses do not represent a true 'control area'. The issue of spillover effects in evaluation studies of safety cameras has been discussed at length in the literature (Retting, Ferguson & Hakkert 2003; Aeron-Thomas 2005; Erke 2009; Hoyos 2013; Ko, Geedipally, Walden 2013; Porter, Johnson, Bland 2014; McCartt, Hu 2014; Pulugurtha, Otturu 2014; Vanlaar, Robertson, Marcoux 2014). It is acknowledged that in evaluations such as this study, spillover effects may result in an underestimation of the effects of cameras although they may indicate that the public awareness aspect of the camera introduction has been effective.

Another limitation of the study is that road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations considered could not be directly assessed in this study. Moreover, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

The speed survey data used in the present study was derived from surveys on particular streets that were undertaken at irregular intervals. As a result, for any given month all speed survey results were averaged (aggregated separately by case and control streets). Thus the monthly speed survey results used in the statistical models were discrete time data, which may limit the specificity and applicability of the results. It is preferable that each street location had continuous data, such that the statistical models could be stratified by location, such as was the case for the monthly crash counts. However, such data were not available for the speed surveys. It is recommended that subsets of streets with and without cameras are identified, and future surveys be performed on these streets in a regular manner (with the period being defined by resource limitations). This would provide more meaningful results in future speed meta-assessments. It is also noted that assessments of several speeding-related indicators could not be assessed in the present study, including proportion of vehicles speeding, proportion more than 20km/h over the speed limit, etc. More detailed information on the speed surveys performed might have provided further insights into driver speeding. These data are stored on an old computer system from which it was not possible to extract bulk data (i.e. for the 1,758 speed surveys assessed in the present study). Consequently, the present study used data from the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

6. Final brief conclusions

Along with the conclusions listed at the front of this report, the following summary conclusions are provided for completeness of the report.

Mobile cameras seem to have been effective initially as seen by reductions in serious crashes in the period 2002-2006 and the pre/post analysis for cases but not for controls. The serious injury crashes increased in case streets following 2006 and seemed to coincide with decreasing and less consistent enforcement which is what would be expected if the cameras were located in the high risk streets compared to controls.

Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. The increase in speeds would explain the increase in serious crashes. Avoidance mechanisms could be based on prediction of location and/or time/ and or/day and/or the vehicles being used, or provision of information from various sources.

Fixed cameras did not seem to be as effective in regards to all crashes as they showed increases on case locations compared to controls which then returned to baseline levels. However, this may have been the result of changes in rear-end crashes which may have been because drivers became aware of where the fixed cameras were. This in turn may have had an effect on rear end crashes mostly. The continuing increase in traffic demand could also have played a role. Nevertheless, there appeared to be a fall in serious injury crashes.

These results suggest that more work needs to be done to understand why serious crashes have increased since 2007 and what can be done to improve the effectiveness of cameras since the initial introduction and the research literature demonstrates that they can be effective. In the ACT it would be beneficial for road safety to develop a more sustained programme of re-implementation and evaluation of safety cameras and road safety public awareness campaigns.

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Appendix A: Case and control streets and intersections

STREETS

CASES	CONTROLS
Anthill St	A'Beckett St
Athllon Drv	Archibald St
Barry Drv	Ballumbir St
Barton Hwy	Boldrewood St
Bateman St	Brigalow St
Beasley St	Canopus Cr
Belconnen Way	Chrisholm St
Canberra Ave	Condamine St
Carruthers St	Cowper St
Chuculba Cr	Culgoa Cct
Clift Cr	Dalrymple St
Clive steele Ave	Davenport St
Darwinia Ter	De Burgh St
David St	Emu Bank
Drakeford Drv	Fincham Cr
Dryandra St	Flemington Rd
Ellerston Ave	Forbes St
Federal Hwy	Foveaux St
Florey Drv	Goodwin St
Gilmore St	Grey St
Ginninderra Drv	Hawdon St
Gladstone St	Hopetoun St
Goyder St	Knox St
Groom St	Krefft St
Gungahlin Drv	Langdon Ave
Heyson St	Mackennal St
Hindmarsh Dr	Macpherson St
Kent St	McCaughey St
Kitchener St	McCulloch St
La perouse St	Melba St
Lady Denman Drv	Miller St
Launceston St	Moore St
Learmonth Drv	Mortimer Lewis
Livingston Ave	Murranji St
Macgregor St	Palmer St
Melrose Drv	Paul Coe Cr
Monaro Hwy	Ratcliffe Cr
Namatjira Drv	Scrivener St
Northbourne Ave	Spalding St
Novar St	Vanisttart Cr
Officer Cr	Verbrugghen St
Petterd St	Victoria St
Phillip Ave	Watson St
Ross smith Cr	Wattle St
Theodore St	William Slim Dr
Tillyard Drv	Windeyer St
Tuggeranong Pkwy	Wisdom St
Williamson St	

INTERSECTIONS

CASES	CONTROLS
Northbourne Ave and London Circuit	Northbourne and Swinden
Northbourne Ave and Barry Drive	Northbourne, Eloura and Gould
Drakeford Drive and Marconi Cres	Drakeford, Sulwood and Tuggeranong
Northbourne Ave and Antill Street	Northbourne, Girrahween and Masson
Ginninderra Drive and Aikman Drive	Ginninderra and Kingsford Smith
Hindmarsh Dr and Tuggeranong Pkwy	Hindmarsh and Monaro
Ginninderra Drive and Coulter Drive	Ginninderra and Lance Hill
Barry Drive and Marcus Clarke Street	Barry and McCaughey
Hindmarsh Drive and Yamba Drive	Hindmarsh and Streeton
Hindmarsh Drive and Ball Street	Hindmarsh and Jerrabomberra
Hindmarsh Drive, Newcastle St and Canberra Ave	Hindmarsh and Larakia
Canberra Ave, Captain Cook Cres and Manuka Circle	Canberra and Dalby
Gungahlin Drive and Gundaroo Drive	Gungahlin and Sanford

Appendix B: Results of literature searches

Table B1: Results of review of peer-reviewed scientific published literature for each search engine

Database	Search Term	# Retrievals	Repeats	Remaining	Final	Search Strategy
Web of Science	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "topic")	7				Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	25				Search in "Topic"
	Red light camera + Enforcement + Evaluation	14				Search in "Topic"
	Speed (search in "title") + Camera (search in "title") + Enforcement (search in "topic")	27				
Subtotal		**73**	**19**	**54**	**51**	
PsycINFO	Speed + Camera + Evaluation	3	22			Search in "Abstract", Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	0				Search in "Abstract"
	Red light camera + Enforcement + Evaluation	1				Search in "Abstract"
	Speed (search in "abstract") + Camera (search in "abstract") + Enforcement (search in "all fields")	16				
Subtotal		**20**	**3**	**17**	**8**	
Scopus	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "abstract")	5	12			Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	27				Search in "Article title, abstract, keywords"
	Red light camera + Enforcement + Evaluation	19		The		Search in "Article title, abstract, keywords"
	Speed + Camera + Enforcement	12				Search in "Article title"
Subtotal		**63**	**14**	**49**	**14**	
PAIS International	Speed + Camera + Evaluation	0	49			Search in "Anywhere"
	Speed enforcement camera* + Evaluat*	1				Search in "Anywhere"
	Red light camera + Enforcement + Evaluation	1				Search in "Anywhere"
	Speed + Camera + Enforcement	7				Search in "Anywhere"
Subtotal		**9**	**1**	**8**	**6**	
Final repeats			**49**			
Total		**165**	**86**	**128**	**79**	

Table B2: Australian government road safety authority websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
NSW - Roads & Traffic Authority	1	0	0	1	0	0	0	1
NSW - Transport for NSW - Centre for Road Safety	1	1	1	1	0	0	0	1
VIC - VicRoads	0	0	0	0	0	0	0	0
VIC - Cameras Save Lives	1	0	0	0	0	0	0	0
WA - Department of Transport	0	0	0	0	0	0	0	0
QLD - Department of Transport and Main Roads	1	1	1	1	1	0	0	0
SA - Department of Planning, Transport and Infrastructure	1	1	1	1	1	1	1	0
SA - Government of South Australia	0	0	0	0	0	0	0	0
NT - Northern Territory Transport Group	0	0	0	0	0	0	0	0
TAS - Department of Infrastructure, Energy & Resources - Transport	0	0	0	0	0	0	0	0
AU - Department of Infrastructure and Transport	1	1	0	0	0	0	0	1

Table B3: Individual Road Safety organisation websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
US - National Highway Traffic Safety Administration (NHTSA)	0	0	0	0	0	0	0	0
US - Liberty Mutual Research Institute for Safety	0	0	0	0	0	0	0	0
CA - Transport Canada	1	1	0	0	0	0	0	0
UK - Department for Transport (DfT)	1	1	1	1	1	0	0	1
EU - Eurosafe (European Association for Injury Prevention and Safety Promotion)	0	0	0	0	0	0	0	0
EU - European Agency for Safety and Health at Work	0	0	0	0	0	0	0	0
AU - Australian Transport Safety Bureau (ATSB)	0	0	0	0	0	0	0	0
AU - Austroads	1	1	1	1	1	0	0	1
AU - Roadwise	0	0	0	0	0	0	0	0
AU - Standing Council on Transport and Infrastructure (SCOTI, formerly Australian Transport Council)	1	0	0	1	1	0	0	0
AU - Australian Bureau of Statistics (ABS)	1	0	1	1	0	0	0	0
AU - Australiasian College of Road Safety (ACRS)	1	0	1	1	0	0	0	1
AU - RACV	1	1	1	1	1	0	0	0
AU - Queensland Travelsafe Committee	1	1	1	1	0	0	0	1
AU - NSW Bureau of Crime Statistics	0	0	0	0	0	0	0	0
AU - NRMA	0	0	0	0	0	0	0	0
AU - NRMA - ACT Road Safety Trust	0	0	0	0	0	0	0	0
AU - NSW StaySafe Committee	0	0	0	0	0	0	0	0
AU - NSW Motor Accidents Authority	0	0	0	0	0	0	0	0
AU - Transport Accident Commission (TAC) in Victoria	0	0	0	0	0	0	0	0
AU - The State Attorney-General's Departments	0	0	0	0	0	0	0	0

NZ - Transport Agency	1	1	0	0	1	0	0	1
NZ - Ministry of Transport	0	0	0	0	0	0	0	0
SW – Swedish Transport Administration (Trafikverket)	1	0	1	0	0	0	0	1
Ireland – Road Safety Authority	1	0	1	0	0	0	0	0
The Netherlands – EuroRAP	0	0	0	0	0	0	0	0
France – Institut National De Recherche Sur Les Transports Et Leur Securite (INRETS)	0	0	0	0	0	0	0	0

Table B4: Research centre websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
QLD - Queensland University of Technology - CARRS-Q	1	0	1	1	0	0	0	1
VIC - Monash University - MUARC	1	1	1	0	1	0	0	1
SA - University of Adelaide - Centre for Automotive Safety Research	1	1	0	1	0	0	0	1
NSW - Sydney University - Institute of Transport and Logistics Studies	0	0	0	0	0	0	0	0
NSW - UNSW - TARS	1	1	1	1	0	0	0	1
AU - Australian Road Research Board	1	1		1	0	0	0	0
US - Research and Innovative Technology Administration: National Transportation Library	1	1	1	1	0	1	0	1
US - Transportation Research Board	0	0	0	0	0	0	0	0
US - American Transportation Research Institute	0	0	0	0	0	0	0	0
UK - Transport Research Laboratory	1	1	0	1	0	0	0	1

Appendix C: Results of ACT community attitudes to speeding surveys

"In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"

Year	Increased (%)	Same (%)	Decreased (%)	Don't Know (%)
2011	64	27	5	4
2009	65	26	4	6
2008	63	27	8	2
2006	69	22	4	5
2005	72	21	3	3
2004	71	15	8	7
2003	77	15	5	3
2002	62	22	7	8
2001	74	13	7	5
2000	69	29	7	4
1999	58	30	6	5
1998	56	34	8	2
1997	55	33	7	5
1996	54	26	8	13
1995	59	28	4	9

"Have you personally been booked for speeding in the last two years?"
…and, if so, "Have you personally been booked for speeding in the last six months?"

Year	Last 2 years (%)	Last 6 months (%)
2011	20	9
2009	19	9
2008	15	6
2006	17	6
2005	24	9
2004	21	3
2003	28	8
2002	21	9
2001	17	8
2000	16	4
1999	11	3
1998	13	5
1997	25	11
1996	20	10
1995		9

"Thinking about 60km/h speed zones in urban areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	64	31	64	20
2009	65	34	64	22
2008	64	36	65	21
2006	64	32	64	15
2005	64	33	64	12
2004	65	28	65	13
2003	64.2	33	65.4	10
2002		51	64.9	15
2001		44		
2000		38		
1999		49		
1998		49		
1997		49		
1996		42		
1995		34		

"Thinking about 100km/h speed zones in rural areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	106	25	106	21
2009	110	23	107.9	15
2008	105.5	28	108	14
2006	107	18	107	5
2005	109	20	109	7
2004	110	23	109	8
2003	106.8	22	108.7	6
2002		35	109.2	10
2001		26		
2000		25		
1999		28		
1998		36		
1997		23		
1996		27		

Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:

- Fines for speeding are mainly intended to raise revenue
- I think it is okay to exceed the speed limit if you are driving safely
- Speed limits are generally set at reasonable levels
- If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
- An accident at 70km/h will be a lot more severe than an accident at 60km/h

Year	Speeding fines mainly intended to raise revenue (%)	OK to speed if driving safely (%)	Speed limits generally reasonable (%)	More likely to be involved in accident if increase speed by 10km/h (%)	Accident at 70m/h more severe than 60km/h (%)	TOTAL: Cautious / Conservative attitude to speeding / speed limit enforcement (%)
2011	51	29	85	62	92	26
2009	59	21	86	73	92	25
2008	55	38	85	65	94	22
2006	50	29	88	71	96	26
2005	51	28	87	67	91	28
2004	51	34	87	66	93	
2003	49	33	86	70	91	
2002	48	34	89	63	95	
2001	51	34	87	71	95	
2000	48	38	85	67	89	
1999	53	39	94	69	89	

"Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?" … and then,
"Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"

Year	Level of enforcement			Severity of penalties		
	Should increase (%)	Should decrease (%)	Stay the same (%)	Should increase (%)	Should decrease (%)	Stay the same (%)
2011	44	8	44	27	6	63
2009	46	7	43	24	9	61
2008	45	5	48	23	6	63
2006	37	7	54	23	8	62
2005	37	10	52	20	8	68
2004	47			25		
2003	34			17		

"Do you think that 50km/h in residential area is too low or too high, or about right?" and
"Do you think that limits below 60km/h should be set on more streets, fewer streets, or is it about right as is?"

Year	50km/h speed limit in residential areas are:			Speed limits below 60km/h should be set on:		
	Too low (%)	Too high (%)	About right (%)	Increase the number of <60km/h streets	Decrease the number of <60km/h streets	About right
2009	13	7	80	20	6	74
2008	11	4	86	20	7	73
2006	20	3	77	16	18	66
2005	20	2	78	22	13	65
2004	20	<1	80	24	19	57

"Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways"

They were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"

Year	Approve strongly (%)	Approve somewhat (%)	Total approve (%)	Not care either way (%)	Disapprove somewhat (%)	Disapprove strongly (%)	Don't Know (%)
2003			91				
2002	42	34	77	4	10	10	0
2001	45	27	72	6	15	6	1
2000	28	27	55	8	13	22	1
1999	27	33	60	4	15	20	2
1998	39	18	58	13	12	18	0
1997	17	24	41	13	26	20	1
1996	38	20	58	3	19	20	0
1995	17	28	45	9	26	18	2

"How often do you drive at 10km/h or more over the speed limit?"

Year	%
2011	5
2009	11
2008	5
2006	9
2005	8
2004	9

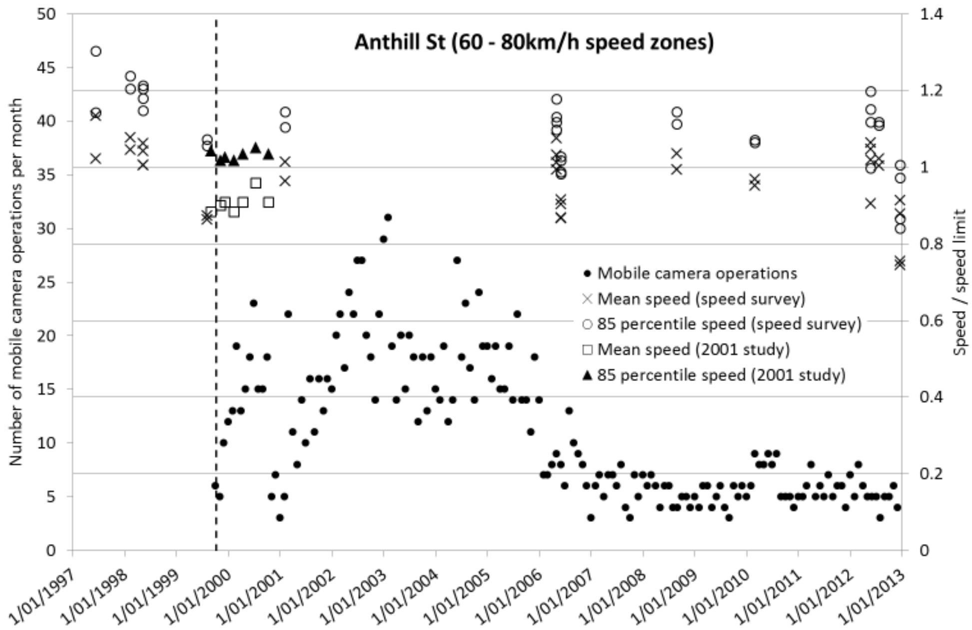
"In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

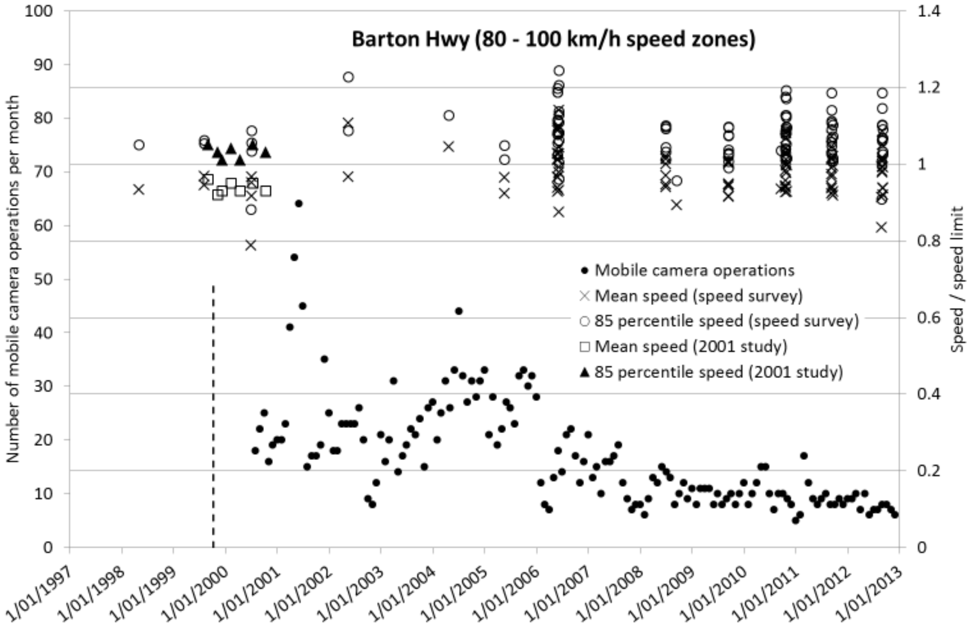
Year	Increased (%)	Stayed the same (%)	Decreased (%)
2011	1	76	23
2009	4	73	23
2008	4	73	23
2006	7	68	25
2005	2	69	29
2004	5	65	28
2003	6	67	25
2002	5	66	28
2001	5	62	32
2000	4	61	33
1999	6	70	21
1998	4	73	23
1997	6	62	32
1996	7	52	41
1995	11	62	26

Appendix D: Individual speed survey results for case and control streets

This appendix contains plots for most of the case and control street locations used in this study (a few streets were excluded due to plotting issues). The available speed surveys provided by the Territory and Municipal Services Directorate are plotted for all streets, where mean and 85th percentile speeds are normalised to the speed zone in which the survey was undertaken (in some cases surveys were undertaken on sections of the same street with different speed limits). Additional speed surveys undertaken by ARRB in the 18 months following the introduction of cameras in October 1999 are also plotted where available (Edgar, A., 2001. Evaluation of the Effectiveness of Speed Cameras in the ACT, Final Report 1. NRMA-ACT Trust Project Evaluation Reports, ARRB Transport Research). The start date of October 1999 is identified on all plots. For case streets the number of mobile operations undertaken per month along that particular street are also plotted.

CASE STREETS




Barton Hwy (80 - 100 km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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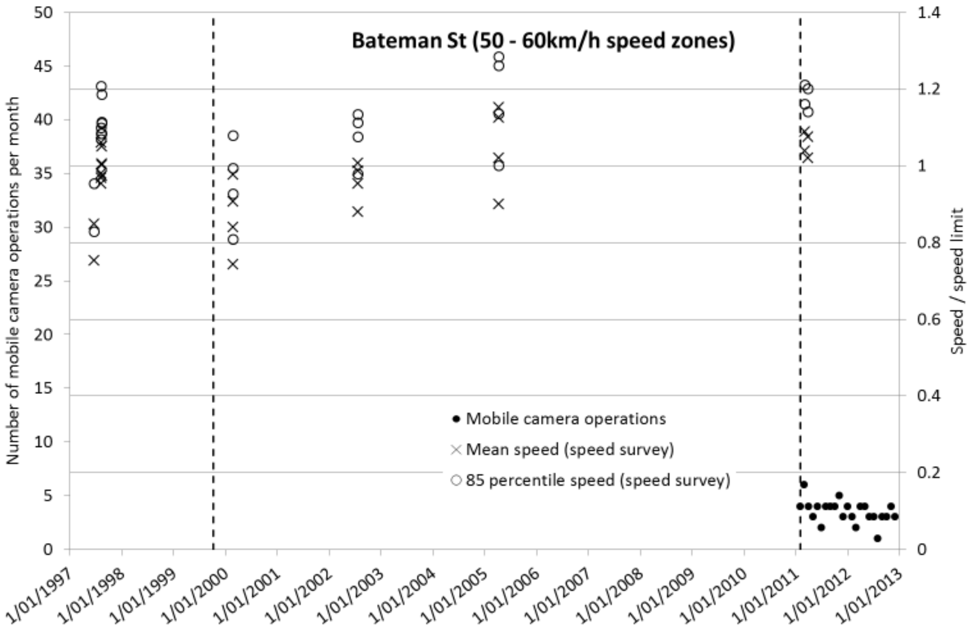
1/01/2012
1/01/2013


Bateman St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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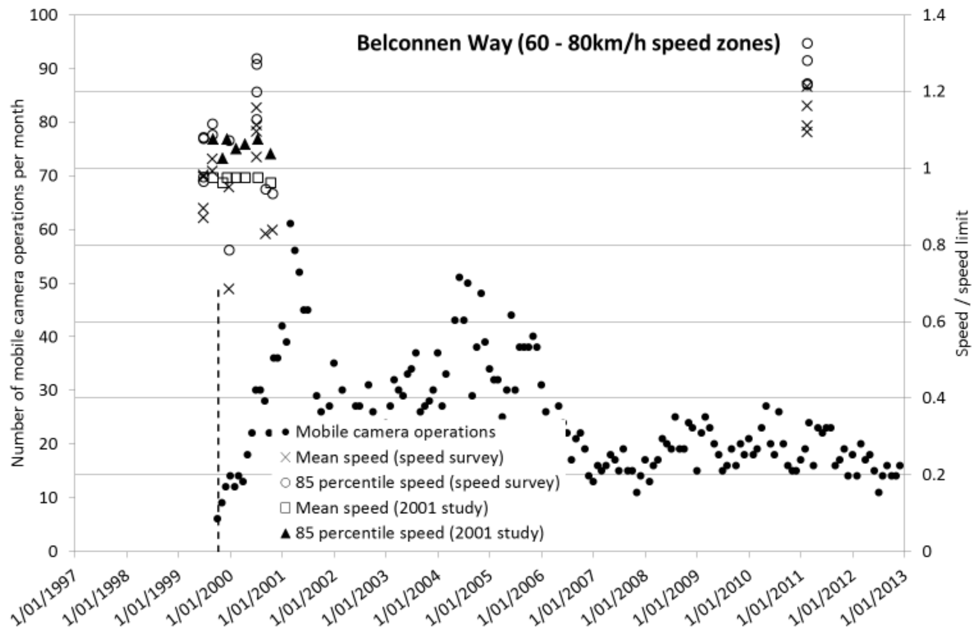
1/01/2012
1/01/2013


Belconnen Way (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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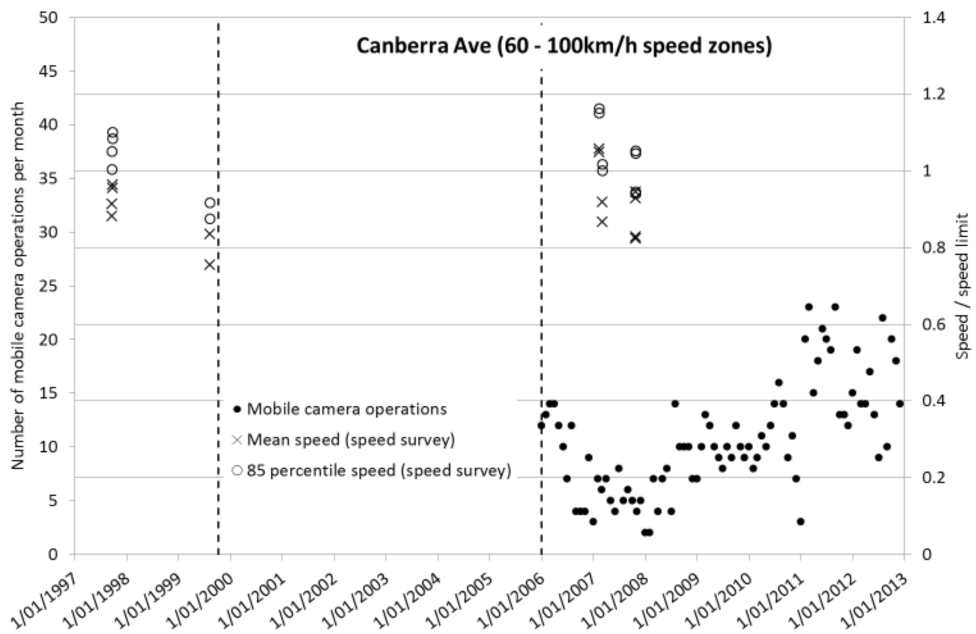
1/01/2013


Canberra Ave (60 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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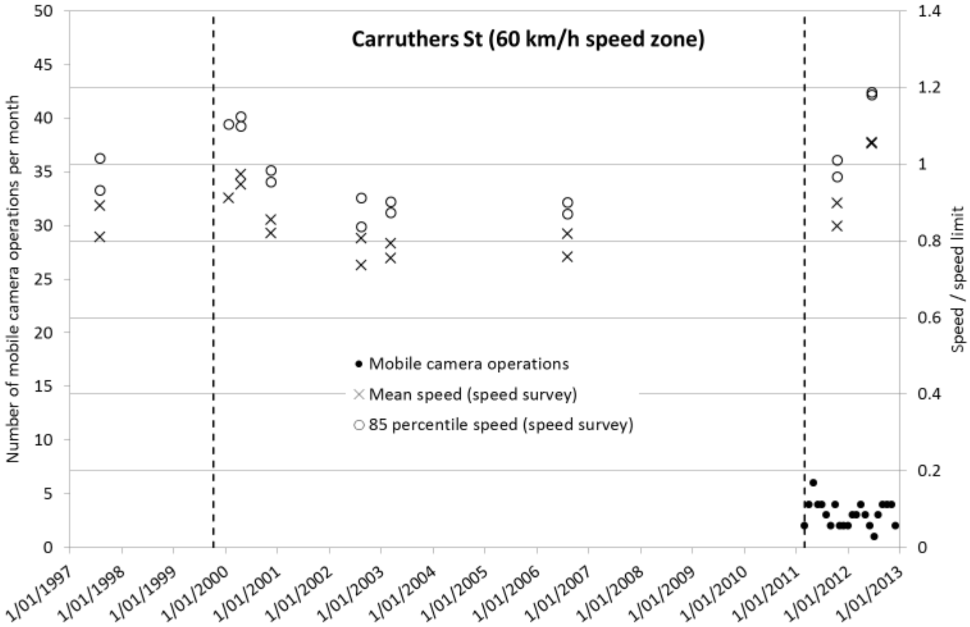
1/01/2011
1/01/2012
1/01/2013


Carruthers St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
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10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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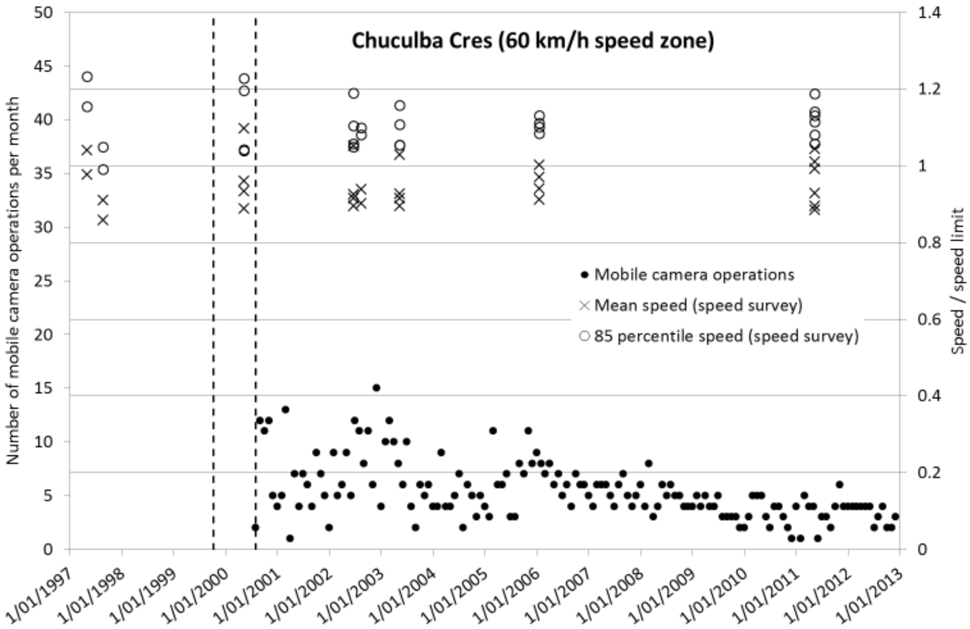
1/01/2012
1/01/2013


Chuculba Cres (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
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5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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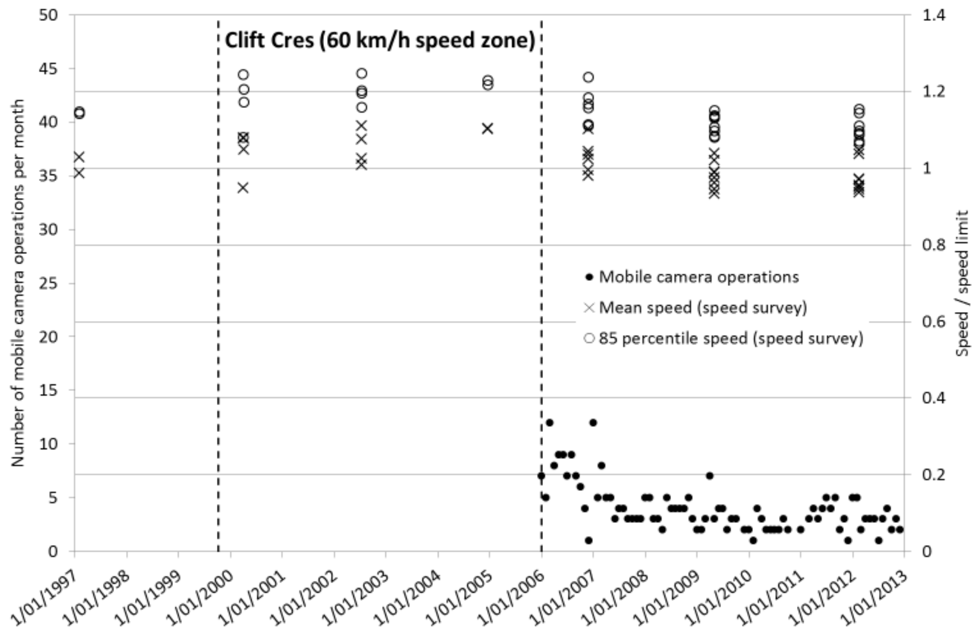
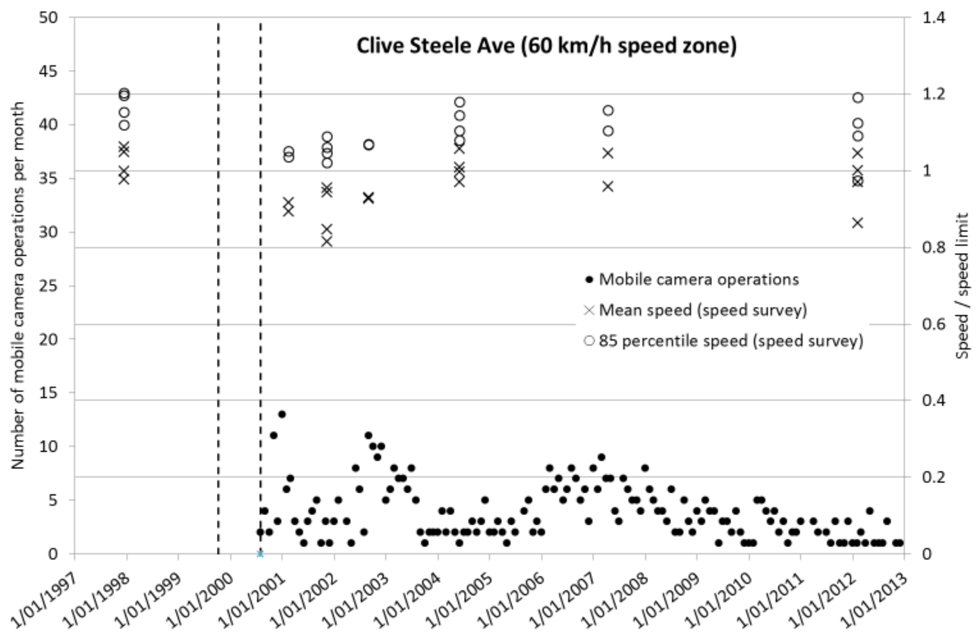
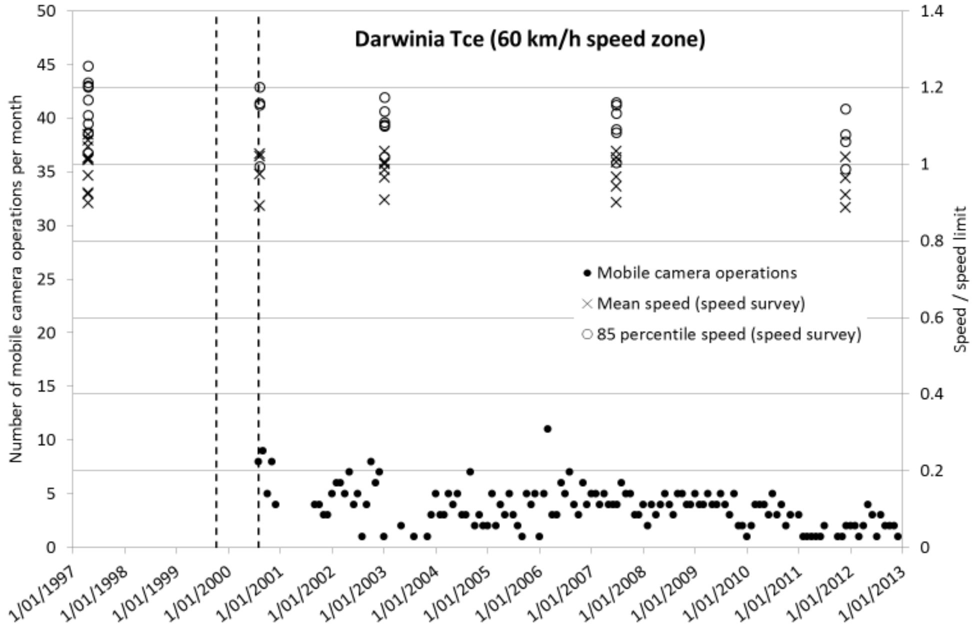
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



Clift Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)



Clive Steele Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)


Darwinia Tce (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
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10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
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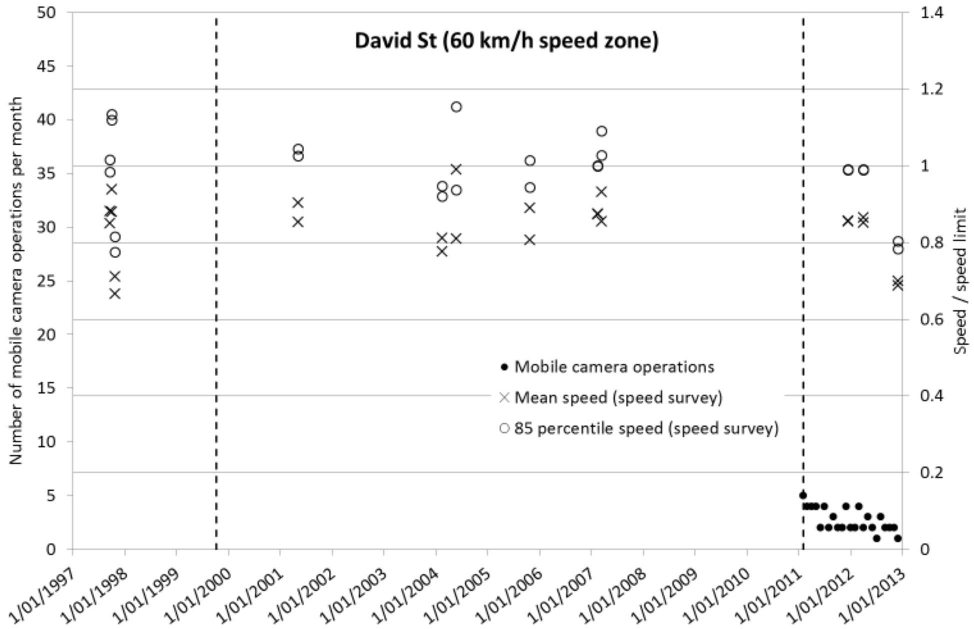
1/01/2012
1/01/2013


David St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
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10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
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1/01/1997
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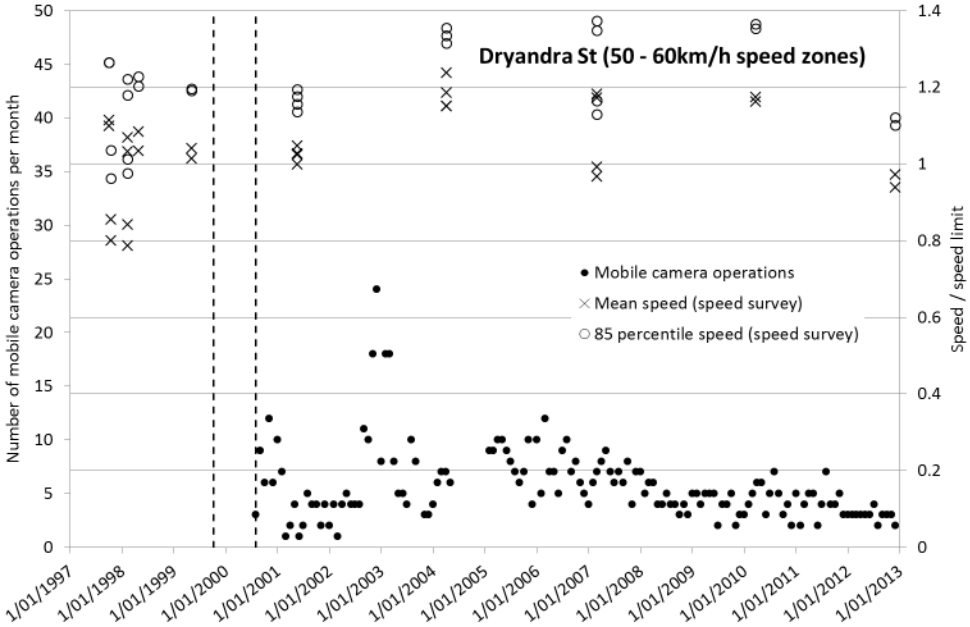
Dryandra St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
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45
40
35
30
25
20
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0
1.4
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1/01/1997
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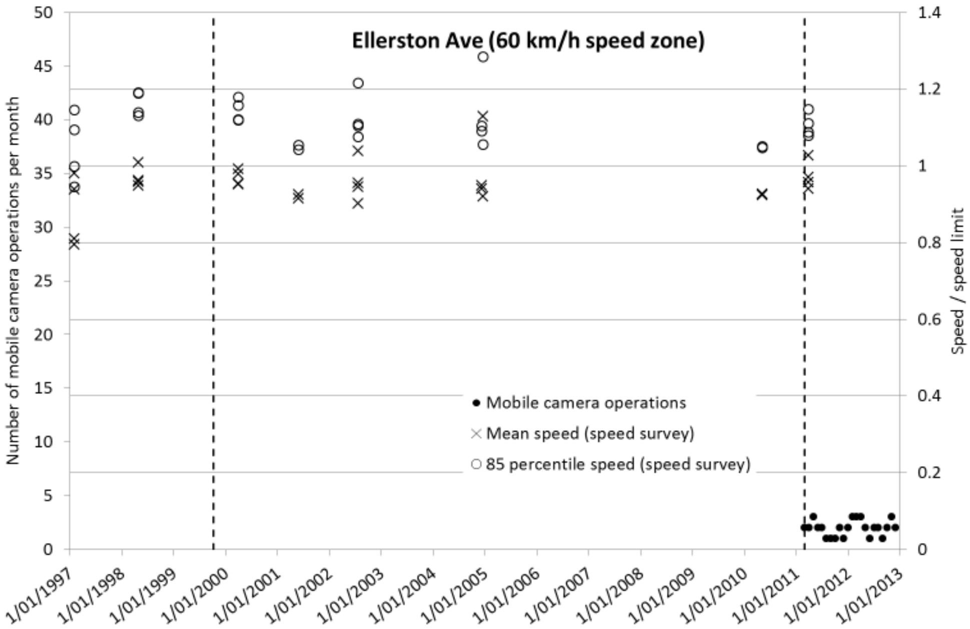
1/01/2013


Ellerston Ave (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
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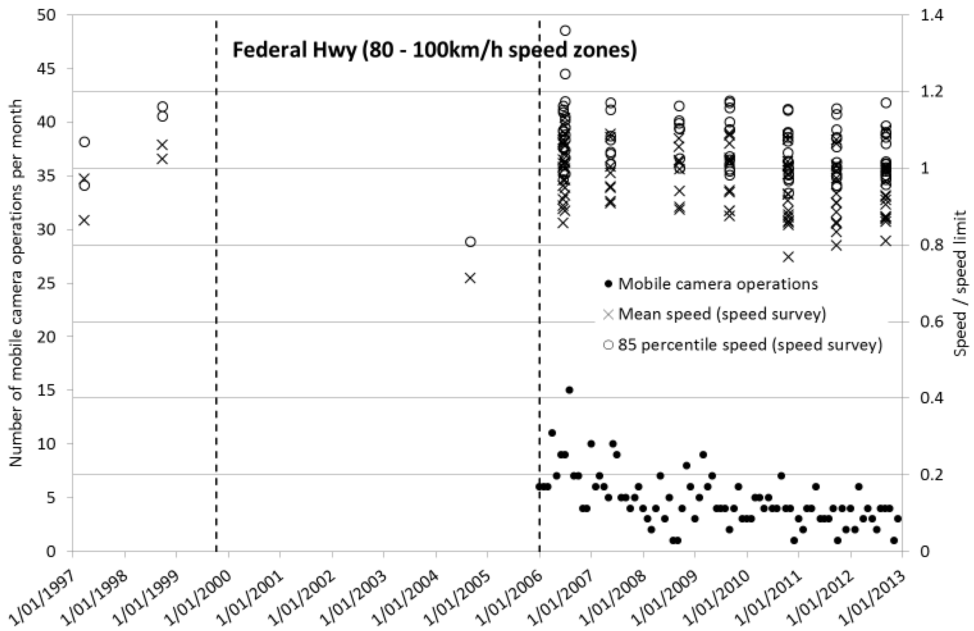
Federal Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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25
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35
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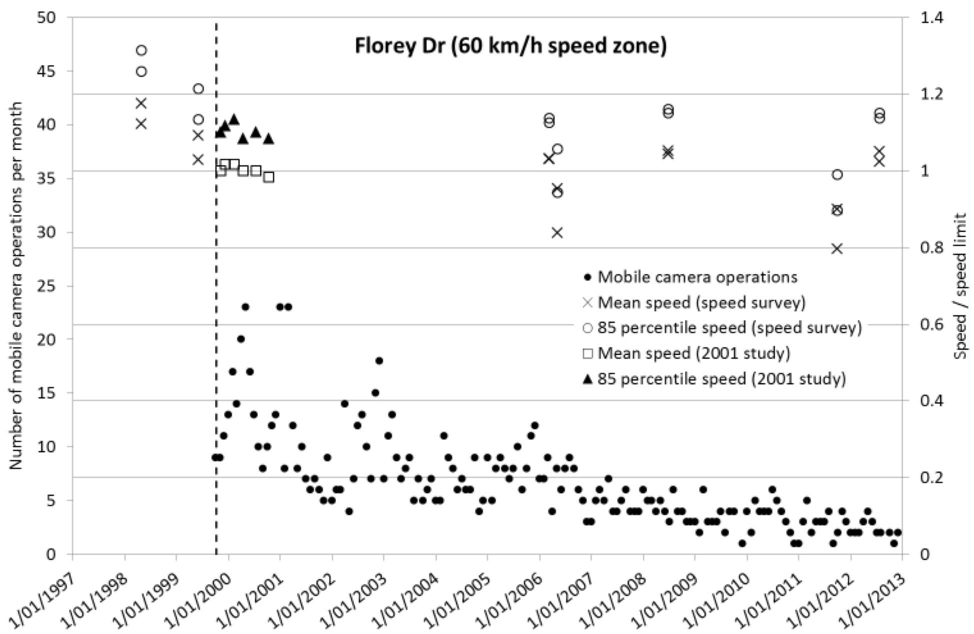
Florey Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
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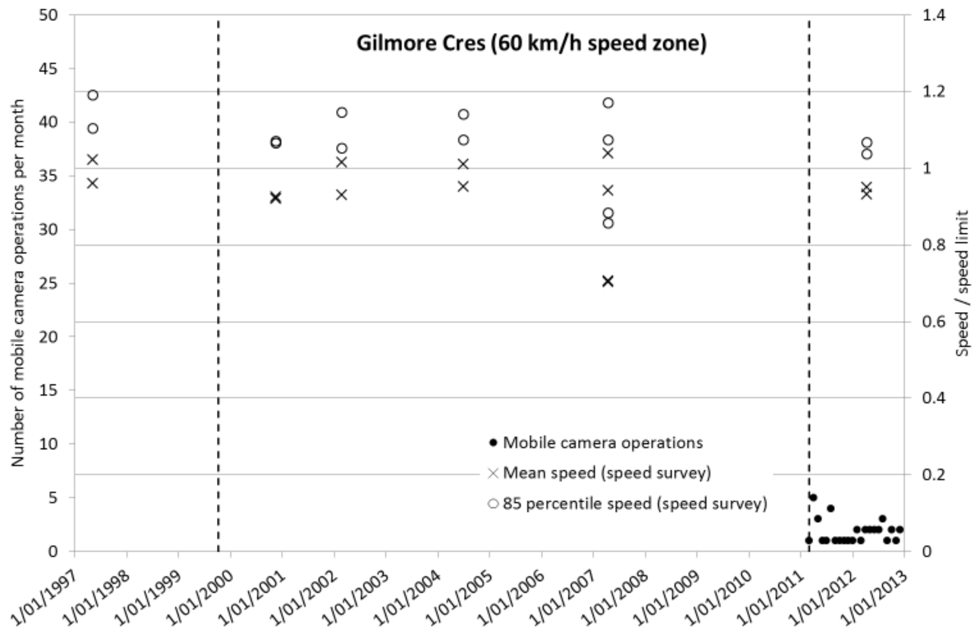

Gilmore Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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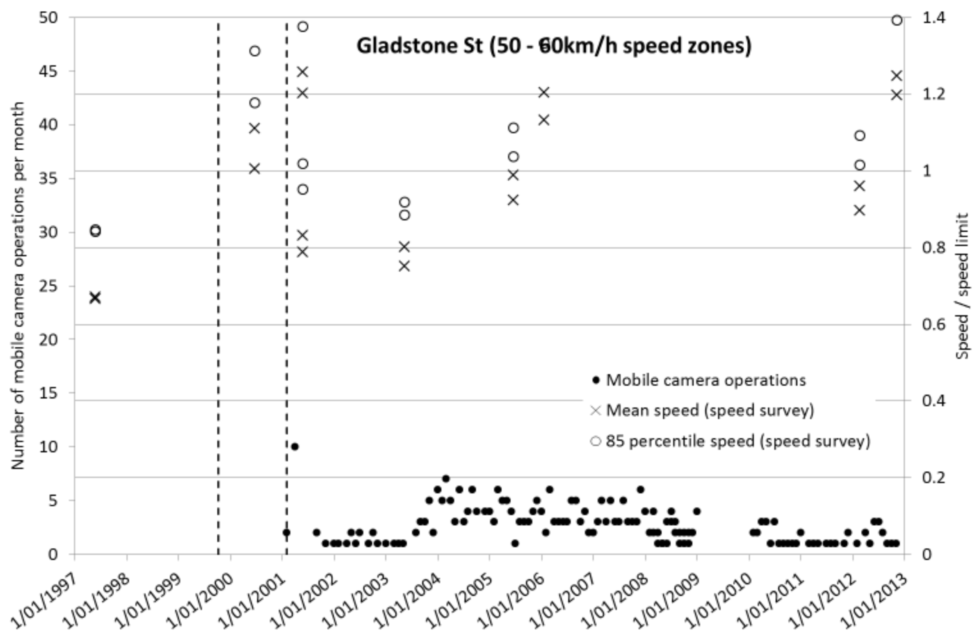

Gladstone St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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5
10
15
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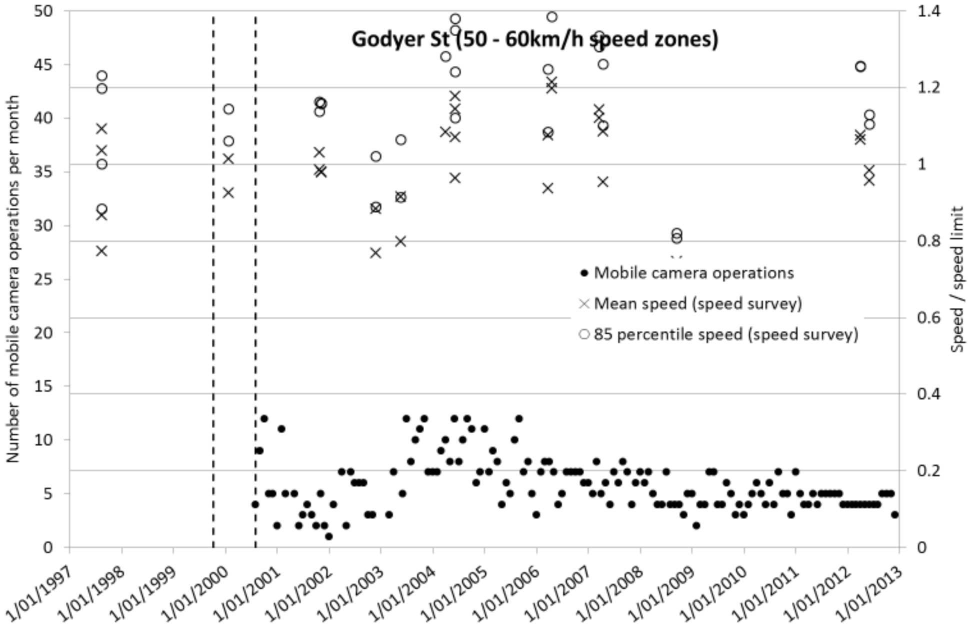
Godyer St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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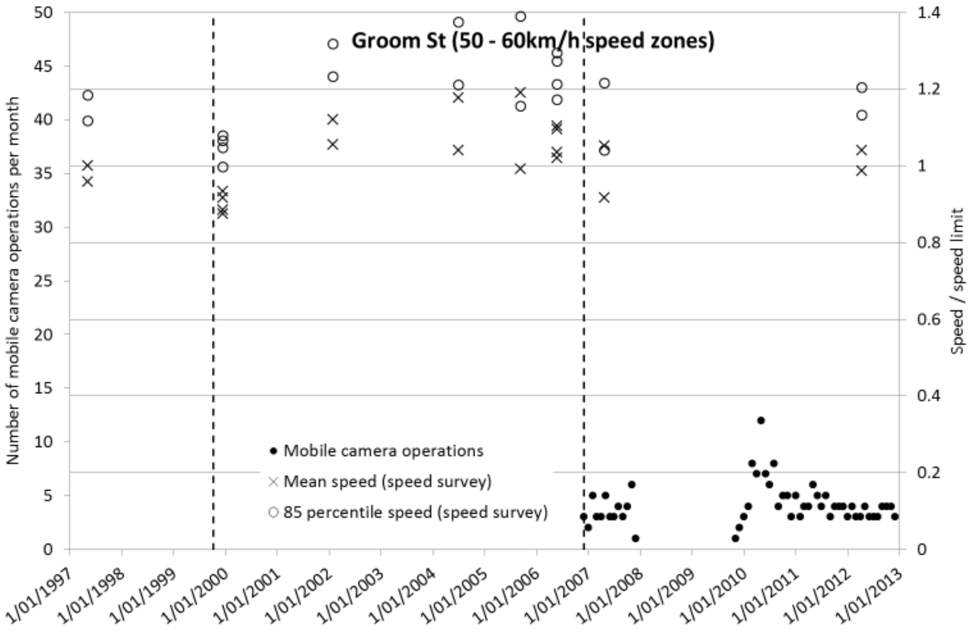
Groom St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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0.8
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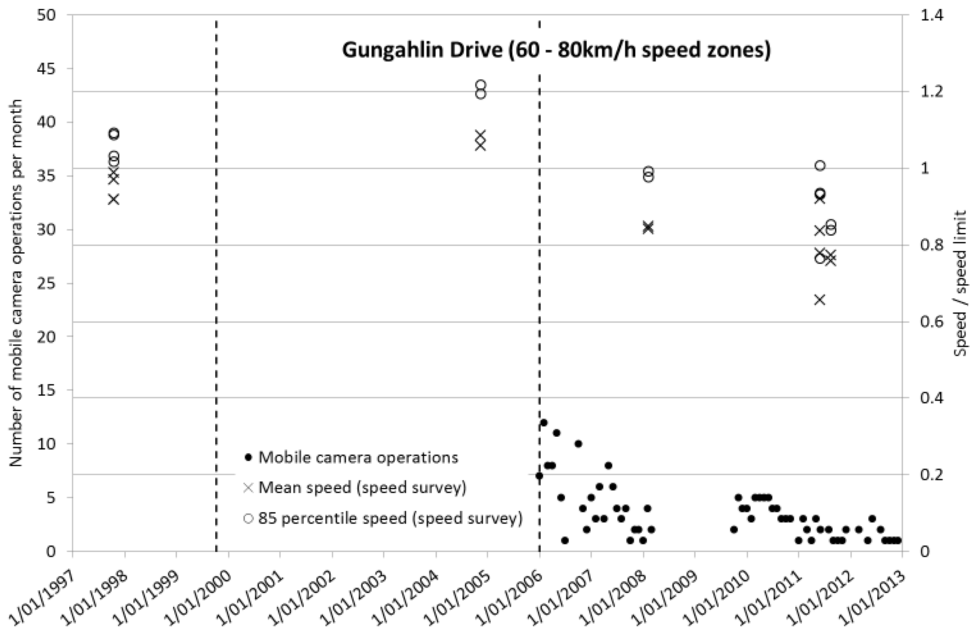
1/01/2013


Gungahlin Drive (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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10
15
20
25
30
35
40
45
50
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0.8
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1.4
1/01/1997
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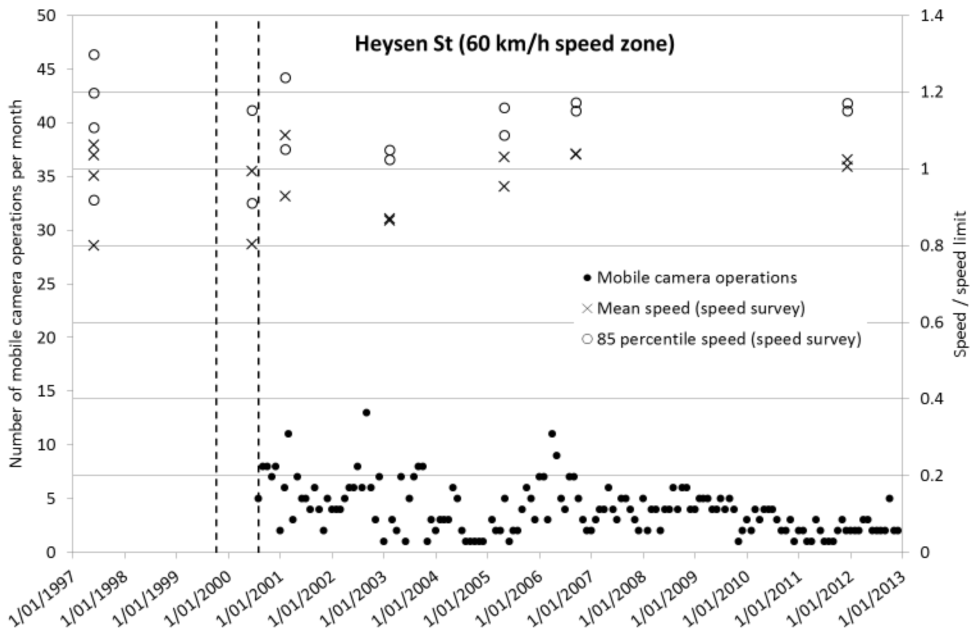
1/01/2013


Heysen St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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20
25
30
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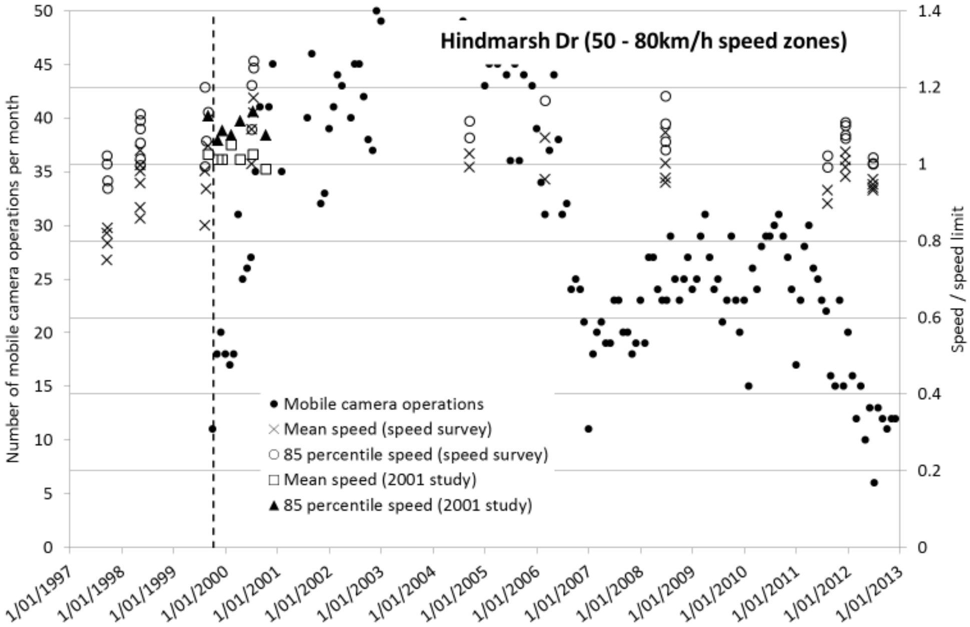
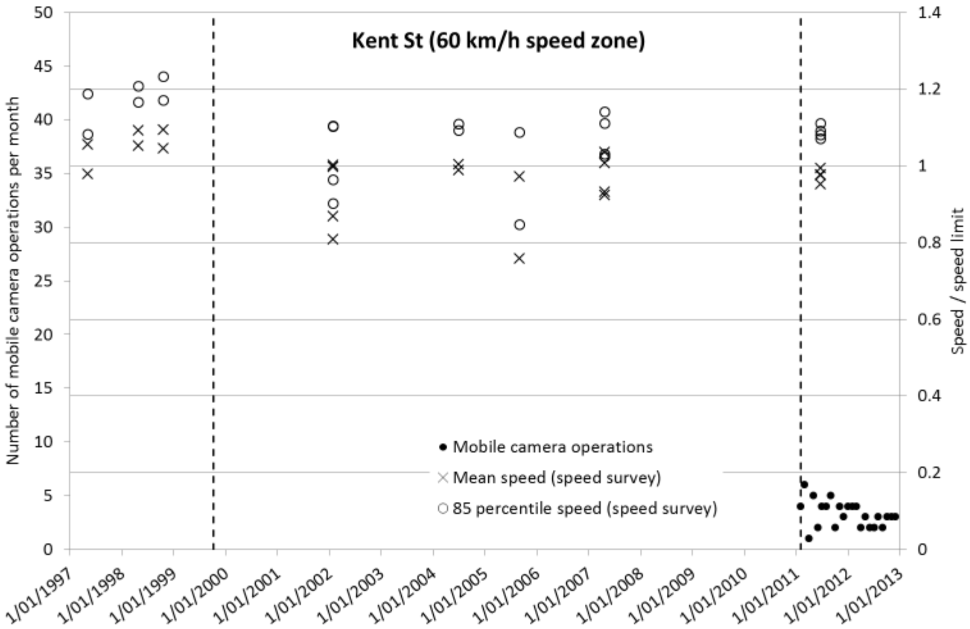
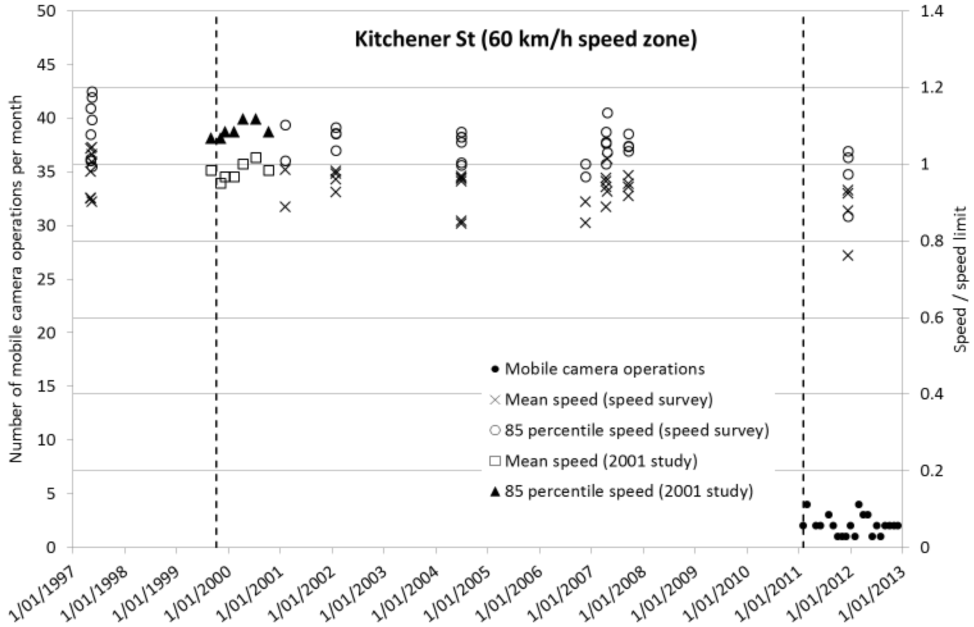
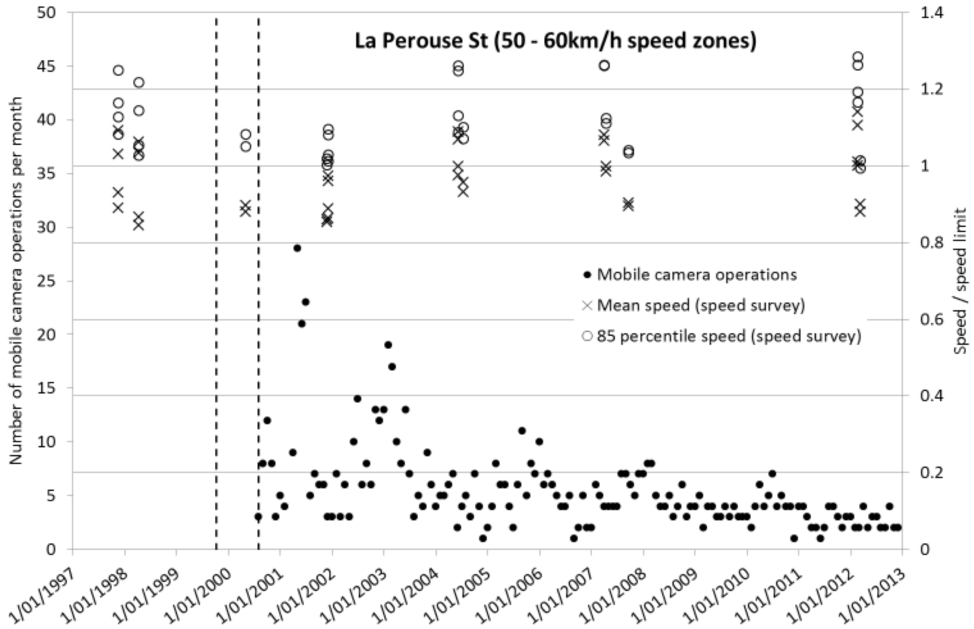
1/01/2012
1/01/2013


Hindmarsh Dr (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

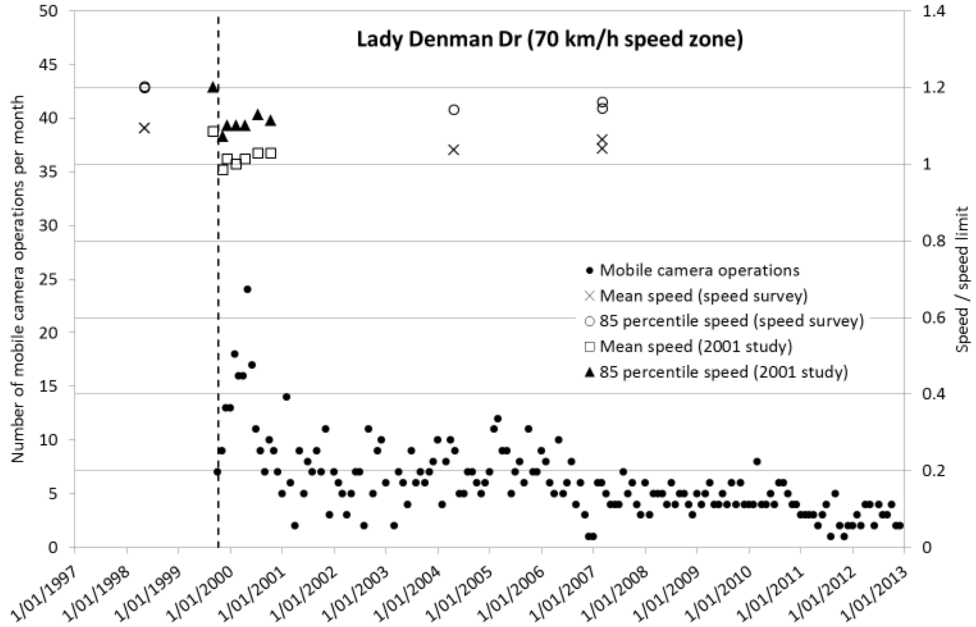

Kent St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

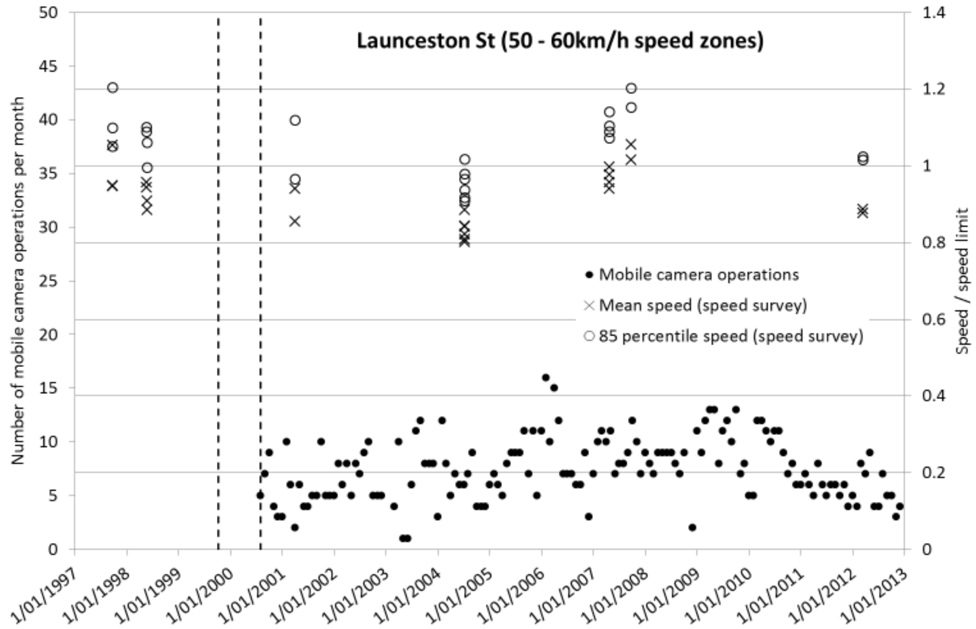


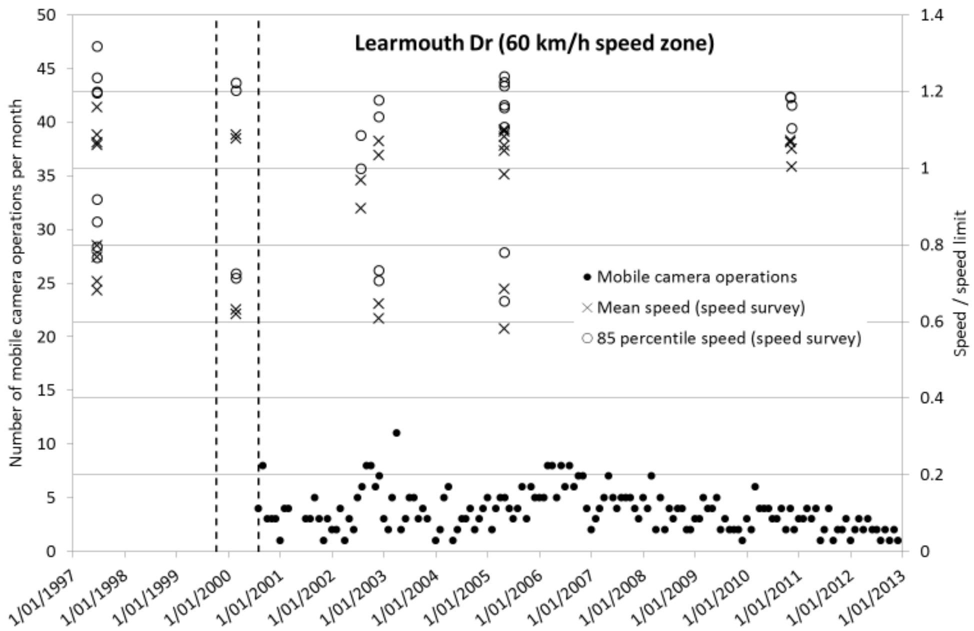
Kitchener St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)

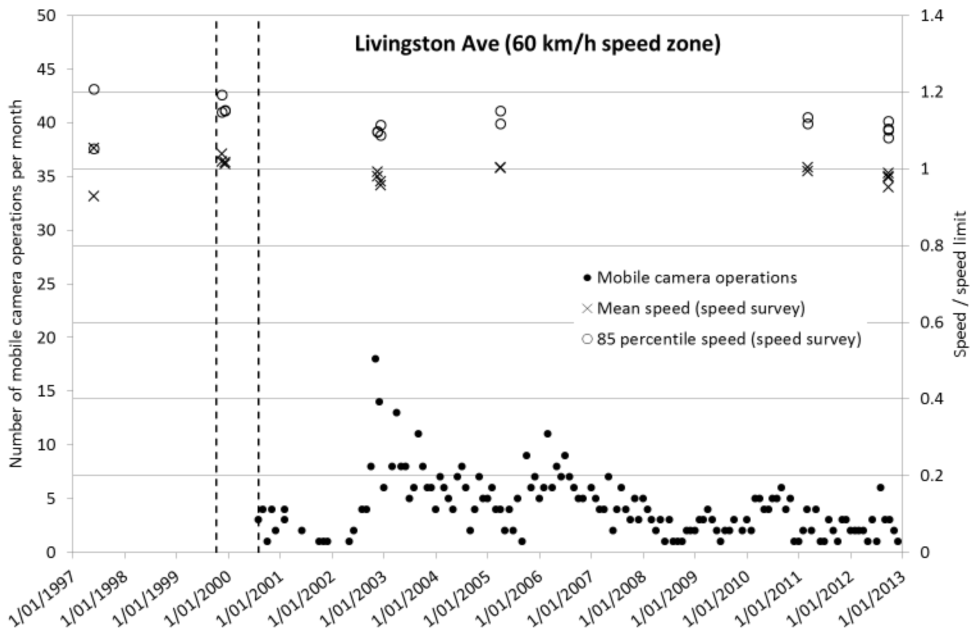


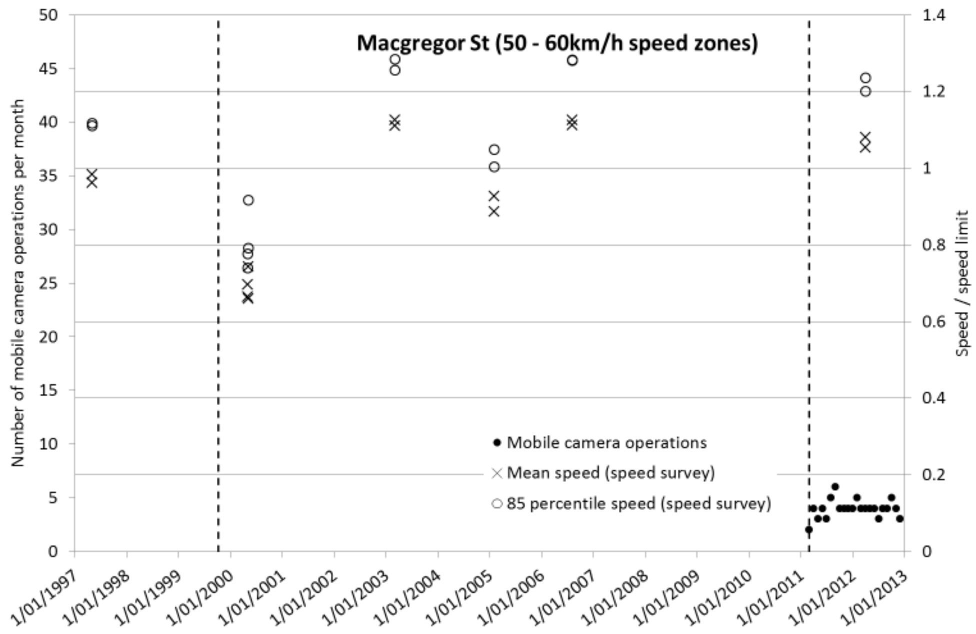
La Perouse St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)

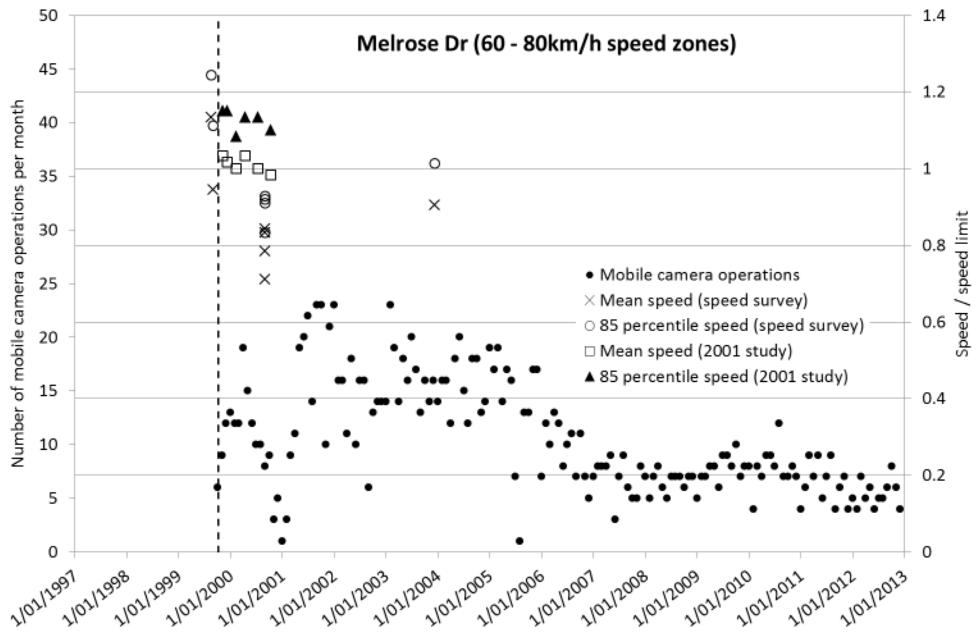

Lady Denman Dr (70 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Launceston St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Learmouth Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Livingston Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Macgregor St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Melrose Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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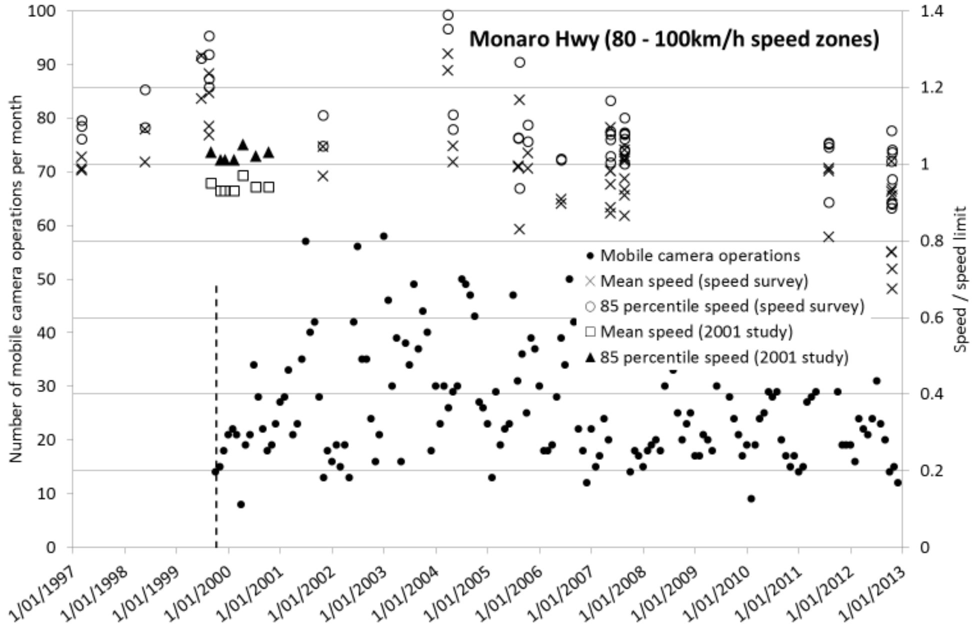
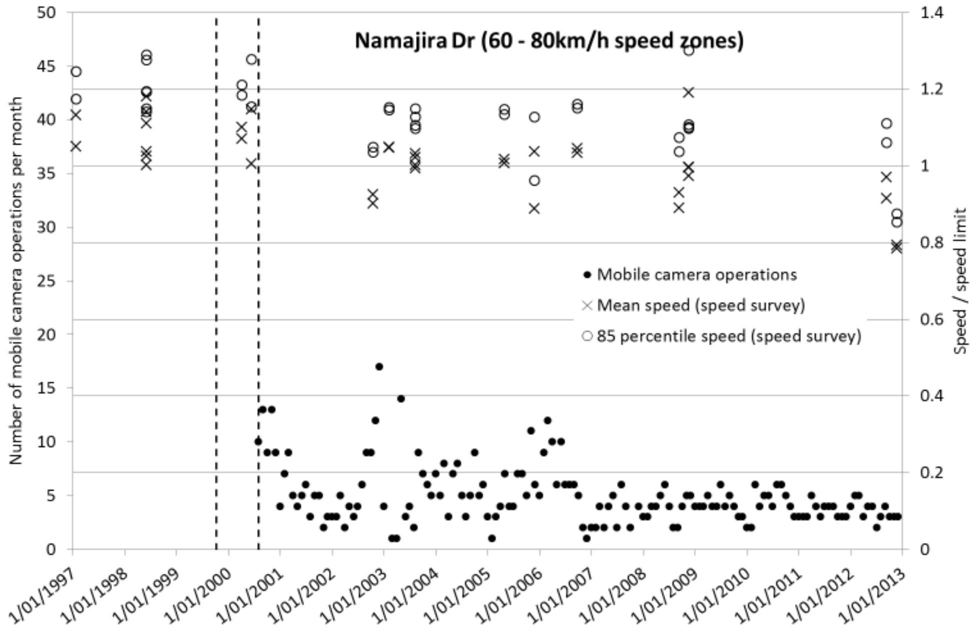
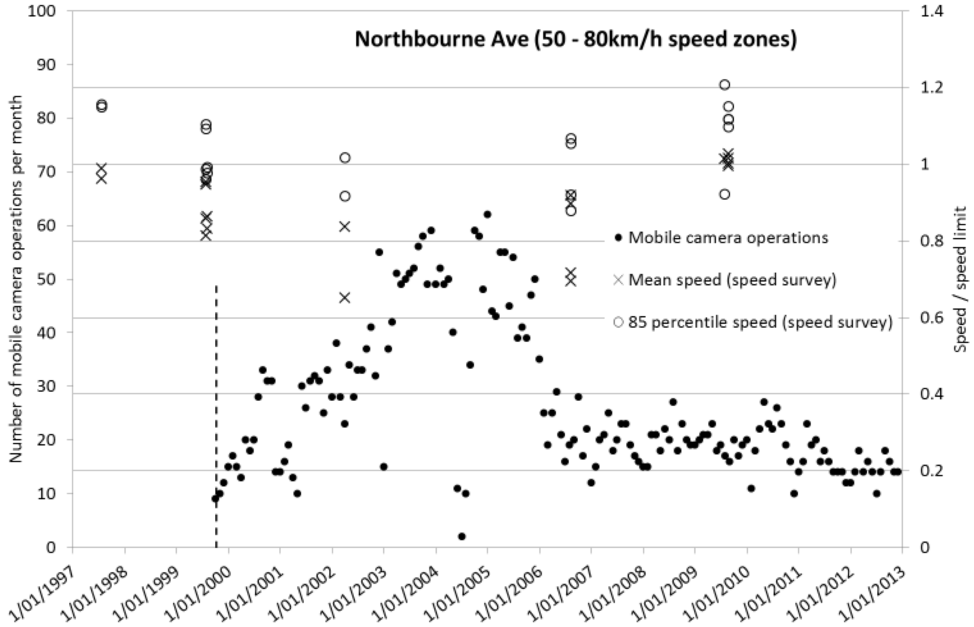
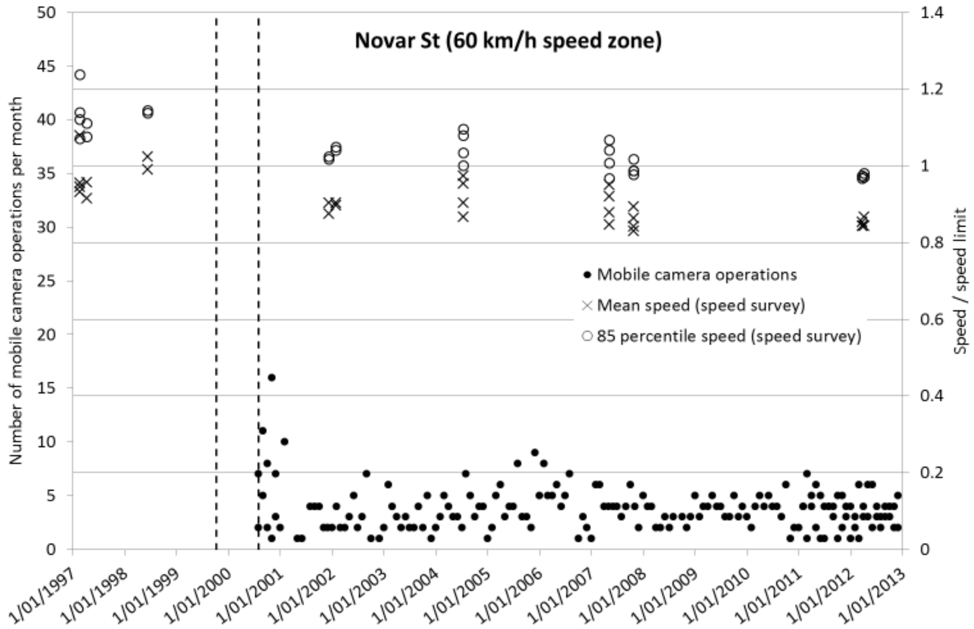
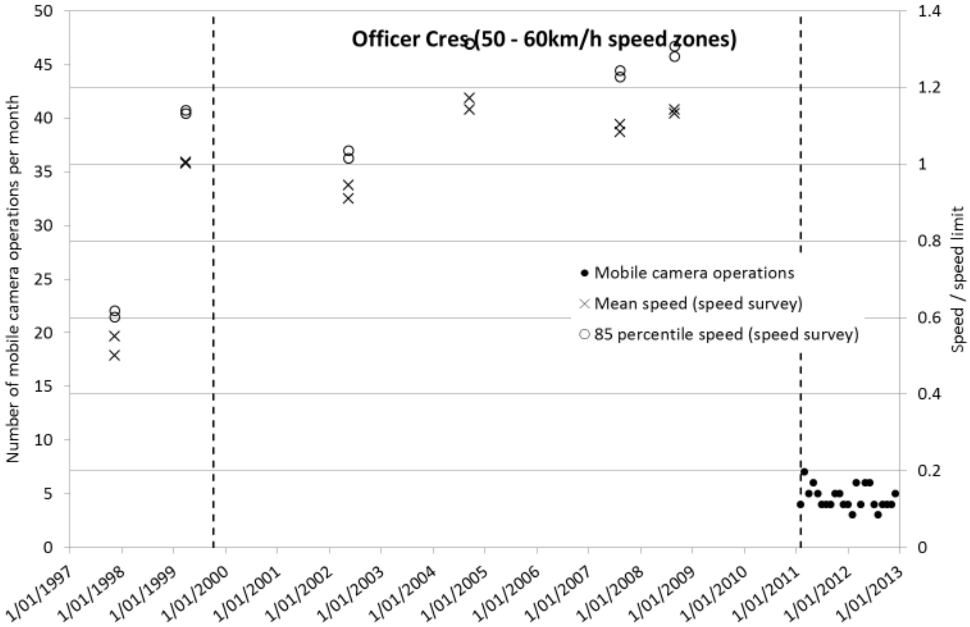
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

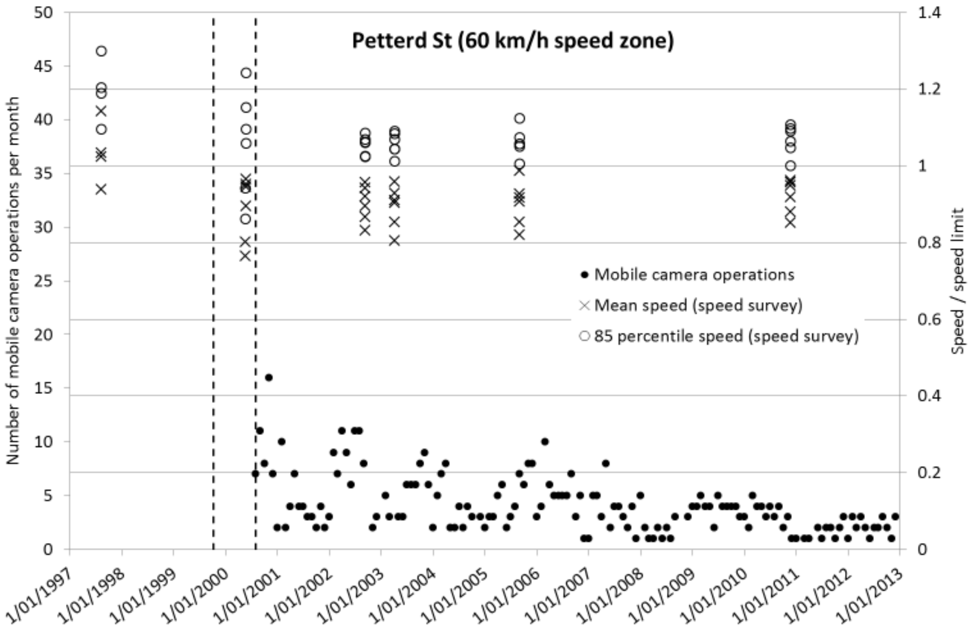

Monaro Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

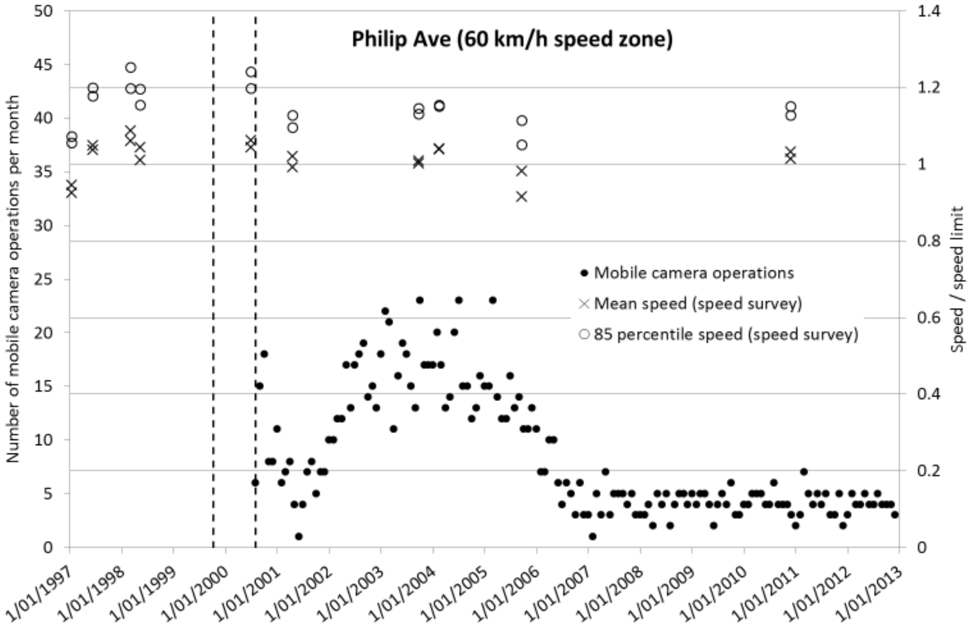

Namajira Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

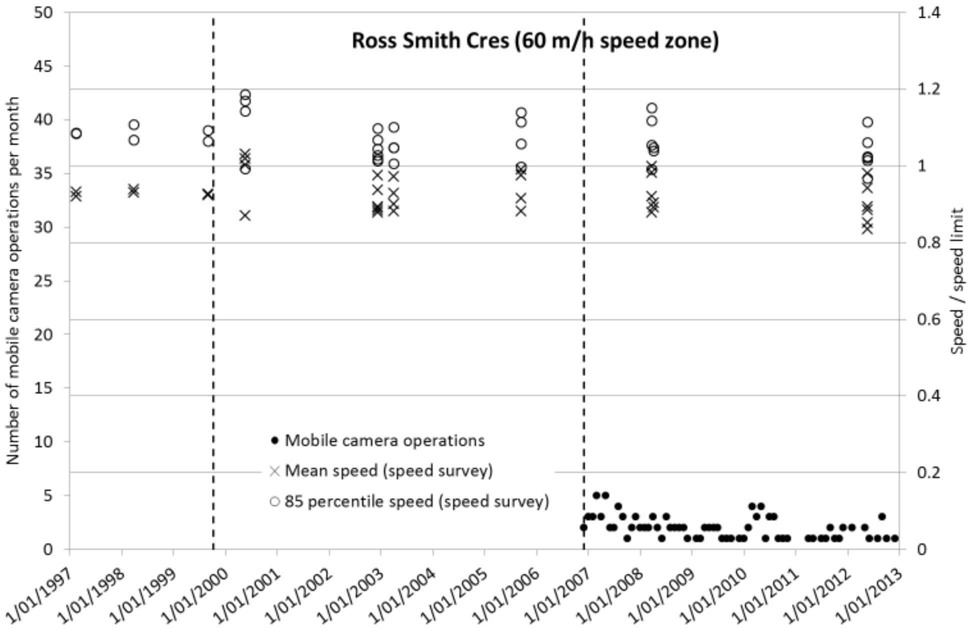

Northbourne Ave (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

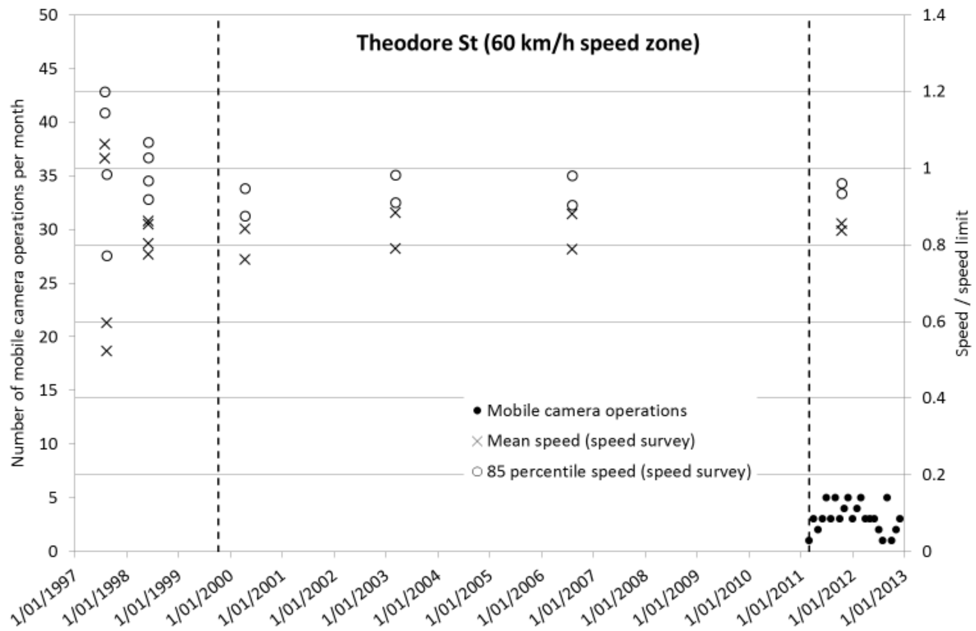

Novar St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

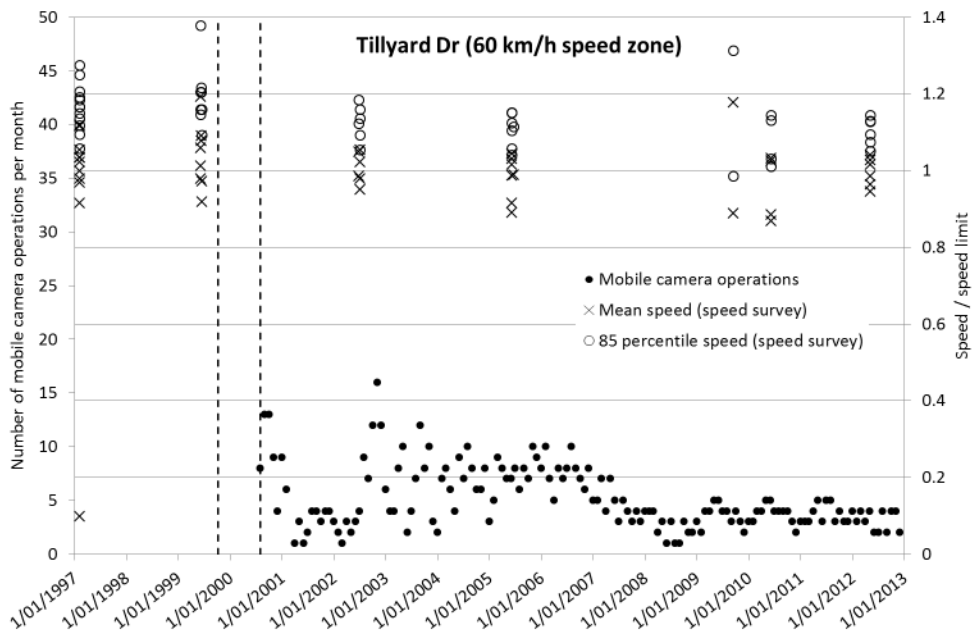

Officer Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Petterd St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Philip Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Ross Smith Cres (60 m/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Theodore St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Tillyard Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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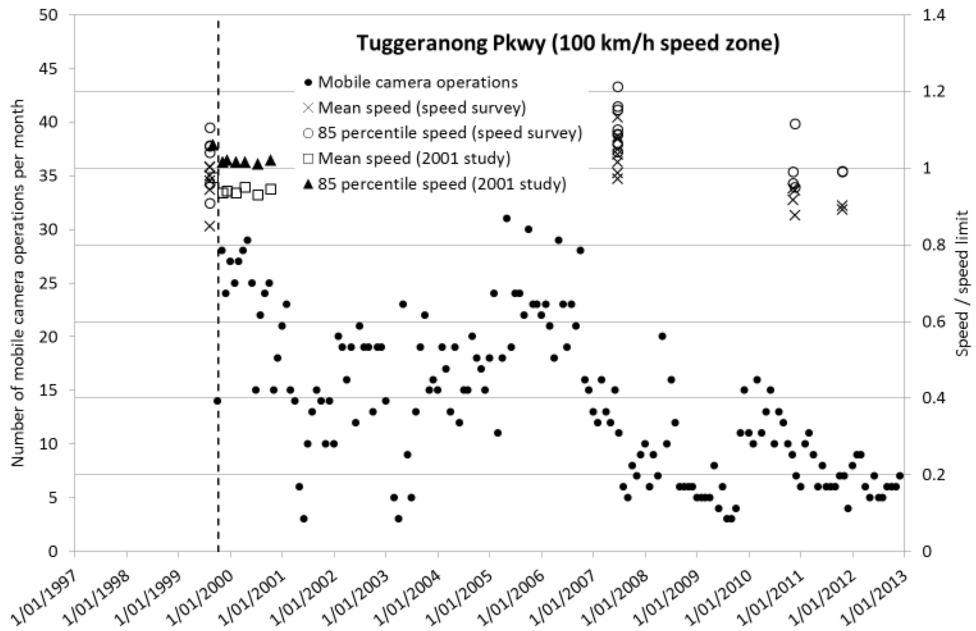
1/01/2012
1/01/2013


Tuggeranong Pkwy (100 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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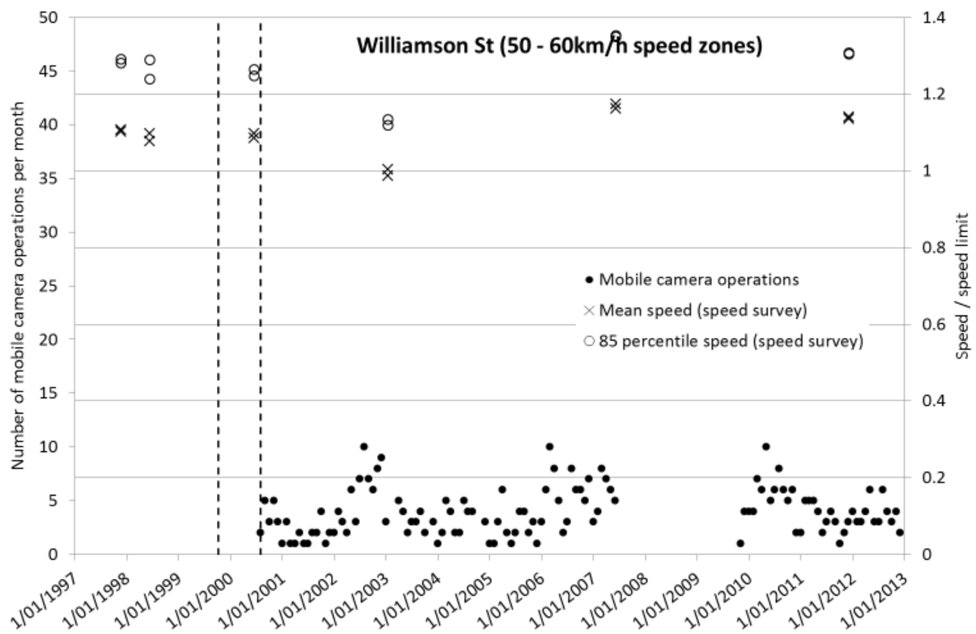
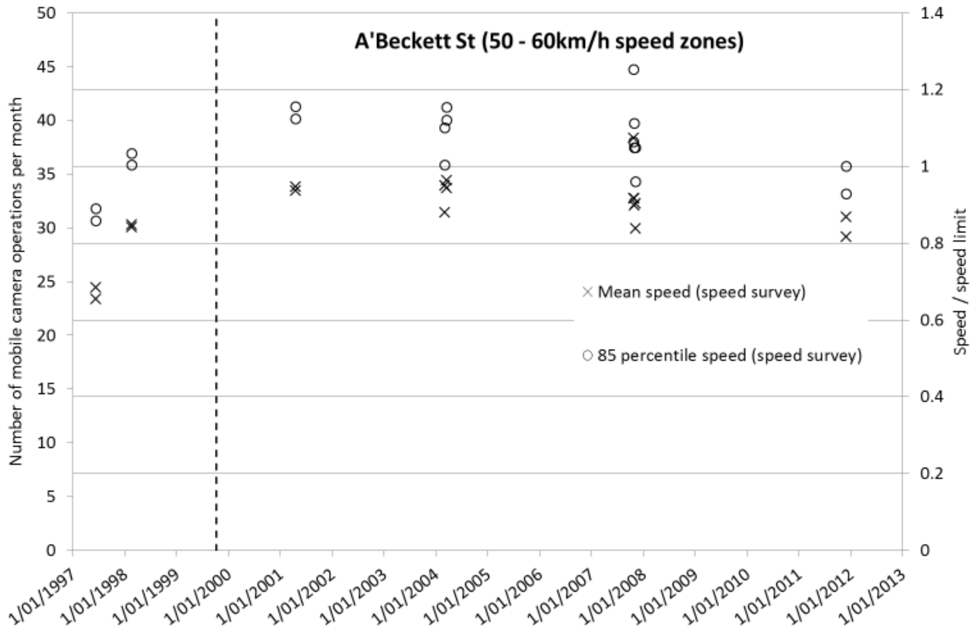
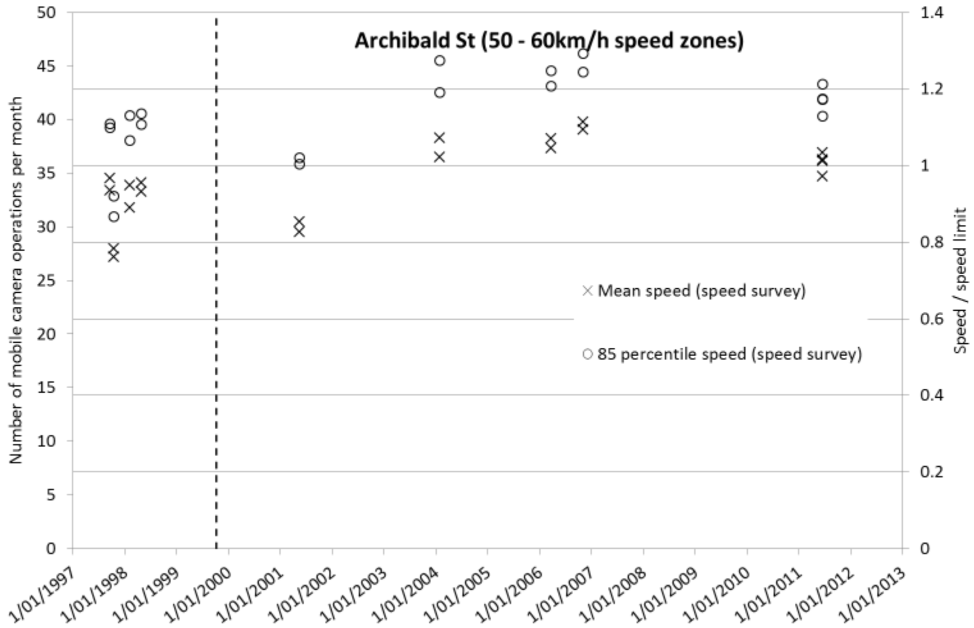
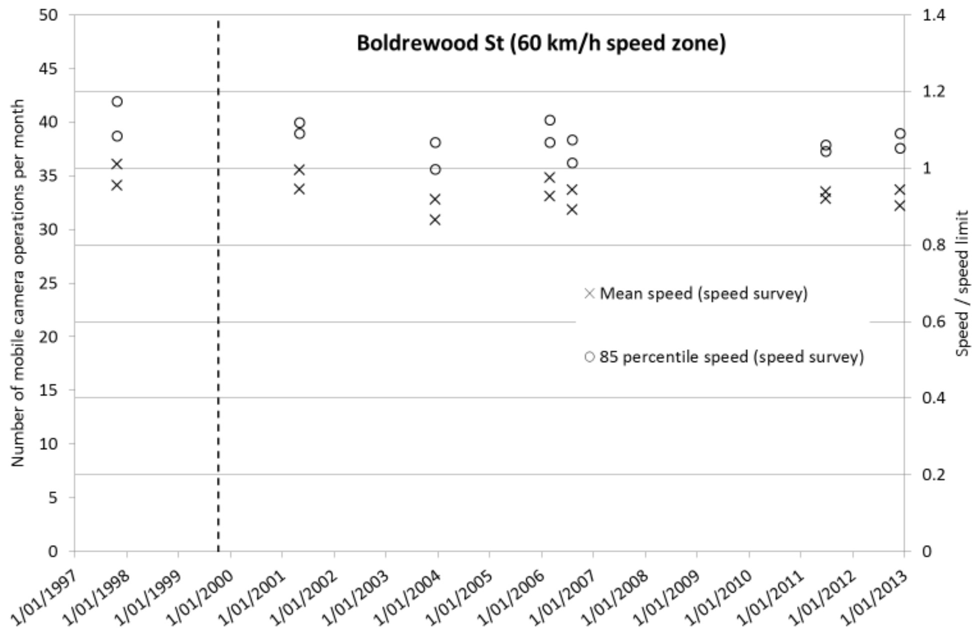
1/01/2012
1/01/2013


Williamson St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

CONTROL STREETS






Boldrewood St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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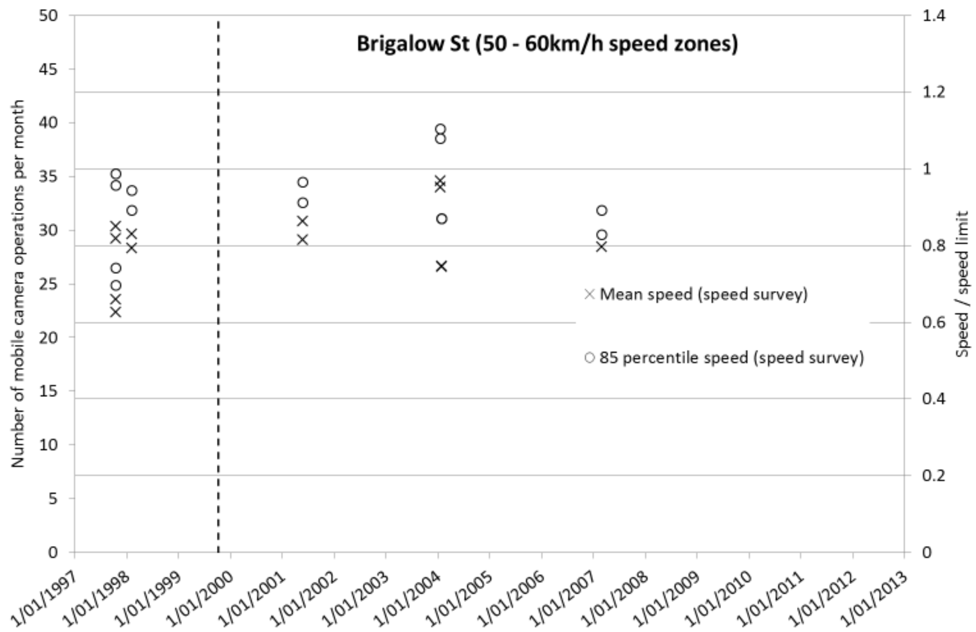
1/01/2011
1/01/2012
1/01/2013


Brigalow St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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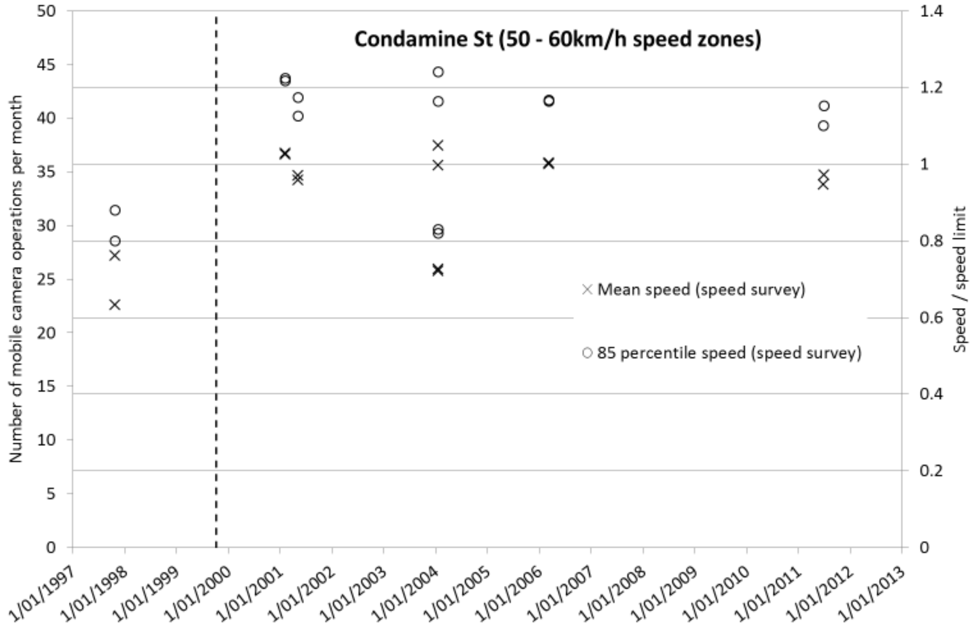
1/01/2012
1/01/2013


Condamine St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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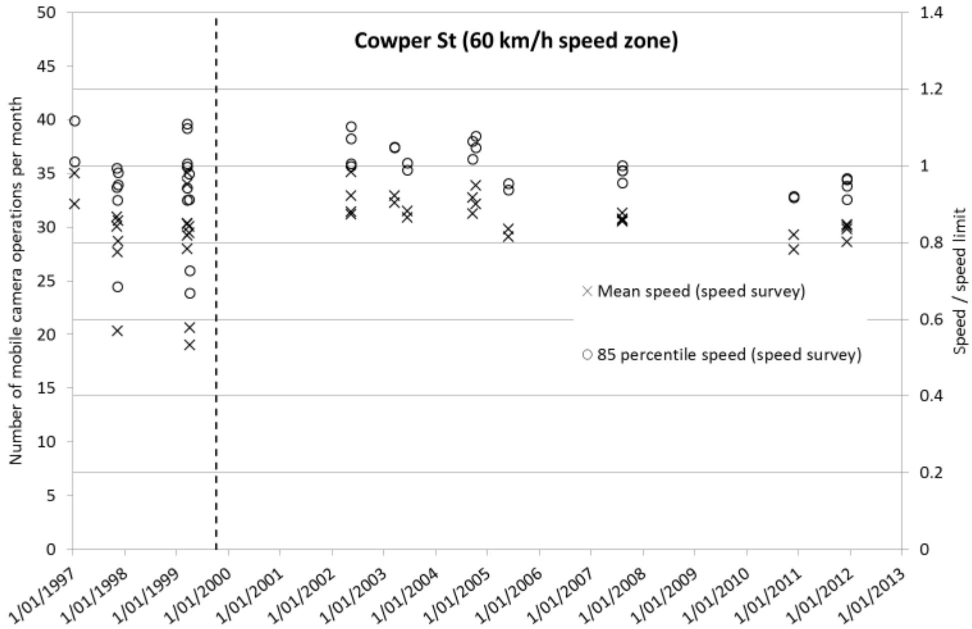
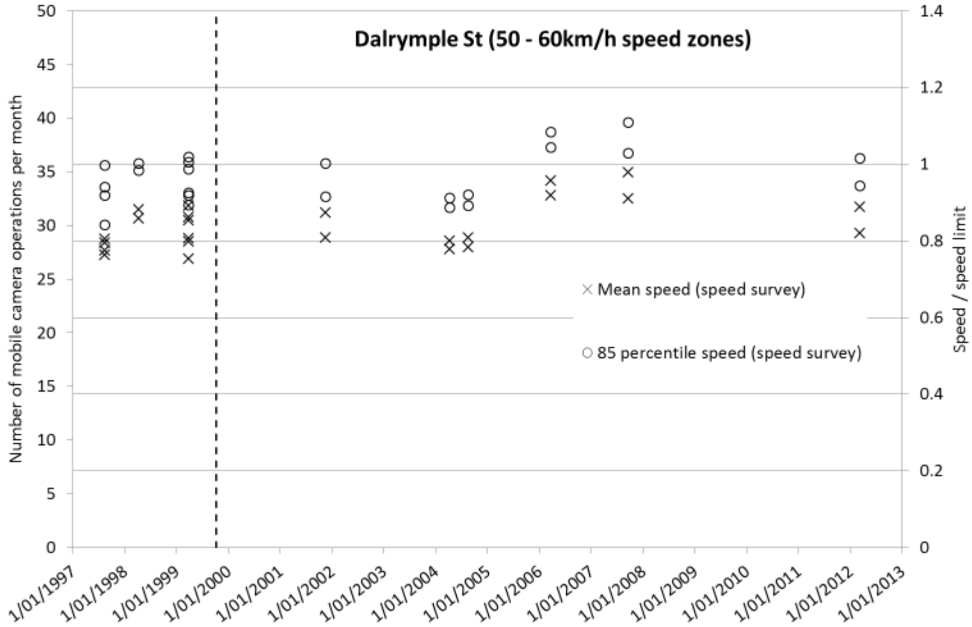
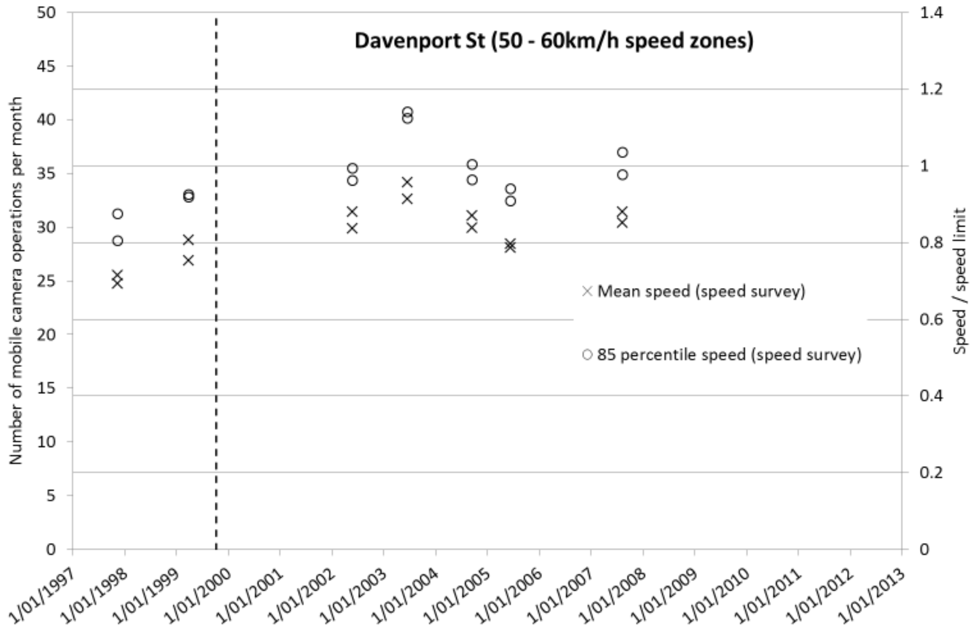
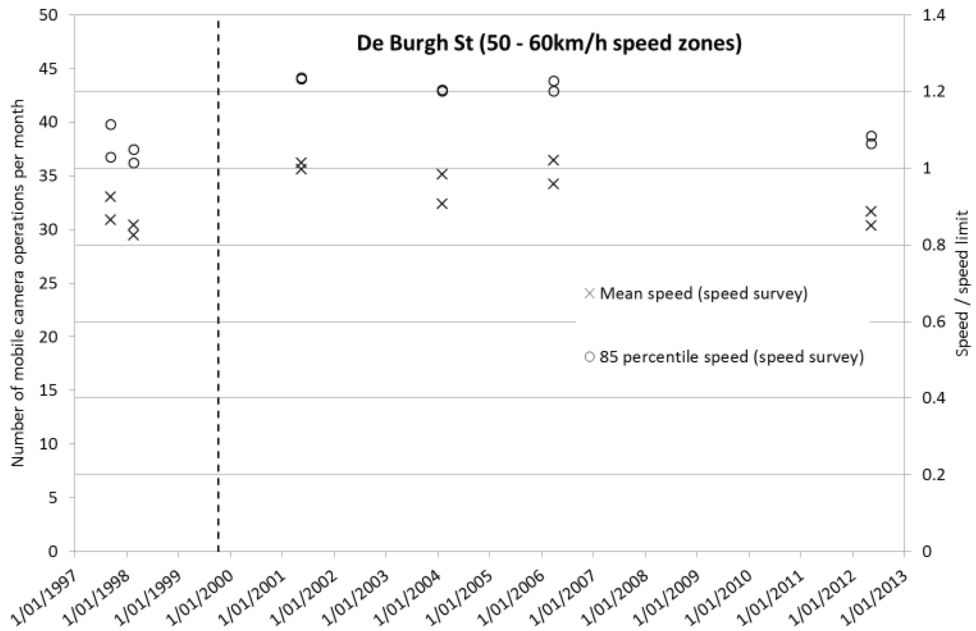
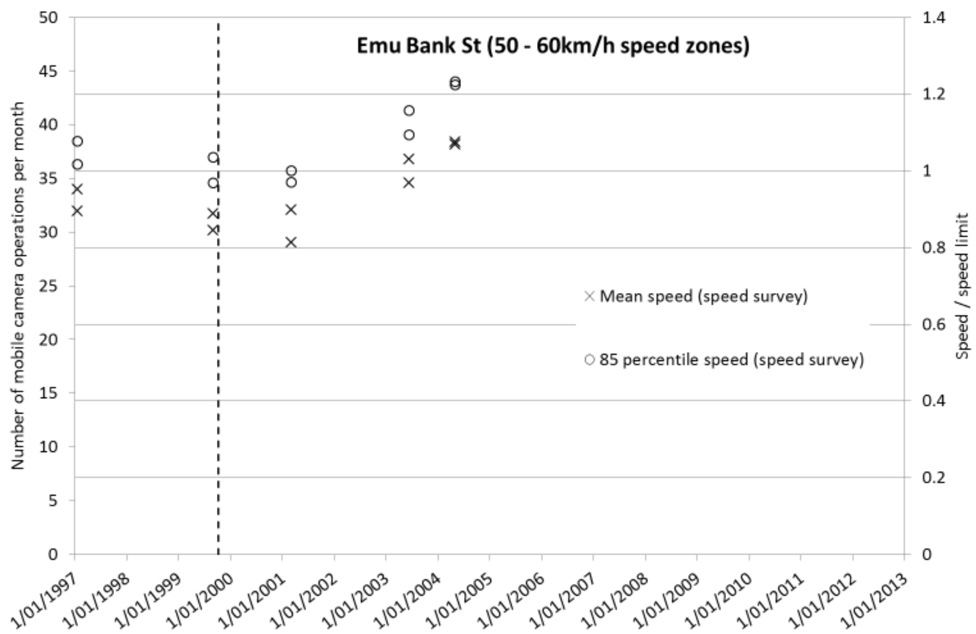
1/01/2012
1/01/2013

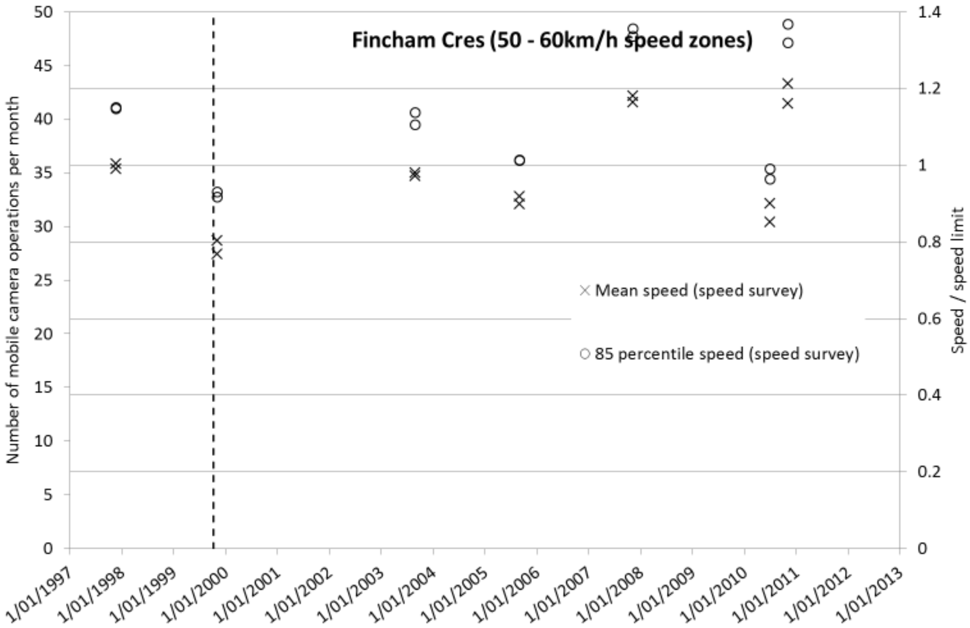

Cowper St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

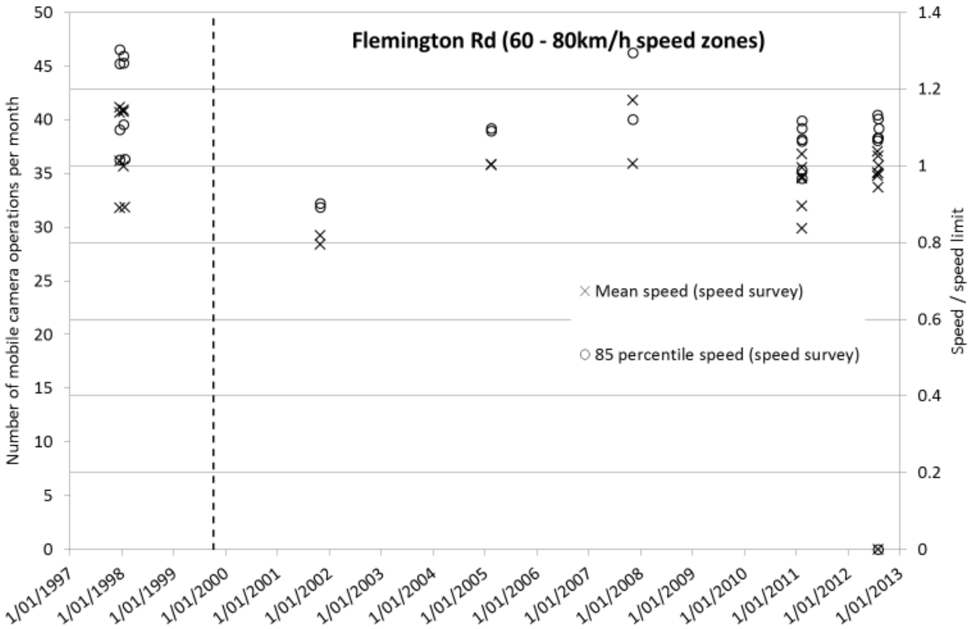

Dalrymple St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

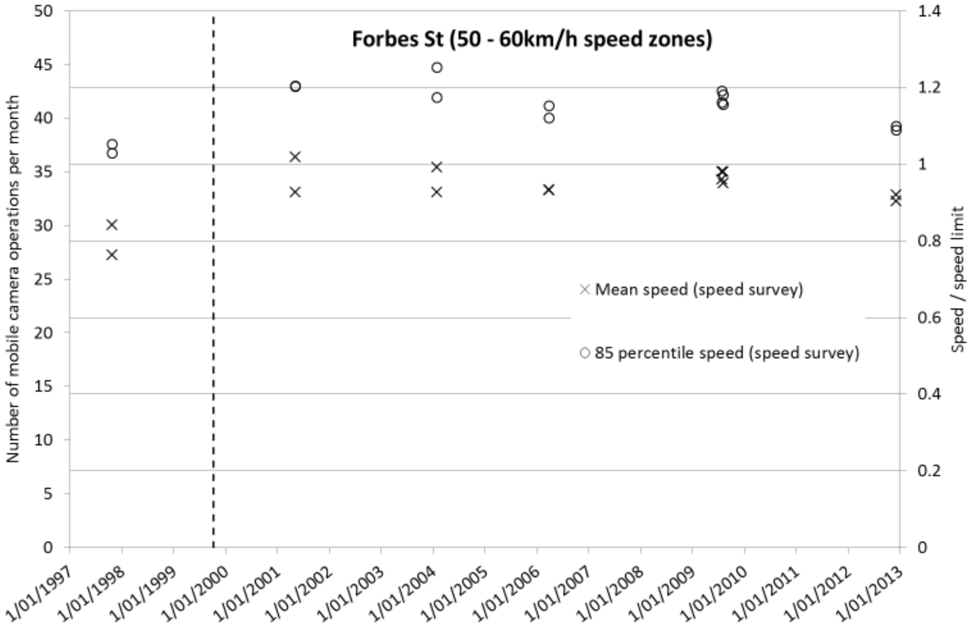

Davenport St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

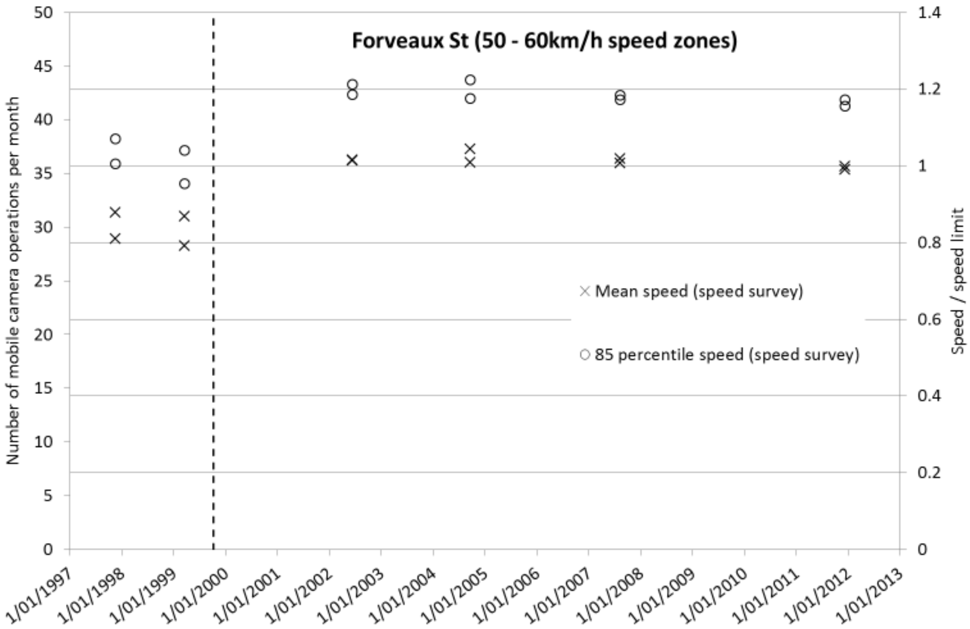

De Burgh St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

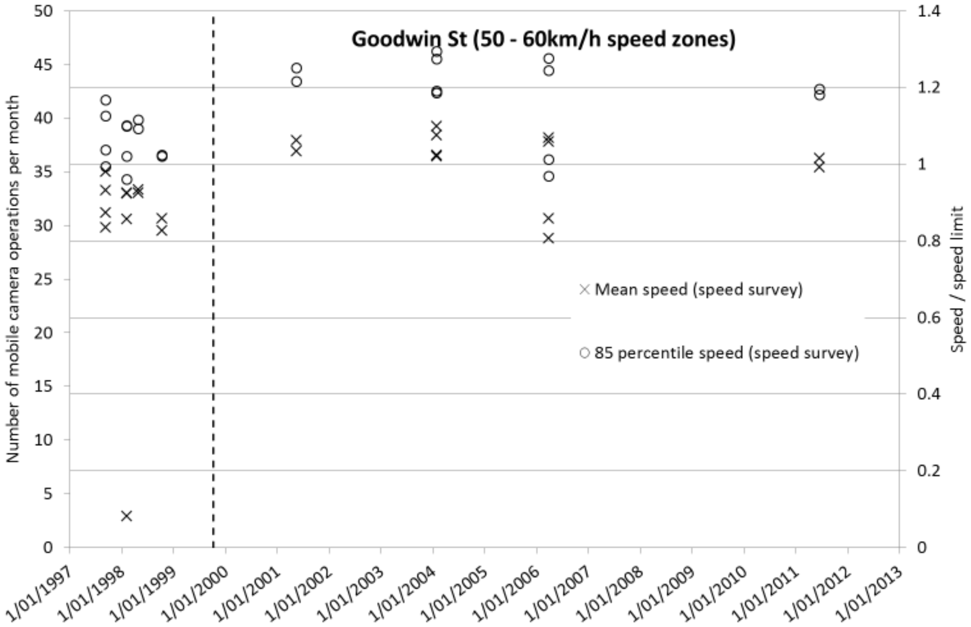

Emu Bank St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Fincham Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Flemington Rd (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Forbes St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Forveaux St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Goodwin St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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15
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25
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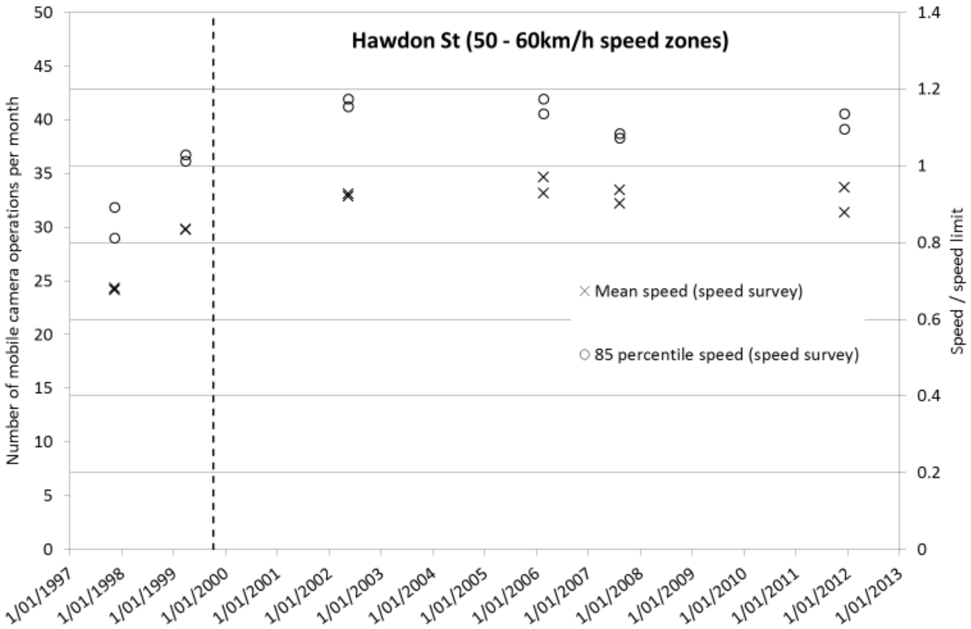
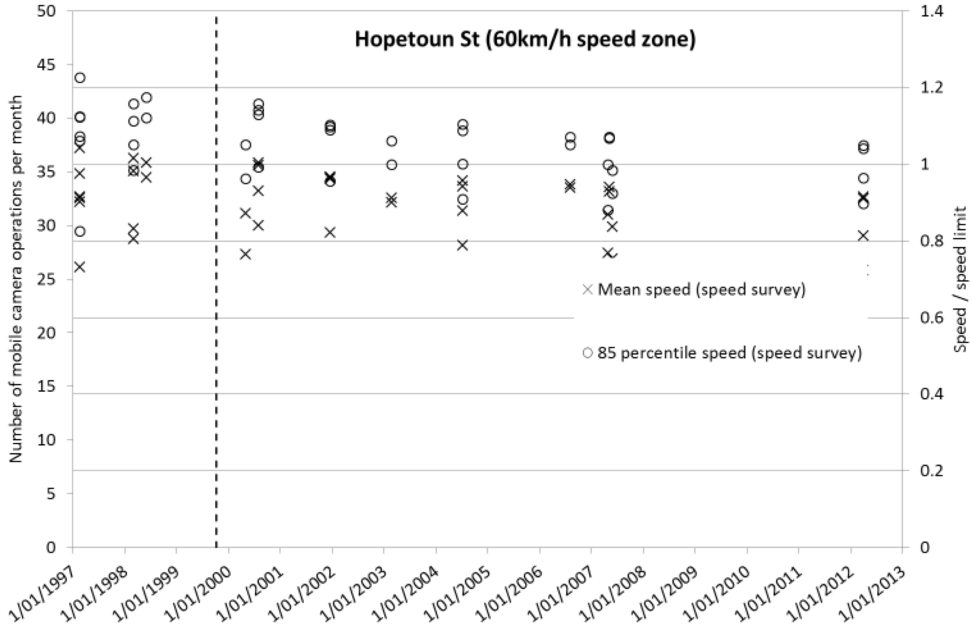
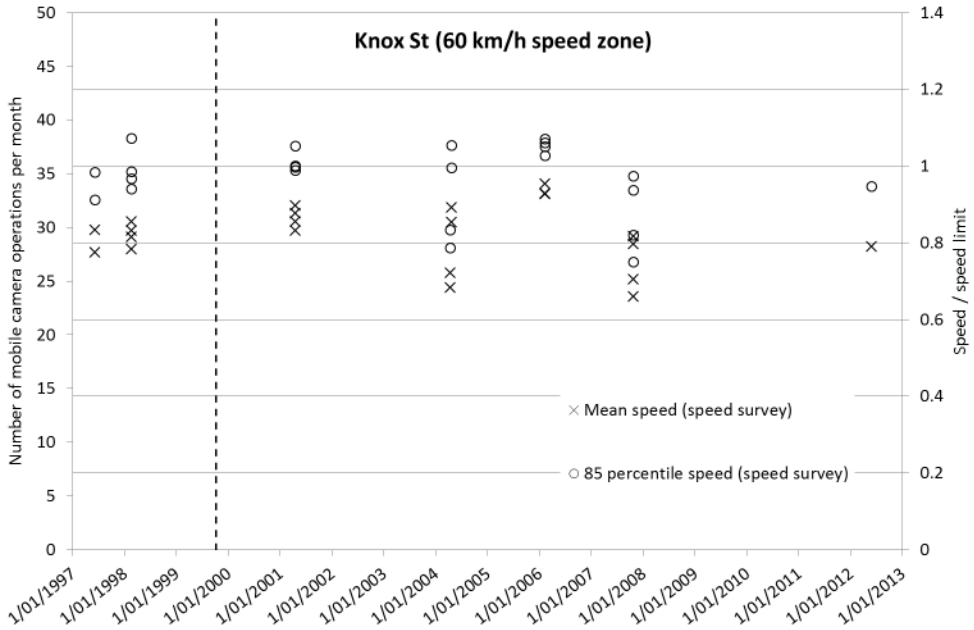
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hawdon St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hopetoun St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Knox St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2007
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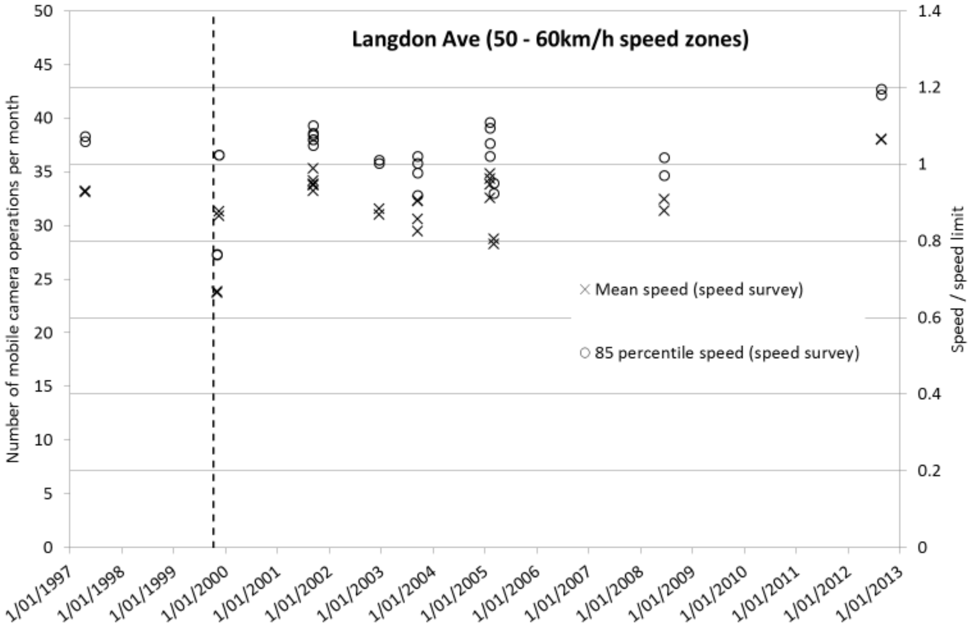
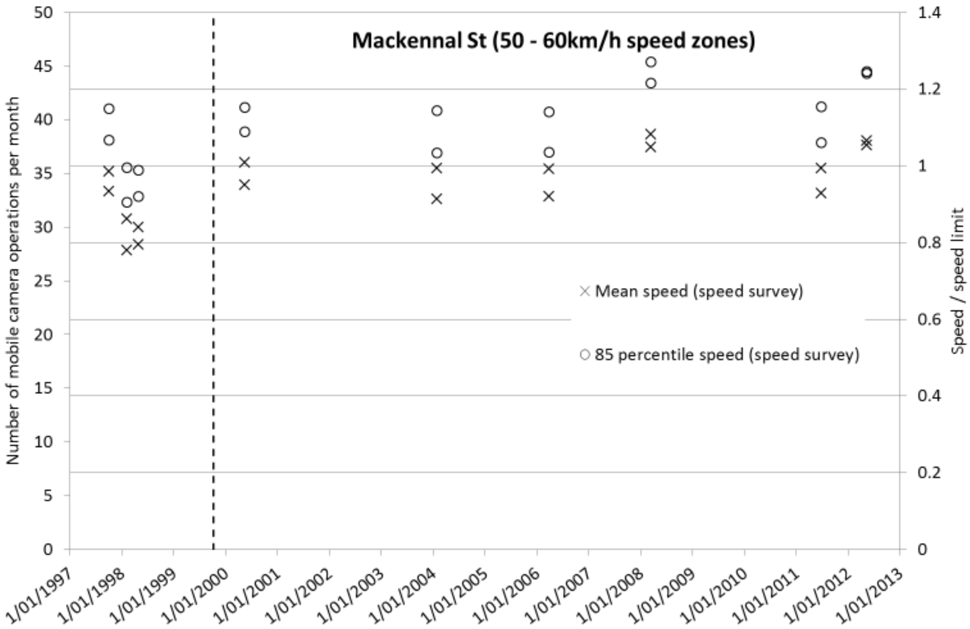
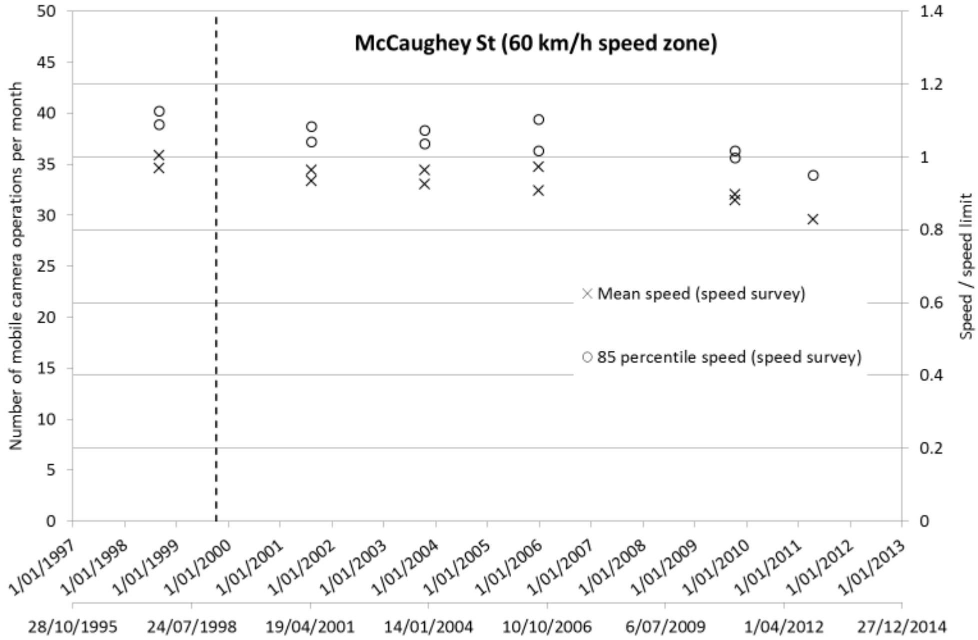
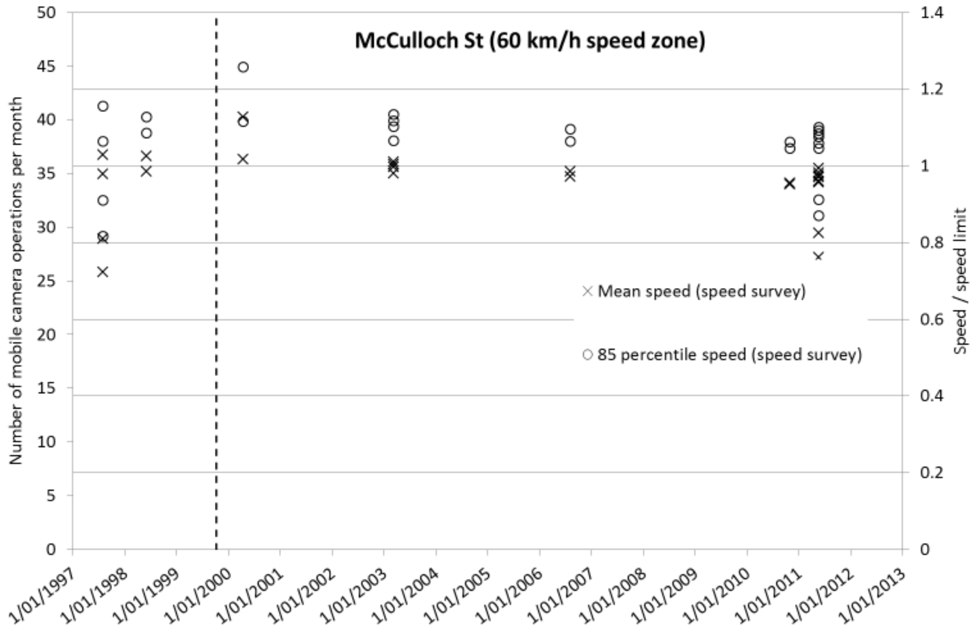
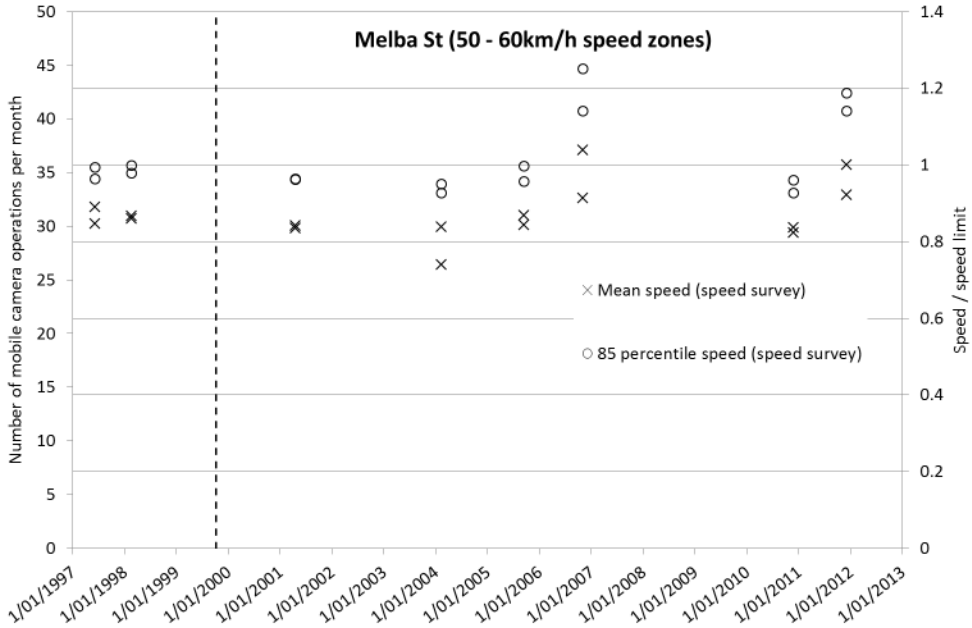
1/01/2010
1/01/2011
1/01/2012
1/01/2013

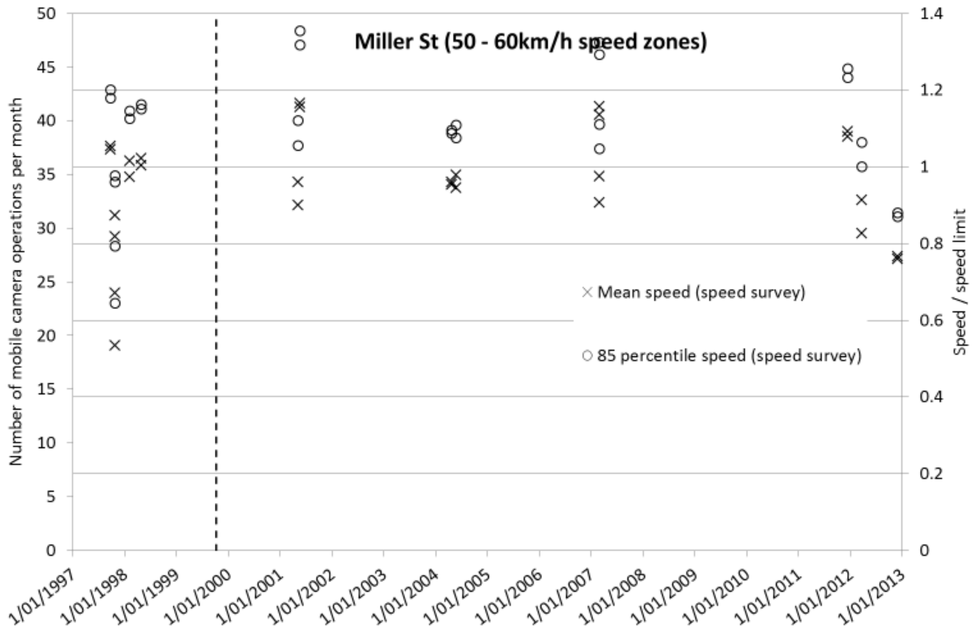

Langdon Ave (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Mackennal St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


McCaughey St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014


McCulloch St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Melba St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Miller St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
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35
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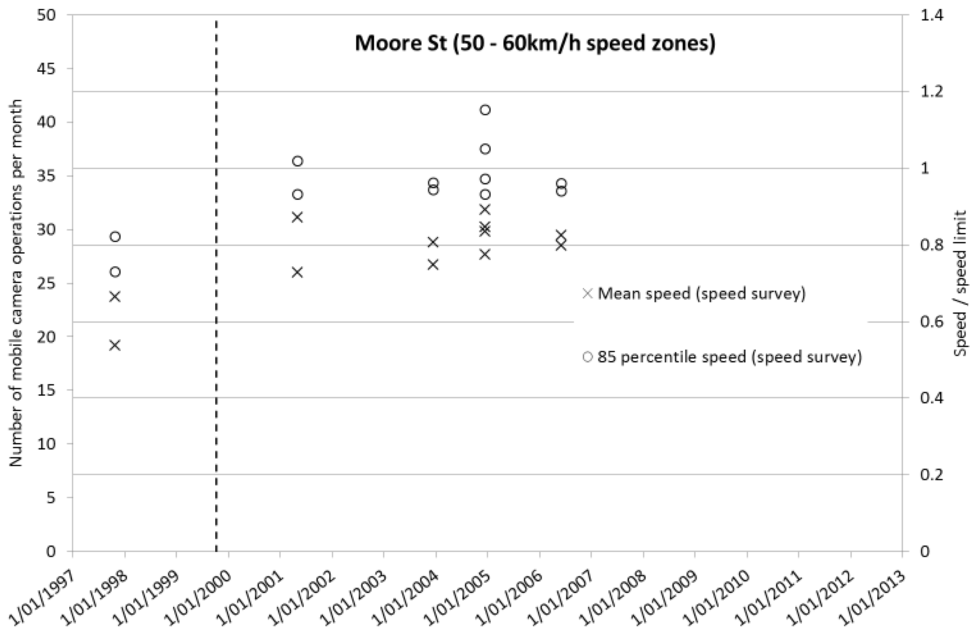
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Moore St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
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25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2008
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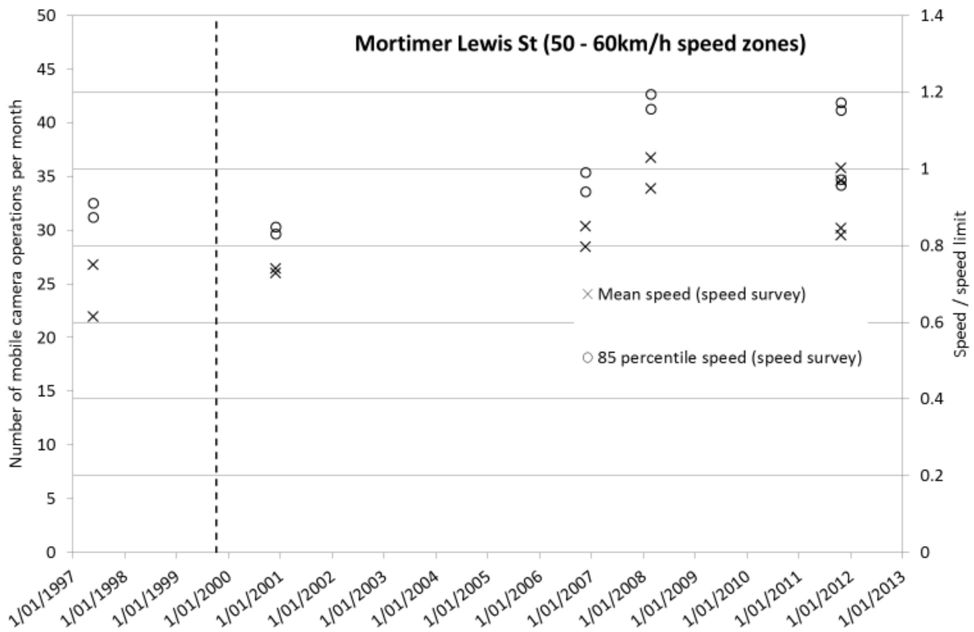
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Mortimer Lewis St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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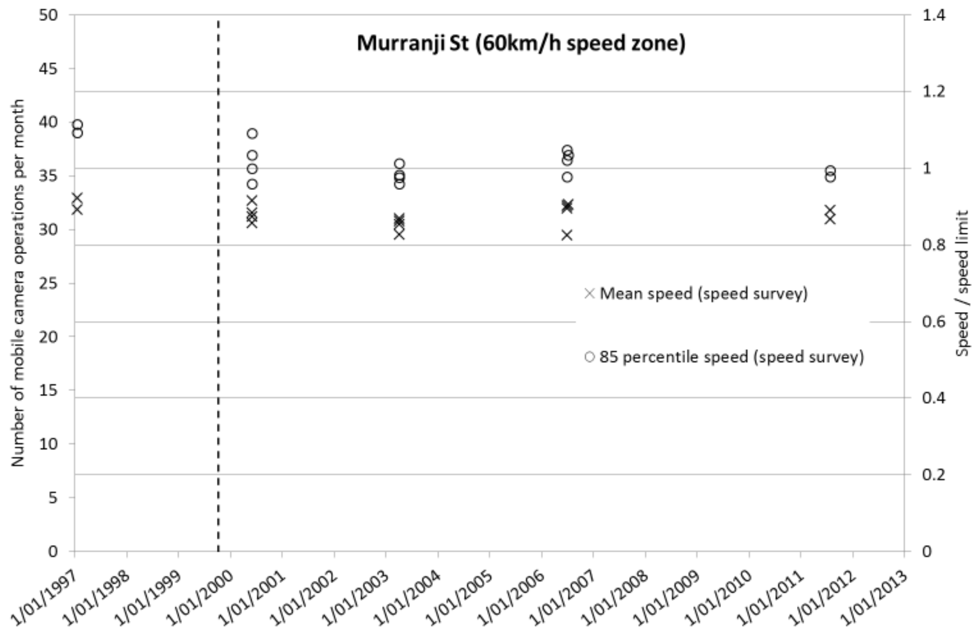
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Murranji St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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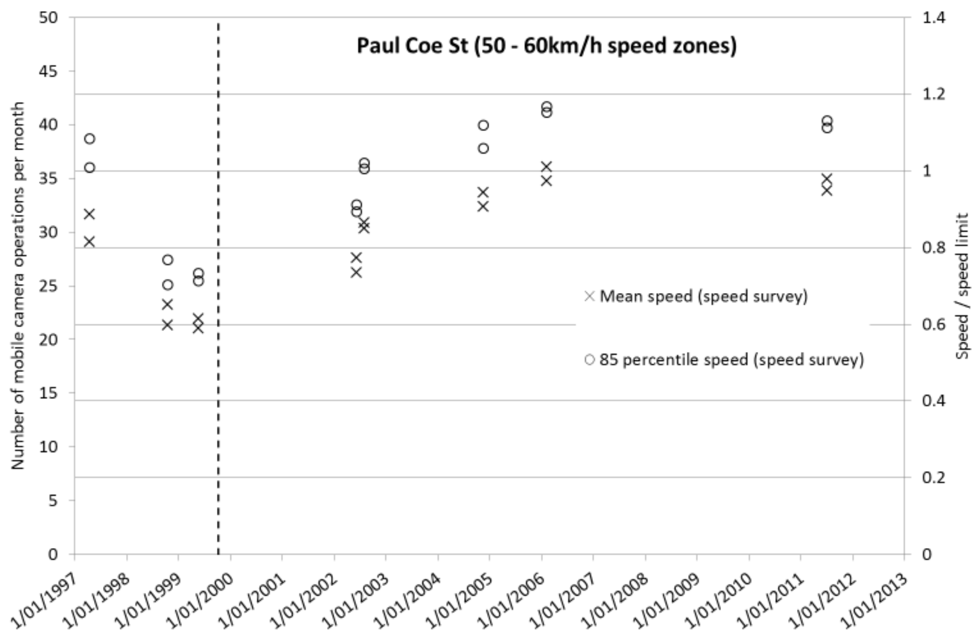
1/01/2012
1/01/2013


Paul Coe St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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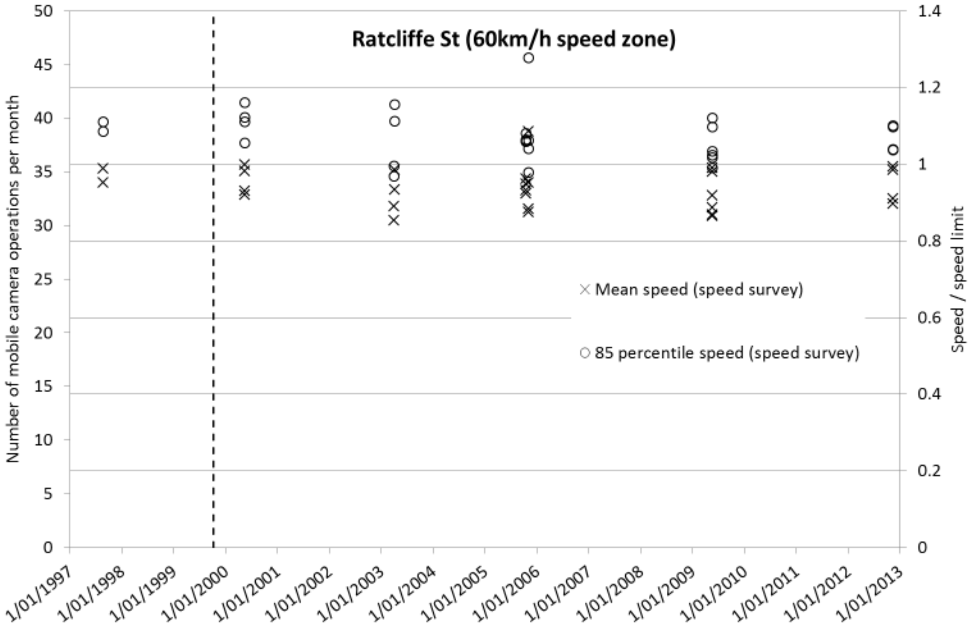
1/01/2012
1/01/2013


Ratcliffe St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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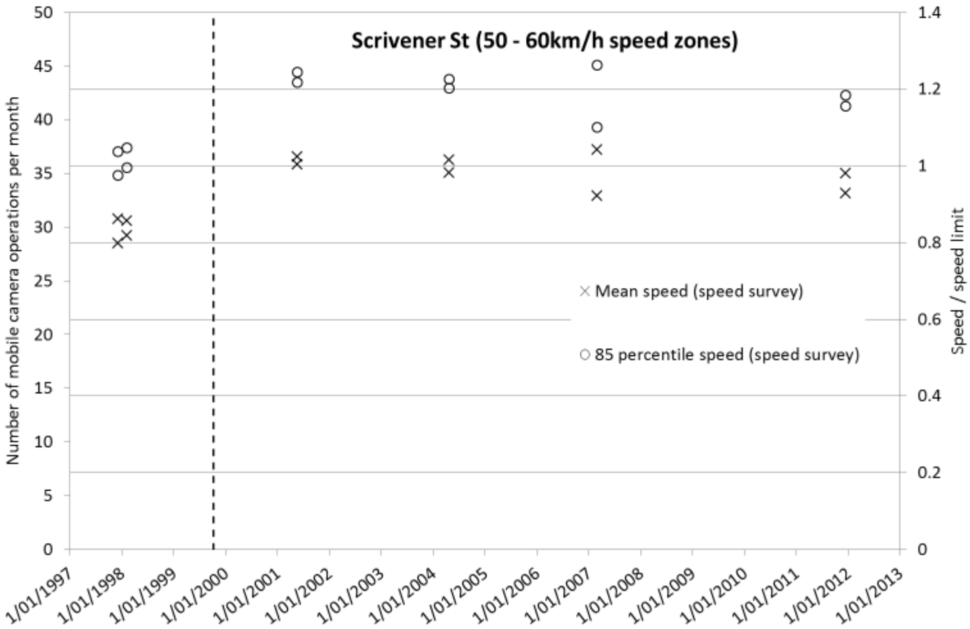
1/01/2012
1/01/2013


Scrivener St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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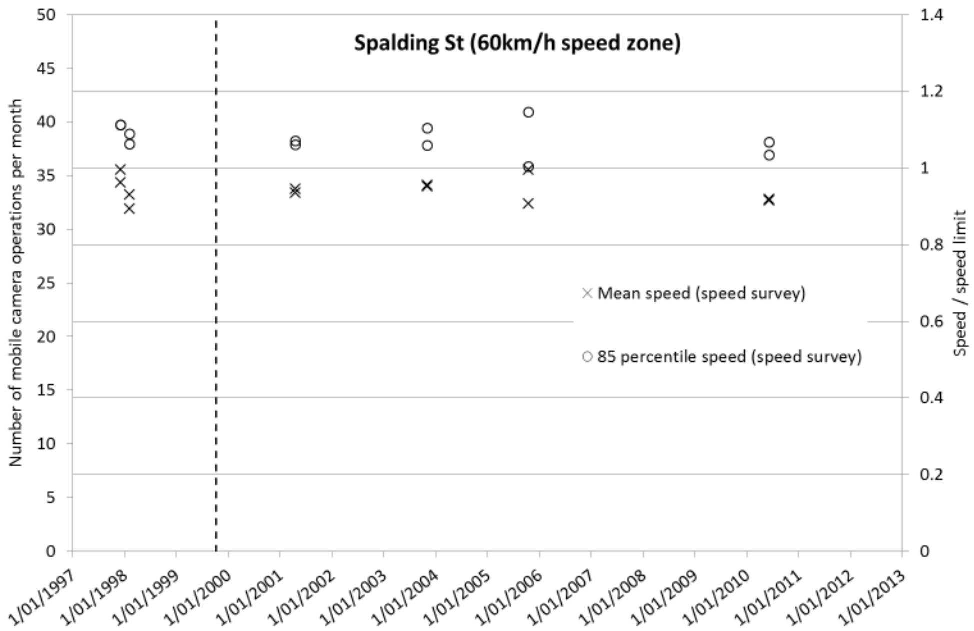
1/01/2012
1/01/2013


Spalding St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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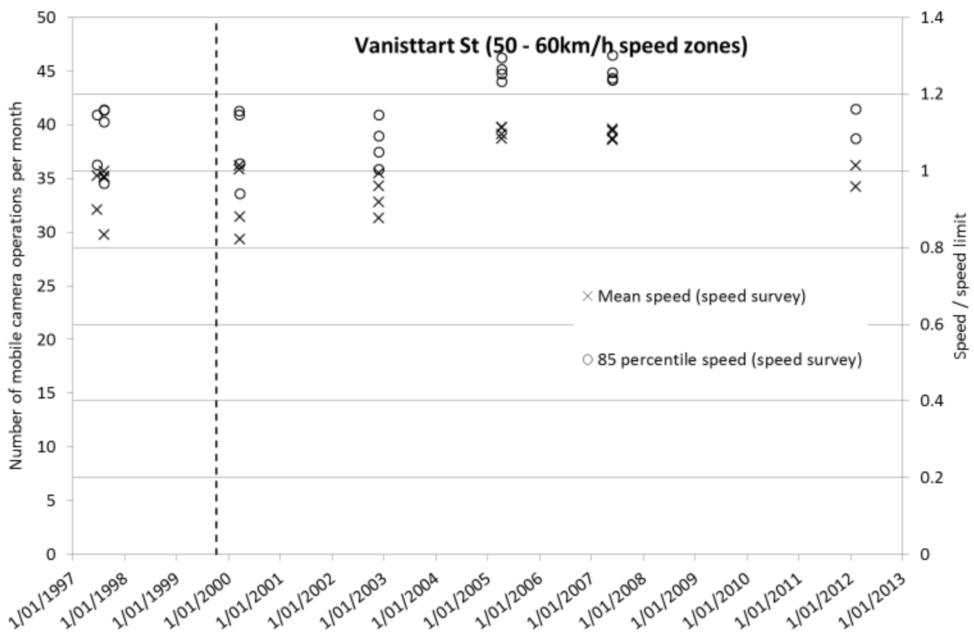
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Vanisttart St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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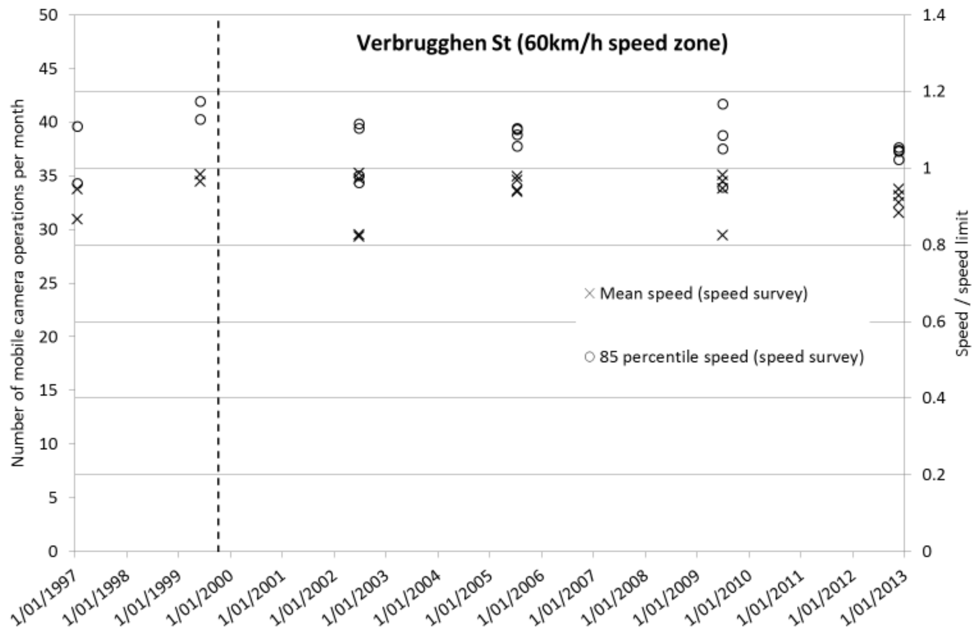
Verbrugghen St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
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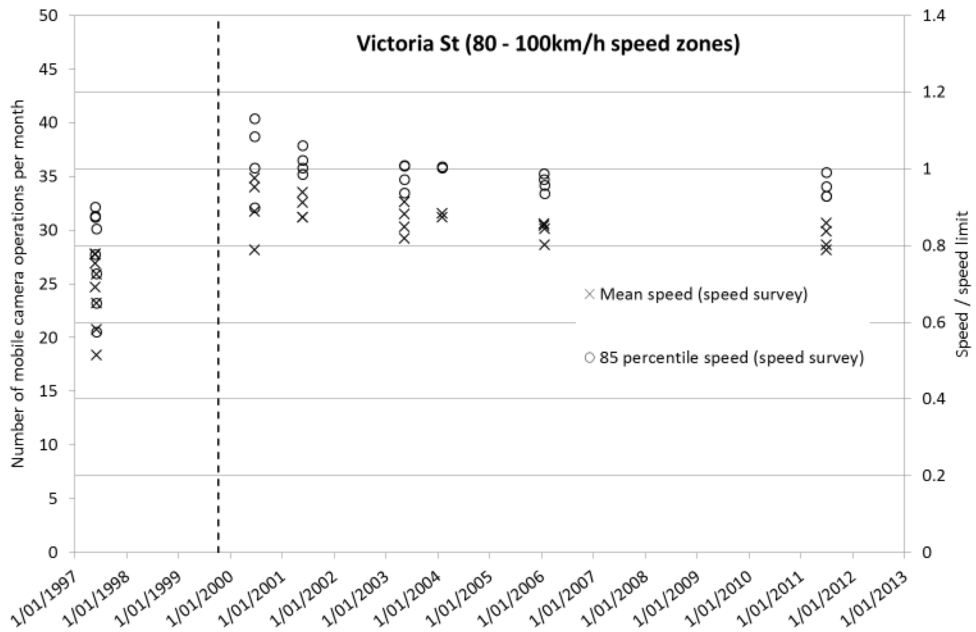
Victoria St (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
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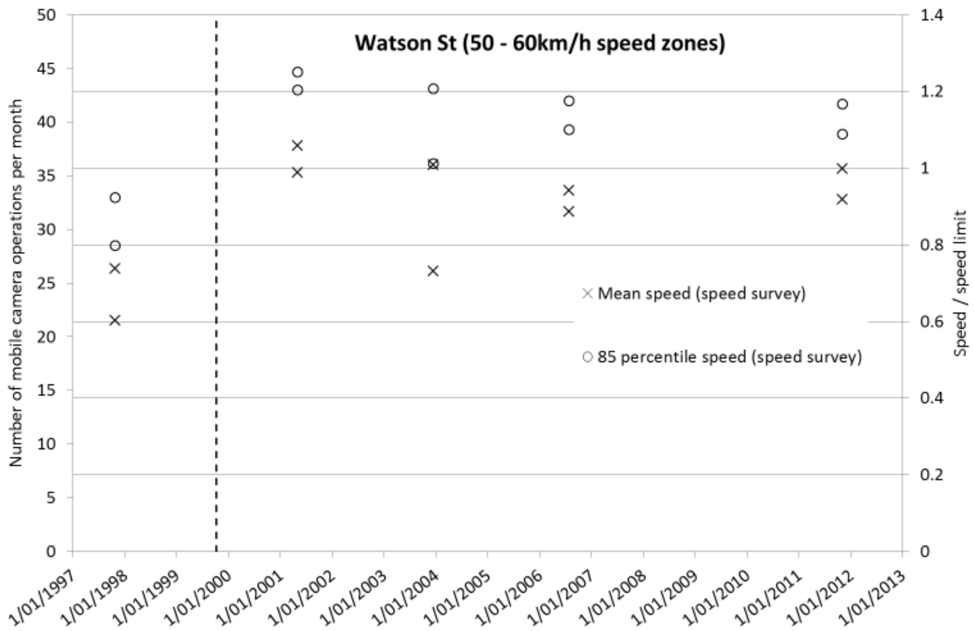
Watson St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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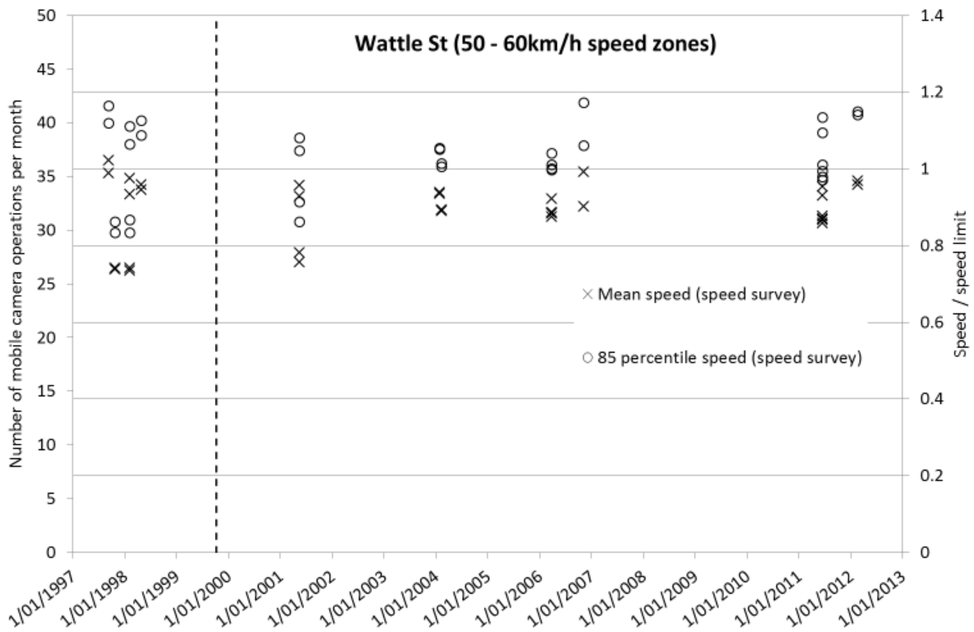
Wattle St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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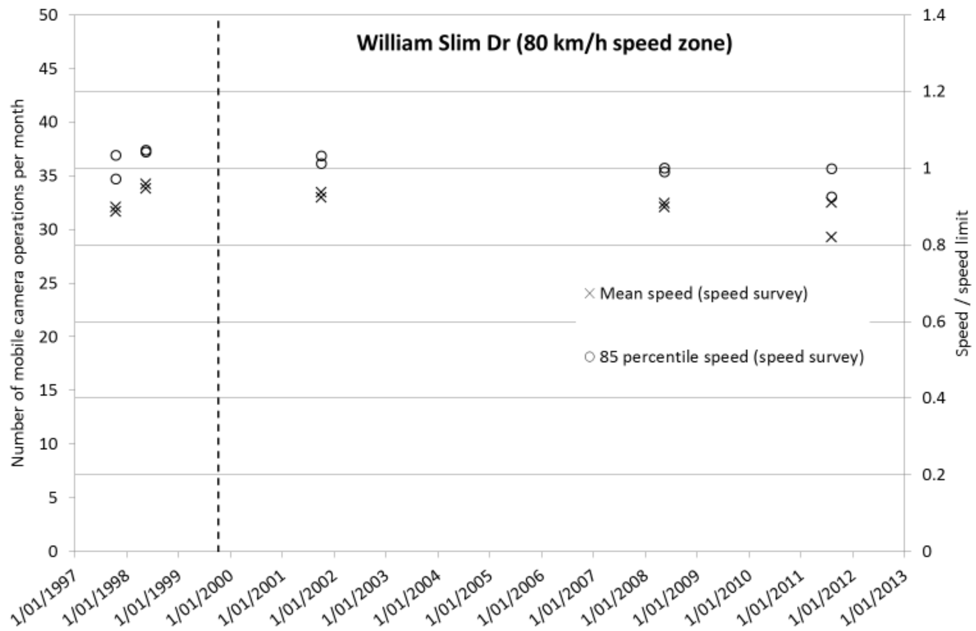
William Slim Dr (80 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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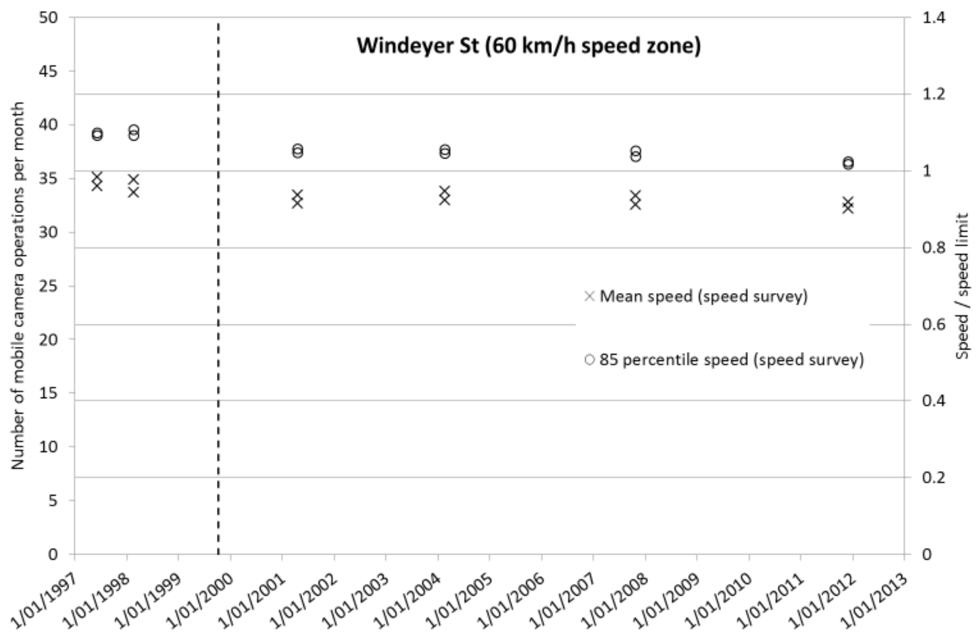
Windeyer St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
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Report:

Evaluation of the ACT Road Safety Camera Program

A TARS Research report for the ACT Government Justice and Community Safety Directorate

July 2014

TRANSPORT AND ROAD SAFETY
(TARS) RESEARCH

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Definitions

Road crash – police-reported road crash that occurred on a public ACT roadway, resulting in property damage, injury or fatality
Serious road crash – police-reported road crash that occurred on a public ACT roadway, resulting in injury or fatality
Casualty crash – fatal and serious injury crashes
Case streets – ACT streets on which road safety cameras were installed/operated
Control streets – ACT streets on which road safety cameras were not installed/operated
Driver – Vehicle driver including light and heavy drivers and motorcycle riders
Intervention 1 – Introduction of the ACT Road Safety Camera Program, on the 6th October 1999
Intervention 2 – Reduction of mobile camera operations on ACT streets, around October 2006
Begin-date – Date of the introduction of cameras on a particular street/intersection
CL_L – Lower 95% confidence limit
CL_U – Upper 95% confidence limit
Statistically significant – a statistical result with a *p* value less than 0.05
Mean speed – the mean of all vehicle speeds measured during a speed survey
85th percentile speed – the speed below which 85% of vehicles were travelling during a speed survey (conversely, the speed 15% of vehicles were exceeding)
RTM – Regression to the mean
Spillover effect – when the effects of a fixed camera extend further along a roadway from the camera location

Executive Summary

Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, in order to guide improvement of the Program. The evaluation process is outlined in the Detailed Statement of Requirements provided in Appendix E. This report delivers that independent evaluation.

Aim

The key aim of this study was to investigate the performance of the ACT Road Safety Camera Program as a whole, including its impact on speeding and road crashes, and identify opportunities for improvement.

Whilst the above aim has been addressed in this report, emphasis in terms of evaluation of the camera program's effectiveness has been placed on whether the program has reduced serious and fatal injury crashes. This emphasis was implemented based on the National Road Safety Strategy (ATC, 2011) vision that no person should be killed or seriously injured on Australia's roads, where the strategy presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. In this context the following statements from that strategy document are particularly relevant: '*Crashes will continue to occur on our roads because humans will always make mistakes no matter how informed and compliant they are. But we do not have to accept a transport system that allows people to be killed or severely injured as a consequence….. This means we must manage the combined effects of the speeds at which we travel, the safety of the vehicles we use, and the level of protection provided by our roads — not only to minimise the number of crashes, but to ensure that when crashes do occur they do not result in death or serious injury.*'

<u>Thus a key question in this evaluation the Authors decided to further consider is whether casualty crashes in the ACT have reduced as a result of the introduction of the ACT Road Safety Camera Program.</u>

Methods

Speed surveys and road crash data were assessed for the period from 1994 to 2012 (inclusive). A sample of 95 ACT streets and 26 ACT intersections were assessed, including 48 case streets (with mobile cameras), 47 control streets (without mobile cameras), 13 case intersections (with fixed cameras) and 13 control intersections (without fixed cameras). It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

Data were collected for a total of 57,809 road crashes, 3,325 serious road crashes, 100 fatal road crashes, 4,261 intersection crashes, 1,758 speed surveys and 87,687 mobile camera operations. The sample represents 40% of the total number of ACT road crashes that occurred in the period. Statistical models were developed to assess speed and crash trends, effects of interventions (introduction of cameras) and perform case-control analyses. Additionally, 66 assessments of road safety camera programs in the scientific literature were summarised, as were surveys of community attitudes to speeding collected from 1995 to 2011 (inclusive).

Results

- The evaluation process outlined in the Detailed Statement of Requirements provided in Appendix E has been addressed as outlined in Section 4.4.
- The number of mobile camera operations undertaken in the ACT increased following their introduction until late 2006, after which they decreased (around 30%) due to resource limitations;
- Mobile camera infringement rates decreased from approximately 6% to 0.6% of vehicles passing cameras during the first three years of operations, and remained thereafter steady at this low rate;
- Mean percentile speeds reduced by 6% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- mean 85th percentile speeds reduced by 8% on streets with mobile cameras in the 2.75 years following their introduction (late-1999 to mid-2002) and remained at the lower speed until 2004, a total of around 4 to 5 years;
- Over the next two years, speeds on streets with mobile camera operations returned to levels similar to those before their introduction (mid-2004 to mid-2006);
- Mean and 85th percentile speeds then reduced by 7% and 9%, respectively, on streets with mobile cameras (mid-2006 to 2012);
- Mean and 85th percentile speeds on streets without mobile cameras were generally constant in the long term, and were lower in magnitude than speeds on streets with cameras reflecting the original reasons for the selection of some streets for camera enforcement;
- 85th percentile speeds were higher in magnitude than mean speeds, and although reduced by the cameras remained above the speed limit during the study period;
- Fatal crashes on streets with cameras generally decreased over the study period;
- Serious injury crashes at intersections were generally lower following the introduction of fixed cameras;
- Crashes at intersections with fixed cameras increased after their installation due to an increase in rear-end crashes which was then followed by a decline to levels slightly below baseline levels;
- Crashes at intersections without fixed cameras remained relatively constant although trending slightly upwards, and were lower in magnitude than crashes at intersections with fixed cameras reflecting the original reasons for the selection of some intersections for camera enforcement;

- There was a decreasing trend in serious crashes around the time of the introduction of mobile cameras, on both streets in which mobile cameras were operating and not;
- There was a large decrease in serious injury crashes in mid-2002 on streets with mobile cameras when mobile camera operations increased from around 400 per month to over 600 per month;
- The large decrease (around 40%) in serious injury crashes commencing in mid-2002 was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend steadily increasing up to 2013 to the same levels when cameras were first introduced;
- The rising trend in serious injury crashes starting from around 2004 through to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period;
- The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006;
- The large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras occurred in the year immediately following the period when more than two-thirds of survey participants reported that enforcement had increased in 2001;
- In the surveys conducted between 1999 and 2001 and in 2001 the percentage of people reporting no change in enforcement clearly fell to its lowest level in the survey period. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years up to 2006, perception of increased speed enforcement remained high. This increased awareness of speed enforcement coincides with the large 40% decrease in serious injury crashes commencing in mid-2002 until the end of 2004;
- More ACT residents reported decreasing their own driving speed in 2000 up until around 2005, being the period following the introduction of mobile and red light cameras and the period when there was a large decrease in serious injury crashes starting in mid-2002 on streets with mobile cameras. However, since 2008 around three quarters of drivers reported no change to their speed coinciding with the period of steady increase in serious injury crashes;
- More ACT residents reported supporting lowering residential speed limits following the introduction of mobile and red light cameras;
- Since the introduction of cameras in, the proportion of residents that agree that safe speeding is ‘OK’ has decreased, however around one half agree with the view that speeding fines are for revenue raising;
- Evaluations of red light cameras in the literature have identified mixed effects: benefits include reduced red light running and right-angle crashes; detriments include increased rear-end crashes (a less severe crash type) during the initial phase when introduced however, right angle crashes are on average more severe than the rear end crashes;
- Evaluations of fixed speed cameras in the literature have identified benefits such as reduced speeds in the vicinity of the camera and reductions in injury and fatal crashes;
- Evaluations of mobile speed cameras in the literature have identified benefits such as reductions in speeds and speeding, and reductions in crashes;

- Evaluations of point-to-point cameras in the literature have identified benefits such as reductions in crashes;

Conclusions

Beginning at the start of 2000, mobile cameras reduced speeds by around 6%-8% in the short-term (late-1999 to mid-2002), and remained at the lower speed until 2004 (a total period of four to five years). Speeds then began to rise back to pre-camera levels over a period of approximately four years (mid-2004 to mid-2007). The 6%-8% fall in speed reached by mid-2002 coincided with a 25% to 30% reduction in serious injury crashes on streets where cameras were present. This reduction in serious injury crashes was sustained until mid-2005. If this fall in serious injury crashes is attributed to the average speed reduction it would be consistent with the Nilsson power model where a 6% to 8% reduction in speed is estimated to result in around 20% serious and fatal (casualty) crashes. This short-term effect of speed cameras is consistent with camera evaluations in other jurisdictions and countries.

It is noted that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. This increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Coinciding with this 25% to 30% fall in serious injury crashes from mid-2002 to the end of 2004 period, the survey of community attitudes to speeding indicated a marked increase in survey participants' awareness from 2001 to 2004 that speed enforcement had increased. This indicates that drivers (includes motorcycle riders) likely adjusted their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. When they found that they were not being caught as often as they thought they would be, their speed started to return to customary levels. Associated with this rise in average speed was a rise in serious injury crashes to the same rates as those when cameras operations started in 1999. Alternatively, it could be other factors like initial bursts of enforcement, which slowed drivers (and riders) down.

The introduction of cameras had a short-term effect on vehicle mean and 85th percentile speeds. This short term effect coincided with driver's awareness that enforcement of speeds had increased. As a result serious crashes fell around mid-2002. However, serious crashes and speeds started to trend upwards since around 2005-2006, finally reaching the same levels of serious injury crashes as when cameras were first introduced. Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. Further speculating, the loss of this benefit may be reflecting an unrelated background trend such as an increase in traffic activity. It could also be due to drivers realising the low risk of detection and possibly weak penalties. When a driver receives an infringement and little changes with respect to penalty fees and to loss of their license, then the impact of detection is weakened. For example, in NSW when the law was introduced that any speeding by a P1 driver would cause them to lose their licence, the speed related fatalities dropped by over on third (Job, 2013). However, it appears that the main cause may have been the drop in mobile camera hours from a peak of 700 operations per month to an average of around 500 per month (around 30% reduction) in 2007. This pattern of data over time, with the decreases in severe crashes and decreases in speeding and then increases in both serious crashes and speed, reinforce the key role of speed in road trauma. Regardless, this increase in serious crashes over the last five to six years presents a substantial road safety challenge to the ACT.

Intersection cameras produced reductions in right angle crashes and small decrease in serious crashes offset by increases in rear end crashes. Concurrently rear-end crashes were on an upward slope at control intersections. Thus, the initial increase in rear-end crashes followed by a steady return to baseline rates at case intersections resulted in a net reduction in serious crashes. On average, whilst the number of injuries resulting from rear end crashes can be substantial in terms of number of lower severity injury claims, and can have long term chronic effects related to whiplash injuries, they are often significantly less severe than side impact crashes, mainly as a result of the crashworthiness crush and occupant protection characteristics of the struck vehicle.

Recommendations

The results strongly suggest that the cameras had a positive effect on reducing speeds and thus serious injury crashes when first introduced, but that this effect began to dissipate starting around the mid-2000's. The reasons for the increases in speeding and in crashing are not clear, but factors that may have played a role were a distinct reduction in the number and consistency of mobile camera operations in approximately late 2006, and avoidance mechanisms by drivers. Simply the threat or even presence of cameras is unlikely to have an effect of reducing speeds unless there is a clear consequence of doing so. A review is recommended of the information sources available for avoidance and improved management of camera operations to create true unpredictability (along with strong publicity warning that these changes are occurring)

Other factors that may have played a role could include less media and community awareness raising of the presence of cameras and the importance of speed as a factor in road safety around 2006 to 2007. The survey data indicates an increase of survey participants reporting no change in enforcement around then. It is therefore recommended that the ACT government re-engages with the community regarding the benefits of reducing speeds for road safety and the role of cameras in reducing speeds.

Alternative accounts of the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Evaluation of these possible accounts through further research is recommended.

Serious crashes have been increasing in the ACT since around mid-2005. It is also worth noting that the total ACT vehicle fleet has increased 25% over the period 2004–2013, and transport modelling of car trips during the morning peak period suggests the total number increase by 7% from 2006 to 2011 and by 13.5 % from 2001 over a ten year period. Given the infrastructure remains relatively constant (approximately the same road area and intersections) this increase in exposure may also be having a non-linear effect on injury outcomes resulting from crashes. It is therefore recommended that further research on injury crashes during this period is performed, in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

The need to monitor and refine the camera program according to the data is critical. Timely regular monitoring and evaluation is essential to the success of any enforcement program by decision makers. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix.

The rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006. Hence it is clear operation needs to increase back to the similar levels per 2006 as a first step. However this needs to be carried out hand in hand with strong communication via various media outlets and timely notices. The community must be taken along with the increase in operations and provided transparency and clear reasoning regarding the strong link between drivers who reduce their speeding to the speed limit and the safety benefits they gain.

There needs to be timely data gathering on speed surveys that are regular and consistent and allow immediate analysis of the number/percentage of drivers exceeding the limit. Again this should be transparent to the community.

Appropriate staffing and financial resources to support that scheme are essential, i.e. highly skilled data analysts that can communicate results to decision makers, sufficiently resourced enforcement agencies for increased mobile operations, sufficient resources for timely processing of infringement notices, and sufficient financial resources for community communication and media advertising with an appropriate communication strategy that takes the community along with the increased enforcement program that demonstrates obvious safety benefits.

It is also strongly recommended that further research on injury crashes during this period is performed, i.e. a linked data analysis between crashes and hospitalisations in order to understand the causes for these changes, and identify priority areas and possible intervention strategies.

History (evidence base) has proven time and again that the presence of a mix of safety camera types (fixed, mobile of both overt and covert, and point-to-point) and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. Promotion and communication and consistent enforcement that are perceived to be wide spread in different forms are a key part of any enforcement program cannot be overstated. Returning the number of mobile operations to the same levels prior to 2006 and including point-to-point cameras in the mobile camera programme would be a first step.

It is important that communications and advertising are related to enforcement, not simply to speeding. Experience and evaluations of the greatest successes in road safety via behaviour change have all been achieved through the close association of strong media promotion of enforcement and the enforcement itself. The immediate effects of these campaigns, which started at or even before the enforcement started, attest to the key role of the communications in these successes. Many communication messages do not alter behaviour because messages are not aligned and based on the threat of enforcement.

An evaluation program that continues to add data each year to the current data set presented in this report would be essential to the development of a successful camera program strategy that improves on the current status. It is critical for decision makers to receive timely feedback from surveys, speed data and crash data and this should be done in a round table mode so that it promotes a culture of team work, focusing on reducing casualties and receiving valuable input from a number of experienced participants at senior level.

In terms of evaluating the effectiveness of mobile cameras on mid-block crashes and point-to-point cameras, this cannot realistically be started until around 2016 because of the reasons of RTM and spillover effects.

Better data gathering on speed surveys that is regular and consistent and allows for regular analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also important.

The need to monitor and refine the program according to the data is critical. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix.

Finally, appropriate staffing to support these proposed improvements is critical.

1. Introduction

1.2 Background

The ACT Government is interested in road safety and committed to improving the safety of the ACT. Thus, the Government (via Justice and Community Safety) sought independent evaluation of the ACT Road Safety Camera Program as a whole, including its impact on crashes and speeding, as well as the governance of the program. The key reason for conducting this evaluation is to identify opportunities for improvement. This report delivers that independent evaluation.

1.2 General

Camera technology has been adopted widely as a means of encouraging drivers to reduce their driving speed. Lack of control of speed is a major challenge to road safety, and is a large contributor to road crashes, especially more severe crashes. The use of photographic or camera enforcement automates and extends the reach of enforcement in an effort to encourage drivers to comply with speed limits.

Red light cameras are used to encourage compliance with traffic signals and by doing so promote lower driving speeds around signalised intersections. Fixed speed cameras being located at specific points in the road network are used to encourage lower speeds usually in areas of higher traffic risk, often regarded as traffic 'black spots'. As fixed cameras become a standard fixture they can be expected to have local effects on driving speeds. On the other hand, mobile speed cameras can be placed at any position in the road network and this position can be varied so drivers will not expect their presence. Mobile cameras therefore would be expected to have a more general effect on driving speeds as drivers cannot predict their presence around the road network. Some jurisdictions, including the ACT, operate mobile cameras overtly and provide information to drivers about the presence of mobile cameras. Others operate mobile cameras covertly, providing only general information to drivers that cameras may be operating 'anywhere, anytime'. Different outcomes might therefore be expected from overt and covert operation of mobile cameras. Overt operations that make the need to reduce speeds clear to drivers might be expected to have effects in their immediate vicinity. The general deterrence effect might be expected to be stronger in situations where mobile cameras are used covertly although this effect is likely to be much weaker as the effect will require drivers to reduce speeds 'just in case' there are cameras in their vicinity, and many other factors are likely to influence this effect including driver attitudes towards road safety and enforcement.

Evaluation of the effectiveness of safety camera programmes requires well-designed studies. Evaluation studies that only include measurement before and after cameras are implemented only provide weak evidence. At the least, study design needs to include appropriately chosen controls where measures are taken at the same time as the camera measures in order to be able to show that any changes seen after the cameras are in place are not simply due to changes in driver behaviour over time. An ideal study design would also include randomisation of locations for cameras and controls to ensure that choice of location does not bias measures of effectiveness of the cameras. In road safety, however, interventions like safety cameras are almost never randomly assigned; rather they are implemented in locations where they are likely to achieve the best improvements in road safety. Nevertheless, evaluation studies should still involve the best design possible and at least a before-after design with control groups.

In evaluating the effectiveness of safety cameras in particular, two other factors commonly cited as potential threats to the validity of safety camera evaluations are Regression to the Mean (RTM) and spillover effects. Non-random assignment of cameras to locations makes these types of evaluations vulnerable to RTM effects. Cameras are almost always implemented at sites that have high demonstrated crash risk and crash risk will be significantly lower after cameras are implemented if they operate as expected. It is possible, however, that the high initial crash risk is due to natural variation in crashing that occurs potentially in any location in the road network, in which case crash risk will decrease for the same reason, rather than due to the presence of cameras. RTM effects can lead to overestimation of the effects of safety cameras and so should be avoided if we want to reveal the effect of the presence of safety cameras. Best study designs for avoiding RTM effects include using long periods for before and after measurement so natural variation can be captured in the study and using statistical means such as empirical Bayes methodology (Hallmark et al, 2010).

It is argued that spillover effects, sometimes also referred to as halo effects, threaten the validity of the evaluation of safety cameras in studies where the chosen control sites may be influenced by the presence of the safety camera such as a similar location in the next section of road. In such locations, it is argued that driver speed may still be low due to a lasting effect of the camera. Spillover effects will underestimate the effectiveness of safety cameras and again invalidate the evaluation of the effect of the camera. It should be recognised, however, that spillover effects are also likely to occur due to general community awareness of speeding and speed-related enforcement that usually occurs around the introduction of safety cameras. Where this is the case, the finding of improvements in road safety outcomes at comparison locations with no camera should be viewed as another outcome of the road safety intervention rather than a nuisance factor in the evaluation. The comparison between camera and no camera sites will then be showing the additional effect of cameras to a road safety program rather than necessarily the whole program itself. Spillover effects of cameras may be less likely for some types of safety cameras. In particular, where camera locations are known and expected, such as fixed location cameras (red light and fixed speed), people come to anticipate their presence and so would be expected to produce less spillover effect as drivers respond to the particular sites that they know are enforced. Overall, to evaluate the effect of a safety camera program in its entirety would ideally ensure that control sites are in areas that will not be influenced by any facets of the program, not just the presence of cameras.

Finally, good evaluation designs should include measures relevant to the outcome expected to change as a result of the intervention. The objective of introducing safety cameras is to reduce driving speeds and as a result to reduce crashes and casualties. As shown in Figure 1, it is expected that the presence of safety cameras and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication is a key part of any enforcement program. The relationship between speed and casualty crashes is well known and has been modelled by many researchers. For example, Figure 2 shows the often cited Nilsson (2004) power model showing the relationship between the change in mean speed and fatal and serious injury crashes. It shows that a 7% reduction in mean speed will result in around 20% fall in Fatal and Serious injury crashes.

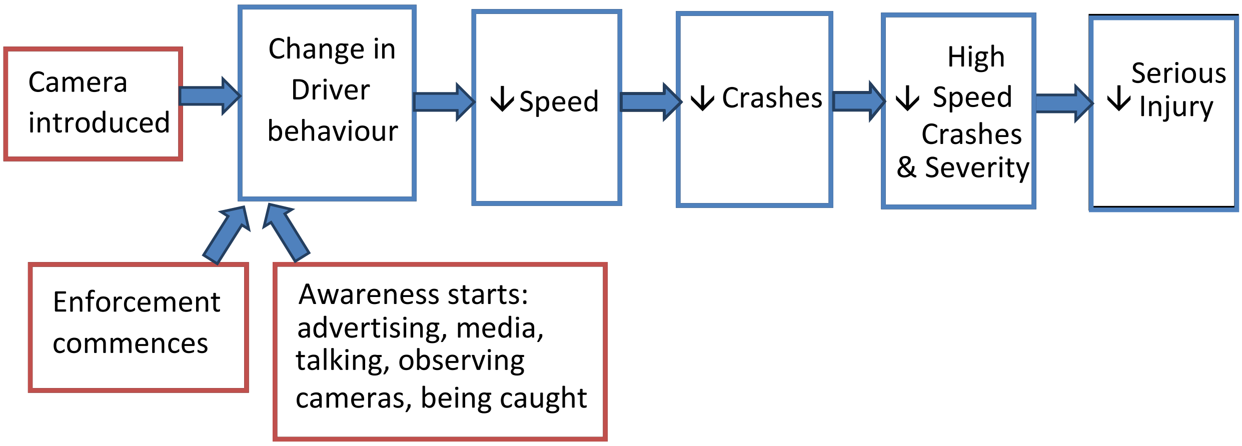


Figure 1: Schematic of the expected effects of safety cameras on road safety outcomes.

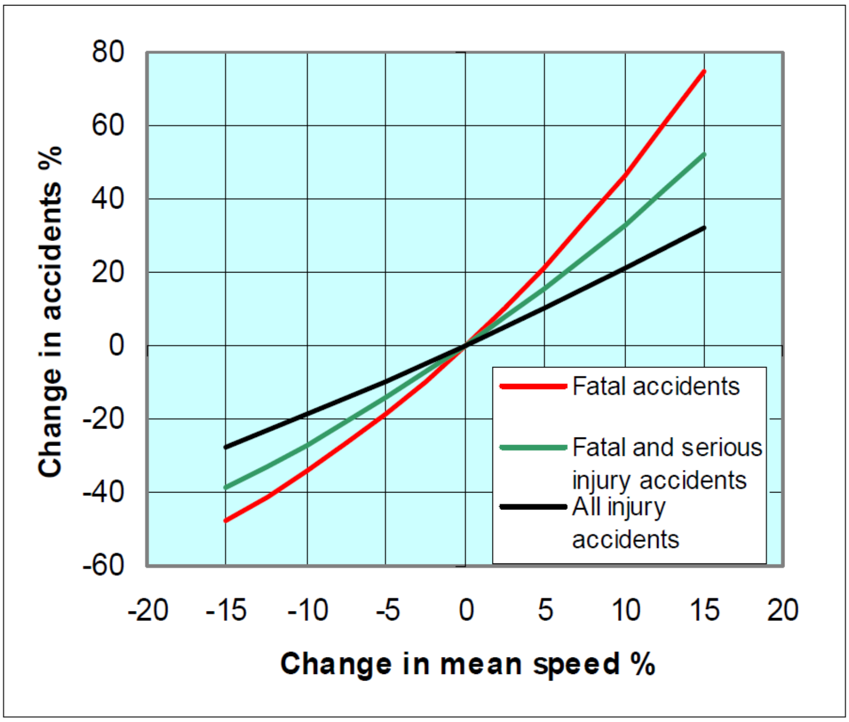


Figure 2: Nilsson (2004) power model showing relationship between casualty crashes and mean speed.

It must not be overlooked that the effect of safety cameras is also through punishment or enforcement of speed limits which also encourages changes in driver behaviour to produce lower speeds, crashes and injury. In this way, simply the presence of safety cameras can have a general deterrence effect on driver behaviour due to the fear of being caught, whereas the use of enforcement together with communication tends to have a specific effect on individual driver behaviour, mainly influencing speeding drivers who are caught.

These three effects of cameras, communication and enforcement are also likely to produce different changes in behaviour in parts of the road network in which cameras are introduced or not. The strongest effects naturally should occur in the safety camera locations where the presence of cameras combined with enforcement and communication provides the greatest encouragement for drivers to comply. It would be expected, that cameras will also influence driver behaviour in areas where some drivers might suspect that cameras are operating and so modify their behaviour accordingly. In most settings, the introduction of safety cameras is publicised and justified through media and other means of dissemination. This will also raise awareness amongst the community of the general presence of safety cameras which would be expected to add incentives for some drivers to change their behaviour and reduce speed because they want to avoid penalties and because they believe that compliance is safer.

The presence of enforcement and consequent speeding infringements for drivers who violate the speed limit, is likely to create further incentive for drivers to reduce their speed in locations where the enforcement occurs. Following the introduction of safety cameras it would be expected that infringements may be initially high, but will reduce as drivers learn about the presence of cameras and enforcement either through their own experience or the publicised experiences of others. With time, infringement rates would be expected to reduce as driver speed is reduced because of the cameras having an effect.

Safety camera evaluations should therefore include measures of changes in driver behaviour, especially speed around speed cameras and speed and red light running around red light cameras. As the ultimate outcome of camera programmes is to reduce injury crashes, these measures should also be included. Measures of enforcement should also be included in camera evaluations because enforcement is an integral aspect of the road safety intervention. Numbers of infringements are not a direct outcome of camera programmes. However, they would be expected to influence driver behaviour both independently and in combination with the presence of cameras. In the present study, efforts have been made to include all the relevant measures (infringement rates, speed, injury and crash data), while minimising the potential confounders (RTM and spillover effect).

2. Method

2.1 Literature review

The review of existing scientific literature on the impact and effectiveness of road safety cameras looked at published studies in the international peer-reviewed literature and unpublished reports from English-speaking countries including all Australian jurisdictions, Canada, UK, NZ and USA and from the top road safety performing countries in the OECD where their websites are translated into English (e.g., Sweden, Netherlands, France). The objective of these literature searches was to identify evidence of best practice in implementation of road safety cameras in order to evaluate the impact of different types of cameras, identify any issues that need to be taken into account in implementing safety camera programs and to determine whether there are new opportunities to improve the effectiveness of the current program in the ACT.

A search of the available published scientific literature was conducted using four major search engines including Web of Science, PsycINFO, Scopus and PAIS International. The key words used included speed, camera, red light camera, evaluation and enforcement in different combinations.

A search of reports of evaluations of safety camera effectiveness was also conducted. This involved a website search of the main websites of road authorities in the different jurisdictions of Australia, Canada, UK, NZ and USA as well as Sweden, Netherlands, France (where their website is in English). The purpose of this search was to identify any grey literature that was not located from the conventional literature search.

2.2 Review of community attitudes to speeding

This review used existing literature to understand changes in community attitudes to speeding in the ACT following the introduction of different types of speed cameras, including the results of the series of community attitude surveys conducted for the Department of Infrastructure and Development and related entities over nearly 25 years. Changes in respondent's views of speeding were linked to the introduction of the different types of cameras in the ACT (i.e., mobile cameras from 1999, fixed red light/speed cameras from 2000, fixed speed cameras from 2007). As community attitudes are an important component of compliance with speed limits, this analysis may provide some other insights into the comparative effectiveness of the road safety camera program.

A series of community attitude surveys have been conducted for the Australian government's transport portfolio, currently the Department of Infrastructure and Regional Development. A total of 22 surveys have been conducted on a regular basis since the late 1980's. Questions about speeding were included in all surveys but since 1995 there has been a standard series of questions about speeding included in each survey. Answers to many of these questions are also available by jurisdiction so that it is possible to track changes in the perceptions and attitudes of ACT residents about speeding over the 15 years between 1995 and 2011. This data also allows investigation of the influence of the introduction of safety camera's on community attitudes towards speed and speeding over the period. With the staggered introduction of different types of cameras in the ACT, it was possible to look at the relative impact of each type of camera on community attitudes. This will allow examination of the general deterrence effect of mobile cameras which were introduced from 1999, the effects of fixed red light cameras operating in specific locations which were introduced from 2000 and fixed speed cameras from 2007.

Each of the 22 Community Attitude surveys conducted by the federal transport authority between 1995 and 2011 were reviewed to establish the series of questions on speeding that had remained the same across each survey.

The questions included were:

- "In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"
- "Have you personally been booked for speeding in the last two years?" And, if so "Have you personally been booked for speeding in the last six months?"
- "Thinking about 60km/h speed zones in urban areas:
  1. How fast should people be allowed to drive without being booked for speeding? (i.e. the 'acceptable' speed tolerance)
  2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"
- "Thinking about 100km/h speed zones in rural areas,
  1. How fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance)

2. How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)”

- Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:
  1. Fines for speeding are mainly intended to raise revenue
  2. I think it is okay to exceed the speed limit if you are driving safely
  3. Speed limits are generally set at reasonable levels
  4. If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
  5. An accident at 70km/h will be a lot more severe than an accident at 60km/h
- "Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?"
- "Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"
- "Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways", they were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"
- "In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

Each survey looked at a national sample of residents 15 years and over. Survey was by telephone with a letter in advance advising the household about the survey. Sampling of all states and territories was stratified by regional probability sampling, but from 1999 the sampling strategy was modified to ensure at least 150 interviews in each jurisdiction. Sample size for the 1995 to 1998 surveys was around 100 interviews in each survey.

2.3 Speed survey and road crash data study

2.3.1 Data collections

The data collections that were accessed for the data study are summarised in Table 1.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 1: Data collections used for the study

Speed survey data was available from 1997 to 2012 (inclusive), and consisted of the annual summaries indicating the site location, speed limit, survey date, 24 hours traffic volume, mean and 85th percentile speeds of the survey. The road crash data consisted of all police-reported crashes that occurred on public ACT roadways, resulting in either property damage, injury or fatality. In order to have five years of crash data prior to the start of the camera program, crash data was extracted from 1994 to 2012 (inclusive). Enforcement data for both fixed and mobile cameras consisted of the number of vehicles checked by the camera, and the number of infringements issued, and was available from the implementation of each camera.

2.3.2 Selection of case and control mobile camera locations

The present study considered two types of roadway locations; streets in which mobile cameras were implemented anytime during the period 1999 to 2012, and streets in which they were not. Streets with mobile camera operations are hereafter termed 'case' streets, while those without cameras are termed 'control' streets. It should be noted that the control streets do not represent a true 'control area', since an area similar to the ACT where speed cameras were not being operated could not be identified. While the control streets did not have camera operations, they may have been affected by the operation of cameras on adjacent streets or suburbs. In other words, the control streets could also be seen as a measure of the broad effect of mobile cameras.

During the implementation of the mobile camera program since 1999, a total of 177 ACT streets were approved for mobile camera operations. Road crash data was available for all public ACT streets on a continuous basis. Speed survey data was available for selected ACT streets on a discontinuous basis, since surveys have been performed in a non-systematic way since 1997. In order to select locations for the present study of mobile camera operations, the speed survey data was deemed to be the limiting data collection and was therefore used.

Initially, streets on which mobile camera operations were introduced were identified in the speed surveys undertaken in 1997. This allowed for as much pre-camera data as possible. These streets were then tracked temporally and the number of years in which at least one survey was undertaken up to 2012 (inclusive) was established. Streets were then ranked according to the total number of years available, resulting in a total of 48 streets with five or more survey years. Streets on which mobile camera operations were not introduced were then selected in the same manner, resulting in a total of 47 streets with five or more survey years available. These analyses were performed manually using the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

This resulted in a total of 95 streets for the mobile camera analysis. The full list of case and control streets is provided in Appendix A. Crash data located anywhere along these streets was then provided by the ACT Territory and Municipal Services Directorate. Each street was then treated as a single location, a location number was assigned to it, and any crash or speed survey located at any position along the full length of that street, was assigned to that location number.

2.3.3 Selection of case and control fixed camera locations

There are three different types of fixed cameras operating in the ACT; combined red light and speed cameras located at intersections, speed cameras located along mid-block sections and point-to-point cameras. Point-to-point cameras were recently installed in 2012, thus insufficient data was available to assess these cameras in this study. Road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. However, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis.

Intersection crashes are identified specifically in the road crash data collection, thus particular intersections were easily identified, and an assessment of the association of the introduction of fixed intersection cameras with crash outcomes could be assessed. Case and control intersections were identified in a similar manner to the mobile cameras, where case intersections were those on which fixed red light and speed cameras were installed. Since there was a relatively small number of these (thirteen), all fixed camera intersection locations were selected. Thirteen control intersections were then identified by randomly selecting other intersections located on the same street as each of the case intersections. This resulted in a total of 26 intersections for the fixed intersection camera analysis. The full list of case and control intersections is provided in Appendix A.

2.3.4 Time periods

The ACT road safety camera program began on the 6th October 1999 with the introduction of mobile camera operations on 22 streets. Fixed cameras began to be introduced shortly thereafter in 2000. There was a reduction in mobile operations in 2006, where due to various resource limitations mobile camera vans performed fewer operations. In order to assess associations with the overall camera program, the two key dates of the introduction (October 1999) and the change (October 2006) were identified, and are hereafter termed Intervention 1 and Intervention 2, respectively.

For each case street, the date on which mobile camera operations began in that street was established, and is hereafter termed the 'begin-date'. Begin-dates for the selected streets ranged between October 1999 and March 2011. In order to perform the case-control analyses, each control street was matched to a case street, based upon traffic volume and speed zone. Since every case and control street had a speed survey performed in 1997, the traffic volume in 1997 was used to establish matched street pairs. Each control street was matched to a unique case street, and the begin-date of the case street was then allocated to the matched control street.

For each case intersection, the date of the installation of the fixed red light and speed camera was established as the begin-date for that street, and ranged between June 2000 and August 2007. Begin-dates were then assigned to control intersections, as the date corresponding to the begin-date of the matched case intersection.

2.3.5 Statistical analysis

The statistical analyses were divided into two categories, assessing the association of the camera program with changes in; vehicle speeds and road crashes. Vehicle speeds were assessed using speed survey mean and 85th percentile values. Road crashes were aggregated into intersection and non-intersection crashes. Intersection crashes were aggregated into serious (injury or fatality), rear-end, non-rear-end and right angle/right turn into oncoming vehicle crashes. Non-intersection crashes were aggregated into fatal, serious and all crashes. Within these categories the analyses were divided into two further categories, assessing associations with regards to; the implementation of the overall camera program and the implementation of cameras at particular streets/intersections. A total of 32 models were developed, as outlined in Table 2. All outcomes of vehicle speeds and crash counts were aggregated into monthly counts.

The aim of assessing the implementation of the overall camera program was to identify the effect of the camera program on the network generally. For this purpose the case and control streets were aggregated and assessed individually, in order to assess the effect of the camera program on streets that had, or did not have, camera operations. These analyses were relative to the start date of the camera program (Intervention 1) and the change date of mobile operations (Intervention 2).

Model #	Outcome	Type	Intervention	Intervention dates
1	Speed surveys – mean	cases	Overall program	Interventions 1 and 2
2	Speed surveys – mean	controls	Overall program	Interventions 1 and 2
3	Speed surveys – mean	cases	Individual mobile cameras	Begin-date of cameras on each street
4	Speed surveys – mean	controls	Individual mobile cameras	Begin-date of cameras on each street
5	Speed surveys – mean	case-control	Individual mobile cameras	Begin-date of cameras on each street
6	Speed surveys – 85th percentile	cases	Overall program	Interventions 1 and 2
7	Speed surveys – 85th percentile	controls	Overall program	Interventions 1 and 2
8	Speed surveys – 85th percentile	cases	Individual mobile cameras	Begin-date of cameras on each street
9	Speed surveys – 85th percentile	controls	Individual mobile cameras	Begin-date of cameras on each street
10	Speed surveys – 85th percentile	case-control	Individual mobile cameras	Begin-date of cameras on each street
11	Serious road crashes	cases	Overall program	Interventions 1 and 2
12	Serious road crashes	controls	Overall program	Interventions 1 and 2
13	Serious road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
14	Serious road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
15	Serious road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
16	Road crashes	cases	Overall program	Interventions 1 and 2
17	Road crashes	controls	Overall program	Interventions 1 and 2
18	Road crashes	cases	Individual mobile cameras	Begin-date of cameras on each street
19	Road crashes	controls	Individual mobile cameras	Begin-date of cameras on each street
20	Road crashes	case-control	Individual mobile cameras	Begin-date of cameras on each street
21	Serious intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
22	Serious intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
23	Serious intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
24	Intersection crashes	cases	Individual fixed cameras	Begin-date of cameras on each street
25	Intersection crashes	controls	Individual fixed cameras	Begin-date of cameras on each street
26	Intersection crashes	case-control	Individual fixed cameras	Begin-date of cameras on each street
27	Intersection crashes-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
28	Intersection crashes-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
29	Intersection crashes-non-rear-end	cases	Individual fixed cameras	Begin-date of cameras on each street
30	Intersection crashes-non-rear-end	controls	Individual fixed cameras	Begin-date of cameras on each street
31	Intersection crashes-right A/T	cases	Individual fixed cameras	Begin-date of cameras on each street
32	Intersection crashes-right A/T	controls	Individual fixed cameras	Begin-date of cameras on each street

Table 2: Statistical models

The aim of assessing the implementation of cameras on particular streets/intersections was to identify the local effect of introducing individual cameras or camera operations. These analyses were relative to the begin-date for case streets/intersections, or the assigned begin-date for control streets/intersections (i.e. the begin-date of the matched case street/intersection). Case and control streets/intersections were first aggregated and assessed individually, then aggregated and assessed in a case-control study. The latter analysis provides statistical measures of the difference between the implementation of cameras on case and control streets/intersections. However, this comes with the caveat concerning the limitations outlined earlier regarding the selection of the control streets and the spillover effects that may be occurring.

Poisson regression was used for all models, and Pearson deviance was used to correct for over-dispersion. Poisson regression fits a log-linear model to the data, and is therefore most appropriate when the data approximates a log-linear trend. Before-and-after studies typically use the same temporal length both before and after, however are not bound by this. For the assessment of the implementation of camera operations on each individual street/intersection, this seemed a rational approach and the temporal period was set by the minimum amount of pre-data available (60 months for the crash data and 33 months for the speed survey data). For the assessment of the implementation of the overall camera program, the raw data was first assessed. For the crash data a relatively linear trend was observed between Intervention 1 and Intervention 2, therefore a single model was fit for this period. For the speed survey data a bilinear trend was observed during this period, therefore two models were fit. The first model used the same temporal length as the pre-camera speed survey data (33 months), while the second model used the remaining period up to Intervention 2. Accordingly, the crash data model was continuous between Intervention 1 and Intervention 2, while the speed survey model was not.

The outcome (COUNT) for the models was either monthly speed survey results (Models 1 – 10) or monthly crash counts (Models 11 – 32). The former were expressed as the measured speed divided by the speed limit (speed rate). Since speed surveys were not continuous over time, for each month all the speed rates for case streets were averaged, as were all the rates for control streets. Monthly crash counts were normalised to monthly vehicle registrations in the ACT (where monthly values were linear interpolations of annual values), for models considering the overall camera program (1994 to 2012). For all statistical models the following two covariates were assessed; TIME and CAMERA. The variable TIME represents monthly intervals and was a continuous covariate centred on the intervention date being considered. CAMERA was a binary variable which had the value zero prior to the intervention, and one following the intervention. For all models of crash counts, the locations (i.e. individual streets) were treated as subjects, where responses from different subjects were assumed to be statistically independent, while responses within subjects were assumed to be correlated. These models took the form of Equation 1. For the case-control models (Models 5, 10, 15, 20, 23, and 26), the identification of the location as a case or control street was included as an additional binary variable CASE. These models took the form of Equation 2. Interactions between variables were also considered. It should be noted that in all 32 statistical models the outcome considered was based on a period of one month, however in many results figures plotted in the following sections the raw crash counts are plotted with respect to three months, purely for clarity in the figures. SAS version 9.3 was used for all statistical analyses. Statistical significance was measured at the 0.05 level.

$$\log(\text{COUNT}) = \beta_0 + \beta_1 \text{ TIME} + \beta_2 \text{ CAMERA} + \beta_3 (\text{TIME} \times \text{CAMERA}) \quad (1)$$

$$\log(\text{COUNT}) = \beta_0 + \beta_1 \text{ TIME} + \beta_2 \text{ CAMERA} + \beta_3 \text{ CASE} + \beta_4 (\text{TIME} \times \text{CAMERA}) + \beta_5 (\text{TIME} \times \text{CASE}) + \beta_6 (\text{CAMERA} \times \text{CASE}) + \beta_7 (\text{TIME x CAMERA} \times \text{CASE}) \quad (2)$$

3. Results

3.1 Literature review

3.1.1 Evaluations of red light cameras

Appendix B provides a summary of the papers and reports identified in the literature search. Four existing reviews of literature on the effectiveness of red light cameras were identified (Table 3a). The first was a critical review of international literature (Retting, Ferguson and Hakkert, 2003) looking at outcomes of violations and crashes, however no information was provided about how studies were chosen for inclusion in the review, except that they were all controlled evaluations of before and after effects. Only some of the studies included in this review accounted for RTM and spillover effects. The second was a Cochrane Collaboration meta-analysis review (Aeron-Thomas et al, 2005) of violations and different crash types from studies selected based on searches of electronic databases that fulfilled established criteria for inclusion. This review included only studies with controlled before-after designs and controls for regression to the mean (RTM) and spillover effects. The third was a meta-analysis of studies investigating intersection crashes that were identified from searches of electronic databases (Erke, 2009). This review included all designs including uncontrolled before-after studies and only some of the studies included controls for RTM and spillover effects. The fourth was an update and extension of the third review and again involving studies of intersection crashes that were identified from electronic searches, but with no restrictions on design or whether or not RTM and spillover was accounted for (Hoyos 2013). As might be expected there was a significant degree of overlap between the four reviews. Of the 10 papers included in the Cochrane review, 60 percent were shared with the Retting et al (2003) review and all were included in the two most recent reviews which included 14 and 11 new studies respectively. The Retting et al (2003) review included seven studies that were not included in any of the recent reviews.

In addition, the search in the current review of literature found four more recent evaluation studies of red light cameras (Table 3b). Two of these studies were well-designed before-after evaluations of the installation of red cameras (Ko, Geedipally and Walton, 2013; McCartt and Hu, 2014) and the other two involved studies comparing before and after the removal of red light cameras (Porter, Johnson and Bland, 2014; and Pulugurtha and Otturu, 2014). All studies involved controls of some type and all took steps to control for RTM and spillover effects.

The review also identified four evaluation studies of safety cameras that incorporated red light and speed cameras (Table 4). These were included in this review as they were the only evaluations found specifically of safety cameras which combine the two types. Three of these studies involved before and after with control designs (Vanlaar, Robertson and Marcoux, 2014; Kloeden, Edwards and McClean, 2009; Budd, Scully and Newstead, 2011) and one involved description of the change after cameras were introduced and did not include before measures or controls (McKenzie, Kloeden and Hutchinson, 2012). Only two of these studies accounted for RTM effects (Vanlaar et al, 2014; Budd et al, 2011) and only one accounted for spillover effects (Vanlaar et al., 2014)

Overall, each of the reviews concluded that the presence of red light cameras decreased injury crashes especially right angle crashes, however, the extent of the decrease varied between reviews and the extent to which the reviewers took into account RTM and spillover effects. Both

Retting et al (2003) and the Cochrane review concluded that injury crashes were reduced by 25-30%. It is notable however that the conclusion from the Cochrane review was based on a single well-designed study with appropriate controls. In contrast, the most recent reviews concluded either that there was no statistically significant change in casualty crashes (Hoyos, 2013) or a 13 percent increase in such crashes (Erke, 2009). While these reviews were the most comprehensive, including the largest number of studies, unlike the Cochrane review approach, they included all studies regardless of design flaws. Lund et al (2009) criticised the Erke (2009) review and cautioned against accepting its conclusions on the basis that it included a number of poorly designed studies. In response, Hoyos (2013) conducted a revised review that included extensive analysis of the role of potential moderator variables. Hoyos (2013) concluded that when RTM is controlled there is no evidence of significant effects of red light cameras on overall injury crashes, but the presence of red light cameras reduced right angle casualty crashes by 33 percent. The earlier review by Erke (2009) also found a significant, but smaller reduction of 10 percent in right angle crashes once RTM and spillover effects were accounted for. Two recent evaluation studies of the presence of red light cameras (Ko et al, 2013; Pulugurtha and Othuru, 2014) also showed a 24 and 69 percent decrease respectively in right angle crashes. Similarly the three recent A-B/control evaluation studies of red light and speed camera combinations (Vanlaar, et al, 2014; Kloeden et al, 2009; Budd, et al, 2011) all found significant decreases in right angle crashes of over 40 percent. The Cochrane review found no significant effect on right angle crashes but this was based on only two studies with partial control of moderator variables and the Retting et al (2003) review did not look at specific types of crashes. The evidence therefore leads to the conclusion that the presence of red light cameras have a significant benefit of reducing right angle crashes. This conclusion is supported by the nature of the crash that shows the most benefit. We would expect that red light cameras should reduce right angle crashes the most, and the evidence suggests that they do.

On the other hand, almost all of the reviews and studies that included measures of rear-end crashes made the opposite conclusion: rear-end crashes increased by around 40 percent after the introduction of red light cameras (Erke, 2009; Hoyos, 2013; Vanlaar et al, 2014; Pulugurtha and Otturu, 2014) and by around 19 percent for injury crashes (Hoyos, 2013). The exceptions were the Cochrane study which found no significant change across three studies, and two of the red light/speed camera combination evaluations (Kloeden et al, 2009; Budd et al, 2011), none of which accounted for the effects of all moderator variables.

In combination, the above studies indicate that red-light cameras reduce right angle crashes and increase rear-end crashes. While both crash types can be severe, on average right angle crashes are significantly more severe than rear-end crashes mainly as a result of the vehicle's structure and hence occupant protection crashworthiness. For example, in a side impact, the crush distance is small and hence there is little opportunity for ride-down to reduce the severity of the impact. On the other hand, in rear-end impacts, the crush distances are much larger (both the front end of the impacting vehicle and the rear end of the struck vehicle), and with current improved seat back and head rest anti-whiplash design, the severity of the crash would be substantially reduce compared to a side impact.

Red light cameras would also be expected to influence violations in the form of reductions in red light running. The Retting et al (2003) review concluded that these cameras reduced violations by 40 to 50 percent and two recent studies (Ko et al, 2013; McCartt and Hu, 2014) made similar conclusions, with McCartt and Hu (2014) finding that violations involving making very late decisions to run the red light (up to 1.5 seconds after red) were almost eliminated. Again, the

Study	Study design	RTM	Spill over	Outcome	Conclusions
a) Reviews of evaluations: Red light cameras					
Retting, Ferguson & Hakkert (2003)	Review but no detail on study selection	N	Y	Violations (7 studies)	↓ camera sites (22-78%), but ↓ noncamera sites (27-69%) (4 studies) = for control sites (3 studies)
	A-B + controls (15 studies)	some (4)	some (1)	Crashes/injury (8 studies)	↓ camera sites: noncamera (10-39%) (7 studies)
Aeron-Thomas (2005)	Cochrane review A-B+controls (10 studies)	Y	Y	Injury crashes, (5 studies)	↓ camera sites: noncamera/controls (29%)* 1 study ↓ camera sites: noncamera (13%)* (3 studies)
				right-angle (2 studies)	not significant
				rear-end (3 studies)	not significant
				Violations (1 study)	not significant
Erke (2009)	Meta-analysis varied designs (21 studies)	Y	Y	All crashes	↑ camera sites (if control RTM & Spillover effects) (+15%) ↓ camera sites (if no/some controls) (-16-19%)
				Injury crashes	↑ camera sites (if control RTM & Spillover effects) (+13%) ↓ camera sites (if no/some controls) (- 17-25%)
				Right angle	↓ camera sites (if control RTM & Spillover effects) (-10%) ↓ camera sites (if no/some controls) (- 14-49%)
				Rear end	↑ camera sites (if control RTM & Spillover effects) (+43%) ↓ camera sites (if no/some controls) (- 4- +17%)
Hoyos (2013)	Meta-analysis (28 studies)	Y	Y	All crashes	not significant (+6%)
				Injury crashes	not significant (+13%)
				Right angle	↓ camera sites (non-injury: -13%; injury: - 33%)
				Rear end	↑ camera sites (non-injury: +39%; injury: +19%)

Table 3: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
b) Recent evaluations: Red light cameras					
Ko, Geedipally, Walden (2013)	A-B +empirical Bayes (245 cameras, 66 no cameras)	Y	Y	Red light running Right angle Rear end	↓ camera sites (-20%) ↓ camera sites (-24%) ↑ camera sites (+37%)
Porter, Johnson, Bland (2014)	A-B + controls: Cameras removed (4 cameras, 2 local no cameras, 2 outside no cameras)	Y	Y	Red light running	Change 3.1% with cameras to 11.3% after removal Non-treated - 14%
McCartt, Hu (2014)	A-B +controls (4 camera, 4 local no camera, 4 outside no cameras	Y	Y	Violations 1 yr after ticketing commenced	↓ camera sites (-39% for 0.5secs after red) ↓ camera sites (-86% for 1.5secs after red)
Pulugurtha, Otturu (2014)	A-B -C: Cameras removed, empirical Bayes (32 cameras)	Y	Y	intersections with reduced crashes intersections with reduced rear end/ sideswipe crashes	↓ camera sites (-50% for before - after cameras) ↓ camera sites (-16% for before - termination of cameras) ↑ camera sites (+>50%)

Table 3 cont'd: Summary of literature on red light camera evaluations; a) reviews of evaluations, b) recent evaluations

Study	Study design	RTM	Spill over	Outcome	Conclusions
Vanlaar, Robertson, Marcoux (2014)	A-B +controls Time series (4 cameras, 4 local no cameras), no cameras comparison)	Y	Y	Right angle Rear end Speed	↓ camera sites (-46%) ↑ camera sites (+42%) No change
McKenzie , Kloeden, Hutchinson, 2012)	Change after cameras introduced (21 cameras)	N	N	Red light Violations Speed violations	↓ over 12 months (slow change) ↓ over 12 months (rapid change, especially higher range speeding)
Kloeden, Edwards, McClean (2009)	A-B +controls (1988: 8 cameras, all no camera sites in Adelaide) (2001: 24 cameras, all no camera sites)	?	N	Casualty crashes Right angle Rear end	1988 study: ↓ camera sites (-21%) 2001 study: no change 1988 study: ↓ camera sites (-491%) 2001 study: no change No change
Budd, Scully, Newstead (2011)	A-B+controls (76 camera sites: Camera activated, camera not activated)	Y	N	Casualty crashes Right angle/right turn Rear end	↓ camera sites (-47% direction of travel monitored by camera; -26% for all) ↓ camera sites (-44%) No change

Table 4: Summary of literature on red light and speed camera evaluations

Cochrane review failed to find evidence of changes in violations due to red light cameras, but only one study included this measure. One study (Porter et al, 2014) studied the effect of removing red light cameras and found an increase in violations of around 8 percent after they were removed.

3.1.2 Evaluations of speed cameras

The literature search identified three reviews of speed cameras generally (fixed and mobile). This included a meta-analysis by Pilkington and Kinra (2005), which reviewed 14 controlled trials and observational studies and a systematic, narrative review by Thomas, Srinivasan, Decina and Stapin (2008) containing 13 studies chosen because of their methodological strengths. The most recent review was a Cochrane Collaboration review by Wilson, Willis, Hendrika, Brocque and Bellamy (2010), which examined the use of speed cameras for the prevention of road injuries and fatalities. The three reviews overlapped considerably. The Pilkington and Kinra (2005) and Thomas et al. (2008) reviews shared seven studies and the Cochrane review contained all of the studies in the Thomas review and 64.3 percent of those in the Pilkington and Kinra review as well as 20 additional studies, most of which were more recent. The Cochrane review was therefore the most comprehensive and became the basis of the current review.

Overall, the Cochrane review concluded that in the presence of speed cameras, average speed reduced by between 1 and 15 percent and the proportion of vehicles speeding by 14 to 65 percent compared to controls. They also concluded that in the vicinity of cameras, all crashes reduced by 8 to 49 percent and fatal and serious injury crashes by 11 to 44 percent, leading to an overall improvement of between 8 to 50 percent compared to control sites. This provides a good appraisal of the existing well-designed evaluations of speed cameras, however the review did not distinguish fixed and mobile cameras. As the action of these two types of cameras is quite different, the current review included the studies in the Wilson et al review but separated them into those looking at each type of camera in order to determine the separate effects of each type. Additional studies published since the Cochrane review were also included in this analysis.

3.1.3 Evaluation of fixed speed cameras

The Cochrane review (Wilson et al., 2010) included 17 studies of the effectiveness of fixed speeding cameras which were judged to have adequate study designs. In addition to those included in the Cochrane review, the electronic searches for this review identified two additional more recent studies so the review for this report included 19 studies of fixed speed cameras (Table 5).

The studies included in the review involved study designs with pre/post camera implementation measures and control or comparison sites (78.9%) or interrupted time series analysis (21.1%). Using the Cochrane collaboration criteria which require random assignment of treatment and controls, these studies designs would be classified as only of moderate methodological quality. Around half addressed the problem of potential bias due to RTM (52.6%). None of the studies formally addressed spillover effects, although it could be argued that the inclusion of appropriate control or comparison groups provided an opportunity to assess these effects by showing the extent of additional change due to the presence of the camera itself. Around half of the studies looked at the effect of cameras on both speeding and crashes (52.6%), with half of the remainder looking at effects only on speed (21.1%) or crashes (26.3%). The studies were conducted in a

broad range of countries including Australia, Canada, Germany, Spain, Finland, UK, Hong Kong, Netherlands, New Zealand and USA.

All studies showed benefits of fixed speed cameras for reducing speed in the location of the cameras. Overall, the studies showed reductions in mean speed in the vicinity of cameras of 3 to 10 percent or 2 to 8kph reductions in mean speed. Studies that included control of RTM effects showed similar reductions in speed. Of the five studies that looked at the proportion of speeding vehicles in the vicinity of fixed cameras, all showed reductions but there was a very large variation between studies, ranging from 10 to 70%, although the two studies that controlled for RTM showed similar reductions of around 30 percent. Twelve studies measured injury crashes and all found reductions following implementation of fixed cameras ranging from 7 to 32 percent. In studies that controlled for RTM effects, the reductions tended to be greater (20-56%). Only five studies measured fatal crashes specifically, and again all showed reductions after implementation of fixed cameras ranging from 11 to 89 percent.

The greatest effects of fixed cameras are likely to be in their immediate vicinity. In some studies, the effects of cameras may have been underestimated as the effects were measured 2km from the treatment area (Chen et al, 2002; Makinen, 2001) although studies that directly measured distance halo effects showed decreases in road safety benefit with increased distance from the fixed camera site (Mountain, et al., 2004; Hess and Polack, 2003; De Pauw et al, 2013). Figure 3 shows the 85th percentile speeds around a speed camera in NSW and shows that speeding drivers slow for the cameras and speed up again after the camera, i.e. deliberate slowing for the camera (Job 2014).

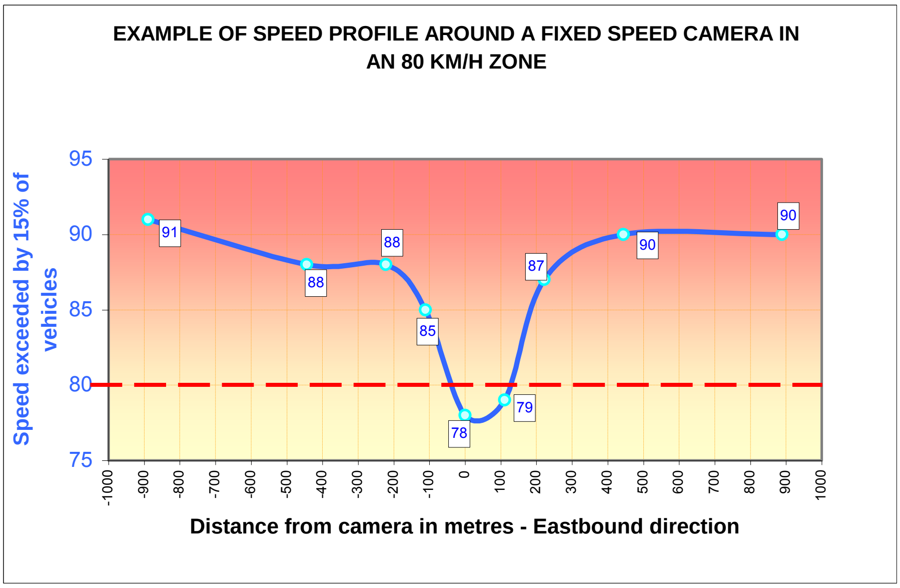


Figure 3: 85th percentile speeds recorded on approach and departure around a sign-posted speed camera in in an 80km/h speed limit in New South Wales

The duration of the benefit of fixed cameras over time was examined in some studies, with findings of fatal crash reductions for up to two years (ARRB, 2005; Perez et al, 2007; Makinen, 2001), but Retting, Kyrychenko and McCartt (2008) showed that positive speed reductions diminished when the enforcement period ended.

Study	Design	RTM	Spillover	Outcome	Conclusions
ARRB Group Project Team (2005)	A-B+Control	N	N	Speed fatal crashes injury crashes	↓ 6.3 km/h mean speeds, 5.8kh/h at 2 years ↓ 70% exceeding speed limit, maintained at 2 years ↓ 86% exceeding speed limits by at least 10 km/h, 88% at 2 yrs. ↓ 22.8% all fatal and injury crashes ↓ 89.8% fatal crashes ↓ 20.1% injury crashes at 1 yr
Diamantopoulou, Corben (2002) (2 reports)	A-B+Control.	N	N	Speed reduction	↓ 3.4% speed reduction ↓66% drivers exceeding the 80km/h posted speed limit ↓ 79% drivers speeding over 90km/h ↓ 76% drivers speeding over 110km/h ↓ 13% fatal crashes ↓ 10% serious injury ↓ 7% overall injuries
Chen, Meckle, Wilson (2002)	A-B+Control	Y	N	crashes Mean speed	↓2.8km/h mean speed at monitoring site 2km from treatment area ↓14% expected crashes at photo-radar locations ↓ 19% at non-Photo-Radar locations ↓ 16% along the study corridor as a whole
Lamm, Kloeckne (1984)	A-B+Control	N	N	Median speed crashes (injury and fatal)	↓ 30kph median speed ↓ 42kph 85th percentile speed ↓ 18 times in injury crash frequency ↓ fatal crashes
Perez, Mari-Dell'Olmo, Borrell (2007)	Interrupted time series	N.	N	crashes injured	RR= 0.69 (95% CI = 0.54 - 0.89) crash 2 years post implementation RR= 0.70 (95% CI = 0.53-0.92) injury = comparison sites.
Makinen (2001)	A-B+Control	N	N	speeding crashes	↓ 8% speeding at 80kph limit in year one, further ↓2% in year two. ↓ 5% speeding at 100km/h in year one, further ↓2% in year two. Distance halo of 3km upstream and 2km downstream. no change in crashes compared to controls

Mountain, Hirst, Maher (2004)	A-B+Control	Empirical Bayes	N	speeds	↓4.4mph mean speeds ↓5.9 mph 85th percentile speeds ↓35% percentage exceeding the speed limit. ↓ 25% personal injury crashes, 11% fatal and serious at 500m post camera ↓ 24% personal injury crashes, 13% fatal and serious at 1km post camera
Hess (2003) (2 reports)	Interrupted time series	Y	N	Injury crashes	↓ 45.74% weighted injury crashes in 250m from camera sites ↓ 20.86% injury crashes in 2000m from the camera.
Gains, Heydecker, Shrewsbury, Robertson (2004) (3 reports)	A-B+Control	empirical Bayes	N	speed Fatal/serious injury injury crashes	↓ 6% mean speed ↓7% 85th percentile speed ↓ 30% exceeding speed limit ↓43% exceeding speed limit > 15 mph ↓42% fatal/serious injury ↓ 24% injury crashes
Highways Agency's London Network and Customer Services (LNCS) (1997)	A-B+Control	N	N	crashes (fatal, serious, and injury)	↓ 12.4% all crashes. ↓69.4% fatal crashes pre/post and 55.7% relative to controls. ↓ 25% serious injuries ↓ 31% fatal/serious crashes combined.
Hung-Leung (2000)	A-B+Control	N	N	speeding cars injury, fatal crashes	↓ 65% speed > 15 km/h over limit. ↓ 23% injury crashes pre/post; ↑32% in the control group. ↓66% fatal crashes.
Oei (1996) (2 reports)	A-B+Control	N	N	speed crashes	↓3 - 5kph mean speed ↓3-8kph 85 percentile speed ↓ 10% to 27% drivers speeding over limit ↓ 35% crashes pre/post and control
Elvik (1997)	A-B+Control	Y	N	injury crashes	↓20% injury crashes
Tay (2000)	A-B+Control	N	N	crashes speed	↓ 9.17% all crashes ↓ 32.4% serious injury = speed, pre/post
Shin, Washington, van Schalkwyk (2009)	A-B+Control	Y	N	crashes	↓44 to 55% crashes ↓ 46-56% injury crashes = rear-end crashes

Retting, Kyrychenko, McCartt (2008)	A-B+Control	N	N	speed	↓ 5mph mean speeds pre/post no change control site ↓ 13% exceeding speed limit after speed camera enforcement suspended both increased.
Retting, Farmer, McCartt (2008)	A-B+Control	N	N	speed	↓10% mean speed ↓ 70% > 10 mph above the speed limits (with warnings and camera enforcement), ↓ 39% > 10 mph above the speed limits (with warning signs only) ↓ 16% on 40 mph residential streets (no warnings or speed cameras).
De Pauw, Daniels, Brijs, Hermans, Wets (2013)	A-B	N	N	injury crashes	↓ 29% serious/fatal injuries in 500m of camera
Novoa, Perez, Santamarina-Rubio, Mari-Dell'Olmo, Tobias	Time series analyses	N	N	Crashes injuries	↓ 30% and 26% on enforced and non-enforced arterial road respectively.

Table 5: Summary of literature on fixed speed camera evaluations

Only eight of the studies mentioned the speed limit at the fixed camera sites. In five studies the cameras were on high speed roads (80+ kph) and the remainder were in the 50-80 kph regions. There were no obvious patterns of effects on speeding or crashes on different speed limit areas. Novoa et al (2010) found benefits of fixed speed cameras on a high speed beltway, but not on lower speed arterial roads, suggesting that there may be influences of speed limit on the effectiveness of fixed cameras.

3.1.4 Evaluation of mobile cameras

A total of 19 of the studies included in the Cochrane review (Willis, et al., 2010) involved an evaluation of mobile cameras. The electronic searches found one further evaluation study (Moon and Hummer, 2010) so the current review involved 20 studies in total (Table 6).

As for the fixed camera evaluations, the majority of studies included involve a pre/post implementation with control design (80%) with the remainder an interrupted time series design. Few studies (25%) included control for RTM effects although this may not be as great a concern for mobile cameras which by definition are moved around so they may not necessarily be located only in locations of high concern for road safety. Spillover effects were also managed indirectly by inclusion of control locations in all studies. Most of the evaluations looked at either speed (40%) or crash (35%) outcomes and only 25% looked at both. Evaluations were from a broad range of countries including Australia, Canada, Denmark, UK, Norway, New Zealand and the USA.

Across evaluation studies, consistent benefits were found for mobile speed cameras. Seven studies cited reductions of mean speeds in the location of mobile cameras with effects ranging from around 1 to 6kph. There was a very large range in the proportion of vehicles exceeding the speed limit, from 10 to 70 percent across five studies. Similarly, the reductions in injury crashes also varied considerably between the six studies that included this measure, from 21 to 71.3 percent although reductions in fatal crashes were more consistent (31-44% across three studies).

As might be expected, there is evidence that the effect of mobile cameras extend well-beyond the immediate vicinity of the camera. Cairney (1988) found effects of reduced speed for up to 14 km downstream of mobile cameras. The study by Newstead and Cameron (2003) measured crashes within 2 kms, 2-4kms and 4-6kms of camera sites and found a decreasing effect on crashes with increasing distance away from cameras, although even at the greatest distance, there were still 10.7 percent reductions in all severity crashes.

A number of studies looked at the time halo or duration of the effect of mobile cameras. Time halo effects ranged from at least two days of continued lower proportion of speeding vehicles (Armour, 1984), three days of lower mean speeds after a single day of enforcement (Hauer and Ahlin 1982) to up to eight weeks of lower mean speeds (Vaa, 1997). On the other hand, Legget (1988) found no time halo effect on mean speed.

The effects of speed cameras may vary with the speed limit of roads, however most studies (55%) failed to mention the speed limit on which the cameras were placed. In seven studies (35%) mobile cameras were sited on higher speed roads of 80kph or greater. Only two studies involved mobile cameras on roads of 60kph or lower.

In the majority of studies, mobile cameras were marked with warning signs to alert drivers to their presence. Two studies looked at the effect of covert or overt placement of mobile cameras.

Diamantopoulou and Cameron (2002) compared the two strategies of camera use and concluded that the best effect on injury crashes occurred when a mix of overt and covert cameras were in

Study	Design	RTM	Spillover	Outcome	Conclusions
Amour (1984)	A-B +Control	N	N	speeders	↓ 70% proportion vehicles exceeding the speed limit with camera Time halo effect ≥ two days
Cairney (1988)	A-B +Control	N	N	Mean speed	↓ 2-3kph mean speed at camera and control sites. Distance halo up to 14km downstream with aerial surveillance
Kearns & Webster (1988)	A-B +Control	N	N	crashes	↓ 23% crashes at camera sites during the day, ↓ 21% at other times, compared to controls
Newstead, Cameron, Leggett (2001)	A-B with comparison group	N	N	fatal crashes	↓ 31% fatal crashes. ↓ 11% total crashes outside of metropolitan Brisbane.
Newstead, Cameron (2003) (2 reports)	A-B +Control	N	N	No. of crashes (fatal and injury)	↓ 45% fatal crashes in 2km of camera sites ↓ 31% hospitalisation crashes in 2km of camera sites ↓ 39% medically-treated crashes in 2km of camera sites ↓ 19% other injury crashes in 2km of camera sites ↓ 21% non-injury crashes in 2km of camera sites All crashes: ↓ 17.5% all severity crashes in 2km of camera sites ↓ 11.4% all severity crashes in 2 - 4km of camera sites ↓ 10.7% all severity crashes in 4 - 6km of camera sites
Cairney, Fackrell (1993) (2 reports)	A-B +Control	N	N	Median traffic speed	↓ 5kph median speeds reduced sharply by 5 km/h on camera roads but then little change despite intensified enforcement, control sites no change
Leggett (1988)	A-B +Control	N	N	Mean speed No. of crashes (injury or fatal)	↓ 3-6kph mean speeds compared to pre, only during enforcement no time halo effect. ↓ 58% serious injury crashes. ↑ 33% serious injury during non-enforced times of day
Cameron, Cavallo, Gilbert (1992) (2 reports)	Interrupted time series	N	N	No. of injury crashes	↓ 30% injury crash on 60km/h city roads with camera over12mths ↓ 20% injury crash on rural 60km/h zones with camera over 12 mths ↓ 14% injury crash on rural 100km/h zones with camera over 12 mths
Diamantopoulou, Cameron (2002) (3 reports)	A-B +Control	N	N	No. of injury crashes	↓ 71.3% injury crashes within 4 days of presence of enforcement ↓73.9% injury crashes with mix of overt/covert enforcement in use.
Chen, Wilson, Meckle, Cooper (2000)	A-B +Control	Y	N	No. of speeding vehicles No. of crashes	↓ 31% speeding vehicles pre/post cameras ↓ 12% speeding at control sites ↓ 17% reduction in daytime crash fatalities

Hauer, Ahlin (1982)	A-B +Control	N	N	Average speed	time halo for three days with1 day enforcement, for six days after five days enforcement
Agustsson (2001)	A-B +Control.	N	N	Mean speed % drivers exceeding spee limit by 10km/hr No. of injury crashes	↓ 2.4 km/ h mean speed ↓ 10.4% exceeding speed limit ↓ 4.5% exceeding the speed limit by 10km. ↓ 22% injury crashes in first year, ↓ 20% in second year post intervention compared to pre
Jones, Sauerzapf, Haynes (2008)	A-B +Control	Y	N	No. of crashes	↓ 19% all crashes at camera sites ↓ 44% for fatal and serious crashes at camera sites .
Christie, Lyons, Dunstan, Jones (2003)	A-B +Control	N	N	No. of injury crashes	↓ 50% injury crashes sustained for two years at camera sites
Goldenbeld, van Schagen (2005)	A-B +Control	Y	N	speeds speeders over the targeted speed limit	↓ 12% speeders at camera sites, ↓ 5% speeders at controls ↓ 21% injury crashes for enforcement period compared to pre
Vaa (1997)	A-B +Control	N	N	Average speed No. Speeding drivers	↓ 0.9 to 4.8kph mean speeds time halo effect of up to eight weeks ↓ 10% speeding drivers
Keall, Povey, Frith (2002) (2 reports)	Interrupted time series	N	N	Mean speed 85th percentile speed No. of injury crashes	↓1.3kph mean speed over 2 years ↓ 4.3kph 85th percentile speeds on open roads ↓ 11% all crashes compared to control areas ↓ 19% injury crashes additional effect for covert cameras period compared to overt cameras ↓ 17% for crashes at camera sites compared to controls ↓ 31% for injury crashes
Cunningham, Hummer, Moon (2005)	A-B +Control	Y	N	crashes, speeds	↓ 12% total crashes in camera corridors compared to expected ↓0.91 miles/hr mean speeds at camera sites, control sites no change ↓ 0.99mph in 85th percentile speeds, controls no change.
Retting, Farmer (2003)	A-B +Control	N	N	Mean speed Proportion of vehicles exceeding the speed limit by more than 10mph	↓ 14% mean speeds at camera sites compared to control sites. ↓ 82% exceeding the speed limit by more than 10mph
Moon, Hummer (2010)	A-B with comparison sites.	Y	N	No. of crashes	↓ crashes in camera sites pre/post.

Table 6: Summary of literature on mobile speed camera evaluations

place, although the additional reductions in injury crashes were not pronounced. A study by Keall, Povey and Frith (2002) compared the effect on injury crashes of a period of overt camera use with a period where camera use was covert and found an additional 19 percent reduction in injury crashes with covert use of cameras. It should be noted however that covert camera use occurred following overt use so some of the effect may be due to the fact that drivers were aware the cameras were in operation.

3.1.5 Point-to-point cameras

The literature for this camera system type is sparse. There are three articles discussing the benefits of point-to-point in terms of reduced speeds and crash reduction. However, only one study by Montella et al (2012) was adequate in its design in terms of providing a rigorous statistical evaluation of a system installed in Italy (Table 7). The system is composed of steel gantries at the section entrance and exit, with one camera and inductive loop detectors for each lane. Data were collected and processed by police at a central monitoring station.

The study analysis period was over 9 years, with a before period of 6.5 years and an after period of 2.5 years. The number of crashes per kilometre in the before period was 4.2, which decreased to 2.2 during the after period. A reduction in crashes per kilometre was observed for all crash types.

The authors used an empirical Bayes methodology evaluation which accounted for regression to the mean, changes over time not due to the treatment being evaluated and overcoming exposure crash rates in normalising volume differences.

The evaluation of the point-to-point cameras revealed a total crash reduction of 31.2%. The greatest crash reductions were observed for 55.6% severe crashes and 43.3% crashes at curves. However they noted an effectiveness decrease over time, i.e. 39.4% total crashes for the first semester and 18.7% in the fifth semester after activation. The authors suggest that the decrease system effectiveness over time may have been due to a reduction in speed enforcement and driver adaptation. They suggest that higher compliance to the speed limits might be achieved by a better strategy of communication and information to the road users and a speed limit management strategy synergic between the highway agency and the Police who actually manage the commitments of fines.

Study	Design	RTM	Spillover	Outcome	Conclusions
Montella, Persaud, D'Apuzzo, Imbriani (2012)	Empirical Bayes observational before-and-after study. Crash data disability lasting at least 15 days.	Y	N	No. of crashes	↓ 31.2% total crash The greatest crash reductions were observed for ↓ 55.6% severe crashes and 43.3% crashes at curves, effectiveness decreased over time ↓ 39.4% total crashes - first semester ; ↓ 18.7% - fifth semester after activation.

Table 7: Summary of literature on point-to-point speed camera evaluations

3.2 Review of community attitudes to speeding

This section summarises the results of the Community Attitude surveys for ACT residents over 1995 to 2011. The detailed collated results are shown in Appendix C.

3.2.1 Perceptions of changes in enforcement

The year following the introduction of mobile speed cameras was associated with an increase in the percentage of ACT residents who perceived that the amount of speed enforcement had changed over the past two years (Figure 4). In the surveys conducted between 1999 and 2001 more than two-thirds of survey participants reported that enforcement had increased and in 2001 there was a clear fall in the percentage reporting no change in enforcement. In 2002, fewer residents reported increased enforcement although by 2003 and for the next four years, perception of increased speed enforcement remained high. Interestingly, the introduction of fixed speed cameras in 2007 was not associated with increased perception of more enforcement activity. However, this question only has a few broad options to choose from and may likely have been too coarse to determine accurate perceptions of change in enforcement.

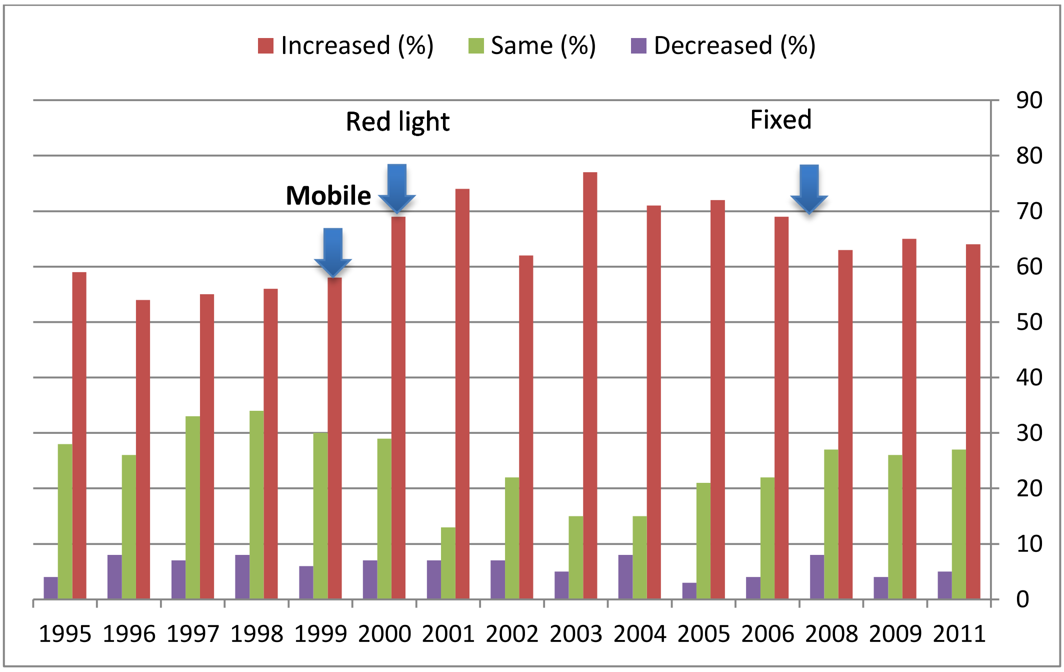


Figure 4: Perceptions of whether the amount of speed limit enforcement has changed over the last two years

The reported likelihood of being booked for speeding varied considerably across the survey years (Figure 5). Reports of being booked in the last two years were lowest in 1999 when mobile cameras were introduced, but between 1999 and 2003 the percentage of survey participants reporting being booked for speeding increased more than two-fold to more than one in four participants. Reports of speeding infringements decreased again to 2008, but following the introduction of fixed speed cameras, there was some increase in reported infringements to 2011. Reports for the last 6 months showed similar patterns. Notably, reports of being booked in the last 6 months were lowest in 2004 compared to all other years, and were lowest compared to other jurisdictions as well.

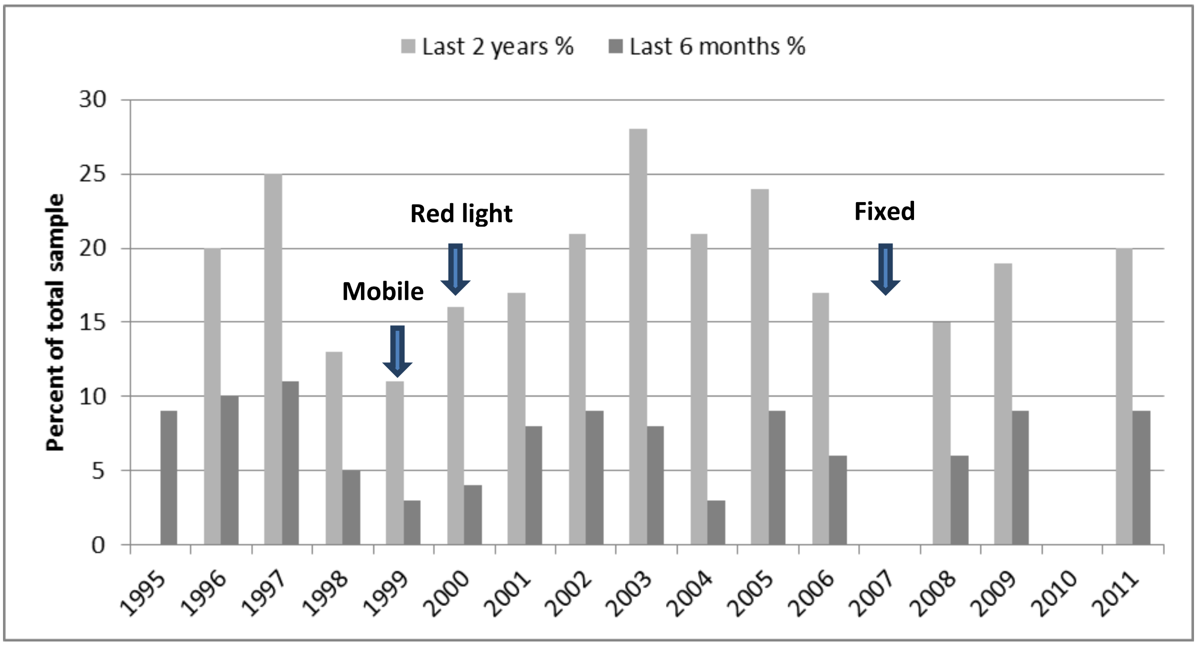


Figure 5: Incidence of being booked for speeding in the last 2 years and the last 6 months

3.2.2 Perceptions of acceptable and actual speed tolerances

ACT residents believe that the median acceptable speed in 60kph urban zones should be around 65 km/h (Table 8). Interestingly, this is almost identical to the median of their reported actual speed. Neither of these judgements showed much variation across the seven surveys in which these questions were asked. Around one-third of Survey participants across all surveys between 2003 and 2011 agreed that there should be no tolerance of speeding in 60kph zones. However in surveys before 2003 nearly half of respondents felt that there should be no tolerance for speeding in 60kph zones. This was coincident with the introduction of the first mobile and red light cameras. It is possible that the strong community response for no tolerance for speeding in 60kph zones that preceded the introduction of cameras may have played a role in their introduction. However, community acceptance of no tolerance for speeding clearly decreased a few years after the first wave of the introduction of cameras so by 2003 and subsequent years, there has been considerably lower support for no tolerance of speeding in these zones.

For 100kph zones, acceptable speeds for respondents were between 105 and 110kph and actual reported speeds were very similar, or higher (Table 9). There were no consistent patterns for judgements of acceptance of no tolerance for speeding with between one in four and one in three respondents supporting no tolerance. In contrast, between 2002 and 2011 there has been notable change in ACT residents perceptions of no tolerance of actual speeding. Where in 2006 almost no ACT respondent perceived no tolerance for speeding over 100kph and this was lower than all other jurisdictions, by 2011 the situation had reversed. Over one in five respondents felt that there was no tolerance for speeding in 100kph zones in the ACT which was significantly higher than other jurisdictions.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1995		34		
1996		42		
1997		49		
1998		49		
1999 **Mobile**		49		
2000 **Red light**		38		
2001		44		
2002		51	64.9	15
2003	64.2	33	65.4	10
2004	65	28	65	13
2005	64	33	64	12
2006	64	32	64	15
2008 **Fixed**	64	36	65	21
2009	65	34	64	22
2011	64	31	64	20

Table 8: Perceived acceptable and actual speed in 60kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
1996		27		
1997		23		
1998		36		
1999 **Mobile**		28		
2000 **Red light**		25		
2001		26		
2002		35	109.2	10
2003	106.8	22	108.7	6
2004	110	23	109	8
2005	109	20	109	7
2006	107	18	107	5
2008 **Fixed**	105.5	28	108	14
2009	110	23	107.9	15
2011	106	25	106	21

Table 9: Perceived acceptable and actual speed in 100kph zones in urban areas of the ACT and perception of the acceptable level and actual level of no tolerance for exceeding speed limits.

3.2.3 Attitudes to speeding, speed enforcement and penalties

ACT survey respondents attitudes to speed-related issues did not change greatly across the 1999 to 2011 period for most questions. The majority of respondents (>85% in all years) viewed speed limits as generally reasonable. Similarly, almost all respondents (>89% in all years) agreed that an accident at 70kph would be more severe than one at 60kph. Notably, fewer felt that they would be more likely to be in an accident if they increased their speed by 10kph, but there was no pattern of change across the survey years on this question.

Two questions showed some evidence of attitudinal changes between 1999 and 2011 that may be associated with safety camera use in the ACT. Associated with the introduction of the mobile and red light cameras in 1999 and 2000 there has been a decrease in respondents agreeing that exceeding the speed limit is okay if you are driving safely. The percentage increased again for the 2008 survey following the introduction of fixed cameras, but decreased to the lowest level in 2009 and remained fairly low in 2011. In contrast, there was no change in the percentage of respondents viewing speeding fines as revenue raising associated with mobile or red light cameras, but 2008 and 2009 following the introduction of fixed cameras saw the highest percentage of respondents viewing speed fines as revenue raising (Figure 6).

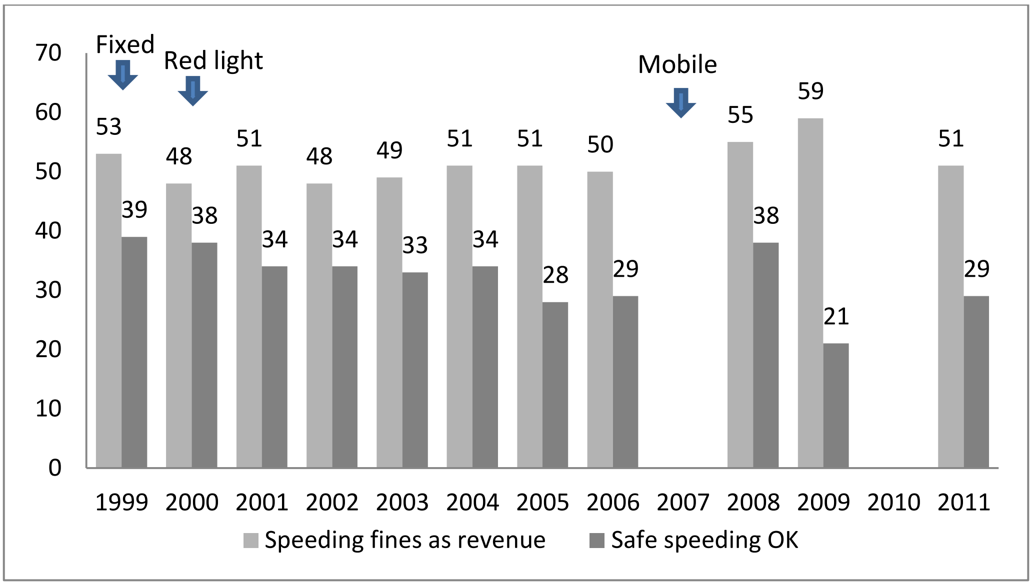


Figure 6: Percentage of ACT resident agreeing with the statements 'Fines for speeding are mainly intended to raise revenue' and 'I think it is okay to exceed the speed limit if you are driving safely'

Questions were asked about their views of the level of enforcement and severity of penalties from the 2003 survey (Figures 7 and 8). Increasing percentages of ACT residents believed the level of enforcement and severity of penalties should increase for 2003 and 2004, but this decreased in the next two years. In the survey following the introduction of fixed speed cameras the percentage of respondents who felt enforcement should increase grew to nearly half and this remained high to the most recent survey in 2011. For severity of penalties, there was not much change before and after the introduction of fixed cameras, although the most recent survey had the highest percentage of respondents reporting that they should be increased.

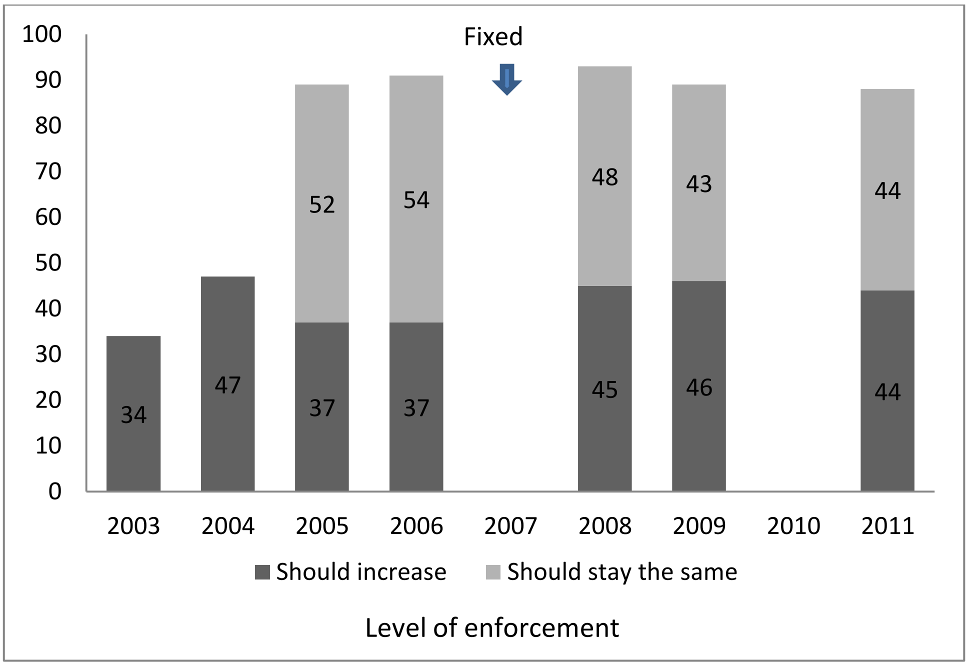


Figure 7: Percentage of ACT residents responding that the level of enforcement should increase or stay the same

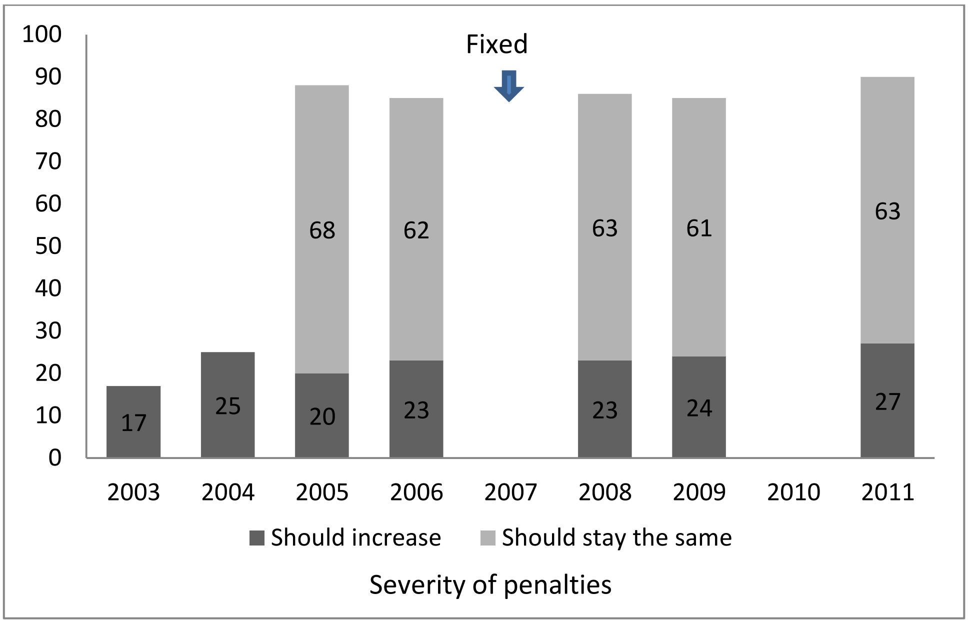


Figure 8: Percentage of ACT residents responding that the severity of penalties should increase or stay the same

The patterns of approval for lowering residential speed limits from 60 to 50 kph show an association with the introduction of mobile and red light cameras (Figure 9). Since 2000 when both types of cameras were in operation, there has been a clear increase in the percentage of survey respondents who showed approval for such a change so that by 2003 the greater majority of respondents were in agreement.

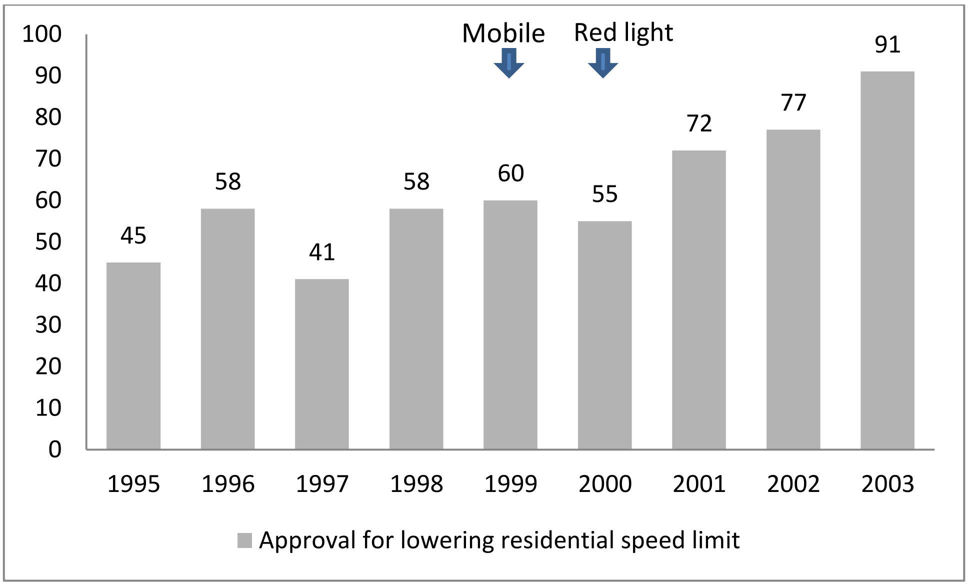


Figure 9: Percentage of ACT residents approving (somewhat and strongly) a potential decision to lower the speed limit in residential areas to 50kph

3.2.4 Changes in self-reported driving speed

Following the introduction of mobile and red light cameras a larger percentage of ACT respondents reported that their driving speed had decreased over the past two years, however since 2008 this effect has decreased somewhat with around three-quarters of drivers reporting no change to their speed (Figure 10).

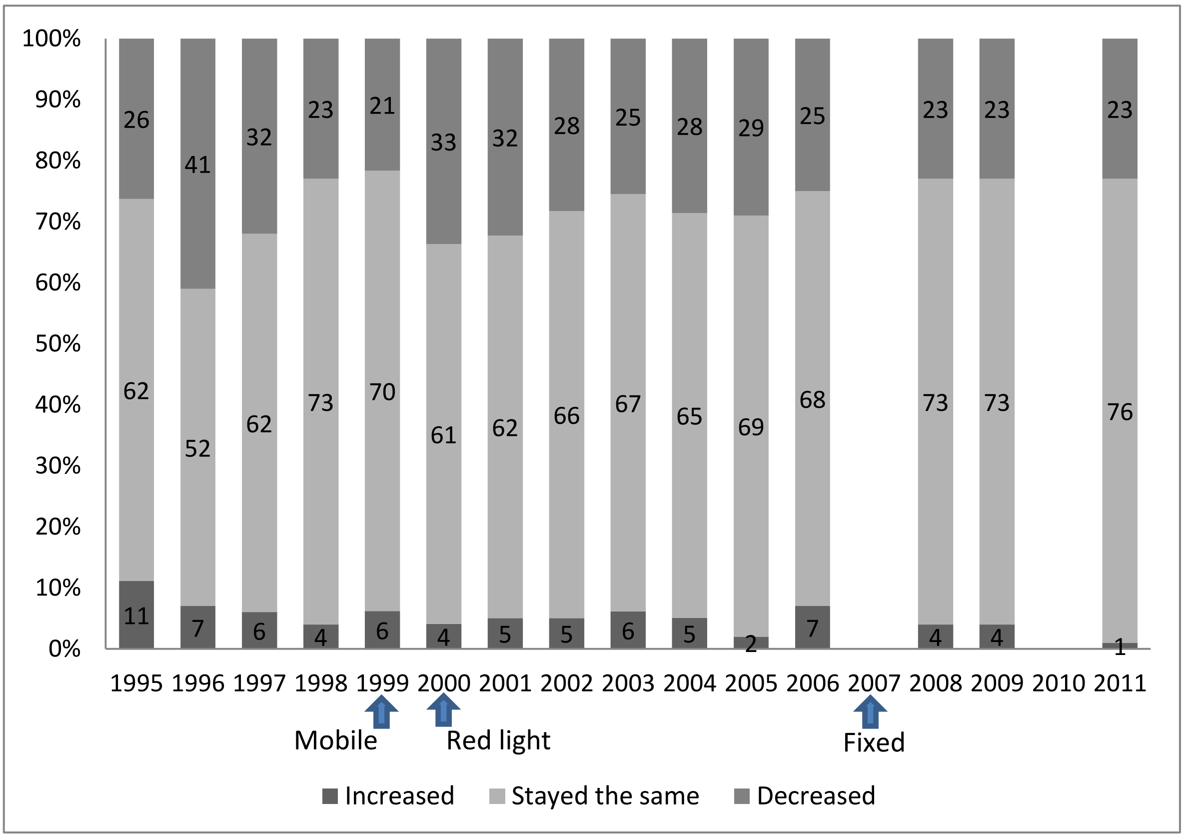


Figure 10: Reported changes in driving speed over the last two years

3.3 Infringements data

The infringements data are expressed as the proportion of infringements issued to vehicles checked, and data were available for the 14 year period from 1999 to 2012 (inclusive). It is noted that all fixed and mobile camera operations data were included, not only those related to the case and control streets/intersections selected for this study. Infringement rates for fixed and mobile cameras over the period are plotted in Figure 11. For the mobile cameras, mean infringement rates were up to 10% initially, however dropped to an average long-term value of approximately 0.6% during a period extending to approximately late 2002. For the fixed intersection cameras, mean infringement rates reduced rapidly to less than 0.2%. It is noted that due to data issues, the fixed camera infringement rates are not plotted beyond 2008 in Figure 11.

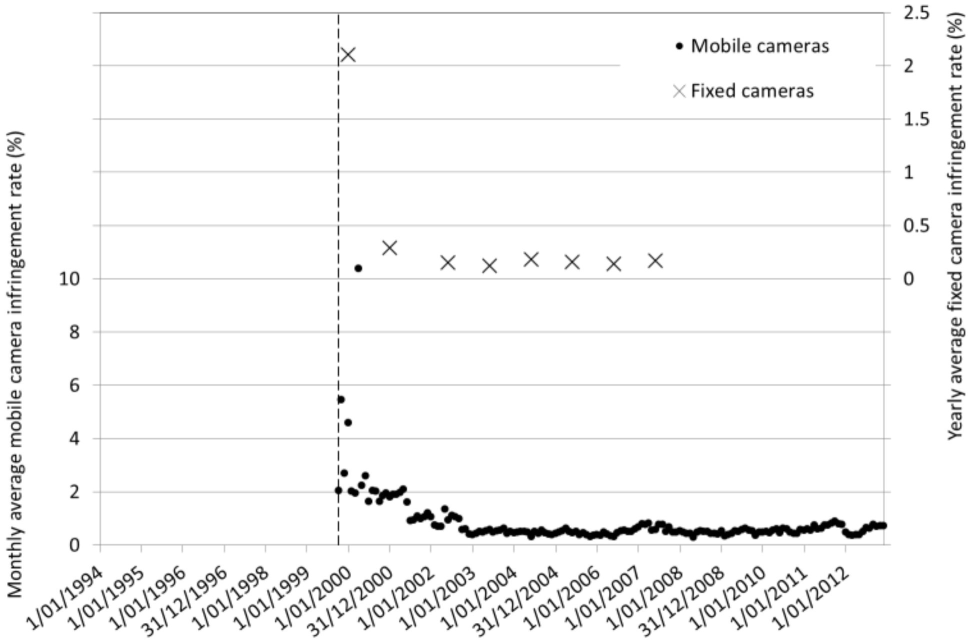


Figure 11: Infringement rates for fixed and mobile cameras

3.4 Speed survey analyses – effects of mobile cameras on mean vehicle speeds (Models 1 to 5)

Speed surveys were assessed for the 95 street locations for the 16 year period from 1997 to 2012 (inclusive). A total of 1,758 speed surveys were identified in the period, including 1,032 that were undertaken on case streets and 726 on control streets. The speed survey results are plotted for case and control streets, and compared with mobile camera operations on each individual street, in Appendix D. Considering an outcome of monthly averaged values of the mean survey speed divided by the speed limit, the statistical models are tabulated in Tables 10 to 12. Models 1 to 4 are plotted in Figures 12 to 14. In Models 1 and 3, trends in mean speeds for case streets showed increases in the pre-intervention period (however in Model 3 the value was very small), and decreases in the post-intervention periods, where the intervention was Intervention 1 (Model 1) or the camera begin-date (Model 3). Trends in mean speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 1). Mean speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 2 and 4). CAMERA

estimates were generally not statistically significant, indicating changes that occurred in mean speeds at the intervention times were not generally significant (Tables 10 and 11).

Annual trend magnitudes for case streets were an increase of 0.7% and decrease of 3.2% prior to and following Intervention 1, and an increase of 1.7% and decrease of 0.9% prior to and following Intervention 2. An increase of 0.1% and decrease of 1.8% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 2.4% and decrease of 0.8% prior to and following Intervention 1, and an increase of 0.1% and decrease of 0.2% prior to and following Intervention 2. A decrease of 3.9% and decrease of 3.8% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 12. The estimate for the CASE variable was highly significant, likely a result of the fact that mean speed values were notably higher for case streets. The estimate for CAMERA × CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The speed survey results for case streets are compared with the mobile camera infringement rates in Figure 15, where the change from a decreasing trend in speeds to an increasing trend approximately corresponds to the beginning of the long-term infringement rate of 0.6%. The regression models for case and control streets (Models 1 and 2) are compared in Figure 16. Mean speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The mean speeds on all streets were predominantly below the speed limit for the full time period.

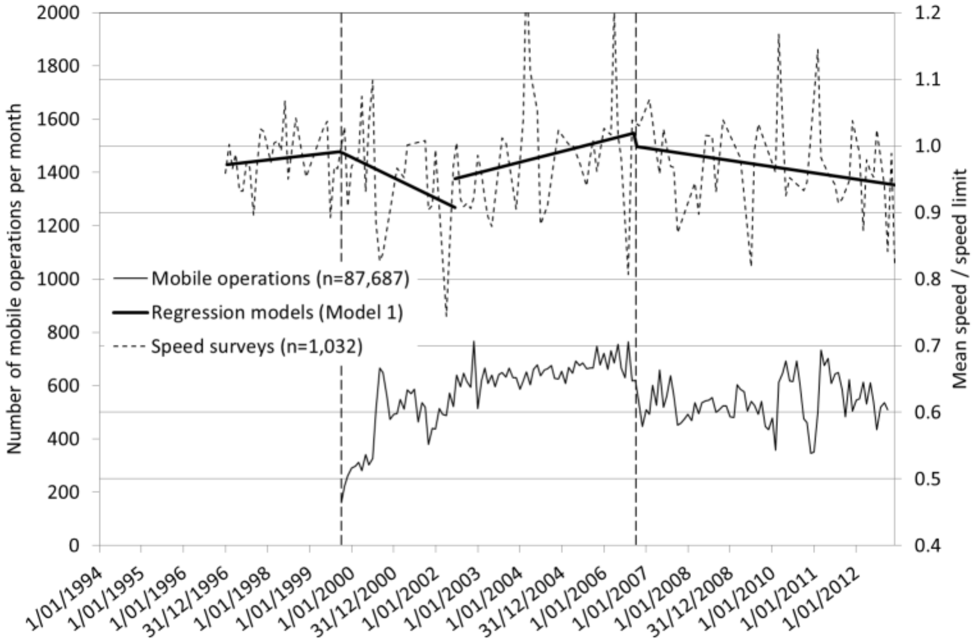


Figure 12: Mean speed survey data relative to the overall camera program – case streets

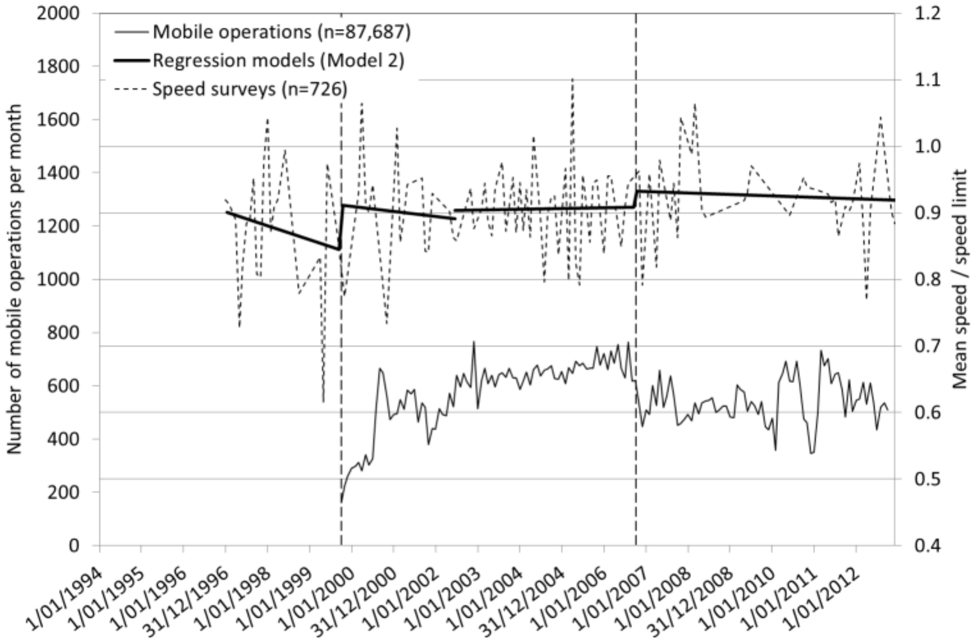


Figure 13: Mean speed survey data relative to the overall camera program – control streets

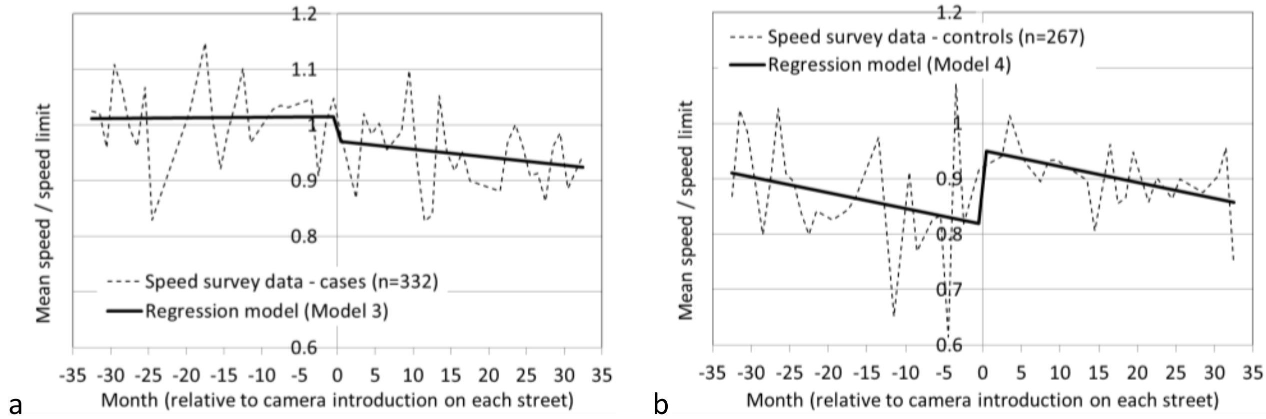


Figure 14: Mean speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

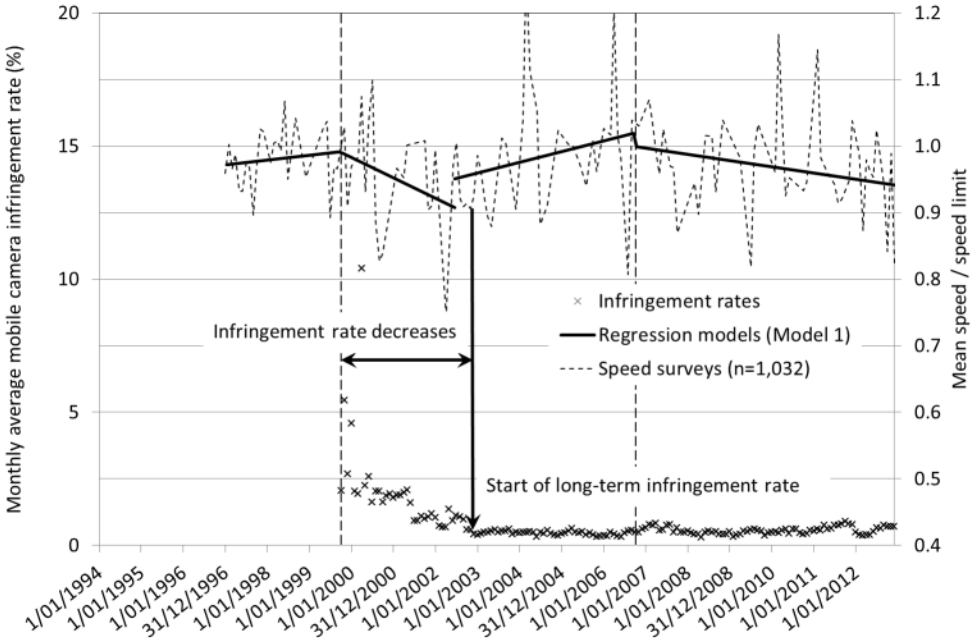


Figure 15: Mean speed survey data relative to the overall camera program – case streets

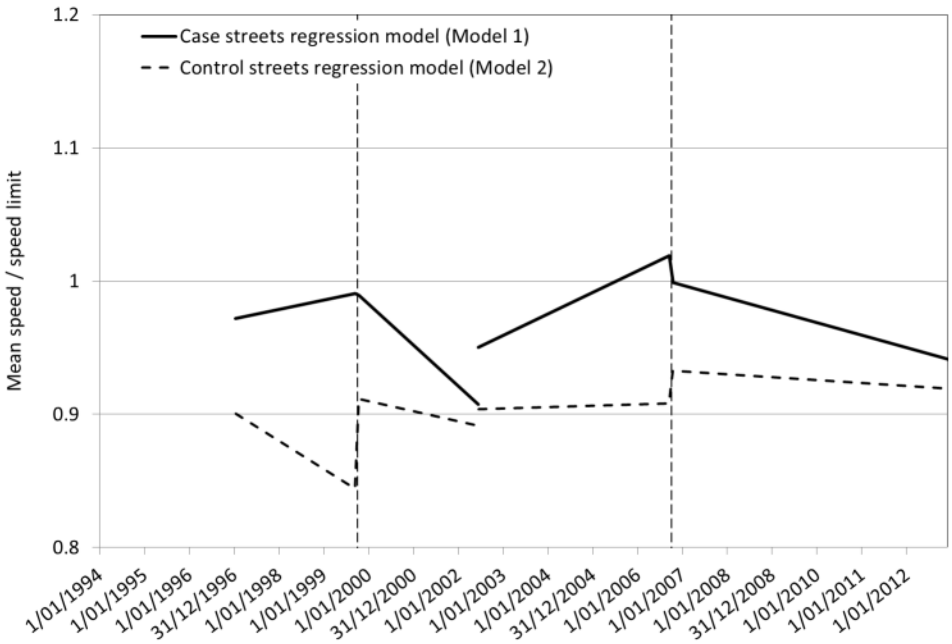


Figure 16: Comparison of the regression models of mean speeds for case and control streets

	MODEL 1 Cases (streets with cameras)								**MODEL 2** Controls (streets without cameras)							
	(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012				(a) 1/1997 – 10/1999 – 7/2002				(b) 7/2002 – 10/2006 – 12/2012			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.009	-0.065	0.047	0.754	0.020	-0.031	0.070	0.442	-0.170	-0.268	-0.073	0.001	-0.096	-0.142	-0.050	<.0001
Time (T)	0.001	-0.002	0.003	0.666	0.001	0.000	0.003	0.087	-0.002	-0.007	0.003	0.386	0.000	-0.002	0.002	0.901
Camera (C)	0.000	-0.079	0.078	0.992	-0.021	-0.090	0.049	0.560	0.078	-0.064	0.220	0.282	0.027	-0.037	0.090	0.408
T x C	-0.003	-0.007	0.001	0.116	-0.002	-0.004	0.000	0.027	0.001	-0.006	0.008	0.711	0.000	-0.002	0.002	0.743

Table 10: Mean speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

	MODEL 3 Cases (streets with cameras)				**MODEL 4** Controls (streets without cameras)			
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	0.015	-0.037	0.067	0.577	-0.201	-0.280	-0.122	<.0001
Time (T)	0.000	-0.003	0.003	0.977	-0.003	-0.007	0.001	0.087
Camera (C)	-0.044	-0.118	0.029	0.236	0.151	0.031	0.271	0.014
T x C	-0.002	-0.005	0.002	0.409	0.000	-0.006	0.006	0.963

Table 11: Mean speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

	MODEL 5			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	-0.201	-0.270	-0.133	<.0001
Time (T)	-0.003	-0.007	0.000	0.049
Camera (C1)	0.151	0.047	0.256	0.004
Case (C2)	0.216	0.124	0.308	<.0001
T x C1	0.000	-0.005	0.005	0.958
T x C2	0.003	-0.001	0.008	0.145
C1 x C2	-0.196	-0.331	-0.060	0.005
T x C1 x C2	-0.002	-0.009	0.005	0.619

Table 12: Mean speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.5 Speed survey analyses – effects of mobile cameras on 85th percentile vehicle speeds (Models 6 to 10)

Considering an outcome of monthly averaged values of the 85th percentile speed divided by the speed limit, the statistical models are tabulated in Tables 13 to 15. Models 6 to 9 are plotted in Figures 17 to 19. In Models 6 and 8, trends in 85th percentile speeds for case streets were relatively constant in the pre-intervention periods, and decreased in the post-intervention periods, where the intervention was Intervention 1 (Model 6) or the camera begin-date (Model 8). Trends in 85th percentile speeds showed increases in the pre-intervention period and decreases in the post-intervention periods for Intervention 2 (Model 6). 85th percentile speeds for control streets reduced prior to Intervention 1/begin-date, however quickly returned and remained relatively consistent between 1999 and 2012 (Models 7 and 9). CAMERA estimates were generally not statistically significant, indicating changes that occurred in 85th percentile speeds at the intervention times were not generally significant (Tables 13 and 14).

Annual trend magnitudes for case streets were an increase of 0.1% and decrease of 1.8% prior to and following Intervention 1, and an increase of 1.4% and decrease of 1.1% prior to and following Intervention 2. A decrease of 0.8% and decrease of 1.7% prior to and following the begin-date were evident. Trend magnitudes for control streets were a decrease of 3.6% and decrease of 0.7% prior to and following Intervention 1, and an increase of 0.2% and decrease of 0.4% prior to and following Intervention 2. A decrease of 4.6% and decrease of 5.2% prior to and following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 15. The estimate for the CASE variable was highly significant, likely a result of the fact that 85th percentile speed values were notably higher for case streets. The estimate for CAMERA $\times$ CASE was highly significant, indicating that the effect of the intervention (begin-date) was significantly different between case and control streets.

The regression models for case and control streets (Models 6 and 7) are compared in Figure 20. 85th percentile speeds were generally higher for case streets initially, while following the introduction of mobile cameras speeds in case streets reduced to a level similar to those in control streets, following which case street speeds gradually recovered to their pre-camera levels, then reduced again slightly. The 85th percentile speeds on all streets were predominantly above the speed limit for the full time period.

Comparison of the mean and 85th percentile speeds indicates that trends were very similar between the two, however the magnitudes of the 85th percentile speeds were higher than the mean speeds. This is also evident in the speed survey results plotted in Appendix D, where mean and 85th percentile speeds are plotted on the same graphs.

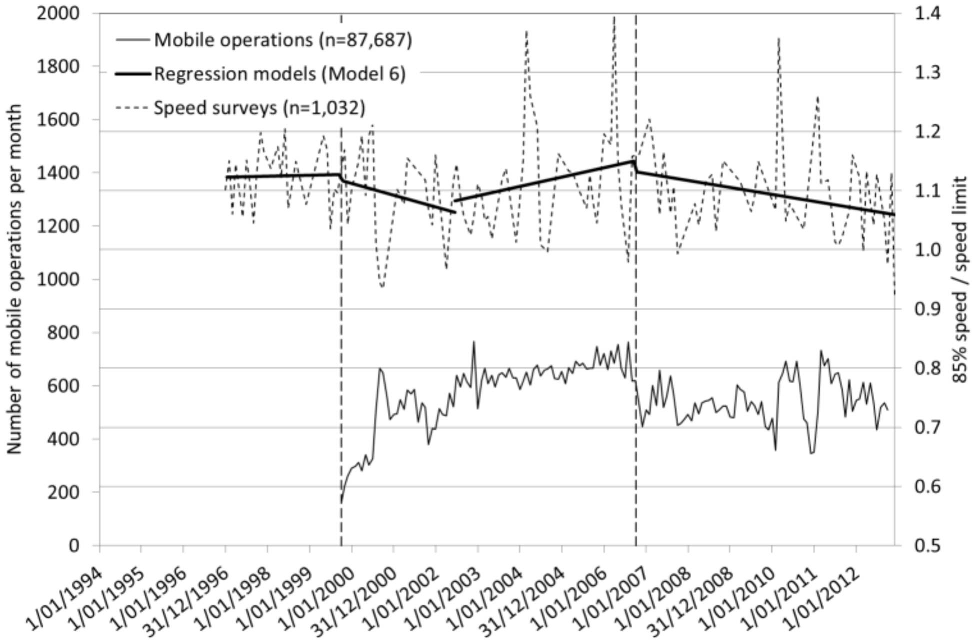


Figure 17: 85th percentile speed survey data relative to the overall camera program – case streets

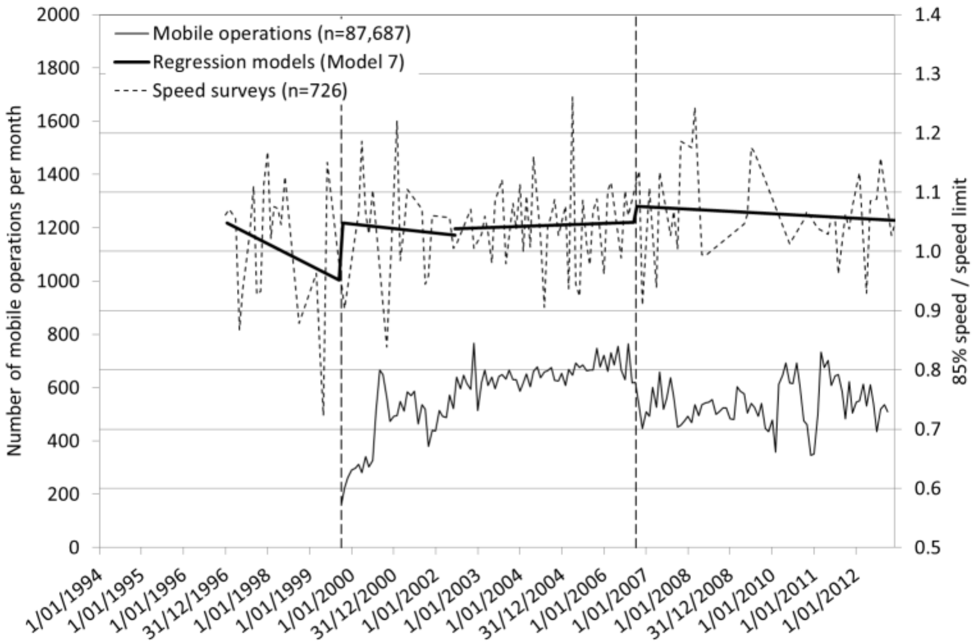


Figure 18: 85th percentile speed survey data relative to the overall camera program – control streets

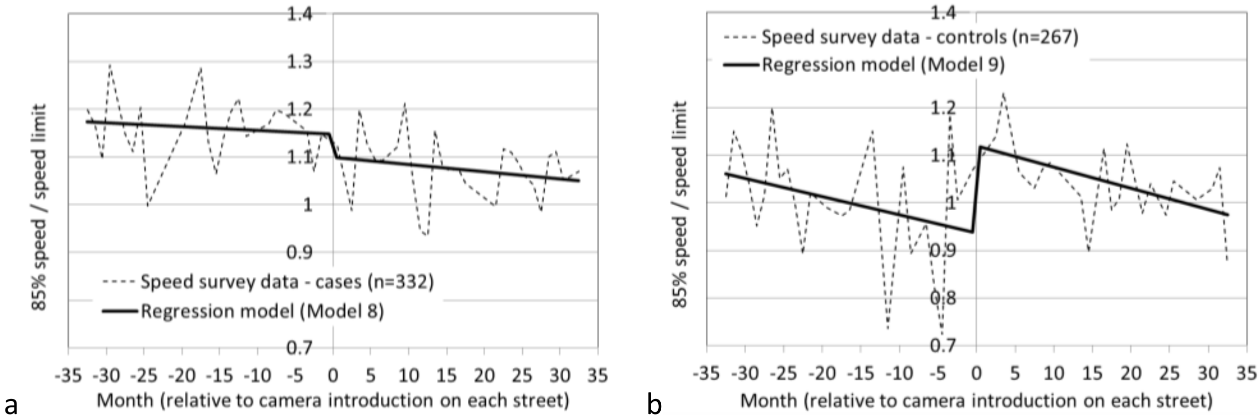


Figure 19: 85th percentile speed survey data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

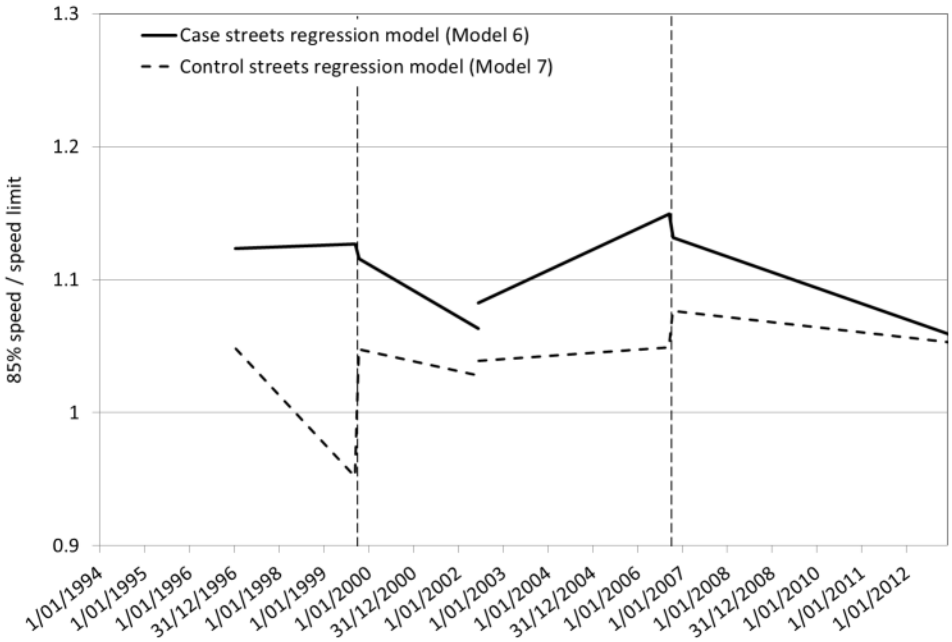


Figure 20: Comparison of the regression models of 85th percentile speeds for case and control streets

Variable	MODEL 6 Cases (streets with cameras) (a) 1/1997 – 10/1999 – 7/2002 Estimate	CL_U	CL_L	*p*-value	(b) 7/2002 – 10/2006 – 12/2012 Estimate	CL_U	CL_L	*p*-value	MODEL 7 Controls (streets without cameras) (a) 1/1997 – 10/1999 – 7/2002 Estimate	CL_U	CL_L	*p*-value	(b) 7/2002 – 10/2006 – 12/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	0.120	0.070	0.169	<.0001	0.140	0.093	0.187	<.0001	-0.051	-0.150	0.048	0.315	0.048	0.002	0.094	0.040
Time (T)	0.000	-0.002	0.003	0.908	0.001	0.000	0.003	0.120	-0.003	-0.008	0.002	0.208	0.000	-0.001	0.002	0.820
Camera (C)	-0.009	-0.079	0.061	0.797	-0.016	-0.081	0.049	0.636	0.098	-0.046	0.241	0.182	0.026	-0.037	0.089	0.426
T x C	-0.002	-0.005	0.002	0.390	-0.002	-0.004	0.000	0.026	0.002	-0.005	0.010	0.508	-0.001	-0.002	0.001	0.618

Table 13: 85th percentile speed survey data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	MODEL 8 Cases (streets with cameras) Estimate	CL_U	CL_L	*p*-value	MODEL 9 Controls (streets without cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	0.138	0.092	0.184	<.0001	-0.065	-0.146	0.017	0.120
Time (T)	-0.001	-0.003	0.002	0.578	-0.004	-0.008	0.000	0.060
Camera (C)	-0.043	-0.108	0.022	0.197	0.179	0.055	0.302	0.005
T x C	-0.001	-0.004	0.003	0.697	-0.001	-0.007	0.006	0.867

Table 14: 85th percentile speed survey data - intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

Variable	MODEL 10 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.065	-0.132	0.002	0.059
Time (T)	-0.004	-0.007	-0.001	0.022
Camera (C1)	0.179	0.077	0.280	0.001
Case (C2)	0.202	0.112	0.293	<.0001
T x C1	-0.001	-0.006	0.005	0.839
T x C2	0.003	-0.001	0.008	0.167
C1 x C2	-0.222	-0.354	-0.089	0.001
T x C1 x C2	0.000	-0.007	0.007	0.967

Table 15: 85th percentile speed survey data - case-control analysis where the intervention is the introduction of camera operations on each street (time is from -33 to 33 months for each street)

3.6 Road crash analyses – effects of mobile cameras on fatal crashes

Fatal crashes for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 100 fatal crashes were identified in the period, including 91 that occurred on case streets and 9 that occurred on control streets. Fatal crash counts are plotted in Figures 21 to 22. Due to small crash counts statistical models were not fitted to these data, however it is clear from visual inspection of Figure 21 that fatal crashes on case streets generally decreased over the study period.

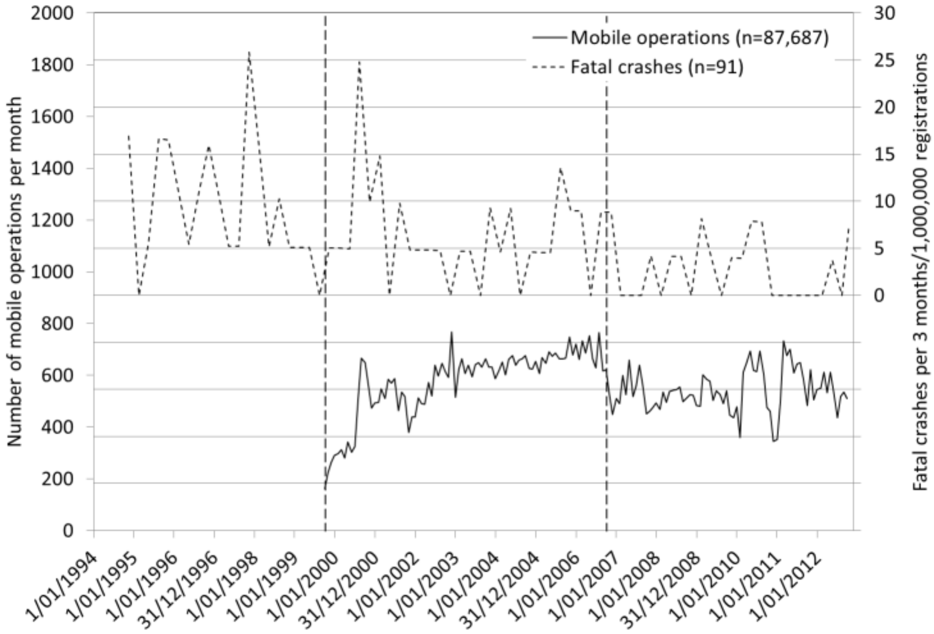


Figure 21: Fatal crash data relative to the overall camera program – case streets

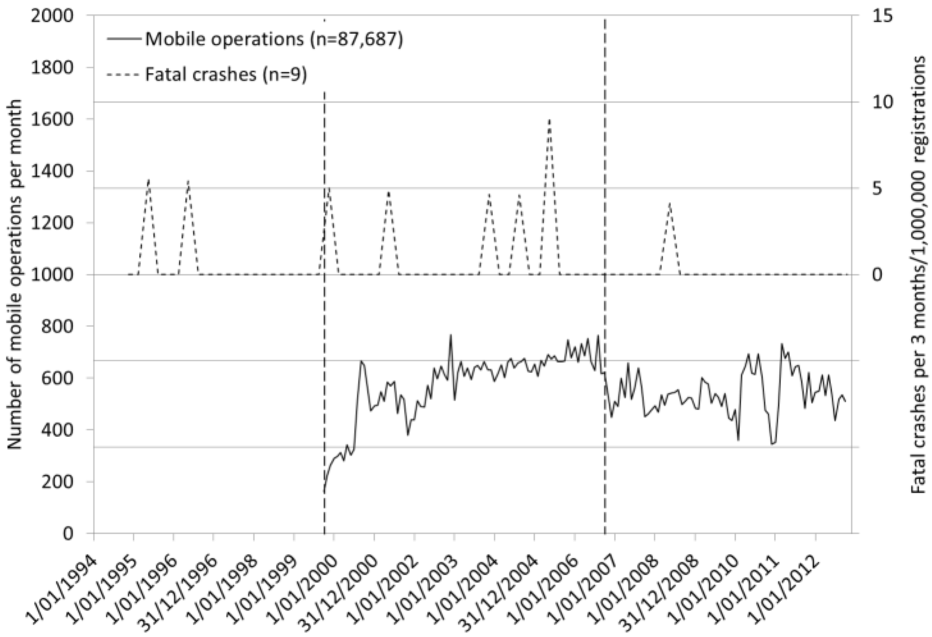
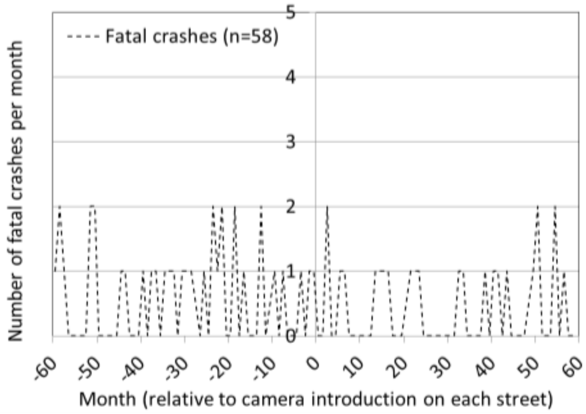
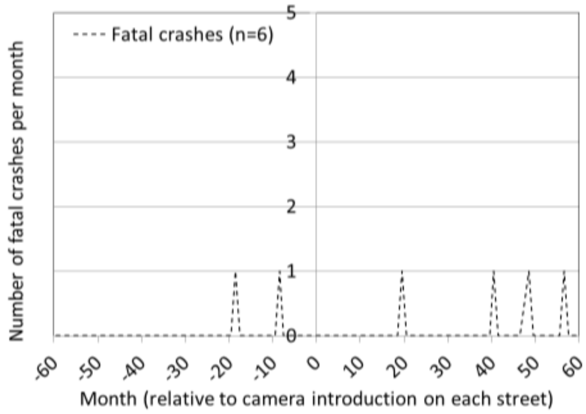


Figure 22: Fatal crash data relative to the overall camera program – control streets



a



b

Figure 23: Fatal crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

3.7 Road crash analyses – effects of mobile cameras on serious crashes (Models 11 to 15)

Serious crashes (injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 3,325 serious crashes were identified in the period, including 2,788 that occurred on case streets and 537 that occurred on control streets. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 16 to 18. Models 11 to 14 are plotted in Figures 24 to 26. In Models 11 and 13, trends in serious crash counts for case streets showed decreases post-intervention, where the intervention was Intervention 1 (Model 11) or the camera begin-date (Model 13). A substantial drop occurred in mid-2002 (around 40% in raw numbers) and was sustained until the end of 2004, with a smaller approximately 20% increase over the next two years, where upon in 2007 serious injury crashes began to oscillate between a very large increase and a very large decrease with the trend following Intervention 2 (Model 11) steadily increasing up to 2013 to the same levels when cameras were first introduced. It should be noted that this rising trend in serious injury crashes from around 2004 to 2013 coincides with the period where the total ACT vehicle fleet has increased 25% and transport modelling for the period 2006 to 2011 suggested there was an increase of 7% in the total number of car trips during the morning peak period.

Serious crash counts for control streets were at much lower levels at around one quarter that of the case streets. Trends for control streets (Models 12 and 14) were similar, however the drop in 2002 was much less pronounced. Negative estimates for CAMERA in Models 11 to 14 indicates that crash counts were generally lower following Intervention 1/begin-date, while positive estimates following Intervention 2 indicates crash counts were higher. CAMERA estimates were generally not significant, however this may have been influenced by the relatively small serious crash counts.

Annual trend magnitudes for case streets were a decrease of 3.2% prior to Intervention 1, decrease of 3.7% between Intervention 1 and 2, and increase of 7.1% following Intervention 2. An increase of 1.1% prior to the begin-date and decrease of 10.3% following the begin-date were evident. Trend magnitudes for control streets were an increase of 4.7% prior to Intervention 1, a decrease of 24.5% between Intervention 1 and 2, and an increase of 1.4% following Intervention 2.

Decreases of 6.1% prior to the begin-date and 2.5% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 18. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, however this may reflect the relatively small serious crash counts.

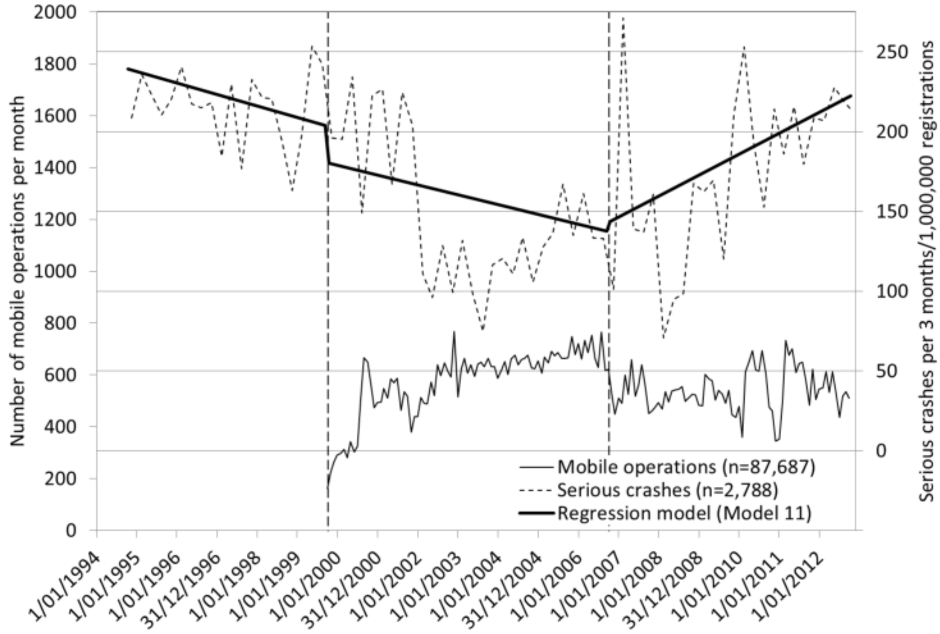


Figure 24: Serious crash data relative to the overall camera program – case streets

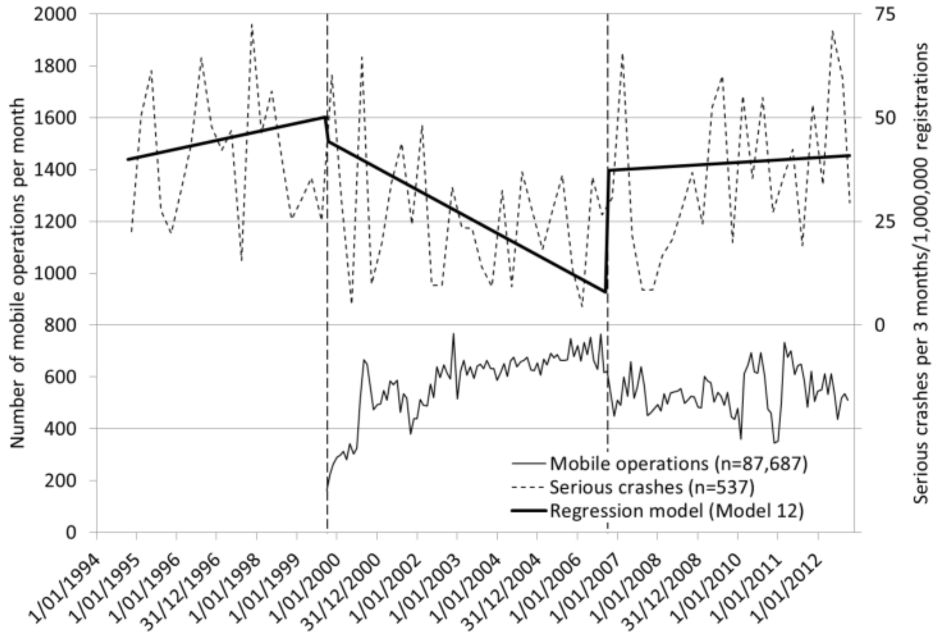


Figure 25: Serious crash data relative to the overall camera program – control streets

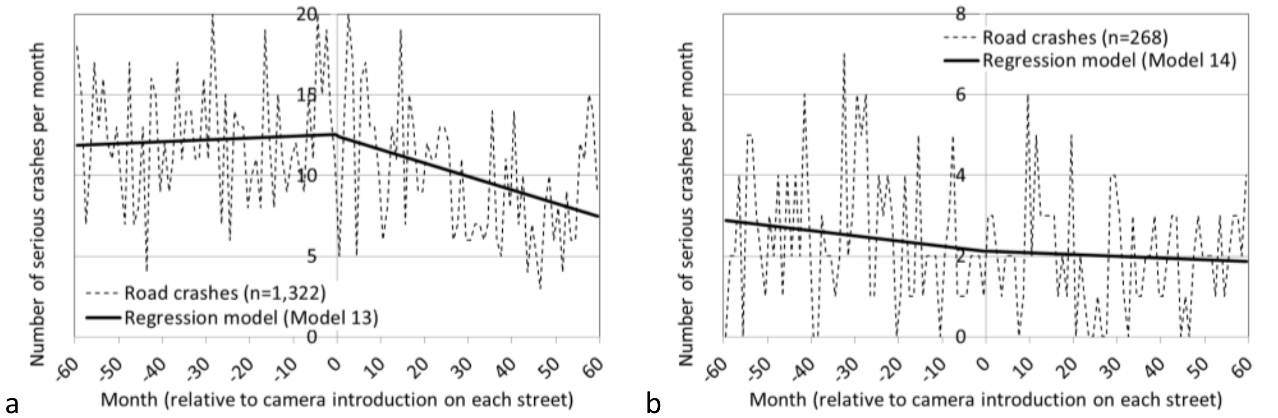


Figure 26: Serious crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

Variable	MODEL 11 Cases (streets with mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value	MODEL 12 Controls (streets without mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	-13.381	-13.873	-12.889	<.0001	-13.776	-14.238	-13.314	<.0001	-14.634	-15.092	-14.176	<.0001	-16.482	-17.397	-15.567	<.0001
Time (T)	-0.003	-0.009	0.003	0.353	-0.003	-0.009	0.002	0.265	0.004	-0.010	0.018	0.596	-0.021	-0.036	-0.005	0.011
Camera (C)	-0.122	-0.533	0.289	0.561	0.043	-0.266	0.353	0.785	-0.119	-0.824	0.586	0.742	1.550	0.678	2.423	0.001
T x C	0.000	-0.008	0.007	0.916	0.009	0.002	0.016	0.016	-0.024	-0.042	-0.007	0.007	0.022	-0.002	0.045	0.068

Table 16: Serious crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	MODEL 13 Cases (streets with mobile cameras) Estimate	CL_U	CL_L	*p*-value	MODEL 14 Controls (streets without mobile cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	-0.998	-1.460	-0.536	<.0001	-2.886	-3.189	-2.583	<.0001
Time (T)	0.001	-0.004	0.006	0.720	-0.005	-0.011	0.001	0.108
Camera (C)	-0.007	-0.247	0.233	0.955	-0.002	-0.377	0.373	0.991
T x C	-0.010	-0.017	-0.002	0.010	0.003	-0.007	0.013	0.566

Table 17: Serious crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

Variable	MODEL 15 Estimate	CL_U	CL_L	*p*-value
Intercept	-2.885	-3.188	-2.582	<.0001
Time (T)	-0.005	-0.011	0.001	0.108
Camera (C1)	-0.002	-0.376	0.372	0.991
Case (C2)	1.889	1.337	2.441	<.0001
T x C1	0.003	-0.007	0.013	0.566
T x C2	0.006	-0.002	0.014	0.135
C1 x C2	-0.005	-0.449	0.440	0.983
T x C1 x C2	-0.013	-0.025	0.000	0.050

Table 18: Serious crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.8 Road crash analyses – effects of mobile cameras on all crashes (Models 16 to 20)

All road crashes (property damage, injury or fatality) for the 95 street locations were assessed for the 19 year period from 1994 to 2012 (inclusive). A total of 57,809 road crashes were identified in the period, including 48,733 that occurred on case streets and 9,076 that occurred on control streets. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 19 to 21. Models 16 to 19 are plotted in Figures 27 to 29. In Models 16 and 18, trends in crash counts for case streets showed decreases in both the pre- and post-intervention periods, where the intervention was Intervention 1 (Model 16) or the camera begin-date (Model 18), and following Intervention 2 (Model 16). Large positive CAMERA estimates were evident for case streets at Intervention 1/begin-date, which were statistically significant, which indicates a significant increase in crash counts at this time. Crash counts for control streets indicated very similar trends (Models 17 and 19), however the changes that occurred at the time of the interventions was less pronounced.

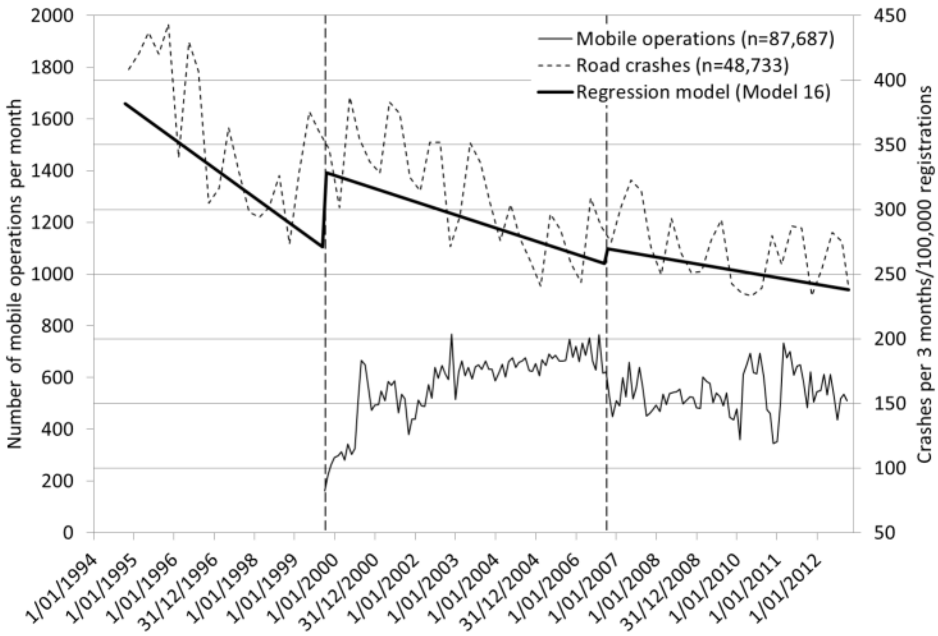


Figure 27: All crash data relative to the overall camera program – case streets

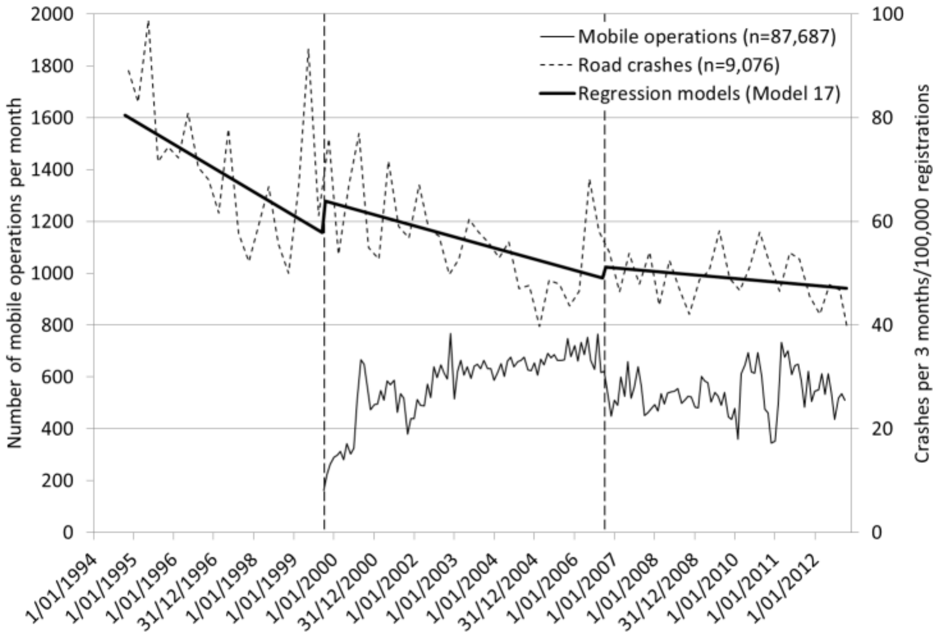


Figure 28: All crash data relative to the overall camera program – control streets

Annual trend magnitudes for case streets were decreases of 6.9% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 2.0% following Intervention 2. Decreases of 3.6% prior to the begin-date and 1.7% following the begin-date were evident. Trend magnitudes for control streets were decreases of 6.7% prior to Intervention 1, 4.2% between Intervention 1 and 2, and 1.0% following Intervention 2. Decreases of 2.9% prior to the begin-date and 3.6% following the begin-date were evident. All trend magnitudes are per year.

The results of the case-control analysis are presented in Table 21. The estimate for the CASE variable was highly significant, likely a result of the fact that crash counts were substantially higher for case streets. The estimate for CAMERA × CASE was not significant, indicating that the effect of the intervention (begin-date) was not significantly different between case and control streets. However, another explanation may be that limitation concerning the selection of control streets, i.e. that the control streets identified for the analyses do not represent a true 'control area'.

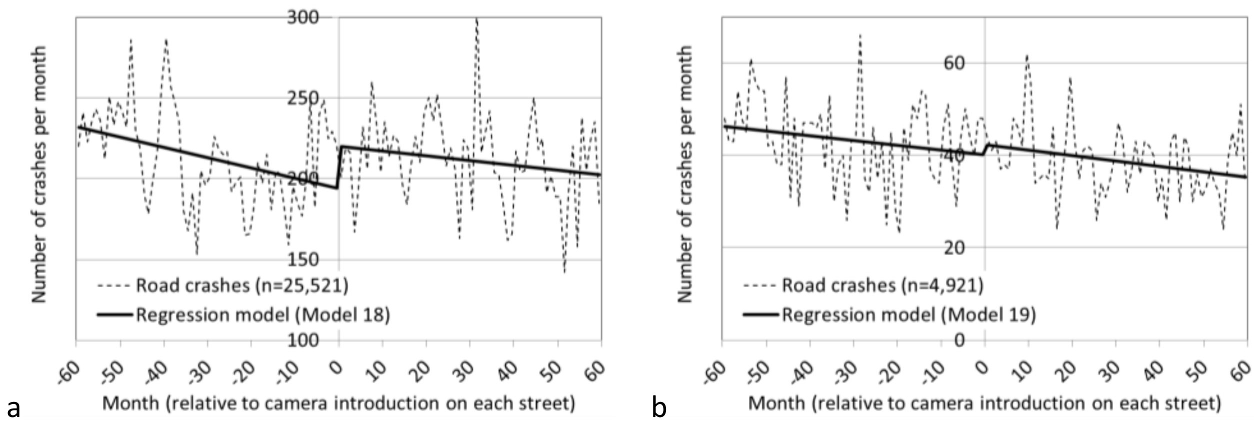


Figure 29: All crash data relative to the introduction of cameras on individual streets; a) case streets, b) control streets

Variable	**MODEL 16** Cases (streets with mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value	**MODEL 17** Controls (streets without mobile cameras) (a) 10/1994 – 10/1999 – 10/2006 Estimate	CL_U	CL_L	*p*-value	(b) 10/1999 – 10/2006 – 10/2012 Estimate	CL_U	CL_L	*p*-value
Intercept	-10.796	-11.240	-10.351	<.0001	-10.844	-11.276	-10.413	<.0001	-12.245	-12.669	-11.821	<.0001	-12.409	-12.858	-11.960	<.0001
Time (T)	-0.006	-0.007	-0.004	<.0001	-0.004	-0.005	-0.002	<.0001	-0.006	-0.008	-0.004	<.0001	-0.004	-0.006	-0.001	0.006
Camera (C)	0.196	0.136	0.255	<.0001	0.047	-0.024	0.117	0.193	0.104	0.014	0.194	0.024	0.044	-0.093	0.181	0.532
T x C	0.002	-0.001	0.005	0.119	0.002	0.000	0.004	0.104	0.002	-0.002	0.006	0.262	0.002	-0.001	0.005	0.102

Table 19: All crash data - interventions are; a) start of the camera program (Intervention 1 - October 1999), b) change of the program (Intervention 2 - October 2006)

Variable	**MODEL 18** Cases (streets with mobile cameras) Estimate	CL_U	CL_L	*p*-value	**MODEL 19** Controls (streets without mobile cameras) Estimate	CL_U	CL_L	*p*-value
Intercept	1.741	1.300	2.182	<.0001	0.004	-0.413	0.420	0.986
Time (T)	-0.003	-0.005	-0.001	0.000	-0.002	-0.005	0.000	0.063
Camera (C)	0.127	0.081	0.173	<.0001	0.052	-0.053	0.157	0.331
T x C	0.002	-0.002	0.005	0.371	-0.001	-0.005	0.004	0.788

Table 20: All crash data - intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

Variable	**MODEL 20** Estimate	CL_U	CL_L	*p*-value
Intercept	0.001	-0.415	0.417	0.997
Time (T)	-0.002	-0.005	0.000	0.063
Camera (C1)	0.052	-0.053	0.157	0.332
Case (C2)	1.742	1.136	2.348	<.0001
T x C1	-0.001	-0.005	0.004	0.789
T x C2	-0.001	-0.004	0.002	0.698
C1 x C2	0.075	-0.040	0.190	0.201
T x C1 x C2	0.002	-0.003	0.008	0.446

Table 21: All crash data - case-control analysis where the intervention is the introduction of mobile camera operations on each street (time is from -60 to 60 months for each street)

3.9 Road crash analyses – effects of fixed cameras on serious intersection crashes (Models 21 to 23)

A total of 152 serious (injury or fatality) intersection crashes were identified in the period for the 26 intersection locations, including 78 that occurred at case intersections and 74 that occurred at control intersections. The statistical models considering monthly serious crash counts as the outcome are tabulated in Tables 22 and 23, and Models 21 and 22 are plotted in Figure 30. The negative estimates for CAMERA indicates that serious intersection crash counts for case and control intersections were generally lower following the introduction of fixed cameras, and the similar magnitudes indicates that the drop was similar at case and control locations. Model results were not significant, including those for the case-control Model 23, likely a result of the small crash counts.

Annual trend magnitudes for case intersections were a decrease of 5.2% prior to the begin-date and an increase of 0.4% following the begin-date. Trend magnitudes for control intersections were a decrease of 5.0% prior to the begin-date and an increase of 8.2% following the begin-date. All trend magnitudes are per year.

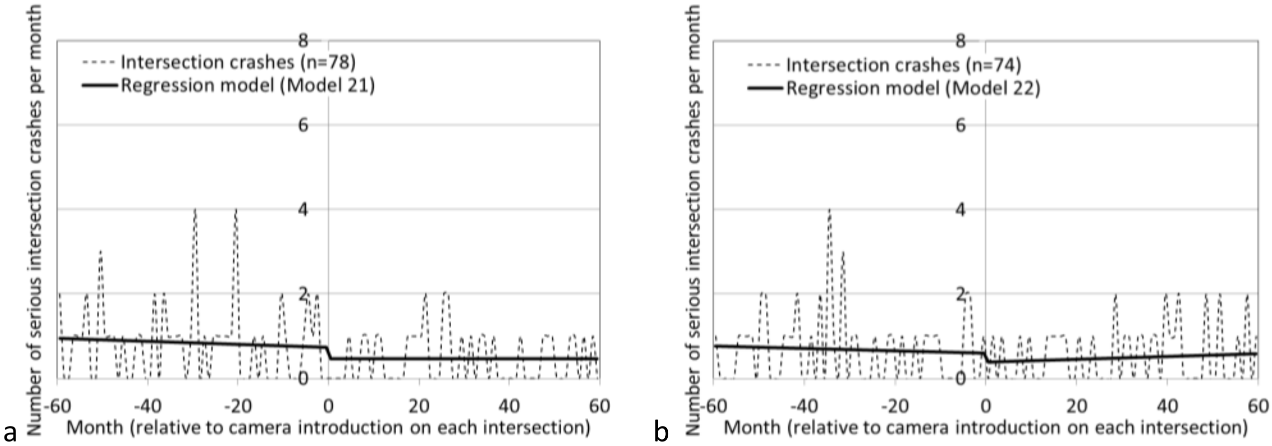


Figure 30: Serious intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

Variable	MODEL 21 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 22 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	-0.315	-0.891	0.261	0.283	-0.509	-1.167	0.149	0.130
Time (T)	-0.004	-0.020	0.012	0.598	-0.004	-0.023	0.014	0.656
Camera (C)	-0.454	-1.396	0.488	0.345	-0.430	-1.438	0.578	0.403
T x C	0.005	-0.022	0.031	0.738	0.017	-0.011	0.044	0.230

Table 22: Serious intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 23 Estimate	CL_U	CL_L	*p*-value
Intercept	-0.509	-1.156	0.138	0.123
Time (T)	-0.004	-0.022	0.014	0.650
Camera (C1)	-0.430	-1.421	0.561	0.395
Case (C2)	0.194	-0.679	1.067	0.664
T x C1	0.017	-0.010	0.044	0.222
T x C2	0.000	-0.025	0.024	0.991
C1 x C2	-0.024	-1.403	1.355	0.973
T x C1 x C2	-0.012	-0.051	0.026	0.534

Table 23: Serious intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

3.10 Road crash analyses – effects of fixed cameras on all intersection crashes (Models 24 to 32)

A total of 4,261 intersection crashes (property damage, injury or fatality) were identified in the period for the 26 intersection locations, including 2,826 that occurred at case intersections and 1,435 that occurred at control intersections. The statistical models considering monthly crash counts as the outcome are tabulated in Tables 24 to 28 and are plotted in Figures 31 to 33. Trends in crash counts for case intersections showed an increase in crashes following the introduction of the fixed cameras followed by a decline to rates slightly lower than baseline levels. On the other hand, crash counts for control intersections were relatively consistent before and after. The positive estimate for CAMERA in Model 24 indicates that case intersection crash counts were generally higher following the introduction of fixed cameras, and this result was significant. Disaggregating intersection crashes by rear-end crashes indicates that, at intersections where fixed cameras were introduced, this increase resulted from an increase in rear-end crashes which then returned to levels slightly below baseline levels. This is evidenced in the estimates for CAMERA, where a large positive value was estimated for rear-end crashes (0.277, Model 27), and this result was significant. Conversely, a small value was estimated for non-rear-end crashes (0.007, Model 29).

Comparison with the generally consistent frequency of rear-end crashes before and after at intersections without fixed cameras (small negative value for CAMERA estimate in Model 28), indicates that the initial increase in rear-end crashes at intersections with fixed cameras was likely a result of the introduction of these cameras. This is further evidenced by the statistical results for the case-control analysis in Model 26, where the estimate for CAMERA $\times$ CASE was highly significant, indicating that the effect of the introduction of fixed intersection cameras was significantly different between case and control streets.

Negative estimates for CAMERA in the models for right angle collision/right turn into oncoming vehicle intersection crashes indicate that crash counts were generally lower following the introduction of fixed cameras, at both case and control intersections.

Annual trend magnitudes for case intersections were decreases of 3.4% prior to the begin-date and 6.2% following the begin-date. This included decreases of 0.5% prior to the begin-date and 6.5% following the begin-date for rear-end crashes, decreases of 8.9% prior to the begin-date and 5.5% following the begin-date for non-rear-end crashes, and decreases of 1.6% prior to the begin-date and 2.2% following the begin-date for right angle collision/right turn into oncoming vehicle

crashes. Trend magnitudes for control intersections were a decrease of 1.6% prior to the begin-date and an increase of 2.2% following the begin-date. This included an increase of 1.2% prior to the begin-date and an increase of 2.2% following the begin-date for rear-end crashes, a decrease of 6.0% prior to the begin-date and an increase of 0.7% following the begin-date for non-rear-end crashes, and a decrease of 13.6% prior to the begin-date and an increase of 3.0% following the begin-date for right angle collision/right turn into oncoming vehicle crashes. All trend magnitudes are per year.

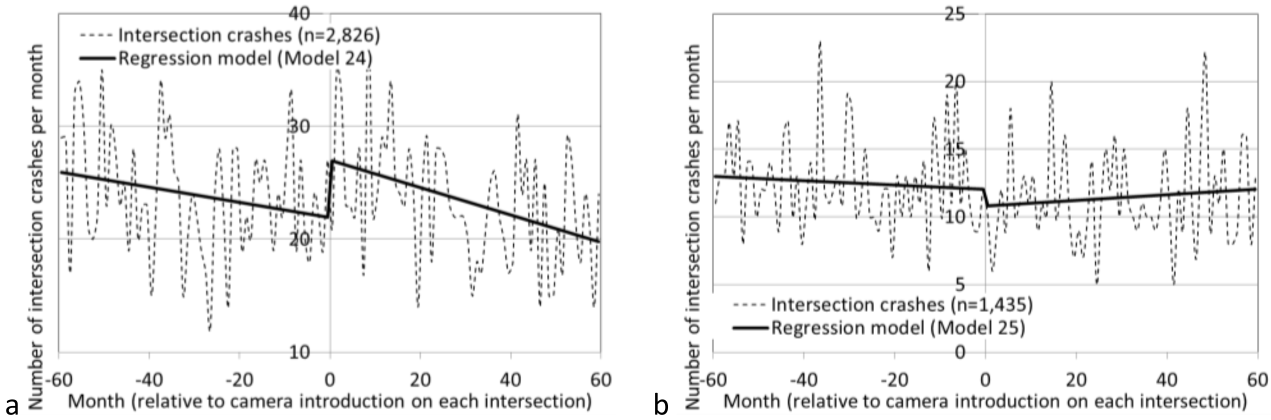


Figure 31: Intersection crash data relative to the introduction of fixed cameras on individual intersections; a) case intersections, b) control intersections

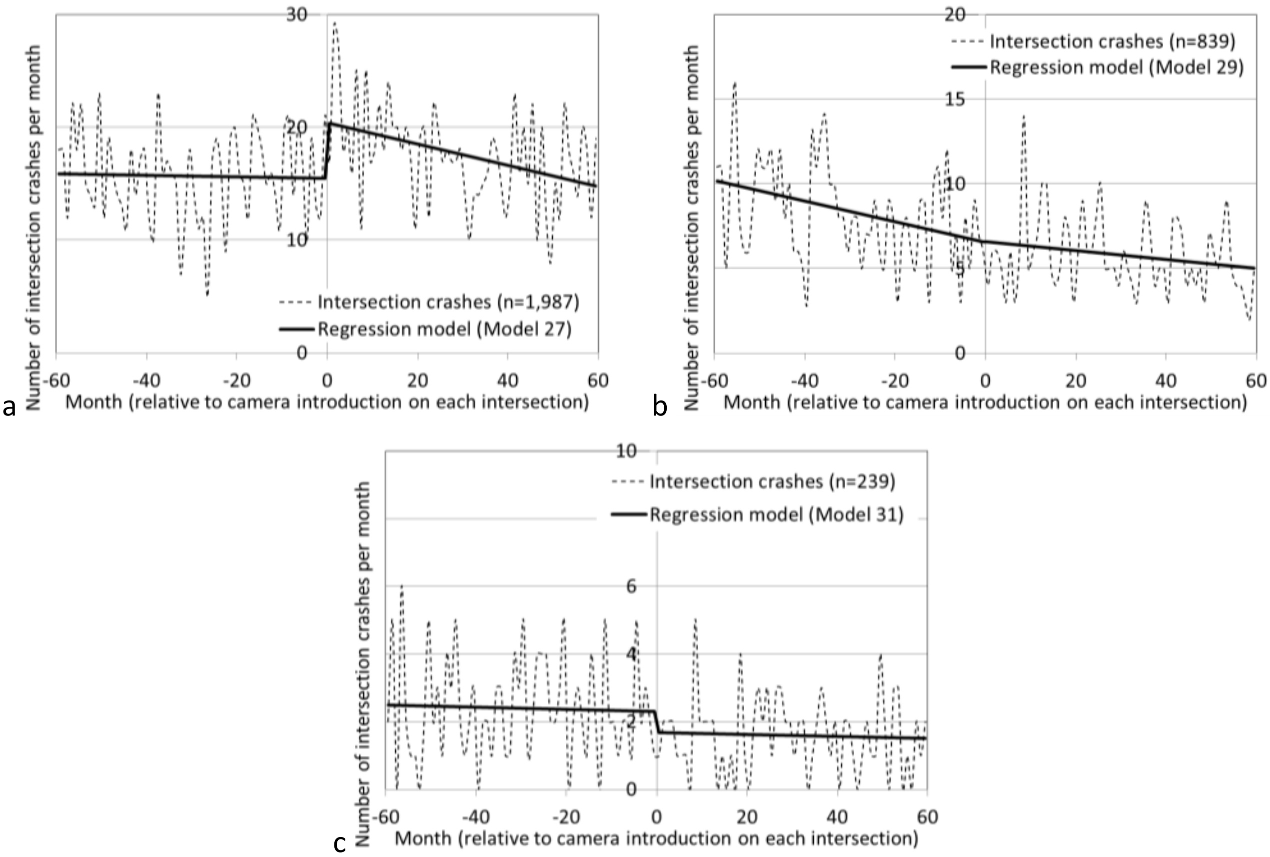


Figure 32: Case intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

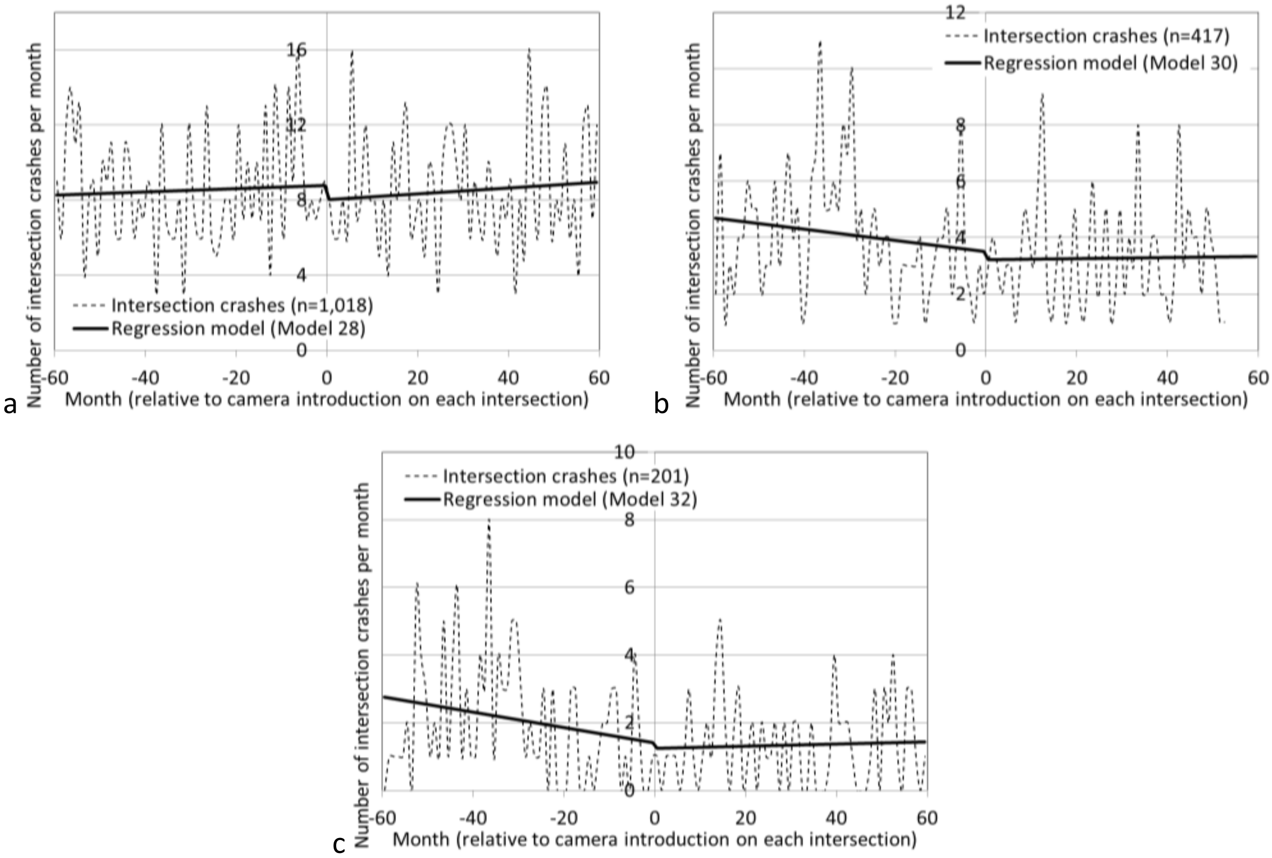


Figure 33: Control intersection crash data relative to the introduction of fixed cameras on individual intersections; a) rear-end crashes, b) non-rear-end crashes, c) right angle collision/right turn into oncoming vehicle

	MODEL 24	Cases (with fixed cameras)			MODEL 25	Controls (without fixed cameras)		
Variable	Estimate	CL_U	CL_L	*p*-value	Estimate	CL_U	CL_L	*p*-value
Intercept	3.089	2.977	3.200	<.0001	2.487	2.346	2.628	<.0001
Time (T)	-0.003	-0.006	0.000	0.082	-0.001	-0.005	0.003	0.520
Camera (C)	0.207	0.053	0.362	0.009	-0.107	-0.312	0.097	0.303
T x C	-0.002	-0.007	0.002	0.298	0.003	-0.003	0.009	0.297

Table 24: Intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

	MODEL 26			
Variable	Estimate	CL_U	CL_L	*p*-value
Intercept	2.487	2.340	2.634	<.0001
Time (T)	-0.001	-0.006	0.003	0.537
Camera (C1)	-0.107	-0.321	0.106	0.323
Case (C2)	0.601	0.420	0.783	<.0001
T x C1	0.003	-0.003	0.009	0.318
T x C2	-0.002	-0.007	0.004	0.575
C1 x C2	0.315	0.055	0.575	0.018
T x C1 x C2	-0.006	-0.013	0.002	0.149

Table 25: Intersection crash data - case-control analysis where the intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 27 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 28 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	2.740	2.611	2.868	<.0001	2.171	1.995	2.348	<.0001
Time (T)	0.000	-0.004	0.003	0.834	0.001	-0.004	0.006	0.690
Camera (C)	0.277	0.103	0.451	0.002	-0.090	-0.342	0.163	0.487
T x C	-0.005	-0.010	0.000	0.056	0.001	-0.007	0.008	0.839

Table 26: Rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 29 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 30 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	1.878	1.706	2.050	<.0001	1.250	0.975	1.525	<.0001
Time (T)	-0.007	-0.012	-0.003	0.002	-0.005	-0.013	0.003	0.193
Camera (C)	0.007	-0.249	0.262	0.959	-0.085	-0.498	0.327	0.686
T x C	0.003	-0.005	0.010	0.458	0.006	-0.006	0.017	0.344

Table 27: Non-rear-end intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

Variable	MODEL 31 Estimate	Cases (with fixed cameras) CL_U	CL_L	*p*-value	MODEL 32 Estimate	Controls (without fixed cameras) CL_U	CL_L	*p*-value
Intercept	0.836	0.498	1.173	<.0001	0.343	-0.147	0.833	0.170
Time (T)	-0.001	-0.011	0.008	0.789	-0.011	-0.024	0.002	0.090
Camera (C)	-0.322	-0.850	0.205	0.231	-0.130	-0.875	0.615	0.733
T x C	-0.001	-0.016	0.015	0.950	0.014	-0.007	0.034	0.190

Table 28: Right angle collision/right turn into oncoming vehicle intersection crash data - intervention is the introduction of fixed cameras at each intersection (time is from -60 to 60 months for each street)

4. Discussion

The views of drivers about speeding and enforcement of speed limits is likely to influence their on-road behaviour. For this reason, in evaluating the effects of road safety initiatives like safety cameras, it is useful to take into account changes in driver and community views about speed and enforcement. The community attitude surveys conducted between 1992 and 2012 provide some insights into changes in attitudes over the period of introduction of safety cameras in the ACT.

Drivers choose the speed of travel from moment to moment based on a range of factors that might be loosely grouped into the driving environment and their preferred driving style. The driving environment includes the physical conditions that can have a large impact on the driver's chosen speed and the regulatory speed limits. Driving style also undoubtedly plays a considerable role in speed choice with the behavioural style of individual drivers influencing their perception of speed and of the importance of regulating speed according to the environment. The majority of drivers make considerable effort to conform to speed limits. Compliance with speed limits and, as a consequence, to general driving conditions is encouraged primarily through enforcement such as the use of speed cameras, but drivers differ in their reactions to such enforcement measures. Driver experience of enforcement may also differ depending on the type of camera in use which will also affect whether and how drivers respond to the presence of speed cameras.

The following is a discussion of what was found to be available in the wide literature in terms of evidence base concerning the effectiveness or otherwise of the different camera types, a discussion of the review of community attitudes to speeding, and a discussion of the speed survey and road crash data study. It is hoped that this discussion and the conclusions (placed at the front of report for convenience) will provide insight into some of the questions raised.

Lastly, the evaluation process outlined in the Detailed Statement of Requirements provided in Appendix E has been addressed as outlined in Section 4.4.

4.1 Literature review

Evaluations of red light cameras clearly yield mixed effects. There is good evidence that they have the effect that we expect and hope for: reduce red light running in the form of violations and most importantly produce reductions in right angle crashes. These effects are clearly road safety benefits.

On the other hand, there is consistent evidence that they also increase rear-end crashes, which is clearly not a benefit for road safety, but again might be expected if drivers are responding rapidly to the onset of red lights when cameras are present. It has been argued that the difference in likely severity of crashes offsets the increase in rear-end crashes. Kloeden et al (2009), for example argued that the damage caused in side impact crashes are often much more extreme than that produced in rear-end crashes, so the trade-off for road safety by the presence of red light cameras is in the positive direction. However, it should be noted that whiplash injury, which is often associated with rear-end crashes, may have long term chronic effects which result in both pain and suffering. Whiplash injuries can also result in a substantial financial burden, where a recent study of road-crash related personal injury insurance claims noted that the average injury claim made for the treatment of whiplash injuries was $90,700 (Bambach et al 2013). Clearly, good road safety practice needs to also consider how to reduce increased rear-end crashes even if the severity of the crash is much less extreme than for example a side impact crash resulting in serious injuries. One way may be to consider light phases at intersections.

The available research provides some guidance on the best approaches to implementation of red light cameras. Some focus on the length of phase sequences. Yang, Han and Cherry (2013) reviewed the evidence for modifying signal sequences as a method of sustaining red light camera operations in order to balance safety benefit with revenue raised. They concluded that safety benefits would be obtained by lengthening the all-red clearance phase and from shortening overall cycle length, whereas shortened yellow light sequences increased the likelihood of rear-end crashes. It seems that providing greater opportunity for drivers to make the decision to stop may be effective in reducing red light running. Further, providing an all-red clearance period at intersections reduces red light violations (Schattler, Datta and Hill, 2003) by requiring drivers to pause between the change in direction of traffic flow. However, it needs to be noted that the ACT already has an all-red phase and the other phasing features noted above.

Evaluations of fixed cameras also clearly show they are effective for reducing speeds and crashes in the location where the camera is installed. The results also show a large variation. There are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

Critical to any evaluation is the choice of a control comparison site. Even if a Random Location Control (RLC) non-camera site is chosen some distance away in order to avoid distance or time halo effects, the site is likely to be influenced by the information about the general presence of cameras in the area by the community. The level of enforcement is also likely to increase driver awareness as people are 'caught' when they are speeding at the camera site and then drive through control sites elsewhere. Drivers tend to watch what they are doing through signalised intersections and drivers have warnings of the presence of the camera in the general vicinity.

Another factor that may account for the large variation is the issue of the effectiveness of enforcement using camera technology. For enforcement to be effective, just as for any behaviour change, the punishment and the infringement need to be linked closely; the consequence and the act must be clearly tied. Since cameras produce automatic enforcement, when drivers receive fines or notification of demerit points some considerable time after they have committed the violation, this presents a problem. The link between committing the violation and being made aware of it and/or the consequence is weakened by the length of time between them. Drivers need to know that they have been caught as close as possible to committing the offence. Information available from red camera sites can provide this in the form of camera flashes or feedback to drivers from mobile camera units.

Evaluations of mobile cameras also clearly show they are effective for reducing speed and crash outcomes. The results similarly show some variation between the different studies. Again there are a number of factors that make the comparisons between studies difficult and possibly why there is such large variation.

The same issue exists for this camera type as for fixed cameras in terms of timeliness of issuing the infringement notice and demerit points in relation to the time the violation was committed. Evaluations of this camera type (and for the fixed camera type) likely have not considered this factor in any analysis. A related issue is the extent to which drivers are even aware that they have been detected violating speed limits. The question is whether drivers should be warned they are about to pass a mobile camera or whether no warning should be provided. For example in Victoria, the policy for mobile cameras is that they remain covert. In Victoria the flash of a camera has been removed, and as a result the link between committing the violation and its consequence is significantly weakened. If drivers are not warned that there are cameras in a particular location or even in a general location, the arrival of an infringement notice may be the first time they learn about it. The strategy behind this approach is to impart to the driver the notion that they can be photographed 'any time anywhere' if they are found to exceed the speed limit. Aeron Thomas (2005) noted that the strongest evidence came from a study that had signs at the entrance to the monitored area but not at the camera site itself. It is assumed that making the cameras covert motives the behavioural change in drivers to travel at the speed limit everywhere however the validity of this assumption has not been demonstrated adequately to date.

An associated issue with a weak association between the unsafe act and the consequence is its effect on driver attitudes. Speed enforcement is generally supported by the community, at least in principle, but this support is tempered by a view, unfortunately shared by more than half of the community that speed enforcement is revenue raising (Austroads, 2013). Clearly the belief that speed enforcement does not have a road safety objective is likely to be a significant impediment to drivers complying with speed limits.

This issue that drivers perceive that speed enforcement does not have a road safety objective, is discussed in a paper by Belin et al (2010). They compare speed camera programs in Sweden and Victoria. They state that the "*approach adopted in Victoria is based on the concept that speeding is a deliberate offence in which a rational individual wants to drive as fast as possible and is prepared to calculate the costs and benefits of* their *behaviour. Therefore, the underlying aim of the intervention is to increase the perceived cost of committing an offence whilst at the same time decrease the perceived benefits, so that the former outweigh the latter. The Swedish approach, on the other hand, appears to be based on a belief that road safety is an important priority for the road users and one of the reasons to why road users drive too fast is lack of information and social support."* The Swedish approach is to assist the driver with making a safe speed choice and thus bring about a general cultural behavioural change. On the other hand, in Victoria the system is punitive and treats the offending driver as intentionally carrying out a criminal act. In Sweden however, it is accepted that drivers need to be assisted with making the right speed choice. The approach is engineering based where the choice in what system is used to achieve a particular road safety target can be either through the use of speed cameras or through upgrading the road system.

The relative benefits of the Victorian or Swedish approaches are still to be formally evaluated. There is evidence, however, that the covert approach adopted by Victoria resulted in significant proportions of drivers believing that camera technology was being used for revenue raising (Smith and Senserrick, 2004) and the approach also involves a weak link between the unsafe behaviour that we wish to change (speeding) and the punishment that is intended to change that behaviour. There is evidence that the Victorian approach has produced some benefits of reduced speeding and crashes (Cameron et al, 2003). However, it is unclear what aspects of the approach produced these effects given that it included covert cameras, greater enforcement, increase media and lower speed limits. It is likely, however, that the benefits could be greater if elements of the Swedish approach were included. For example, the underlying premise of the Victorian approach that drivers make deliberate decisions to speed so making them believe that they must always drive slower than the speed limit as they could be caught anywhere and anytime has not been rigorously evaluated. Exceeding the speed limit can occur when drivers are not focussing on their speed due to other activities including driving-related activities. This means that drivers can inadvertently exceed the speed limit even when they did not intend to do so. Current statistics on speed camera infringements in Victoria show that only a smaller percentage of all drivers (around 30%) are caught speeding by speed cameras, but this corresponds to over one million drivers each year. If only a proportion of these drivers, e.g. half did not intend to speed, this may have an impact on community attitudes to speed cameras, which is likely to be negative particularly if they were not immediately aware that they had actually committed the infringement.

Delaney et al (2005) highlight the various controversies which they suggest need to be considered in any speed camera enforcement program. The examples they listed are that speed cameras are seen by some as: revenue raising; unfair in that they do not identify offenders on the spot; not timely in terms of issuing the infringement notices; placed in locations where speed is perceived to be safe because it is felt that the speed limits are too low; lack reliability in terms of instrument measurement; not addressing road safety, i.e. speeding may not be perceived as a road safety problem; intruding into the Privacy of individuals, i.e. big brother is watching. They noted in the case of Victoria: '*Public opinion surveys conducted in Victoria identified the controversies associated with camera use. In the initial years few controversial issues arose, thought to be a result of carefully planned strategies of camera implementation. These strategies included independent technical testing and quality assurance of equipment and procedures, identification of safety (not revenue) as the primary objective, winning public support even though the level of fines was high, and subjecting the program to independent evaluation research to establish its road safety potential.'* Nevertheless, they found that despite Victoria deploying covert cameras across the road network without warning signs, and taking an aggressive approach of reducing the speeding threshold tolerance to 3 km/h, the camera program was widely supported by the public. They advised that any jurisdiction planning to introduce a speed camera program should at a minimum: *'involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important. Finally, it is essential that the equipment and operating procedures used are reliable.'*

The evaluation of the point-to-point cameras in Italy by Montella et al (2012) also clearly show they are effective for reducing speed in the location where the camera system is installed. However, compared to other speed enforcement approaches, point-to-point systems are relatively expensive (Austroads 2012). Nevertheless the cost-benefit ratios appear high and compliance extends over longer distances. A four year evaluation of speed cameras of all types in Britain (Austroads 2012), showed that all types of cameras produced reductions in speeds at the camera site. In all, fixed cameras produced the greatest reductions, followed by point-to-point cameras and mobile speed cameras. However, it should be noted that fixed cameras also produce their effects over the shortest distances.

4.2 Review of community attitudes to speeding

The introduction of mobile and red light cameras occurred fairly close in time: 1999 and 2000. This means that individual effects of each camera are likely to be difficult to disentangle. Nevertheless, a number of changes were found that were associated with the introduction of safety cameras in the ACT. First, initial introduction of mobile and red light cameras was associated with increased perception that enforcement had increased so ACT residents noticed the additional enforcement. Aligned with this finding was the increased reporting of being booked for speeding over the last two years in the two years following the introduction of mobile and red light cameras, although this effect trended down between 2006 and 2008. Furthermore, more

ACT respondents reported decreasing their own driving speed in the period following the introduction of mobile and red light cameras. Combined, these findings suggest that the initial implementation of the safety camera programme with mobile and red light cameras may have influenced the amount and impact of speed enforcement and even had effects on driver behaviour through reducing their driving speed. The data shows that around this time serious injury crashes dramatically fell by around 40% from around mid-2002 and was maintained until 2004 after which the trend began to steadily rise.

The introduction of fixed cameras in 2007 was not associated with increased perception of increased enforcement, even though more respondents reported being booked for speeding over the past two years and six months in 2009 and 2011 following the introduction of fixed cameras. Alternatively, the lack of reported change in perception of enforcement may reflect an insensitivity of the question (lack of detailed questioning) which has only a few available responses compared with the question on being booked. In addition, the personal experience of being booked is memorable whereas the amount of enforcement years earlier may not be.

Interestingly, there was a relationship between increased reporting of being booked for speeding between 2002 and 2005 and a clear drop in the percentage of ACT respondents who supported no tolerance for speeding in 60 and 100kph zones, especially after 2002. It may be that the more widespread experience of being booked made ACT respondents review their attitude to speed limits so fewer supported a tougher 'no tolerance' approach.

Many attitudes to speeding in the ACT seem to have changed little since 1995, although there are a few exceptions. Since the introduction of safety cameras, far fewer ACT respondents agree with the idea of safe speeding. Similarly, support for increasing levels of enforcement and even severity of penalties has increased or at least stayed the same following introduction of safety cameras. The initial introduction of safety cameras in the ACT was also associated with a marked increase in support for lowering residential speed limits. While there may not have been a direct causal relationship between the effect of safety cameras and views in the ACT about speed limits, the presence of cameras clearly did not have a significant influence on attitudes about speed limits as in 2003 over 90 percent of respondents supported lower speeds.

On the other hand, around half of respondents in the ACT agree with the view that speeding fines are for revenue raising. Unfortunately, support for this view increased in the two years immediately following the introduction of fixed cameras. Although this effect dropped in the most recent survey, to the same levels as before the introduction of fixed cameras.

These findings suggest some clear targets for further consideration in order to enhance community support for speed management in the ACT. There seem to have been some very clear benefits for community perceptions and attitudes from the first introduction of safety cameras in the ACT. People noticed their effect and at least reported reducing their driving speed but they maintained support for establishing lower speed limits, increased enforcement and stricter penalties for speeding. Factors that challenge these encouraging findings include the suggestion from this research that being booked may have an effect of reducing support for stricter enforcement of limits and potentially general support for speed management. Also, the commonly held view that speeding fines are revenue-raising is clearly not supportive of programmes that include speeding fines. Further understanding is needed of both of these factors, in order to encourage more supportive community attitudes towards speed management programmes in general.

This analysis of changes in community attitudes also suggests that the implementation of fixed cameras may not have been as successful as the introduction of the mobile and red light cameras. It is possible that the difference is related to a general reduction in effectiveness of the whole safety camera programme, since a number of other studies have demonstrated that most benefits of camera programmes occur immediately after implementation. Even so, the introduction of fixed cameras did not produce the same initial changes in enforcement perception, and self-reported speed behaviour as the mobile and red light cameras. Furthermore, fixed cameras were associated with a temporary increase in community perceptions of the revenue-raising nature of speeding fines. Based on these patterns of community attitude change, it would be worthwhile to review communications strategies that articulate the rationale for speed cameras and how they are being used, and also simultaneously review the operation of fixed cameras in the ACT in order to determine whether there are specific aspects of their operation that may have had negative effects on community support for the safety camera programme.

4.3 Speed survey and road crash data study

The infringements data indicate that the rate of fixed camera infringements (per vehicle checked) has been very low, where after the first year the rate remained below 0.2%. The rate of mobile camera infringements decreased consistently for approximately three years following the introduction of cameras in late 1999. After approximately late 2002, the rate of mobile camera infringements levelled off to a long-term rate of around 0.6%. Several issues may have been influencing these rates, including; drivers were not infringed at the same rate, drivers may not have been communicated to via various media outlets adequately and consistently that their speeding could result in a ticket, location of the camera, and the tolerance levels used by the cameras (i.e. the speed above the speed limit at which an infringement is issued – however camera tolerance levels are not publicly available information). During this approximately three year period of reducing infringement rates, vehicle speeds were also reducing. This indicates that drivers were getting used to the cameras and adjusting their behaviour in response to their changed expectations about the presence of cameras and/or their expectations about the consequences of speeding.

However, following 2004, mean vehicle speeds began increasing back to the same levels when cameras were first introduced. Maybe this was because initially drivers were concerned that they would be caught speeding so slowed down. Possibly when they found that they were not being caught very much or at all, or they found the penalty was not severe, or drivers have learnt how to speed and yet avoid detection, their speed started to return to customary levels. In other words, the reduced effects of the cameras may relate to the perception that there is still a low probability of detection (thus reduced general deterrence), that enforcement tolerances mean drivers can still speed without being caught (thus again, reducing general deterrence), and that the penalties for speeding are not sufficient to create clear specific deterrence. Finally, with more awareness, drivers may come to believe that they are able to detect speed cameras ahead and so slow and avoid detection while still being able to speed at other times. Alternatively, it could be other factors like initial bursts of enforcement and the relevant new publicity, which were not able to sustain mean speed reduction over longer periods. Evaluation of these possible accounts through further research is recommended. Moreover, it is recommend that the ACT examine how to make all aspect of mobile cameras less predictable in terms of location, time and vehicle used, and whether this is effective in reducing speeds and hence serious injury crashes.

It is notable that vehicle mean speeds on control streets decreased substantially immediately prior to the introduction of cameras in late 1999, which indicates that the publicity about their presence and likely effects was possibly having the desired effect of getting drivers to slow down. The introduction of cameras possibly increased the perception that drivers were likely to be caught if they exceeded the speed limit because cameras will photograph all who infringe. The effect will of course diminish when drivers find that this is not actually the case. It could be expected that speeds decrease where cameras are first introduced (and as above, even before) due to the community expectations about their effects. But then it would be expected for drivers mean speed to return to levels previous to their mention and introduction on control streets, because there are no cameras, but on camera streets the speeds would be expected to reduce as a result of the cameras photographing infringing drivers who are speeding and a ticket being issued. This effect was found initially for case streets although the effect dissipated over time.

The longer term mean and 85th percentile speed data indicated that vehicle speeds on control streets remained relatively constant, indeed annual trends remained below 1% for the full period from 1999 to 2012. These results indicate that mobile speed camera operations likely had minimal effect on speeds on streets in which cameras were not introduced.

Meanwhile, case streets saw an increase in speeds followed by a decrease in speeds before and after Intervention 2, indicating that after increases in speeds, speeds levelled off and decreased slightly with long-term mobile camera operations. Changes that occurred around Intervention 2 were small in magnitude and insignificant, indicating little effect on speeds from the drop in mobile camera operations that occurred at this time. As noted in the discussion of the literature review, many studies have shown that the effect of cameras on mean speeds is typically small in magnitude. Nevertheless, these small values can have a significant effect on casualty crashes as demonstrated in Figure 2 by Nilsson (2004). With a very small percentage of people speeding (which is known from the infringement rates), the mean speed will not decrease much but will actually reflect a significant effect on the number of speeding drivers.

It is noted that prior to the introduction of mobile cameras, speeds in case streets were higher than those in control streets. This is likely related to the fact that streets with known speed problems and/or speed-related crash problems were targeted for mobile camera operations. The drop in speeds on camera streets could be related to RTM and, as a consequence may overestimate camera effects when comparing pre and post camera introduction. However, the opposite effect might be expected due to spillover since control streets will have also been influenced by the general community awareness of cameras, which is likely to have an effect of underestimating camera effects if differences between camera and control sites is looked at.

Serious injury crashes (injury or fatality) generally decreased on streets following the introduction of mobile cameras although there was a continuing smaller trend that was evident for the five years prior to their introduction. There was a large drop in mid-2002, i.e. around two and half years after the introduction of cameras. Careful inspection of the both the number of mobile operations and serious injury crashes shows an alignment of the sudden fall of serious injury crashes with the camera operation rise over a 12 month period from around 400 to around 600 (30% increase). Fatal crashes also appeared to generally decrease after the introduction of cameras commencing around 2001. This appears to align with the period when casualty crashes started to drop. Further analysis of the nature of the serious crashes would be helpful in understanding the circumstances surrounding this sudden fall in mid-2002. Additionally, it appears the trends in serious crashes do not align well with trends in vehicle speeds. While speeds increased slightly from 2004 to 2007, they then decreased slightly until present, meanwhile serious crash counts increased steadily albeit interspersed with sudden oscillations of large increases and large decreases. Further analysis of the nature of crashes would be useful to attempt to understand these changes. If the causes of crashes varied across the study period, it may be possible to understand whether speed indeed played a role consistently across the period and whether speed cameras were likely the likely source of the casualty crashes.

Nevertheless, this two-fold increase (normalised to vehicle registrations) in serious crashes over the most recent ten years is a major road safety concern for the ACT. It was noted earlier that during the period 2004–2013, the total ACT vehicle fleet increased 25% while from 2006 to 2011 transport modelling suggests there was an increase of 7% in the total number of car trips during the morning peak period and previous modelling of car trips from 2001 shows a 13.5 % increase during the morning peak over a ten year period. Whilst the serious crashes were normalised to vehicle registrations, the road network may not have changed significantly. In other words, vehicle density is likely rising and as a result traffic conflicts have risen. This increase in exposure may be having a non-linear effect on injury outcomes resulting from crashes that is not clear until further research is carried out into the nature and severity of the injuries sustained by casualties.

Further research is recommended to understand these changes in injury crashes, and develop countermeasures and prevention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties. It is possible that changes in police-reported injury crash rates might be related to changes in how police identify individuals as ‘injured’, thus linkage to hospital records provides a more accurate assessment of crash casualties (and allows assessments of individual injuries and injury severity).

Considering all road crashes (property damage, minor injury, serious injury or fatality), before and after the introduction of cameras there was a relatively consistent decreasing trend in all crash counts for both streets with and without mobile cameras. Increases in crashes around the time of the introduction of cameras were evident on both streets with and without mobile cameras, and were more pronounced on streets with cameras, likely because this was the basis for choosing camera streets. It is noted that the magnitudes of crash counts were substantially higher for the case streets compared with the control streets (by an average of 5.4 times), which is likely a result of the fact that mobile camera operations were more likely to be located on streets with high crash counts and/or traffic volumes. It could be argued that both of these effects may be at least partly due to RTM.

The results of the analyses of all intersection crashes (property damage, injury or fatality) indicated that the introduction of fixed red light and speed cameras increased the frequency of crashes followed by a decline to a level slightly lower than baseline levels, while serious intersection crashes decreased slightly along with non-rear-end crashes/right angle collision/right turn crashes. This initial increase in intersection crashes resulted directly from an increase in rear-end crashes at intersections where the cameras were installed but then declined to baseline levels. This trend that did not occur at intersections where fixed cameras were not installed, i.e. rear end crashes continued to rise on control streets. As noted in the literature review, many studies have noted a similar result (Erke 2009, Hoyos 2013, Vanlaar et al 2014, Pulugurtha and Otturu 2014). It is clear that the road safety benefit is confounded, because it is more crashes in the initial stages of camera installation albeit in this study the crashes reduced to levels slightly below baseline levels. Some authors have argued that road safety might tolerate a trade-off of reducing serious speed-related side-impact crashes for increased lower severity rear-end crashes (Kloeden et al 2009). However, this needs to be further researched.

4.4 Evaluation scope and detailed requirements

Appendix E details the evaluation scope and detailed statement of requirements. They are as follows:

The evaluation is to assess the impact of the ACT's Road Safety Camera Program, which includes mobile, fixed mid-block, point to point and red light/speed cameras, on the road safety objectives of:

(a) reducing crashes;

(b) reducing speeding (and thereby reducing crash risk).

Part (a) is presented in Sections 3.6 to 3.10 and Part (b) is presented in Section 3.4. Discussions concerning Parts (a) and (b) are presented in Section 4.3. Conclusions regarding the reduction of speeds and crashes are presented in the Executive Summary under the header 'Results' and in Section 6.

The evaluation is to utilise:

(c) available ACT data, including crash data, speed surveys, and infringement data;

(d) relevant research and findings of other jurisdictions' evaluations of the effectiveness of road safety cameras and road safety camera programs; and

(e) any other relevant data, studies, evaluations or information.

Part (c) is addressed in the Executive Summary under the header 'Methods' and Section 2.3 (Speed survey and road crash data) and hence subsections 2.3.1 to 2.3.5.

Parts (d) and (e) is addressed in Section 1.2, Section 2.1, Section 3.1 which includes subsections 3.1.1 to 3.1.5, and Section 4.1.

The evaluation is to, as far as possible, having regard to the available data and information:

(f) assess the impact of the ACT Road Safety Camera Program as a whole;

(g) assess the contribution and impact of the various types of cameras used as part of the ACT Road Safety Camera Program; and

(h) assess the governance arrangements for the ACT Road Safety Camera Program.

Part (f) has been addressed in Section 3.2 including subsections 3.2.1 to 3.2.4, Section 3.3 including subsections 3.4 which considers the community attitudes to speeding and community perceived effects. Sections 4.2 also discuss the overall effects of the ACT Road Safety Camera program both from a community attitude perspective and Section 4.3 discuses the overall effects from the speed survey and road crash data.

Part (g) has been addressed in so far that the effects of mobile cameras on speeds and crashes respectively have been presented in Sections 3.4, 3.5, 3.6, 3.7, and 3.8, and for fixed cameras at intersections in Sections 3.9 and 3.10. Section 4.3 also discusses the effects of the mobile and fixed intersection cameras. Figure 11 also provides information concerning the infringement rates for the two camera types. Summary results for both mobile and fixed camera types are also presented in the Executive summary dot points and conclusions as well as in Section 6.

In regards to the red light cameras, these had to be evaluated as a 'job lot' rather than individually. The main reason is that the before-after analysis require a minimum amount of crash data, otherwise the statistical evaluation is meaningless. Due to the low crash counts, the fixed intersection cameras had to be aggregated. Even when aggregated, serious crash counts were too low to make meaningful interpretations (see Figure 30 and Table 22). When each camera was assessed individually, no conclusions could be drawn from the data.

There was no information that could be extracted concerning the point-to-point cameras. Point-to-point cameras were only recently installed in 2012, thus insufficient data were available to assess these cameras in this study.

Moreover, because a rigorous evaluation methodology was adopted, road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period analysed in Section 2.3 and 3.3, thus the nine mid-block fixed speed camera locations could not be directly assessed in this study. Furthermore, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

Nevertheless, since 2011 mid-block crashes can be located. However, there is insufficient data, essentially two years of data at best. Hence any issues concerning evaluating the effectiveness of safety cameras, in particular, the two factors commonly cited as potential threats to the validity of safety camera evaluations being Regression to the Mean (RTM) and spillover effects, cannot be addressed with such a small amount of data. The impact of the introduction of a camera requires at least several years of data both prior to and after the installation (absolute minimum of 2 years either side) or a large number of crashes at baseline. Since mid-block crash data are only available from 2011, mid-block camera installations prior to 2013 cannot be assessed with a before-after analysis with these data. Table 29 summarises the evaluations.

Camera type	Evaluation details
Mobile cameras	Sections 3.4, 3.5, 3.6, 3.7, and 3.8
Fixed intersection cameras	Sections 3.9 and 3.10 – However crash counts were generally low and data had to be aggregated for this camera type.
Fixed mid-block cameras	Prior to 2011 mid-block crash locations could not be accurately identified, therefore crashes occurring in the vicinity of the mid-block cameras could not be identified. Since mid-block crash data is only available from 2011, mid-block camera installations prior to 2013 cannot be assessed with a before-after analysis with these

	data.
Point-to-point	Only installed in 2012 which does not provide sufficient data for before-after analyses.

Table 29: Details of which cameras could be evaluated and what could not be evaluated.

In regards to Part (h) the various holding agencies and governance arrangements for the ACT Road Safety Camera Program for the data are shown in Table 30. It is important to realise that the effectiveness of the enforcement system must be considered as a whole system. It is essential the planning and coordination of data collection be effective and timely. All data (speed, infringements, and crash data that include injury severity, i.e. hospitalisations, deaths, etc.) needs to flow freely to a single data analysis office staffed by one or two highly skilled biostatisticians, where the various regression analyses and trends can be easily compiled with a standard format that readily feeds into a statistical program and the data models generated and critically assessed as presented in this report. Alternatively data could be outsourced, again though in a standard format readily analysed by a statistical package, every 12 months to a facility similar to TARS. However it is essential that the biostatisticians need to be at a high level of competency and fully articulate is statistical modelling. For example, the team assemble at TARS has Australia's leading researchers in the field.

Data type	Data available	Holding agency
Speed	Speed surveys for suburban streets	Territory and Municipal Services Directorate
Enforcement	Camera infringement data	Justice and Community Safety Directorate
	Police infringement data	ACT Policing / Justice and Community Safety Directorate
Crashes	Reported casualty crashes	Territory and Municipal Services Directorate / ACT Policing
	Reported property crashes	Territory and Municipal Services Directorate

Table 30: Holding agencies for the data available

Timely regular monitoring and evaluation is essential to the success of any enforcement program by decision makers. The output generated from the statistical reports need to be presented and analysed in regular review meetings (possibly every 6 or 12 months) held between the analysts, and the experts and senior staff within the various holding and governance agencies to assess the trends, develop a strategy for the ACT road network and plan enforcement strategies. These high level strategy meetings among the decision makers could be run by Justice and Community Safety Directorate in collaboration with the other stakeholders such as ACT Police and Territory and Municipal Services Directorate. Ideal governance arrangements (most of which are occurring in the ACT, which has relevant committees, data monitoring, sound relevant strategy, and as the commissioning of this report shows, a commitment to evaluation) would include:

1. Regular monitoring and analysis of relevant intermediate and final outcome variables, including:
    a. crashes and casualties involving speeding (though these should be treated as an under-estimate of the problem- see below);

b. Speeding behaviour by drivers (not at speed camera locations as well as at speed camera locations);

c. Attitudes and beliefs, especially in relation to the perceived risk of being caught and enforcement avoidance behaviours;

d. Enforcement rates at cameras, and by police.

2. Close working relationships with relevant partners (especially Police) including informal meetings as well as formal committees;
3. Reporting arrangements for committees and organisations to ensure that concerns are elevated to the appropriate decision making levels of the relevant organisations;
4. Mechanisms for consultation with NGOs and the community as well as for obtaining appropriate support and advocacy for sound road safety management of speed;
5. Resources, capacity, policy, and strategy for evolving enforcement, communications, advertising, speed limit reviews, and legislation, as necessary in response to identified issues and monitoring data;
6. Specific accountabilities and responsibilities (organisations and people) assigned for the above governance functions, with these included in job descriptions and performance contracts.

It essential that a team culture focussed on addressing road casualties via successful safe systems approaches is encouraged. Speed management (to reduce both crash risk and the forces to which people are exposed in the event of a crash) is a core element of safe systems. Strong enforcement combined with good community credible communication providing reasons why it is essential speeds must be reduced has been shown to be highly successful.

As mentioned earlier Delaney et al (2005) highlight a speed camera program should at a minimum: *'involve communicating support-enhancing messages to the public that demonstrate the dangers of high speeds in terms of increased injury risk and increased crash risk. Communications strategies must clearly articulate the rationale for speed cameras and how they are being used. Messages about the likelihood of detection and the associated penalties also are important.'* Enforcement and communication and strong detection go hand in hand and do result in average speed reduction and associated crash reductions as was clearly evident in Figure 24 in around 2002/2003.

The evaluation is to identify:

(i) potential opportunities to gain improved road safety effectiveness from the existing resources of the ACT Road Safety Camera Program;

(j) future opportunities to maximise the road safety effectiveness of the ACT Road Safety Camera Program, in relation to both network resources and governance; and

(k) an appropriate ongoing evaluation framework to support an effective ACT Road Safety Camera Program.

In regards to Part (i), the rising trend in serious injury crashes increased at a greater rate when mobile operations were reduced by around 30% due to resource limitations in late 2006. Hence it is clear operation needs to increase back to the similar levels per 2006. However this needs to be carried out hand in hand with strong communication via various media outlets and timely notices.

Better data gathering on speed surveys that is regular and consistent and allows analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also essential.

Formatting of all data gathered needs to be compatible with the statistical analysis programs (whichever one used) such that little effort is required in converting the collected data.

Strategy meetings between analysts and decision makers need to be held and a camera strategy that is effective for the entire road network needs to be developed and maintain with adequate resources. It is important a network approach in terms strategic placement of the mobile operations and fixed cameras and operation of the point-to-point cameras throughout the road network is considered.

Appropriate staffing and financial resources to support that scheme are essential, i.e. highly skilled data analysts that can communicate results to decision makers, sufficiently resourced enforcement agencies for increased mobile operations, sufficient resources for timely processing of infringement notices, and sufficient financial resources for community communication and media advertising with an appropriate communication strategy that takes the community along with the increased enforcement program that demonstrates obvious safety benefits.

It is also strongly recommended that further research on injury crashes during this period is performed, i.e. a linked data analysis between crashes and hospitalisations in order to understand the causes for these changes, and identify priority areas and possible intervention strategies. This could include a detailed study of police-reported road crash records for this period, and/or data linkage with hospital records to more accurately identify injured individuals and understand the nature and severity of the injuries sustained by casualties, and the details of the people involved (for example, is there a change in the age profile and road user type of crash-involved people?).

In regards to Part (j) mix, density and manner of deployment of various camera types as well a supporting measures to improve effectiveness (e.g. community engagement and timely notification of infringement) is essential. Regular (yearly) strategy plans with all stakeholders needs to be developed based on the feedback from the survey, crash and speed data analysis. Any strategy must include both enforcement and public awareness and that this must be maintained.

A rational basis for fixed camera use that is maintained and again enforced effectively and included in the public awareness campaign is critical. The rational for their placement in the road network is usually based on black spots as this is where they are likely most effective. Other approaches could be also be explored such as using powerful network optimisation analysis programs, for example artificial intelligence that considers harm minimisation.

History (evidence base) has proven time and again that the presence of a mix of safety camera types (fixed, mobile of both overt and covert, and point-to-point) and through active advertising, media coverage, talking, seeing cameras on the roadside, or direct experience of being caught, will change driver behaviour; specifically reducing vehicle speeding which in turn will reduce crashes, higher speed crashes, crash severity and thus injury. It is important to note that promotion and communication and consistent enforcement that are perceived to be wide spread in different forms are a key part of any enforcement program. Returning the number of mobile operations to the same levels prior to 2006 and including point-to-point cameras in the mobile camera programme would be a first step.

It is important that communications and advertising are related to enforcement, not simply to speeding. Experience and evaluations of the greatest successes in road safety via behaviour change have all been achieved through the close association of strong media promotion of enforcement and the enforcement itself. Local examples include the very large media campaigns associated with the introduction of RBT in NSW (Job et al., 1997), and the large campaigns which occurred with the re-introduction of mobile speed cameras in NSW (Job, 2013). The immediate effects of these campaigns, which started at or even before the enforcement started, attest to the key role of the communications in these successes. Many communication messages do not alter behaviour because messages are not aligned and based on the threat of enforcement.

Non-enforcement messages are legitimate for other purposes such as setting the agenda (e.g., gaining community acceptance of stronger enforcement).

Opportunity also exists in working with Police to improve the recording of speeding as a factor in crashes. It is clear that the role of speeding is significantly under-estimated in Police crash recording processes globally. Evidence for this includes:

1. It is understandable that speeding is omitted as a factor when the Police have no way of knowing what caused a cash with no witnesses etc., or the driver swears they were not speeding and the other party involved (a pedestrian) is not alive to tell their side of the story;
2. Estimates of the role of speeding have often been below the benefits in serious crash reduction occurring when speed is better managed (e.g. by speed cameras). Thus the role of speeding must have been under-estimated since the cameras only manage speeding, and not even completely;
3. Many countries and states have data which indicate the patent absurdity that speeding is safe behaviour. For example, some countries report data such as over half of all vehicles are speeding in on-road surveys and only 25% of crashes involve speeding.

If police could be moved from a fairly legalistic approach to crash records to a probabilistic estimate of speed involvement, separately from their approach to legal processes, this may help.

In regards to Part (k), an evaluation program that continues to add data each year to the current data set presented in this report would be essential to the development of a successful camera program strategy that improves on the current status. It is critical for decision makers to receive timely feedback from surveys, speed data and crash data and this should be done in a round table mode so that it promotes a culture of team work, focusing on reducing casualties and receiving valuable input from a number of experienced participants at senior level. The data coming from the different camera types and in particular the mid-block crashes since 2011 and from the point-to-point from 2012 can be streamlined to input directly to a statistical software program and every 6 or 12 months updated. Point-to-point cameras should be included in the mobile camera programme (if possible) and hence in the evaluation analysis.

In terms of evaluating the effectiveness of mobile cameras on mid-block crashes and point-to-point cameras, this cannot realistically be started until around 2016 because of the reasons of RTM and spillover effects.

Better data gathering on speed surveys that is regular and consistent and allows for regular analysis of the number/percentage of drivers exceeding the limit, as well as infringement data and crash data that is clearly defined and followed up for consequence in terms of hospitalisation is also important.

The need to monitor and refine the program according to the data is critical. There is value in assessing when and where speeding is occurring as well as how much is occurring to revise the camera mix. For example if motorists are speeding more at non-enforcement sites than at fixed cameras this indicates the cameras are working as black spot treatments but not for general suppression of speeding. If speeding is more common at mobile camera locations when there is no mobile camera present versus when the camera is there, then this indicates that the mobile cameras are being predicted and thus motorists feel that can speed and slow down for the cameras. This destroys general deterrence. This would suggest the need for more covert operations, and/or the need for less predictable locations for enforcement. Monitoring of attitudes and beliefs can also be informative on these issues. This should also include determining if the penalties are sufficient to deter speeding and the possibility of revising these.

Again appropriate staffing to support these proposed improvements is important.

5. Limitations

It should be noted that trends in mean vehicle speeds may have been influenced by other factors not considered in this study. However, driving speeds are, in the main, a very deliberate action by the vehicle operator, and are likely to be influenced directly by enforcement operations that monitor vehicle speeds and penalise operators when they exceed limits, or indirectly by drivers' perceptions of the operation of cameras and related enforcement. Even inadvertent speeding can be influenced by cameras through creating more care to avoid speeding.

The crash study considered nearly two decades of data, over which time many changes may have occurred in the ACT with regards to roadway infrastructure, roadway design, safety devices, vehicle designs, road user type (cyclist, motorcyclists) and road user behaviours (including speeding, alcohol and drug use, protective device use, etc.) in addition to the introduction of speed cameras. There have also been many road safety initiatives in the ACT addressing particular road user groups and behaviours. These factors may have affected crash frequencies, however were not considered in the present study.

As mentioned in the methodology, it should also be considered that the control streets identified for the analyses do not represent a true 'control area'. The issue of spillover effects in evaluation studies of safety cameras has been discussed at length in the literature (Retting, Ferguson & Hakkert 2003; Aeron-Thomas 2005; Erke 2009; Hoyos 2013; Ko, Geedipally, Walden 2013; Porter, Johnson, Bland 2014; McCartt, Hu 2014; Pulugurtha, Otturu 2014; Vanlaar, Robertson, Marcoux 2014). It is acknowledged that in evaluations such as this study, spillover effects may result in an underestimation of the effects of cameras although they may indicate that the public awareness aspect of the camera introduction has been effective.

Another limitation of the study is that road crashes could not be located to the exact mid-block location with sufficient accuracy for the time period considered, thus the nine mid-block fixed speed camera locations considered could not be directly assessed in this study. Moreover, the streets upon which these cameras were installed also had mobile camera operations, and these streets were selected for the mobile camera analysis. That is, the analysis outcomes for the mobile cameras are possibly being confounded by their location near the fixed cameras.

The speed survey data used in the present study was derived from surveys on particular streets that were undertaken at irregular intervals. As a result, for any given month all speed survey results were averaged (aggregated separately by case and control streets). Thus the monthly speed survey results used in the statistical models were discrete time data, which may limit the specificity and applicability of the results. It is preferable that each street location had continuous data, such that the statistical models could be stratified by location, such as was the case for the monthly crash counts. However, such data were not available for the speed surveys. It is recommended that subsets of streets with and without cameras are identified, and future surveys be performed on these streets in a regular manner (with the period being defined by resource limitations). This would provide more meaningful results in future speed meta-assessments. It is also noted that assessments of several speeding-related indicators could not be assessed in the present study, including proportion of vehicles speeding, proportion more than 20km/h over the speed limit, etc. More detailed information on the speed surveys performed might have provided further insights into driver speeding. These data are stored on an old computer system from which it was not possible to extract bulk data (i.e. for the 1,758 speed surveys assessed in the present study). Consequently, the present study used data from the hard-copy annual speed survey summary publications provided by the ACT Territory and Municipal Services Directorate.

6. Final brief conclusions

Along with the conclusions listed at the front of this report, the following summary conclusions are provided for completeness of the report.

Mobile cameras seem to have been effective initially as seen by reductions in serious crashes in the period 2002-2006 and the pre/post analysis for cases but not for controls. The serious injury crashes increased in case streets following 2006 and seemed to coincide with decreasing and less consistent enforcement which is what would be expected if the cameras were located in the high risk streets compared to controls.

Another possible explanation of the increase in speeds since around 2006 is that drivers learned to avoid mobile speed camera detection. This would explain how there is an increase in speeds without a commensurate increase in infringements. The increase in speeds would explain the increase in serious crashes. Avoidance mechanisms could be based on prediction of location and/or time/ and or/day and/or the vehicles being used, or provision of information from various sources.

Fixed cameras did not seem to be as effective in regards to all crashes as they showed increases on case locations compared to controls which then returned to baseline levels. However, this may have been the result of changes in rear-end crashes which may have been because drivers became aware of where the fixed cameras were. This in turn may have had an effect on rear end crashes mostly. The continuing increase in traffic demand could also have played a role. Nevertheless, there appeared to be a fall in serious injury crashes.

These results suggest that more work needs to be done to understand why serious crashes have increased since 2007 and what can be done to improve the effectiveness of cameras since the initial introduction and the research literature demonstrates that they can be effective. In the ACT it would be beneficial for road safety to develop a more sustained programme of re-implementation and evaluation of safety cameras and road safety public awareness campaigns.

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Appendix A: Case and control streets and intersections

STREETS

CASES	CONTROLS
Anthill St	A'Beckett St
Athllon Drv	Archibald St
Barry Drv	Ballumbir St
Barton Hwy	Boldrewood St
Bateman St	Brigalow St
Beasley St	Canopus Cr
Belconnen Way	Chrisholm St
Canberra Ave	Condamine St
Carruthers St	Cowper St
Chuculba Cr	Culgoa Cct
Clift Cr	Dalrymple St
Clive steele Ave	Davenport St
Darwinia Ter	De Burgh St
David St	Emu Bank
Drakeford Drv	Fincham Cr
Dryandra St	Flemington Rd
Ellerston Ave	Forbes St
Federal Hwy	Foveaux St
Florey Drv	Goodwin St
Gilmore St	Grey St
Ginninderra Drv	Hawdon St
Gladstone St	Hopetoun St
Goyder St	Knox St
Groom St	Krefft St
Gungahlin Drv	Langdon Ave
Heyson St	Mackennal St
Hindmarsh Dr	Macpherson St
Kent St	McCaughey St
Kitchener St	McCulloch St
La perouse St	Melba St
Lady Denman Drv	Miller St
Launceston St	Moore St
Learmonth Drv	Mortimer Lewis
Livingston Ave	Murranji St
Macgregor St	Palmer St
Melrose Drv	Paul Coe Cr
Monaro Hwy	Ratcliffe Cr
Namatjira Drv	Scrivener St
Northbourne Ave	Spalding St
Novar St	Vanisttart Cr
Officer Cr	Verbrugghen St
Petterd St	Victoria St
Phillip Ave	Watson St
Ross smith Cr	Wattle St
Theodore St	William Slim Dr
Tillyard Drv	Windeyer St
Tuggeranong Pkwy	Wisdom St
Williamson St	

INTERSECTIONS

CASES	CONTROLS
Northbourne Ave and London Circuit	Northbourne and Swinden
Northbourne Ave and Barry Drive	Northbourne, Eloura and Gould
Drakeford Drive and Marconi Cres	Drakeford, Sulwood and Tuggeranong
Northbourne Ave and Antill Street	Northbourne, Girrahween and Masson
Ginninderra Drive and Aikman Drive	Ginninderra and Kingsford Smith
Hindmarsh Dr and Tuggeranong Pkwy	Hindmarsh and Monaro
Ginninderra Drive and Coulter Drive	Ginninderra and Lance Hill
Barry Drive and Marcus Clarke Street	Barry and McCaughey
Hindmarsh Drive and Yamba Drive	Hindmarsh and Streeton
Hindmarsh Drive and Ball Street	Hindmarsh and Jerrabomberra
Hindmarsh Drive, Newcastle St and Canberra Ave	Hindmarsh and Larakia
Canberra Ave, Captain Cook Cres and Manuka Circle	Canberra and Dalby
Gungahlin Drive and Gundaroo Drive	Gungahlin and Sanford

Appendix B: Results of literature searches

Table B1: Results of review of peer-reviewed scientific published literature for each search engine

Database	Search Term	# Retrievals	Repeats	Remaining	Final	Search Strategy
Web of Science	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "topic")	7				Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	25				Search in "Topic"
	Red light camera + Enforcement + Evaluation	14				Search in "Topic"
	Speed (search in "title") + Camera (search in "title") + Enforcement (search in "topic")	27				
Subtotal		**73**	**19**	**54**	**51**	
PsycINFO	Speed + Camera + Evaluation	3	22			Search in "Abstract", Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	0				Search in "Abstract"
	Red light camera + Enforcement + Evaluation	1				Search in "Abstract"
	Speed (search in "abstract") + Camera (search in "abstract") + Enforcement (search in "all fields")	16				
Subtotal		**20**	**3**	**17**	**8**	
Scopus	Speed (search in "title") + Camera (search in "title") + Evaluation (search in "abstract")	5	12			Note: this returned many irrelevant papers
	Speed enforcement camera + Evaluation	27				Search in "Article title, abstract, keywords"
	Red light camera + Enforcement + Evaluation	19		The		Search in "Article title, abstract, keywords"
	Speed + Camera + Enforcement	12				Search in "Article title"
Subtotal		**63**	**14**	**49**	**14**	
PAIS International	Speed + Camera + Evaluation	0	49			Search in "Anywhere"
	Speed enforcement camera* + Evaluat*	1				Search in "Anywhere"
	Red light camera + Enforcement + Evaluation	1				Search in "Anywhere"
	Speed + Camera + Enforcement	7				Search in "Anywhere"
Subtotal		**9**	**1**	**8**	**6**	
Final repeats			**49**			
Total		**165**	**86**	**128**	**79**	

Table B2: Australian government road safety authority websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
NSW - Roads & Traffic Authority	1	0	0	1	0	0	0	1
NSW - Transport for NSW - Centre for Road Safety	1	1	1	1	0	0	0	1
VIC - VicRoads	0	0	0	0	0	0	0	0
VIC - Cameras Save Lives	1	0	0	0	0	0	0	0
WA - Department of Transport	0	0	0	0	0	0	0	0
QLD - Department of Transport and Main Roads	1	1	1	1	1	0	0	0
SA - Department of Planning, Transport and Infrastructure	1	1	1	1	1	1	1	0
SA - Government of South Australia	0	0	0	0	0	0	0	0
NT - Northern Territory Transport Group	0	0	0	0	0	0	0	0
TAS - Department of Infrastructure, Energy & Resources - Transport	0	0	0	0	0	0	0	0
AU - Department of Infrastructure and Transport	1	1	0	0	0	0	0	1

Table B3: Individual Road Safety organisation websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
US - National Highway Traffic Safety Administration (NHTSA)	0	0	0	0	0	0	0	0
US - Liberty Mutual Research Institute for Safety	0	0	0	0	0	0	0	0
CA - Transport Canada	1	1	0	0	0	0	0	0
UK - Department for Transport (DfT)	1	1	1	1	1	0	0	1
EU - Eurosafe (European Association for Injury Prevention and Safety Promotion)	0	0	0	0	0	0	0	0
EU - European Agency for Safety and Health at Work	0	0	0	0	0	0	0	0
AU - Australian Transport Safety Bureau (ATSB)	0	0	0	0	0	0	0	0
AU - Austroads	1	1	1	1	1	0	0	1
AU - Roadwise	0	0	0	0	0	0	0	0
AU - Standing Council on Transport and Infrastructure (SCOTI, formerly Australian Transport Council)	1	0	0	1	1	0	0	0
AU - Australian Bureau of Statistics (ABS)	1	0	1	1	0	0	0	0
AU - Australiasian College of Road Safety (ACRS)	1	0	1	1	0	0	0	1
AU - RACV	1	1	1	1	1	0	0	0
AU - Queensland Travelsafe Committee	1	1	1	1	0	0	0	1
AU - NSW Bureau of Crime Statistics	0	0	0	0	0	0	0	0
AU - NRMA	0	0	0	0	0	0	0	0
AU - NRMA - ACT Road Safety Trust	0	0	0	0	0	0	0	0
AU - NSW StaySafe Committee	0	0	0	0	0	0	0	0
AU - NSW Motor Accidents Authority	0	0	0	0	0	0	0	0
AU - Transport Accident Commission (TAC) in Victoria	0	0	0	0	0	0	0	0
AU - The State Attorney-General's Departments	0	0	0	0	0	0	0	0

NZ - Transport Agency	1	1	0	0	1	0	0	1
NZ - Ministry of Transport	0	0	0	0	0	0	0	0
SW – Swedish Transport Administration (Trafikverket)	1	0	1	0	0	0	0	1
Ireland – Road Safety Authority	1	0	1	0	0	0	0	0
The Netherlands – EuroRAP	0	0	0	0	0	0	0	0
France – Institut National De Recherche Sur Les Transports Et Leur Securite (INRETS)	0	0	0	0	0	0	0	0

Table B4: Research centre websites

Organisation	Mention Speed Cameras	Mention Type of Camera						Mention Evaluation/Review
		Red Light	Mobile	Fixed	Point-to-Point	School Zone	Rail Level Crossing	
QLD - Queensland University of Technology - CARRS-Q	1	0	1	1	0	0	0	1
VIC - Monash University - MUARC	1	1	1	0	1	0	0	1
SA - University of Adelaide - Centre for Automotive Safety Research	1	1	0	1	0	0	0	1
NSW - Sydney University - Institute of Transport and Logistics Studies	0	0	0	0	0	0	0	0
NSW - UNSW - TARS	1	1	1	1	0	0	0	1
AU - Australian Road Research Board	1	1		1	0	0	0	0
US - Research and Innovative Technology Administration: National Transportation Library	1	1	1	1	0	1	0	1
US - Transportation Research Board	0	0	0	0	0	0	0	0
US - American Transportation Research Institute	0	0	0	0	0	0	0	0
UK - Transport Research Laboratory	1	1	0	1	0	0	0	1

Appendix C: Results of ACT community attitudes to speeding surveys

"In the last two years, in your opinion, has the amount of speed limit enforcement carried out by police and speed cameras increased, stayed the same, or decreased?"

Year	Increased (%)	Same (%)	Decreased (%)	Don't Know (%)
2011	64	27	5	4
2009	65	26	4	6
2008	63	27	8	2
2006	69	22	4	5
2005	72	21	3	3
2004	71	15	8	7
2003	77	15	5	3
2002	62	22	7	8
2001	74	13	7	5
2000	69	29	7	4
1999	58	30	6	5
1998	56	34	8	2
1997	55	33	7	5
1996	54	26	8	13
1995	59	28	4	9

"Have you personally been booked for speeding in the last two years?"
...and, if so, "Have you personally been booked for speeding in the last six months?"

Year	Last 2 years (%)	Last 6 months (%)
2011	20	9
2009	19	9
2008	15	6
2006	17	6
2005	24	9
2004	21	3
2003	28	8
2002	21	9
2001	17	8
2000	16	4
1999	11	3
1998	13	5
1997	25	11
1996	20	10
1995		9

"Thinking about 60km/h speed zones in urban areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	64	31	64	20
2009	65	34	64	22
2008	64	36	65	21
2006	64	32	64	15
2005	64	33	64	12
2004	65	28	65	13
2003	64.2	33	65.4	10
2002		51	64.9	15
2001		44		
2000		38		
1999		49		
1998		49		
1997		49		
1996		42		
1995		34		

"Thinking about 100km/h speed zones in rural areas, how fast should people be allowed to drive without being booked for speeding?" (i.e. the 'acceptable' speed tolerance) and... "How far over the speed limit are people generally allowed to drive without being booked for speeding?" (perceived 'actual' speed tolerance)"

Year	Acceptable Speed		Actual Speed	
	Median (km/h)	No tolerance (%)	Median (km/h)	No tolerance (%)
2011	106	25	106	21
2009	110	23	107.9	15
2008	105.5	28	108	14
2006	107	18	107	5
2005	109	20	109	7
2004	110	23	109	8
2003	106.8	22	108.7	6
2002		35	109.2	10
2001		26		
2000		25		
1999		28		
1998		36		
1997		23		
1996		27		

Respondents were asked to consider five statements on speed issues and express their level of agreement or disagreement:

- Fines for speeding are mainly intended to raise revenue
- I think it is okay to exceed the speed limit if you are driving safely
- Speed limits are generally set at reasonable levels
- If you increase your driving speed by 10km/h you are significantly more likely to be involved in a car accident
- An accident at 70km/h will be a lot more severe than an accident at 60km/h

Year	Speeding fines mainly intended to raise revenue (%)	OK to speed if driving safely (%)	Speed limits generally reasonable (%)	More likely to be involved in accident if increase speed by 10km/h (%)	Accident at 70m/h more severe than 60km/h (%)	TOTAL: Cautious / Conservative attitude to speeding / speed limit enforcement (%)
2011	51	29	85	62	92	26
2009	59	21	86	73	92	25
2008	55	38	85	65	94	22
2006	50	29	88	71	96	26
2005	51	28	87	67	91	28
2004	51	34	87	66	93	
2003	49	33	86	70	91	
2002	48	34	89	63	95	
2001	51	34	87	71	95	
2000	48	38	85	67	89	
1999	53	39	94	69	89	

"Do you think the amount of speed limit enforcement activity by police and speed cameras should be increased, stay the same, or decreased?" … and then,
"Do you think the penalties for exceeding the speed limits should be more severe, or should they be less severe, or should they stay the same as they are now?"

Year	Level of enforcement			Severity of penalties		
	Should increase (%)	Should decrease (%)	Stay the same (%)	Should increase (%)	Should decrease (%)	Stay the same (%)
2011	44	8	44	27	6	63
2009	46	7	43	24	9	61
2008	45	5	48	23	6	63
2006	37	7	54	23	8	62
2005	37	10	52	20	8	68
2004	47			25		
2003	34			17		

"Do you think that 50km/h in residential area is too low or too high, or about right?" and
"Do you think that limits below 60km/h should be set on more streets, fewer streets, or is it about right as is?"

Year	50km/h speed limit in residential areas are:			Speed limits below 60km/h should be set on:		
	Too low (%)	Too high (%)	About right (%)	Increase the number of <60km/h streets	Decrease the number of <60km/h streets	About right
2009	13	7	80	20	6	74
2008	11	4	86	20	7	73
2006	20	3	77	16	18	66
2005	20	2	78	22	13	65
2004	20	<1	80	24	19	57

"Some road safety authorities believe that the speed limit in residential areas should be lowered from 60km/h to 50 or 40km/h. This would only apply to local streets and minor roads, not arterial roads or highways"

They were then asked: "how would you feel about a decision to lower the speed limit in residential areas to 50km/h?"

Year	Approve strongly (%)	Approve somewhat (%)	Total approve (%)	Not care either way (%)	Disapprove somewhat (%)	Disapprove strongly (%)	Don't Know (%)
2003			91				
2002	42	34	77	4	10	10	0
2001	45	27	72	6	15	6	1
2000	28	27	55	8	13	22	1
1999	27	33	60	4	15	20	2
1998	39	18	58	13	12	18	0
1997	17	24	41	13	26	20	1
1996	38	20	58	3	19	20	0
1995	17	28	45	9	26	18	2

"How often do you drive at 10km/h or more over the speed limit?"

Year	%
2011	5
2009	11
2008	5
2006	9
2005	8
2004	9

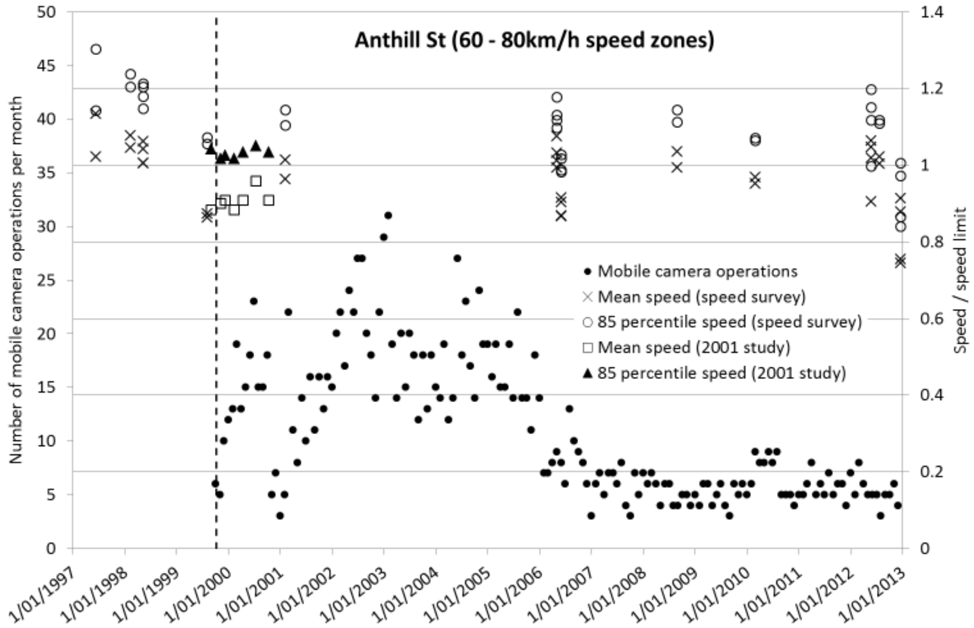
"In the last 2 years has your driving speed generally increased, stayed the same, or decreased?"

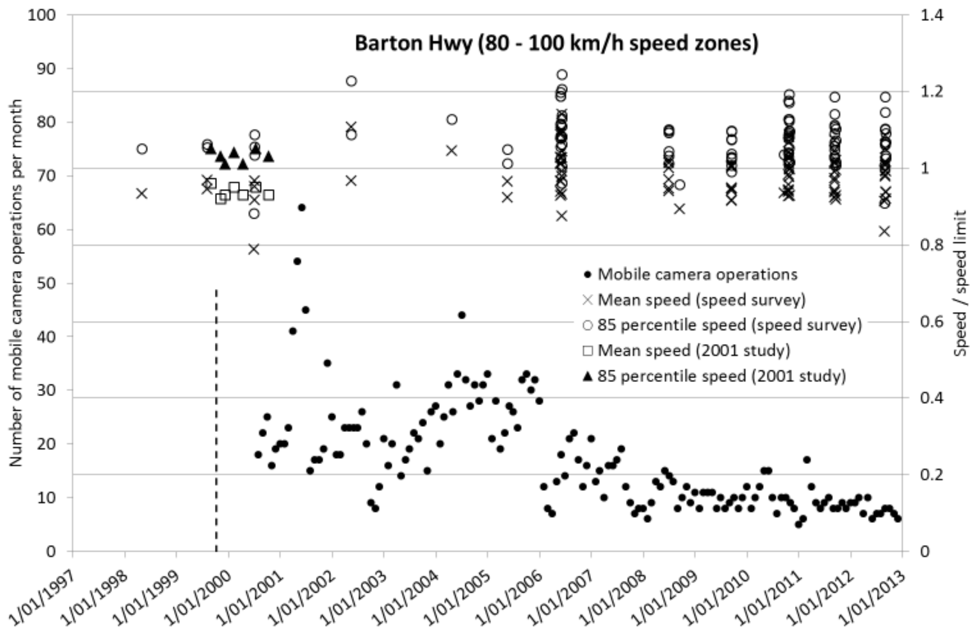
Year	Increased (%)	Stayed the same (%)	Decreased (%)
2011	1	76	23
2009	4	73	23
2008	4	73	23
2006	7	68	25
2005	2	69	29
2004	5	65	28
2003	6	67	25
2002	5	66	28
2001	5	62	32
2000	4	61	33
1999	6	70	21
1998	4	73	23
1997	6	62	32
1996	7	52	41
1995	11	62	26

Appendix D: Individual speed survey results for case and control streets

This appendix contains plots for most of the case and control street locations used in this study (a few streets were excluded due to plotting issues). The available speed surveys provided by the Territory and Municipal Services Directorate are plotted for all streets, where mean and 85th percentile speeds are normalised to the speed zone in which the survey was undertaken (in some cases surveys were undertaken on sections of the same street with different speed limits). Additional speed surveys undertaken by ARRB in the 18 months following the introduction of cameras in October 1999 are also plotted where available (Edgar, A., 2001. Evaluation of the Effectiveness of Speed Cameras in the ACT, Final Report 1. NRMA-ACT Trust Project Evaluation Reports, ARRB Transport Research). The start date of October 1999 is identified on all plots. For case streets the number of mobile operations undertaken per month along that particular street are also plotted.

CASE STREETS




Barton Hwy (80 - 100 km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
100
90
80
70
60
50
40
30
20
10
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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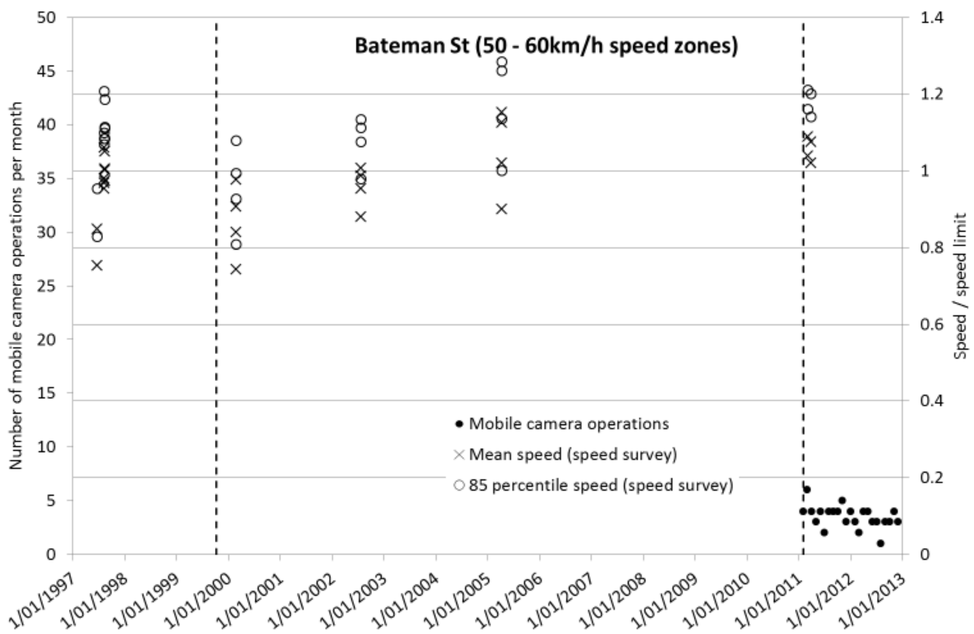
1/01/2012
1/01/2013


Bateman St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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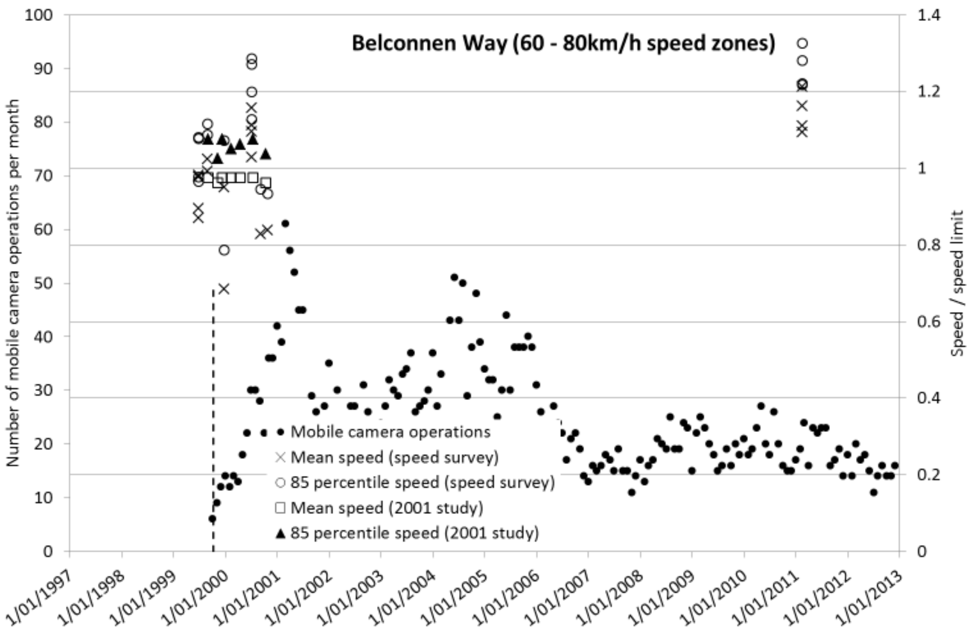
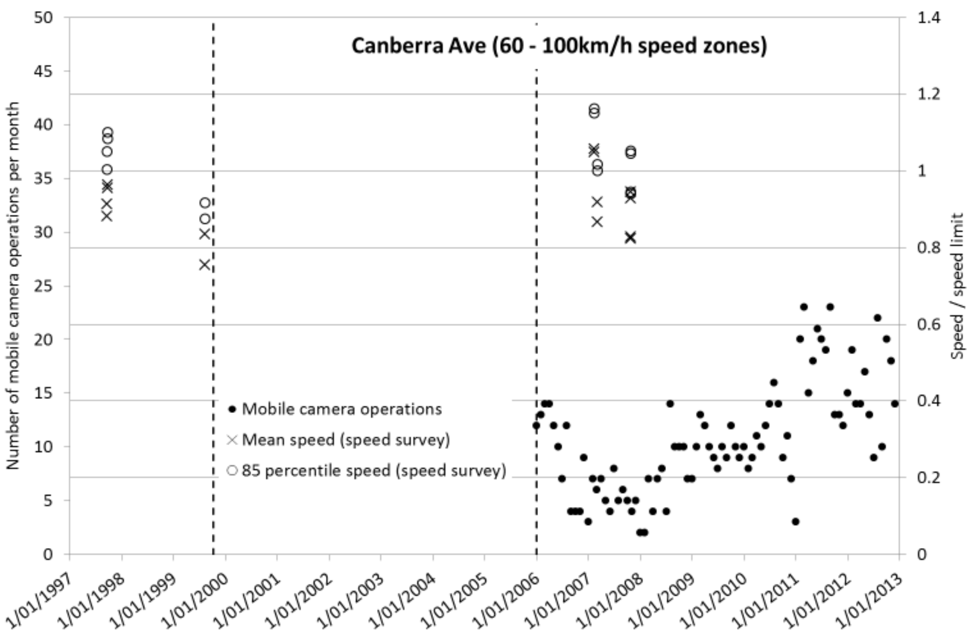
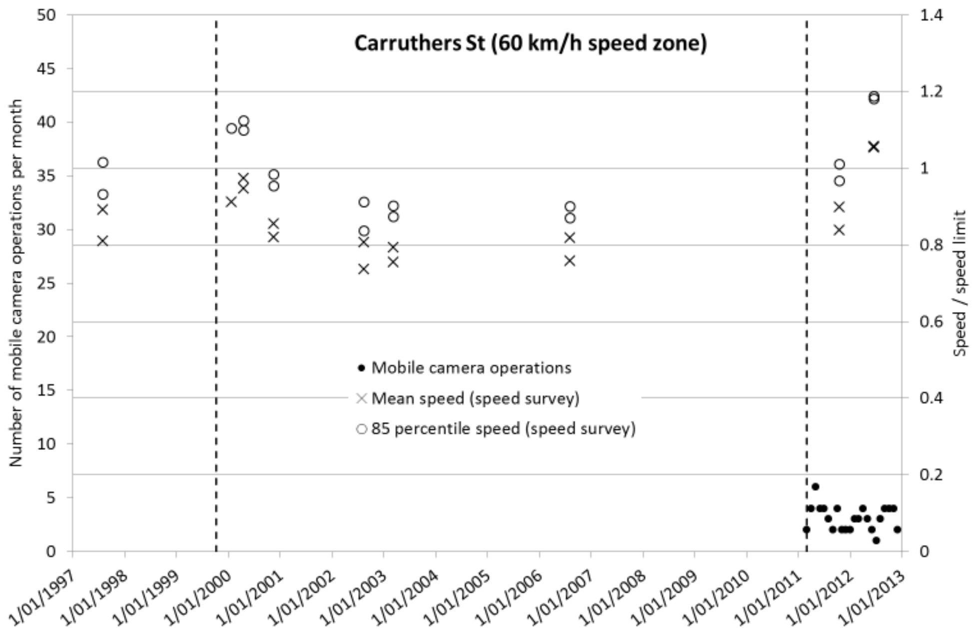
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



Belconnen Way (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)



Canberra Ave (60 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)


Carruthers St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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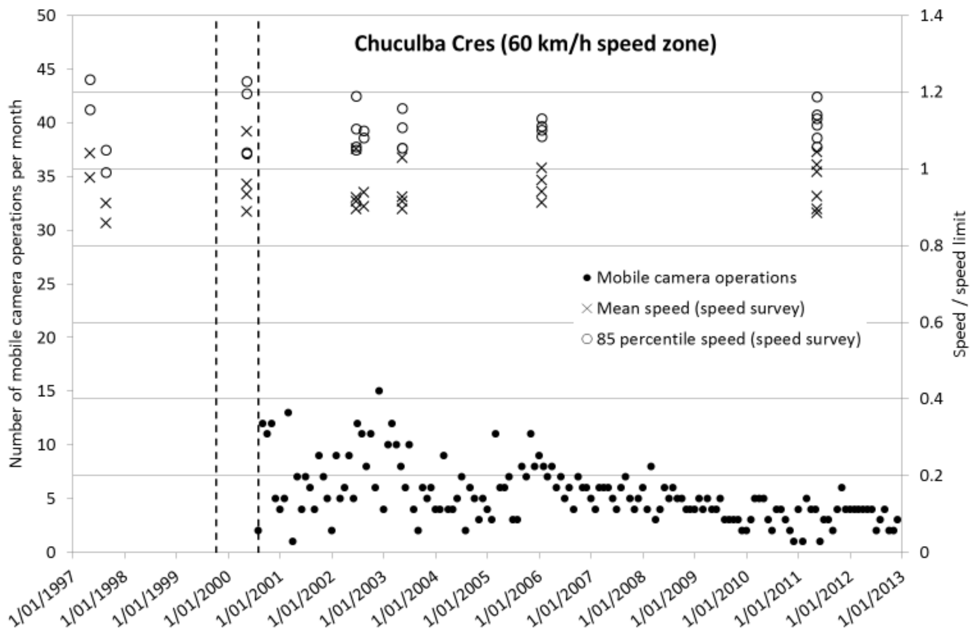
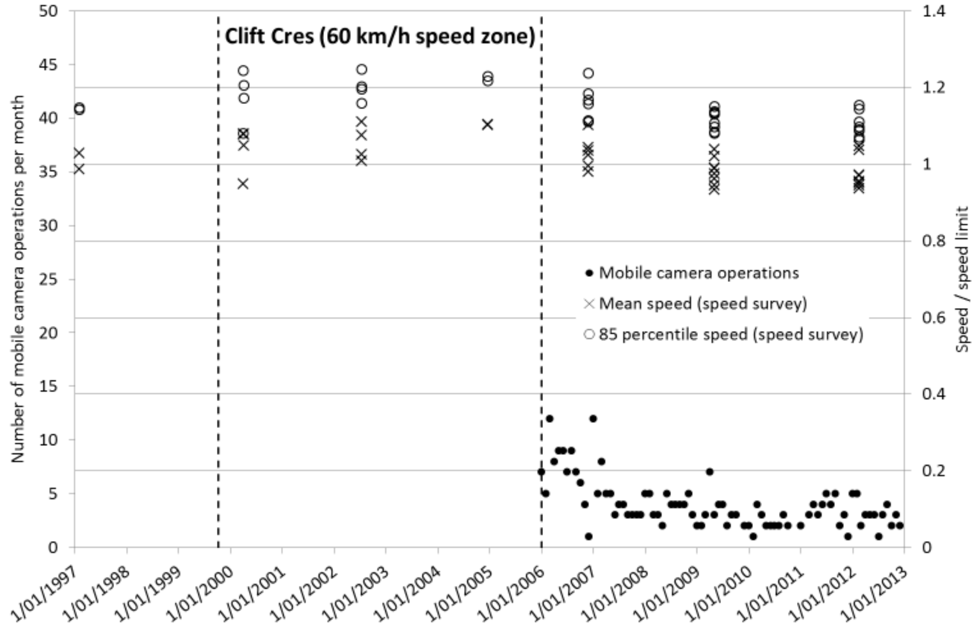
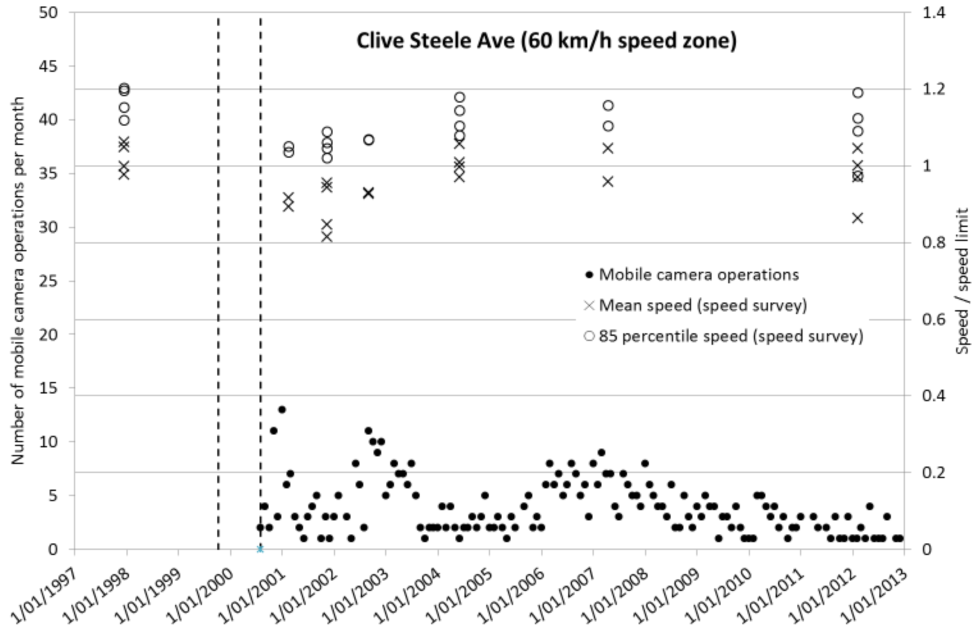
1/01/2012
1/01/2013


Chuculba Cres (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Clift Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Clive Steele Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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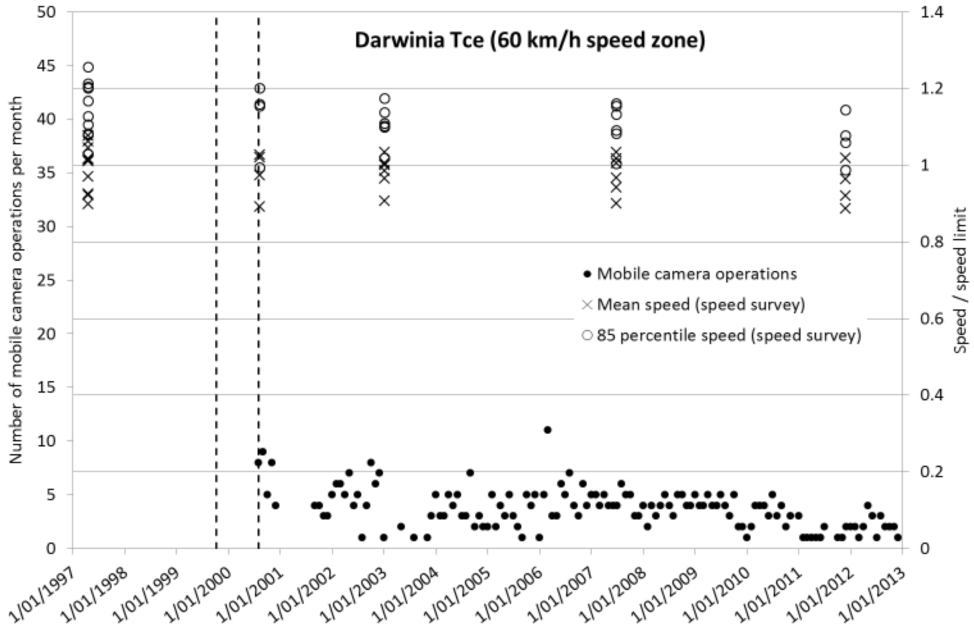
1/01/2011
1/01/2012
1/01/2013


Darwinia Tce (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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1/01/2008
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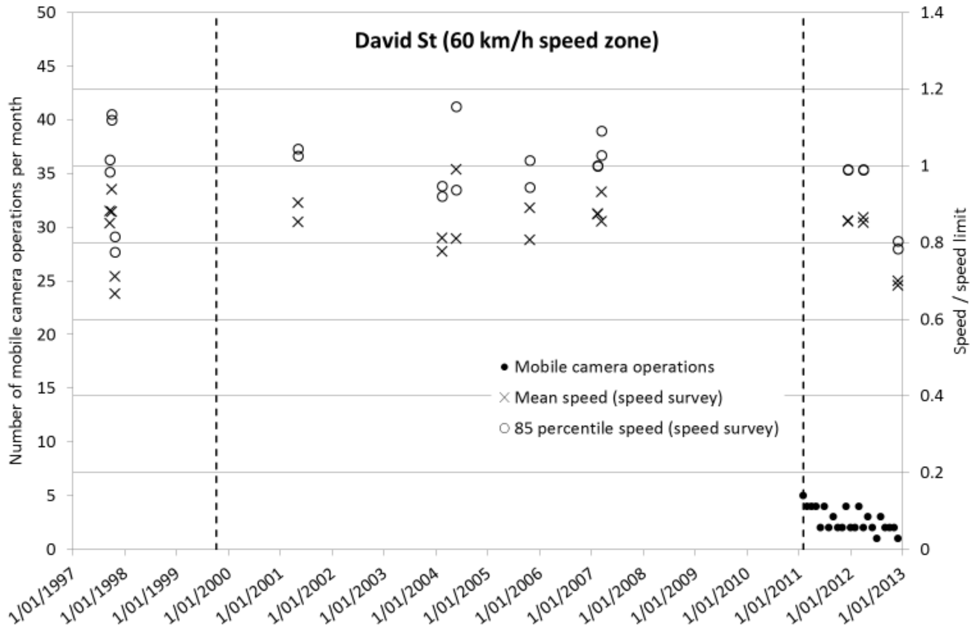
1/01/2010
1/01/2011
1/01/2012
1/01/2013


David St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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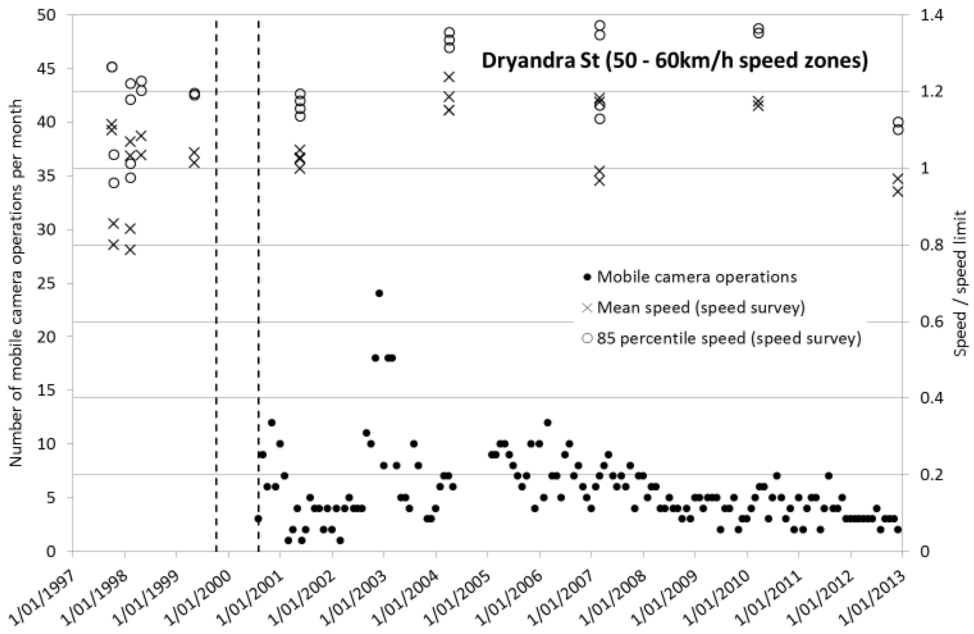
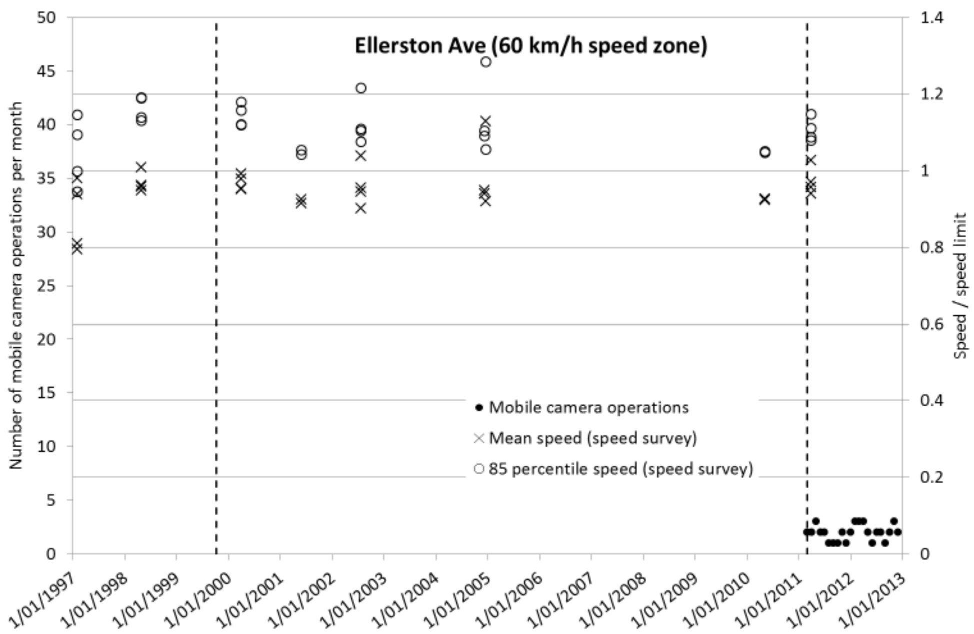
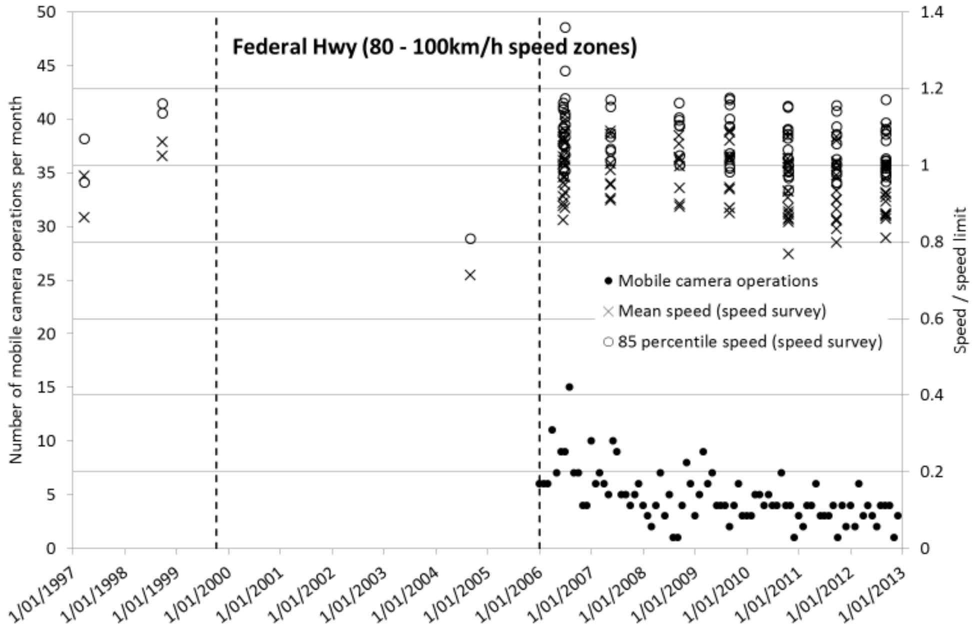
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Dryandra St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit


Ellerston Ave (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit


Federal Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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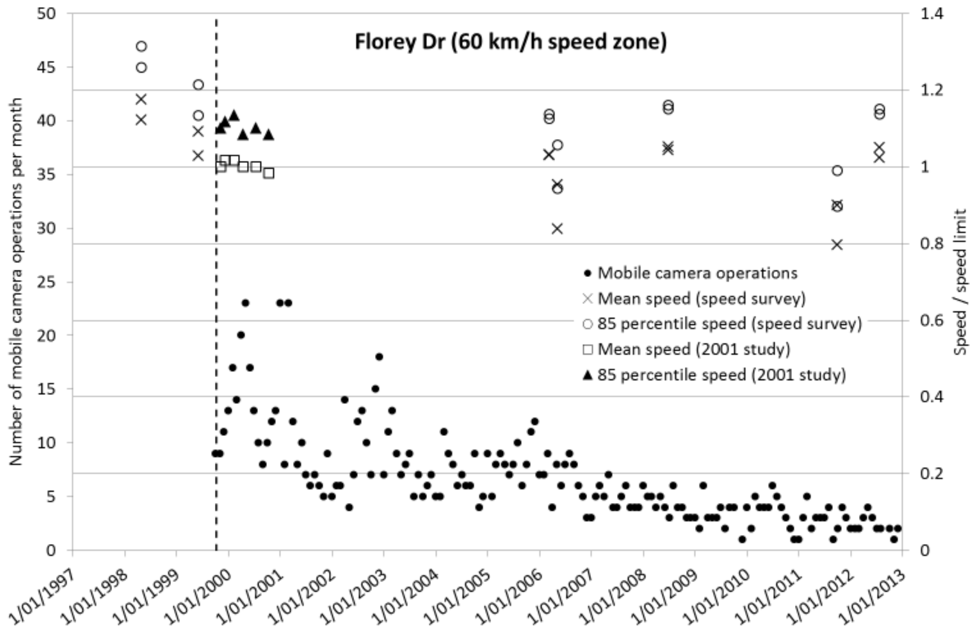
1/01/2011
1/01/2012
1/01/2013


Florey Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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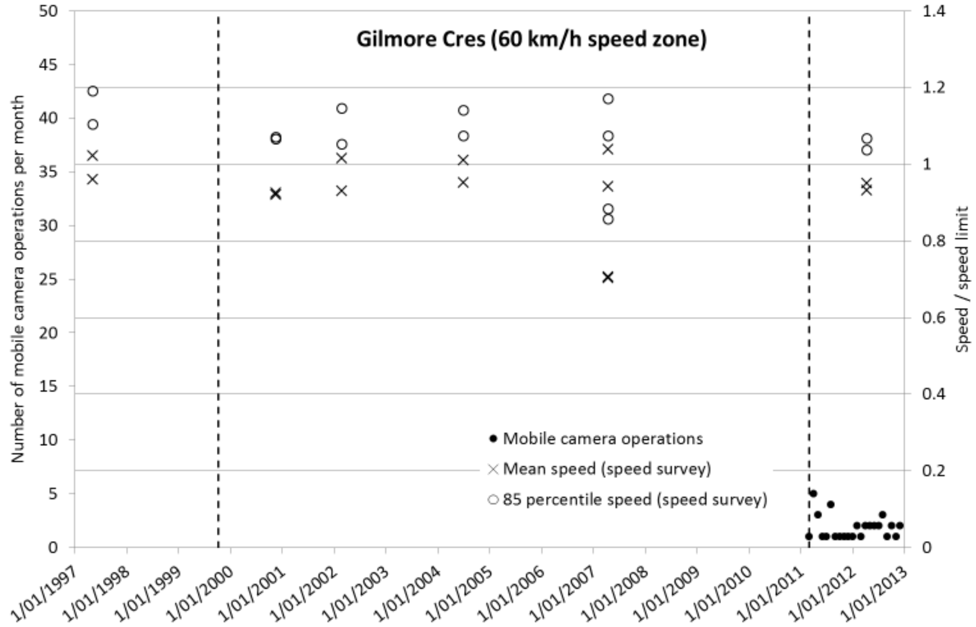
1/01/2012
1/01/2013


Gilmore Cres (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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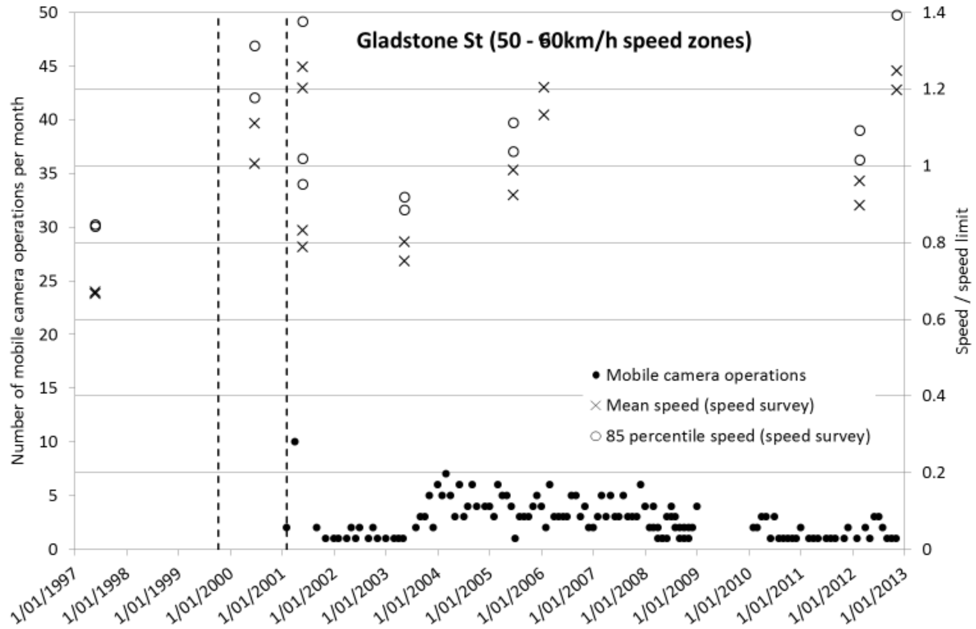
1/01/2012
1/01/2013


Gladstone St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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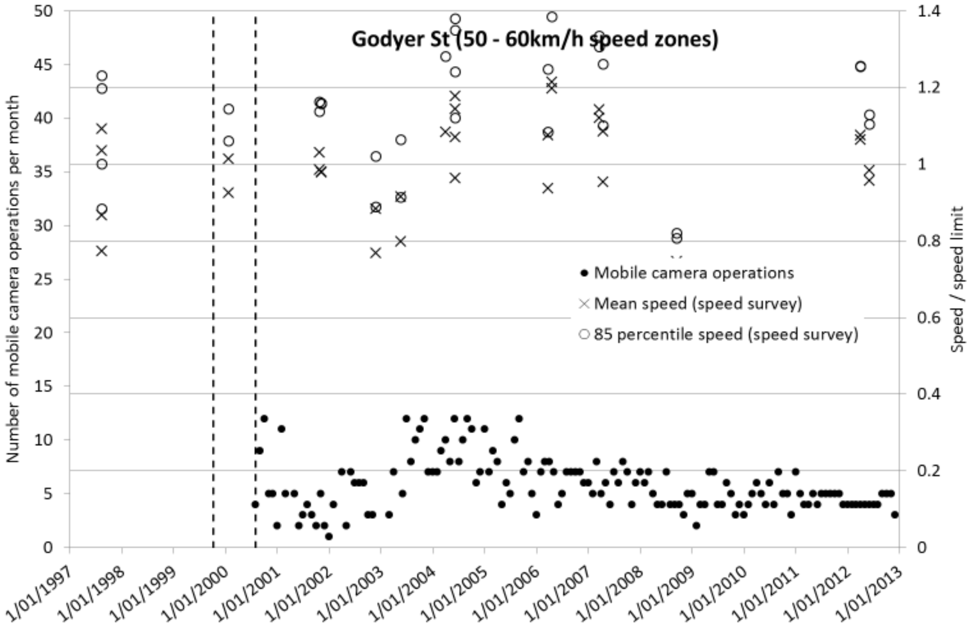
1/01/2013


Godyer St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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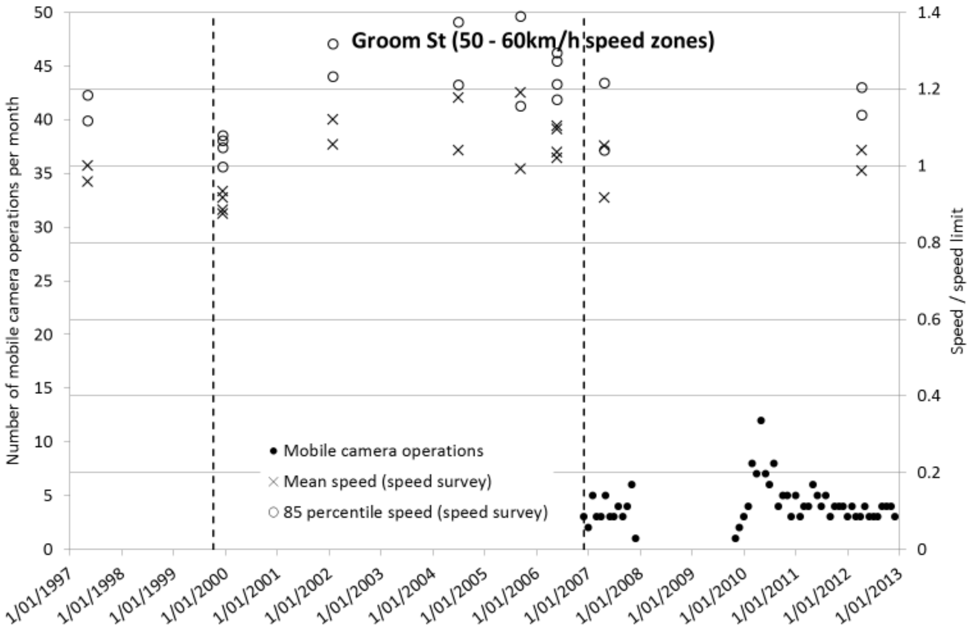
1/01/2013


Groom St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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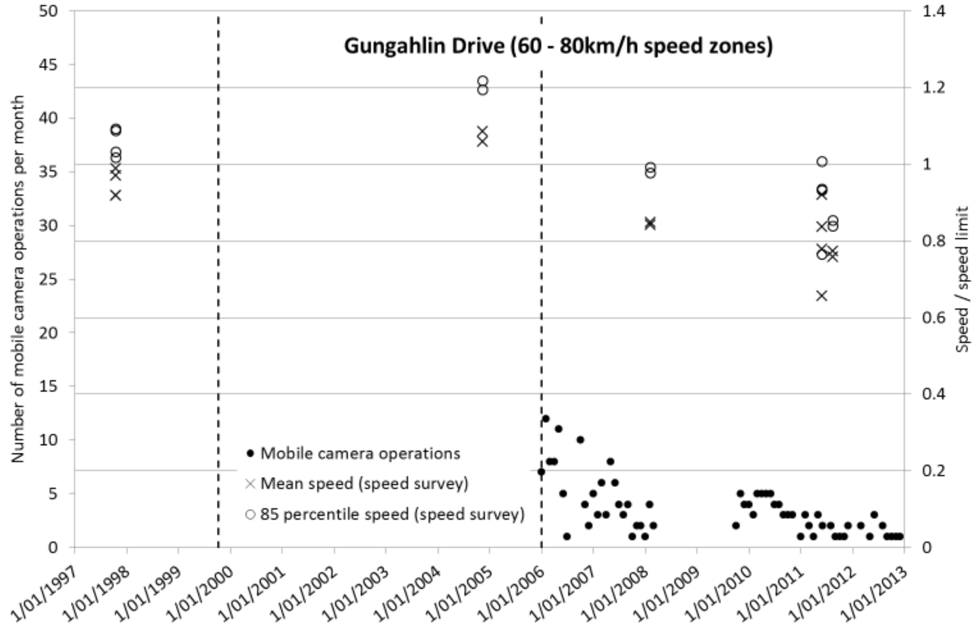
1/01/2012
1/01/2013


Gungahlin Drive (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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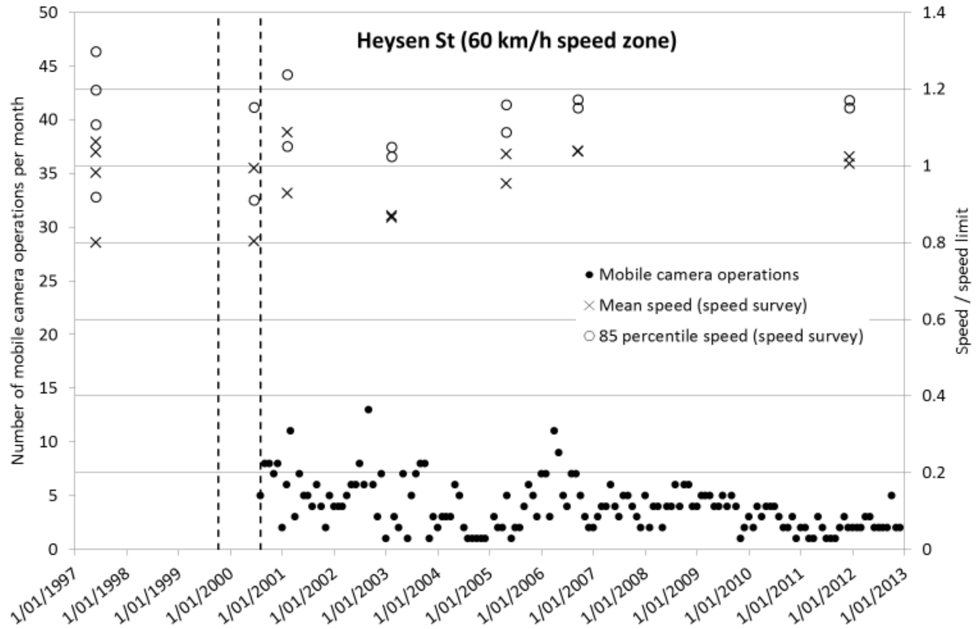
1/01/2012
1/01/2013


Heysen St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
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5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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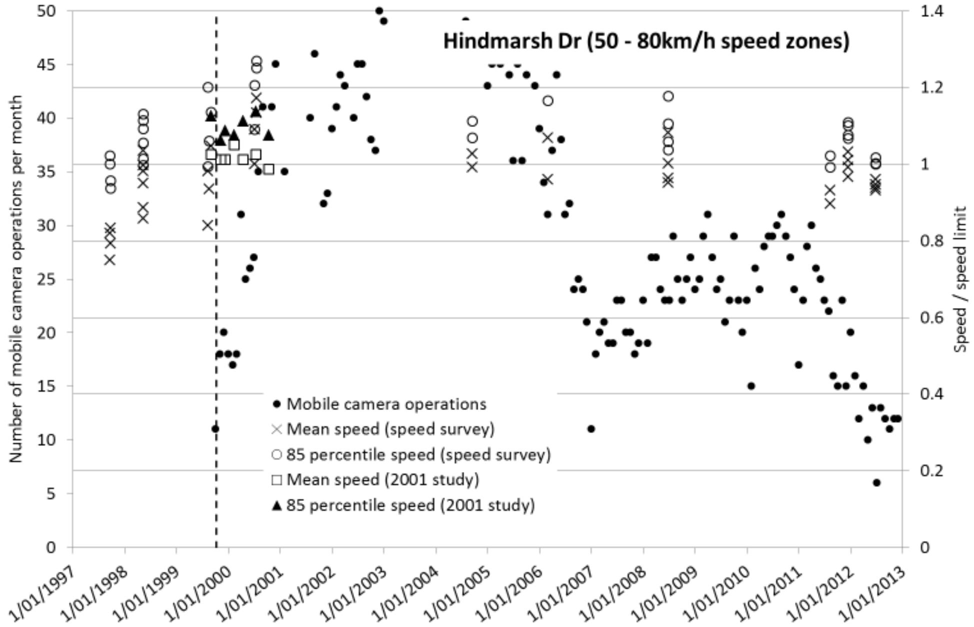
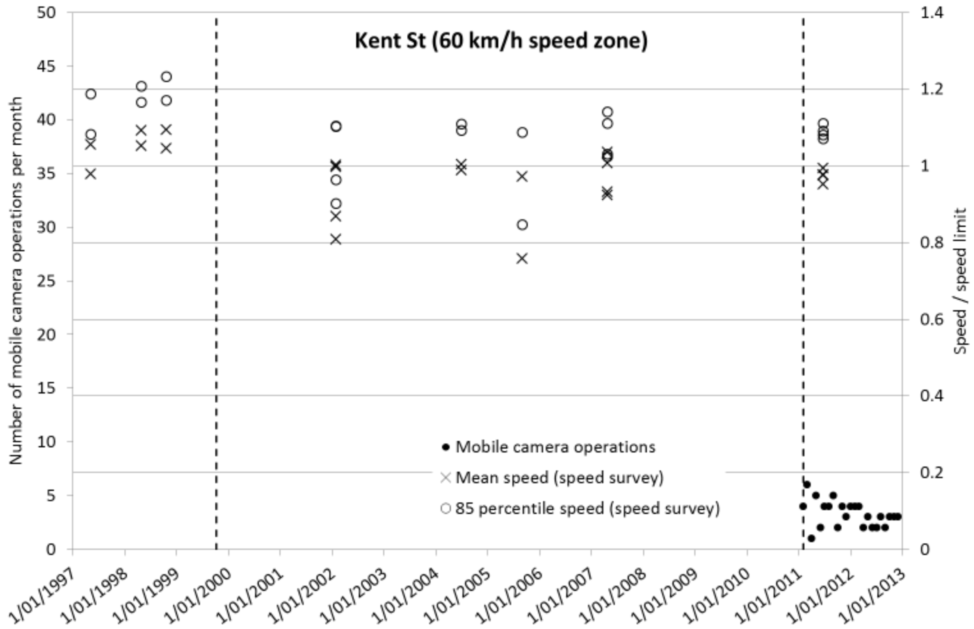
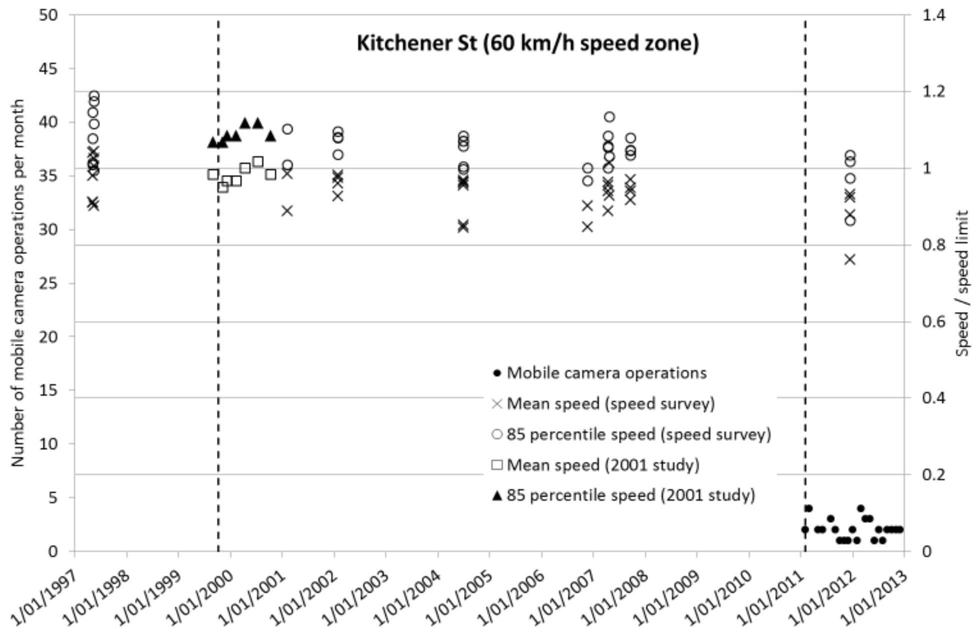
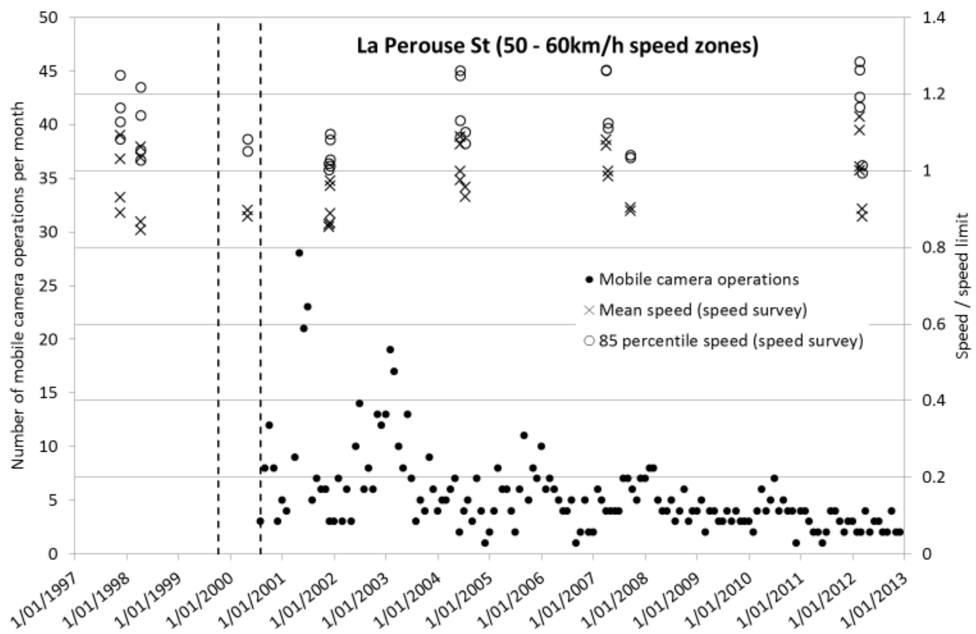
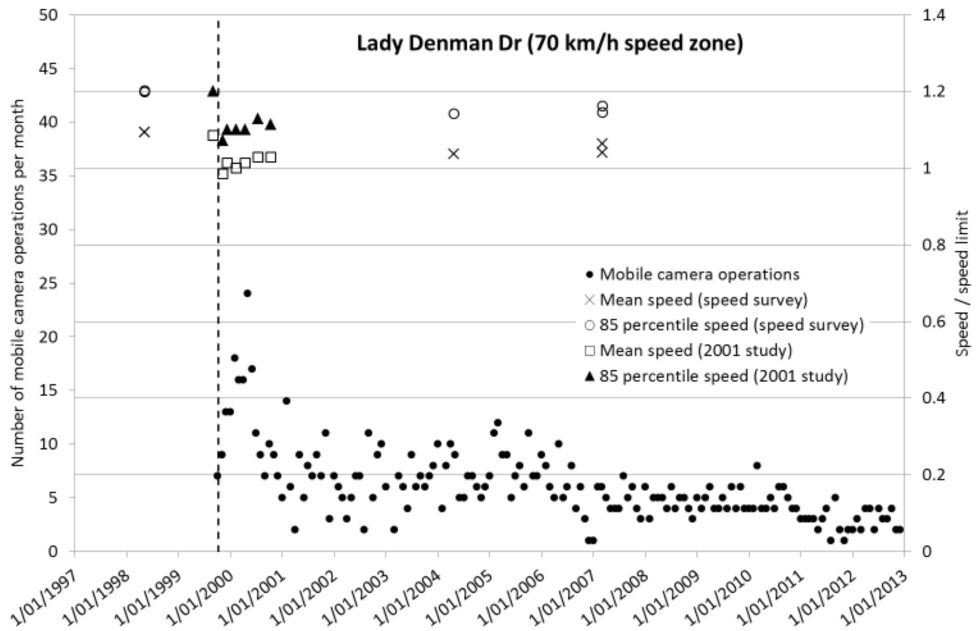
1/01/2013

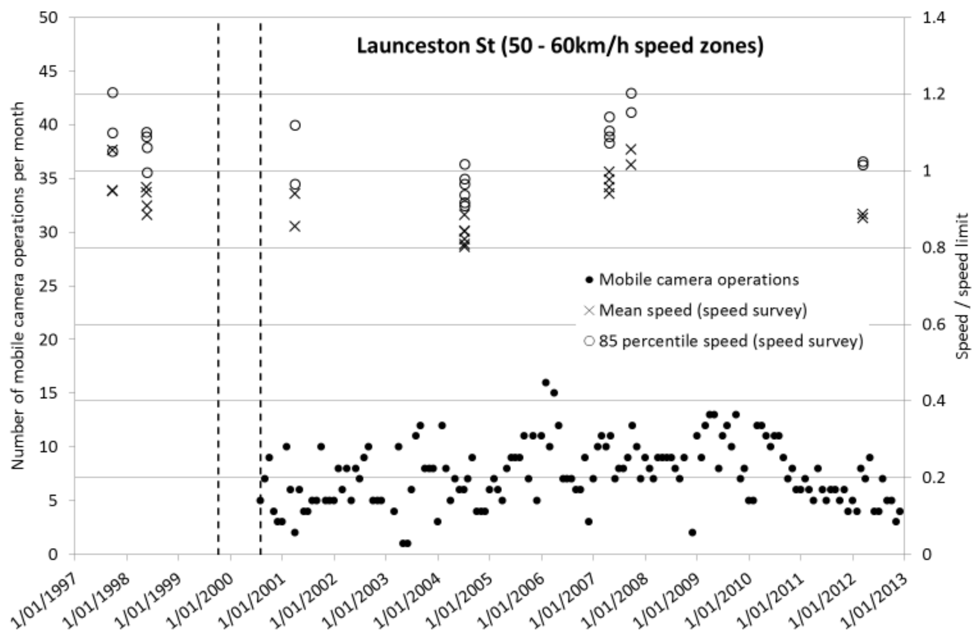

Hindmarsh Dr (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

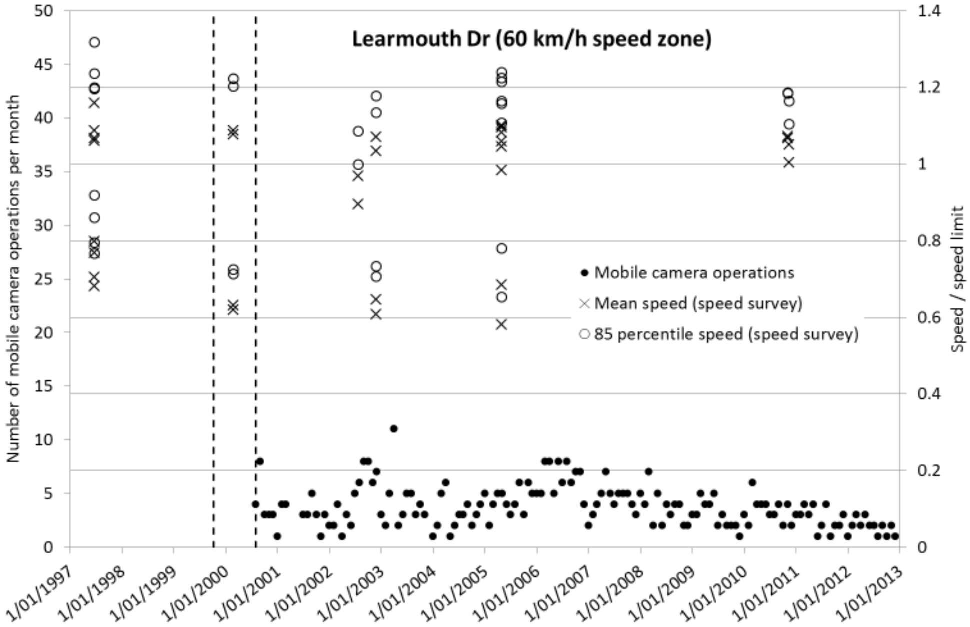

Kent St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

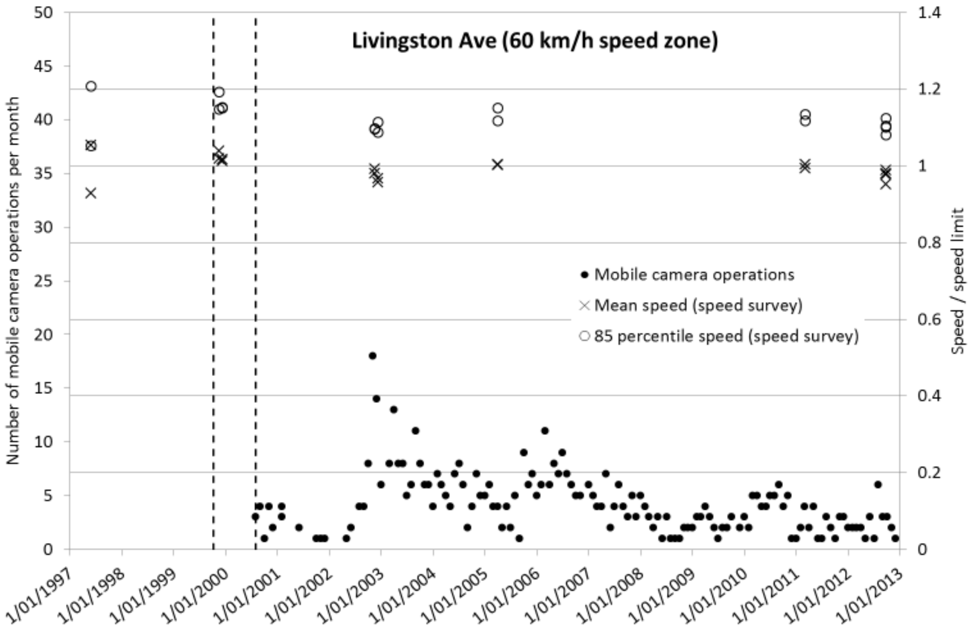

Kitchener St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

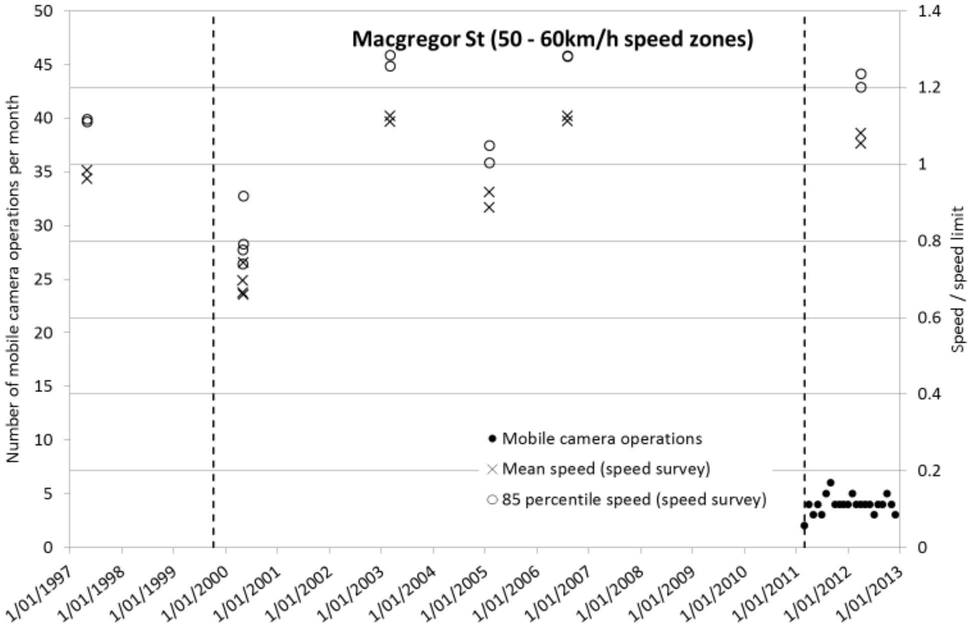

La Perouse St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

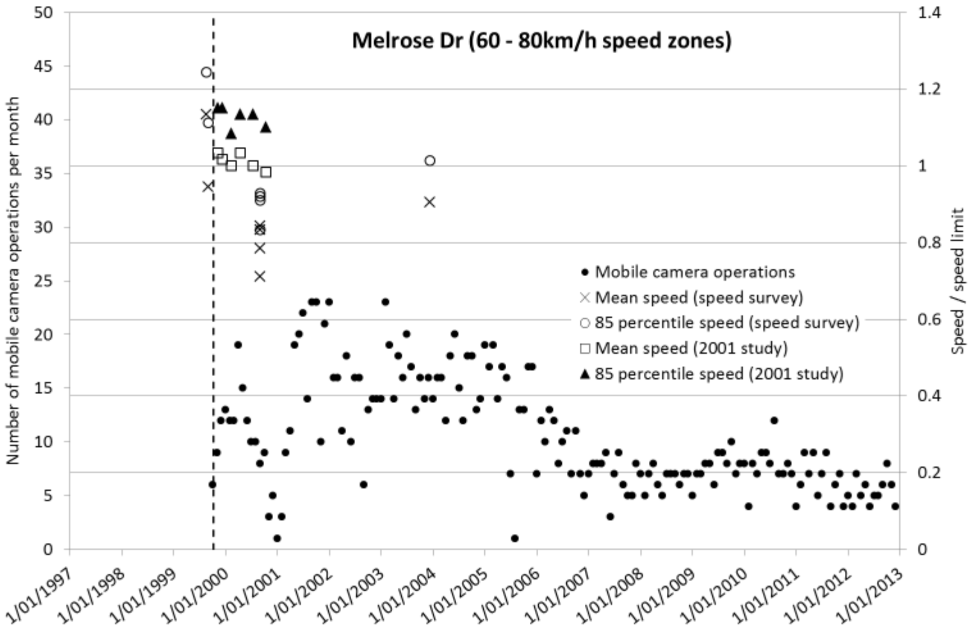

Lady Denman Dr (70 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

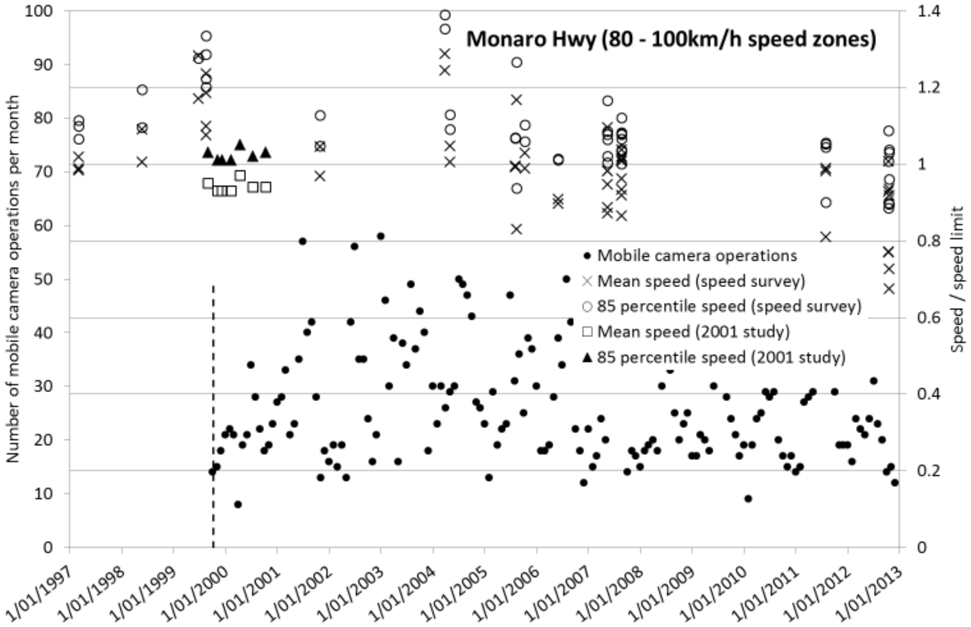

Launceston St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Learmouth Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

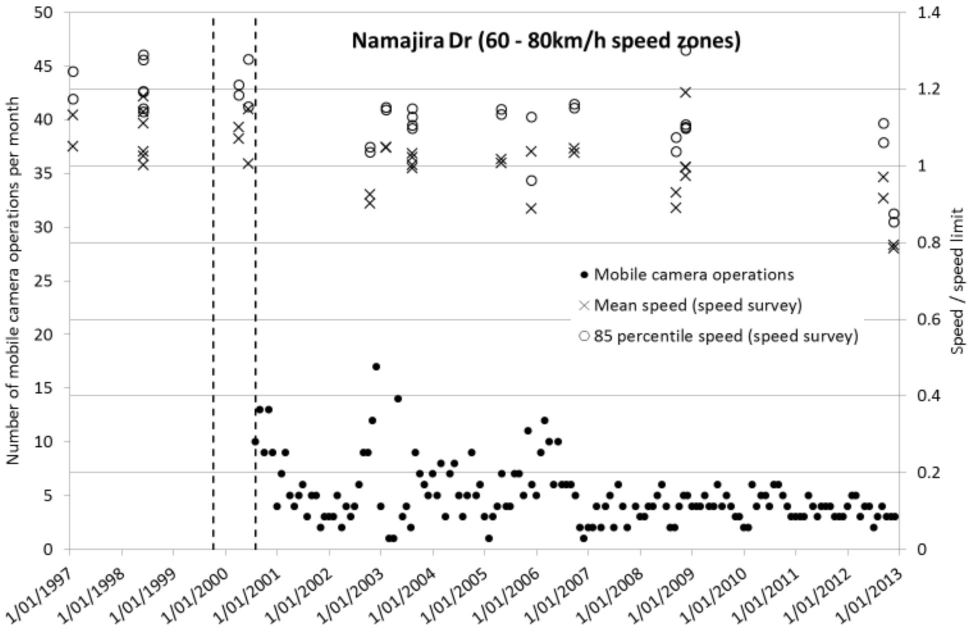

Livingston Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Macgregor St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

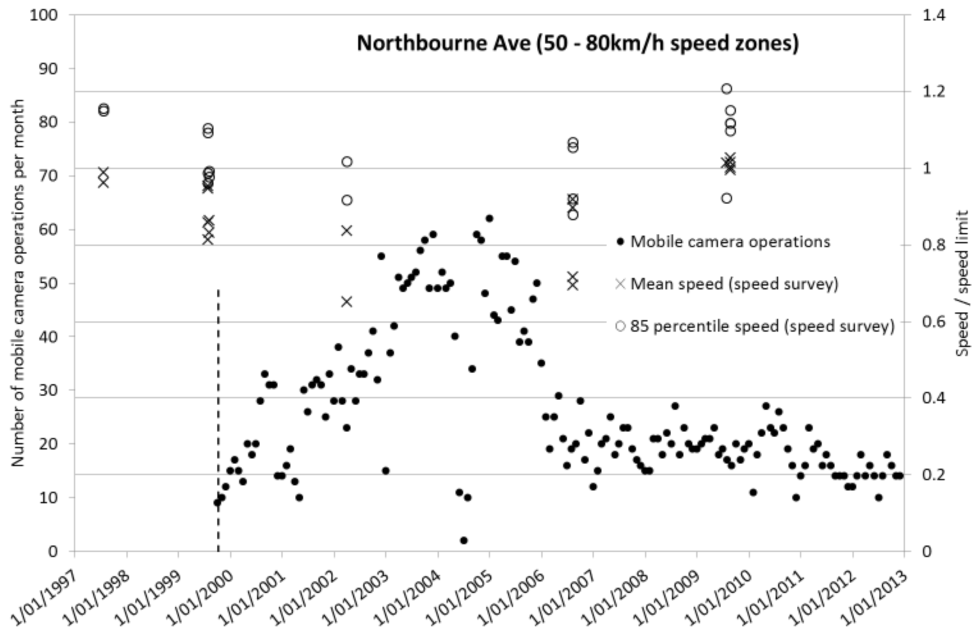

Melrose Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



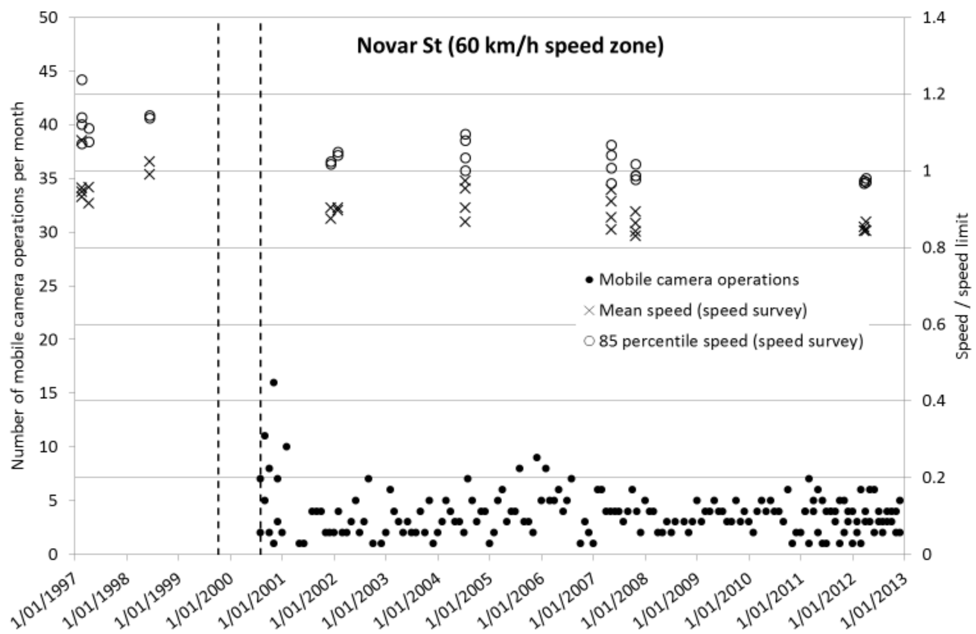
Monaro Hwy (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
0
10
20
30
40
50
60
70
80
90
100
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



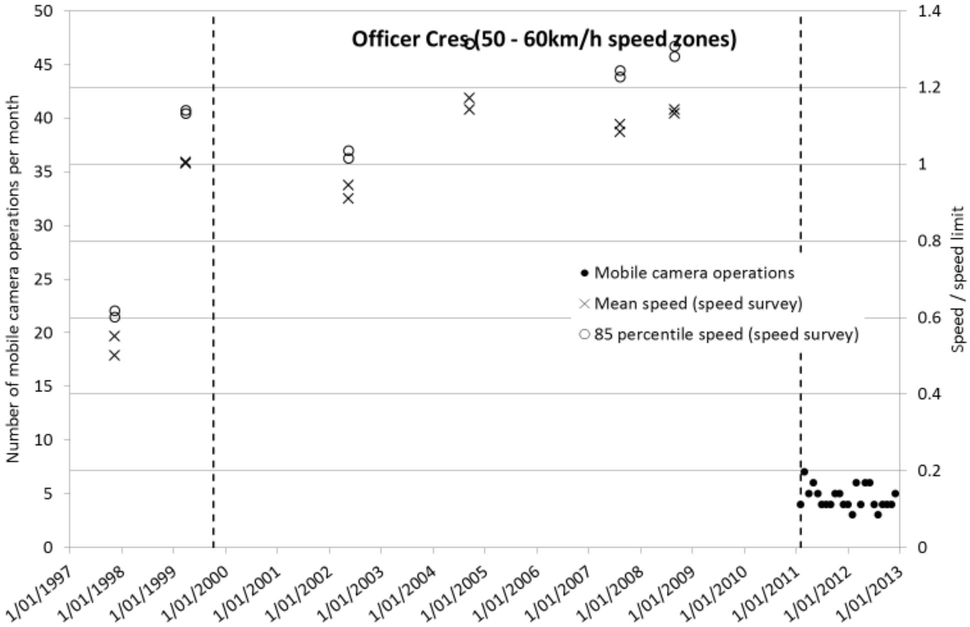
Namajira Dr (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



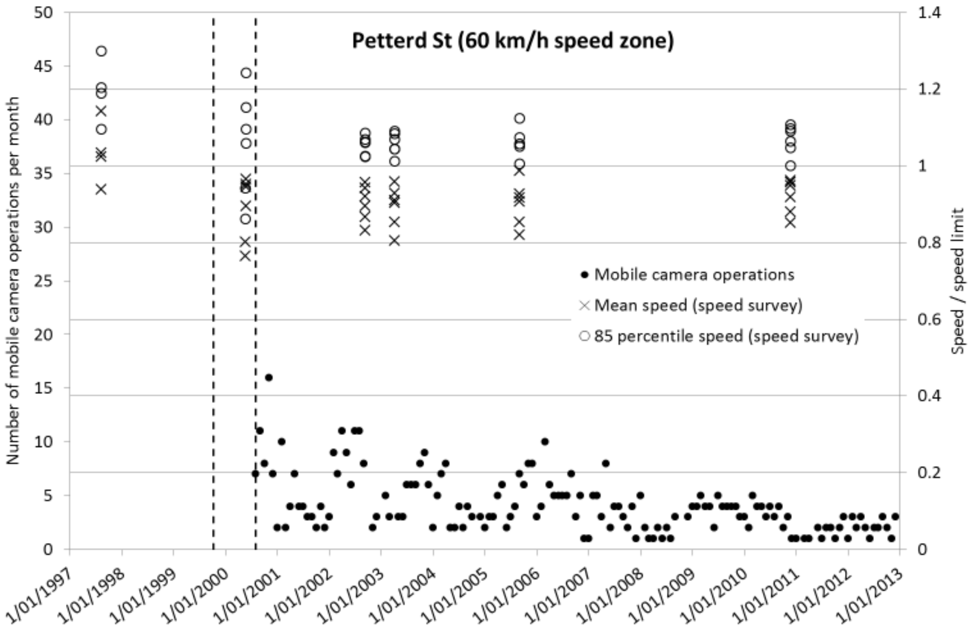
Northbourne Ave (50 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013



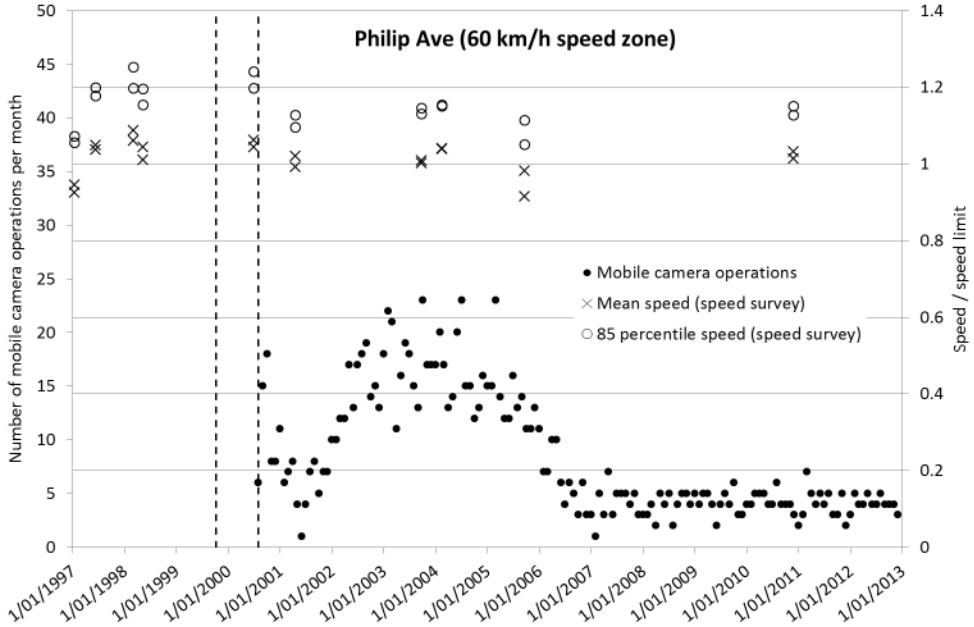
Novar St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

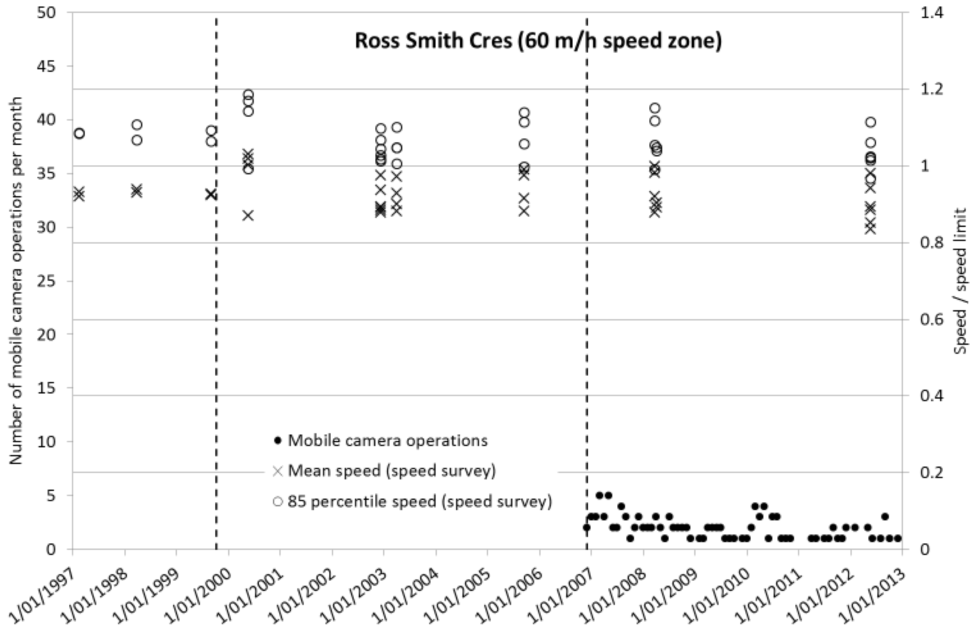


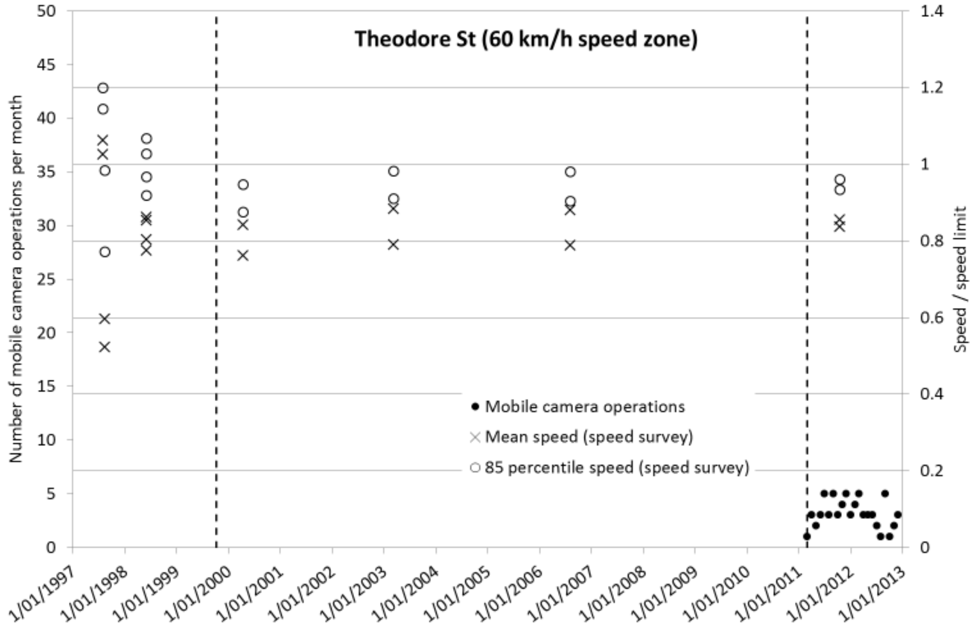
Officer Cres (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit

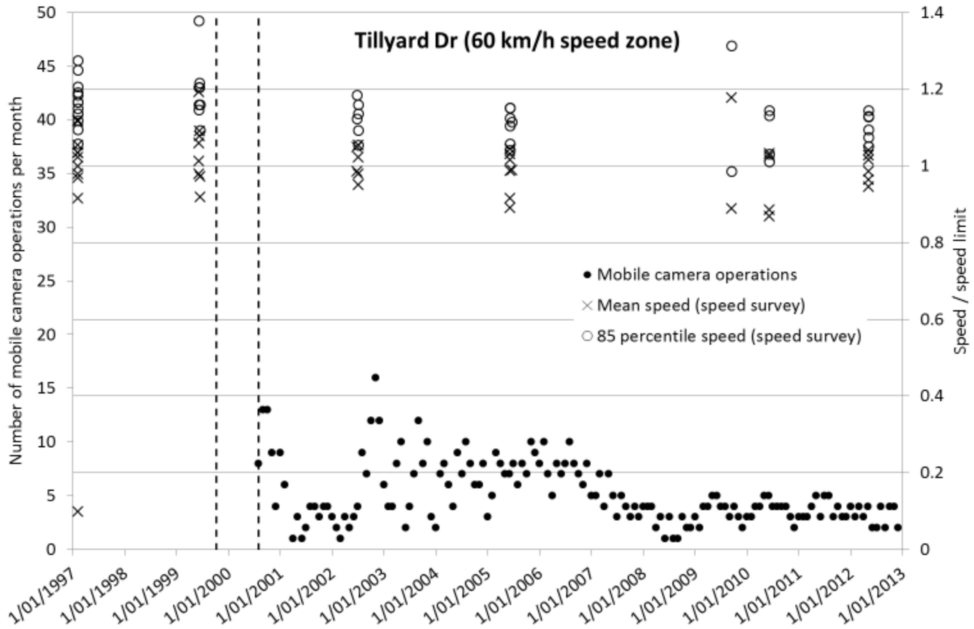


Petterd St (60 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit


Philip Ave (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Ross Smith Cres (60 m/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Theodore St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Tillyard Dr (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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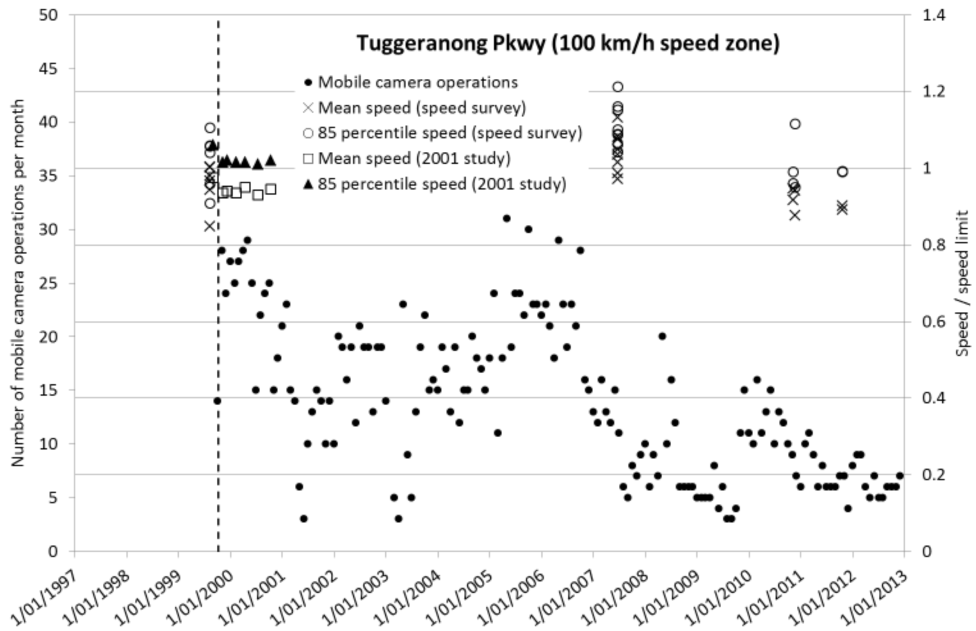
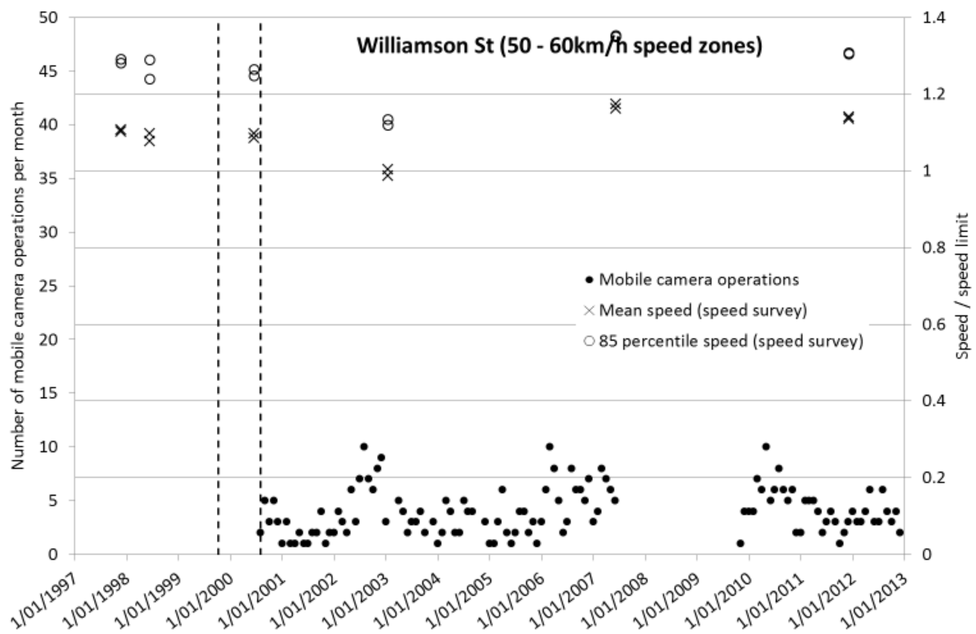
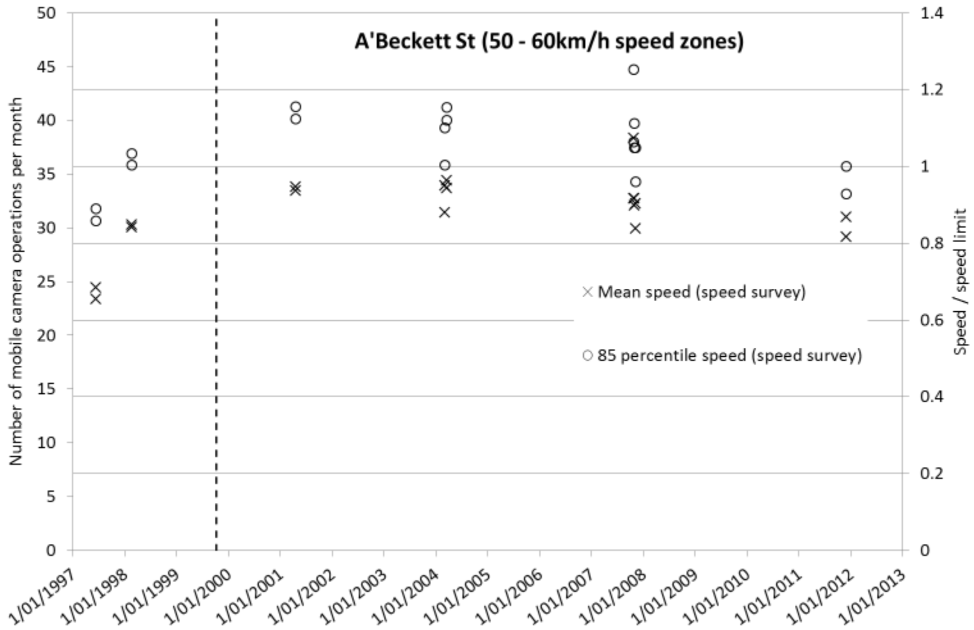
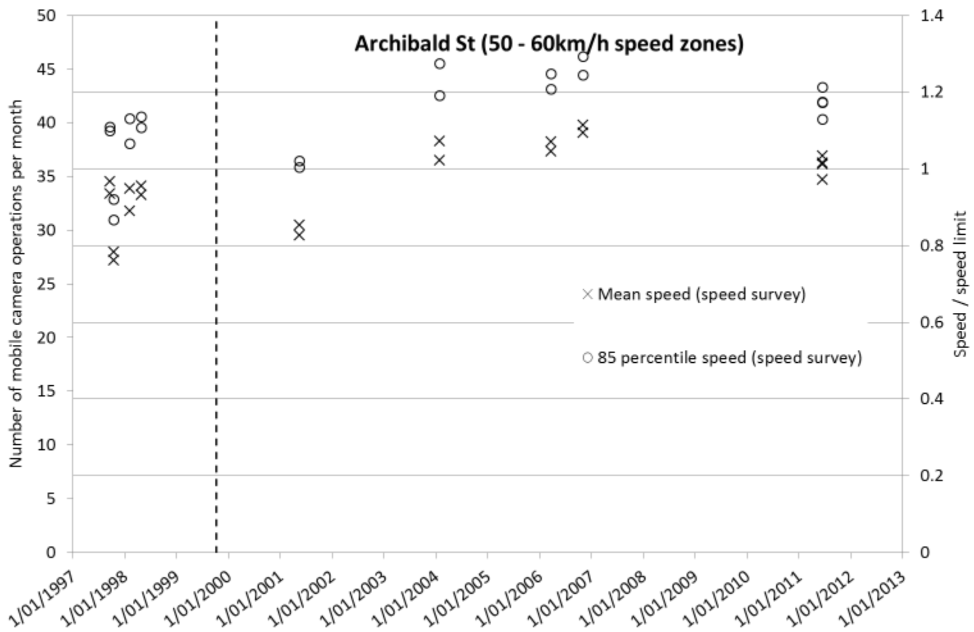
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013

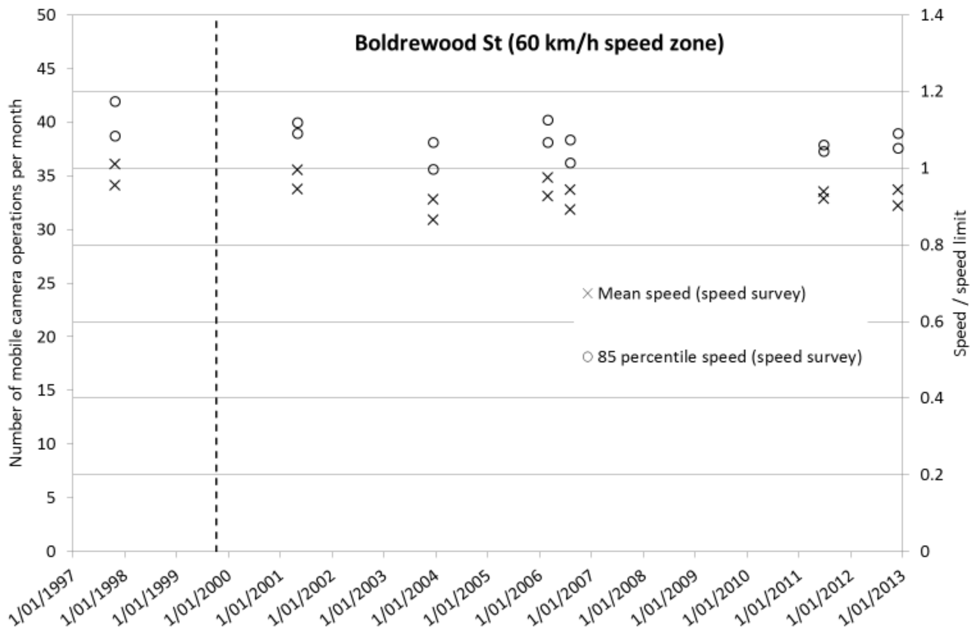

Tuggeranong Pkwy (100 km/h speed zone)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Mean speed (2001 study)
85 percentile speed (2001 study)
Number of mobile camera operations per month
Speed / speed limit
1/01/1997 1/01/1998 1/01/1999 1/01/2000 1/01/2001 1/01/2002 1/01/2003 1/01/2004 1/01/2005 1/01/2006 1/01/2007 1/01/2008 1/01/2009 1/01/2010 1/01/2011 1/01/2012 1/01/2013

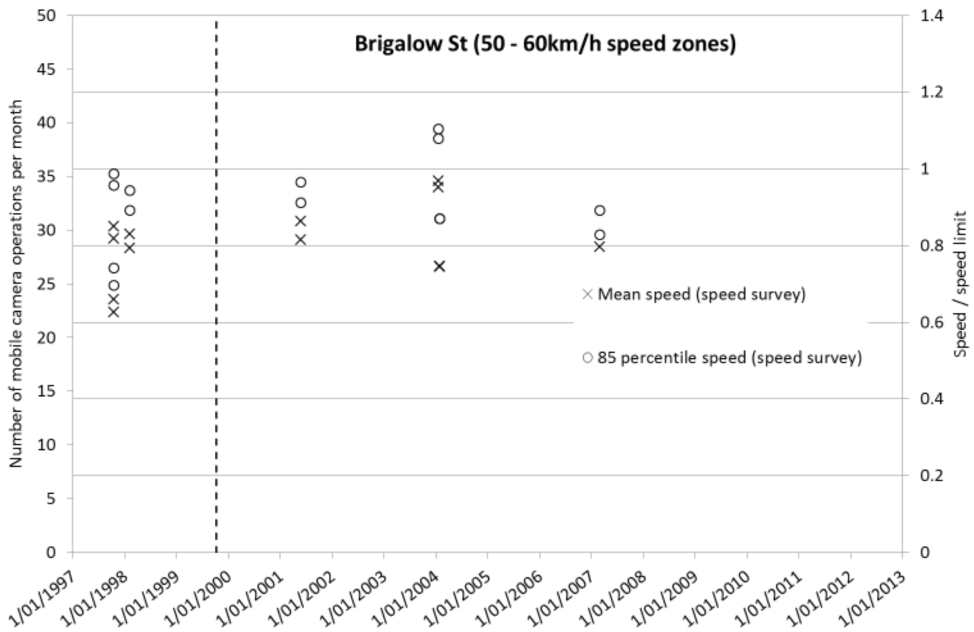

Williamson St (50 - 60km/h speed zones)
Mobile camera operations
Mean speed (speed survey)
85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
1/01/1997 1/01/1998 1/01/1999 1/01/2000 1/01/2001 1/01/2002 1/01/2003 1/01/2004 1/01/2005 1/01/2006 1/01/2007 1/01/2008 1/01/2009 1/01/2010 1/01/2011 1/01/2012 1/01/2013

CONTROL STREETS






Boldrewood St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Brigalow St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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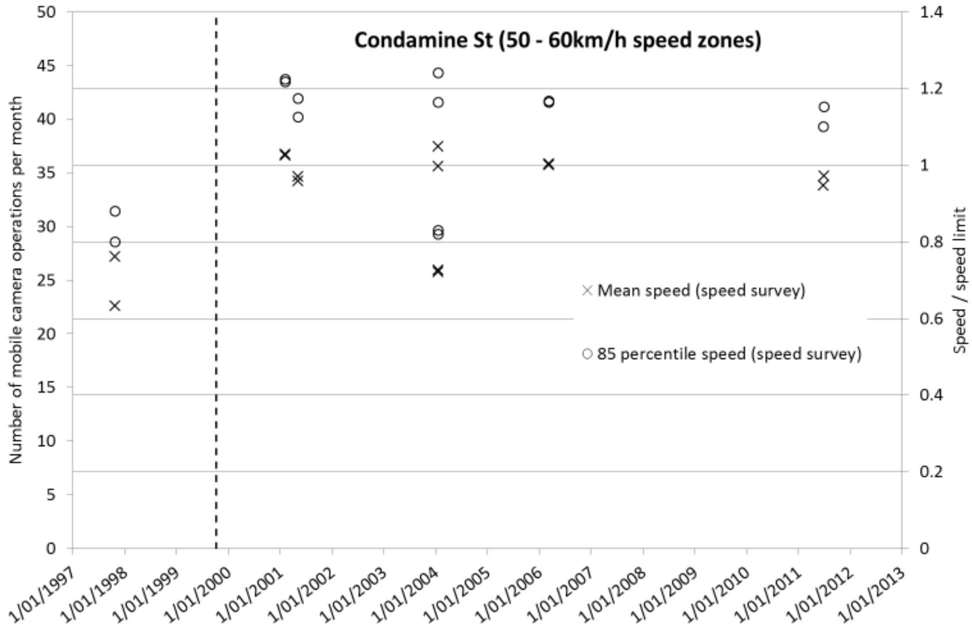
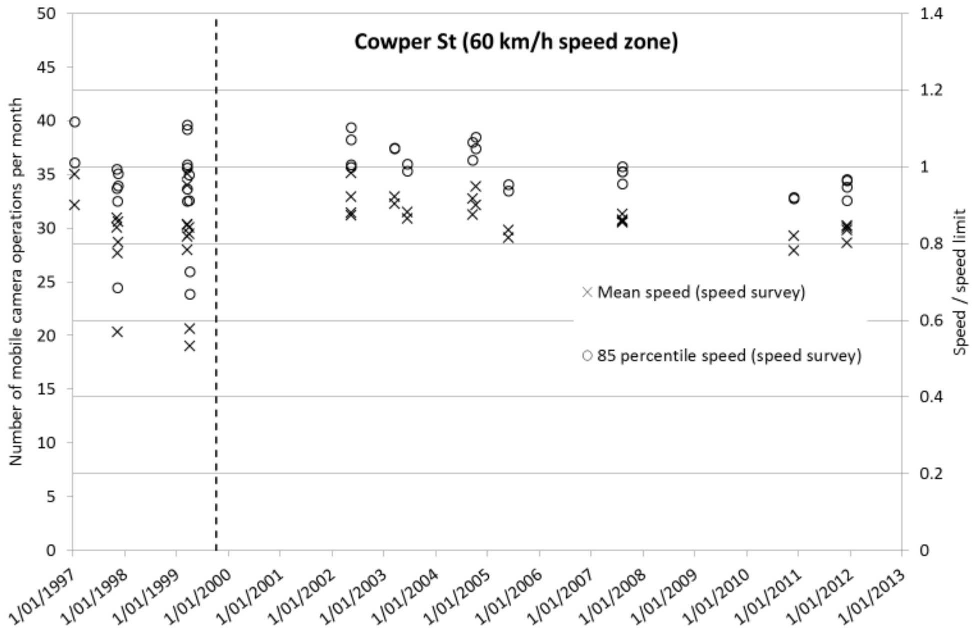
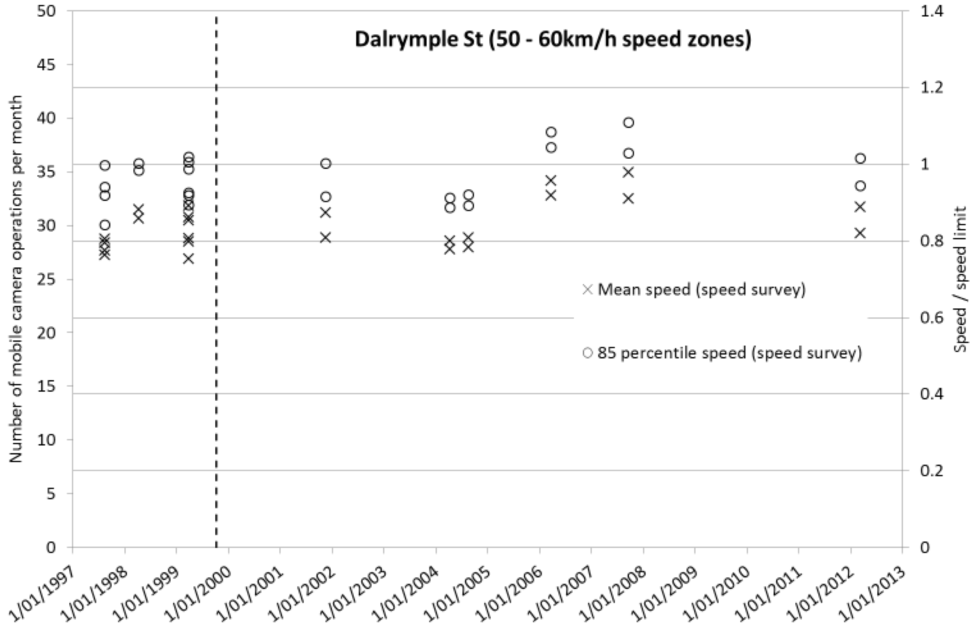
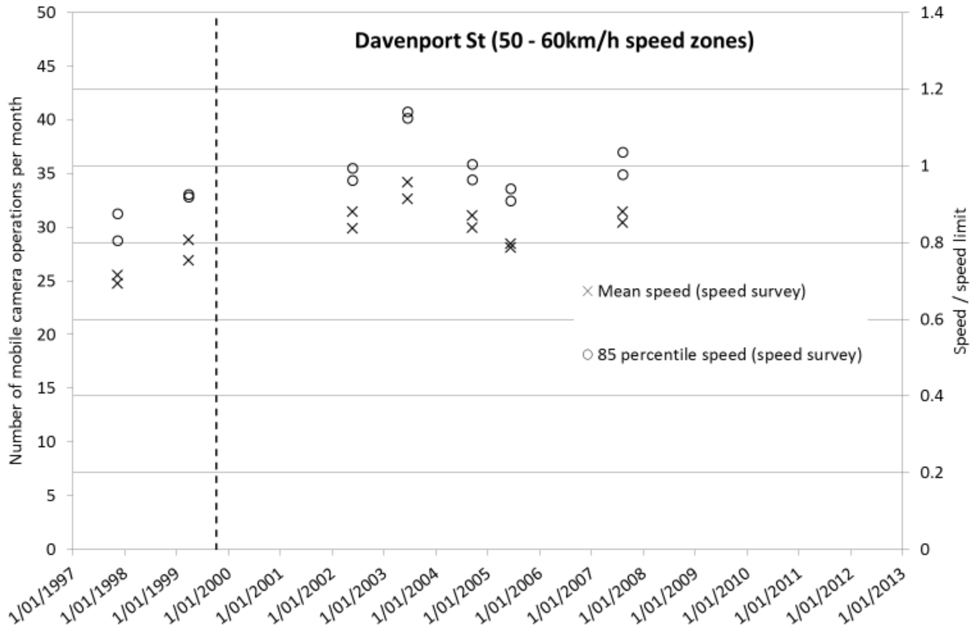
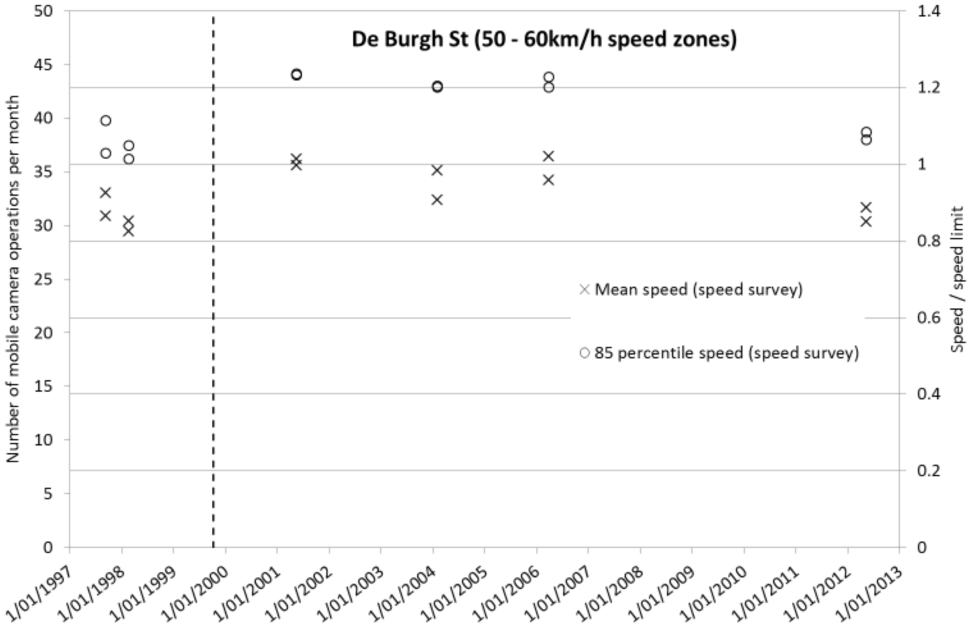
1/01/2011
1/01/2012
1/01/2013


Condamine St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Cowper St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Dalrymple St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Davenport St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


De Burgh St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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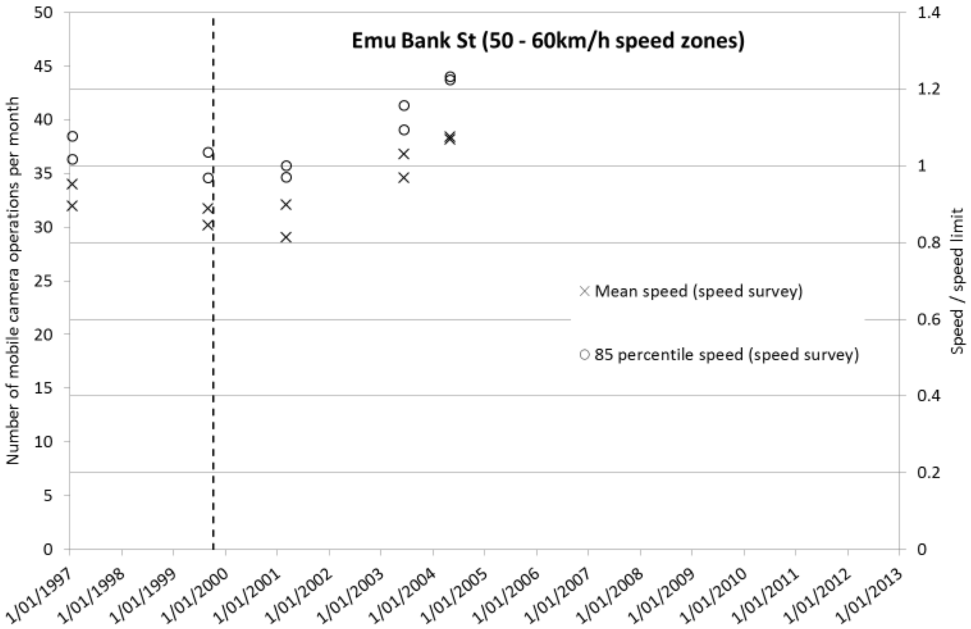
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Emu Bank St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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1/01/2004
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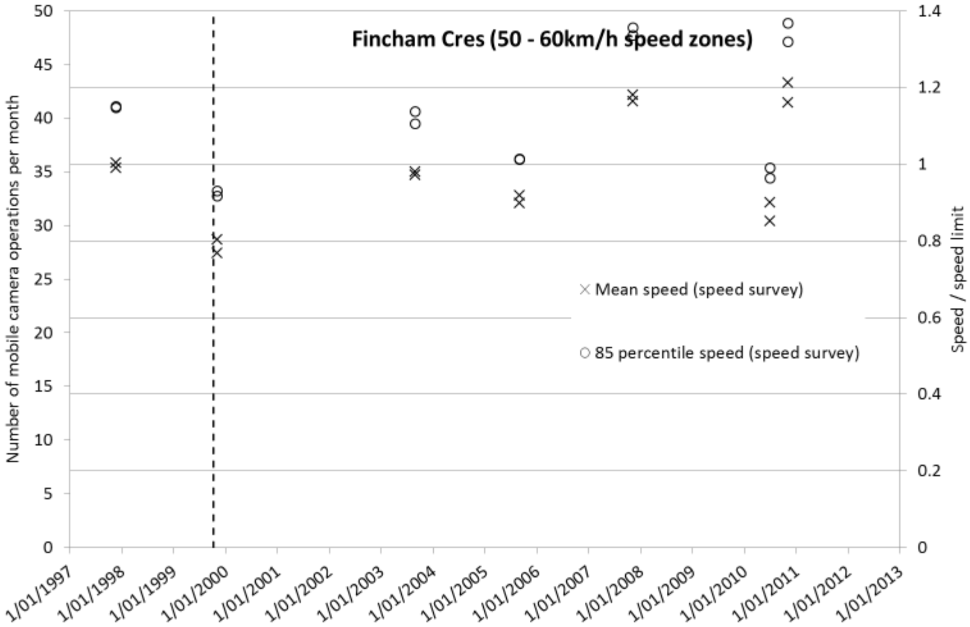
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Fincham Cres (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
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40
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50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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1/01/2005
1/01/2006
1/01/2007
1/01/2008
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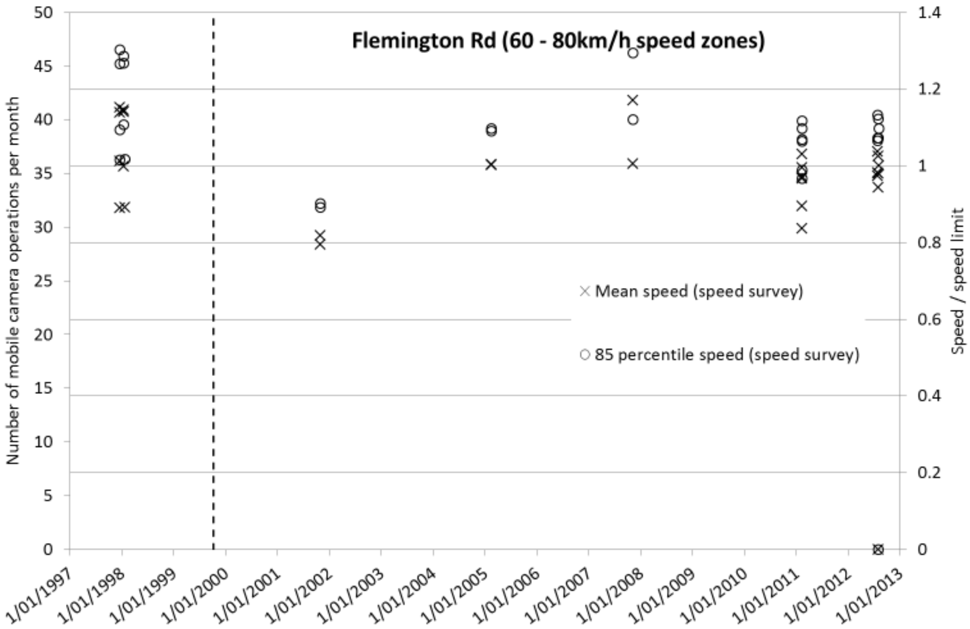
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Flemington Rd (60 - 80km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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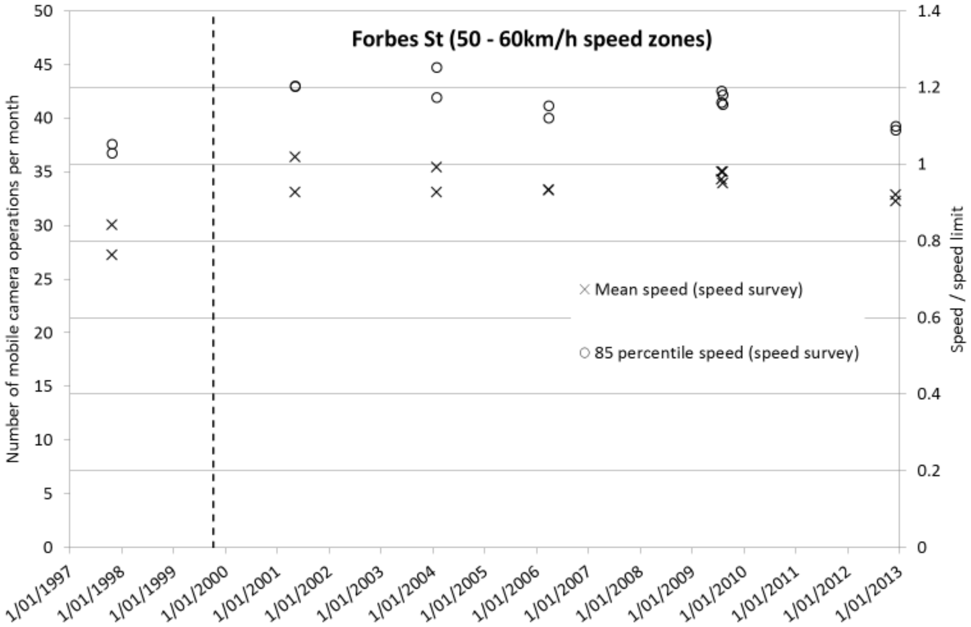
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Forbes St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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0.2
0.4
0.6
0.8
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1.2
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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1/01/2004
1/01/2005
1/01/2006
1/01/2007
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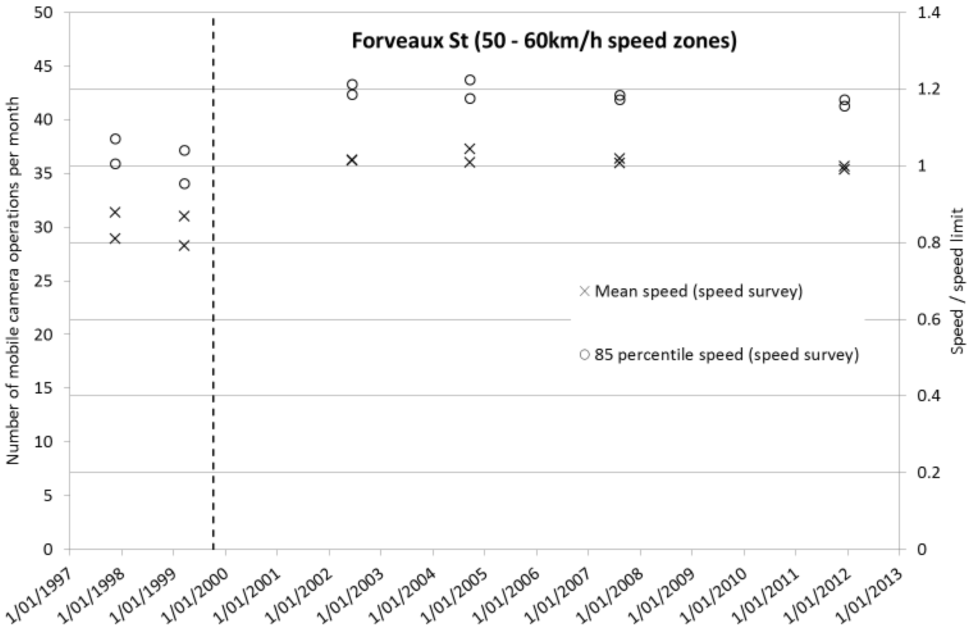
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Forveaux St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
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0.4
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1.2
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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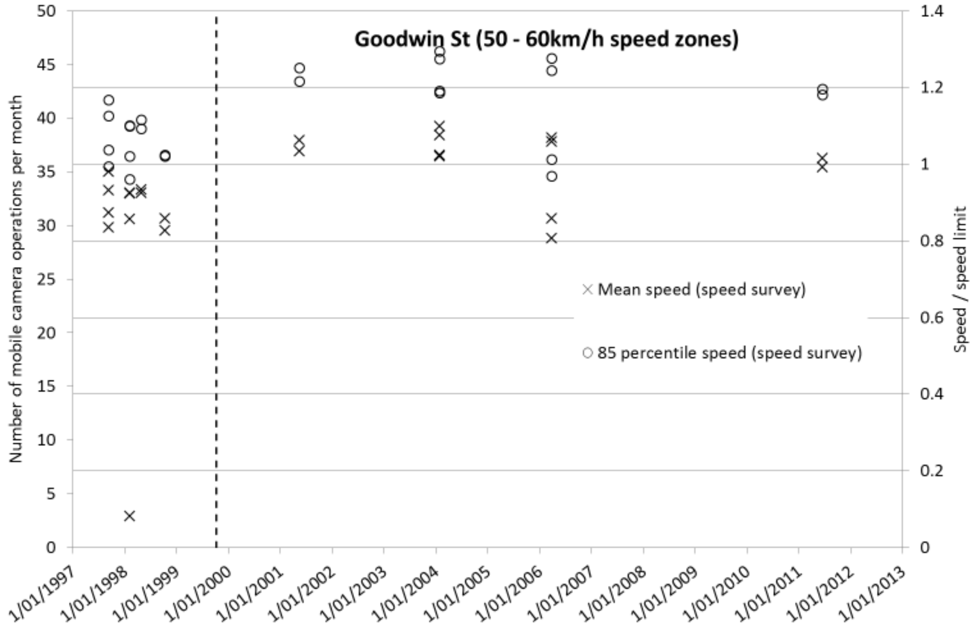
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Goodwin St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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0.2
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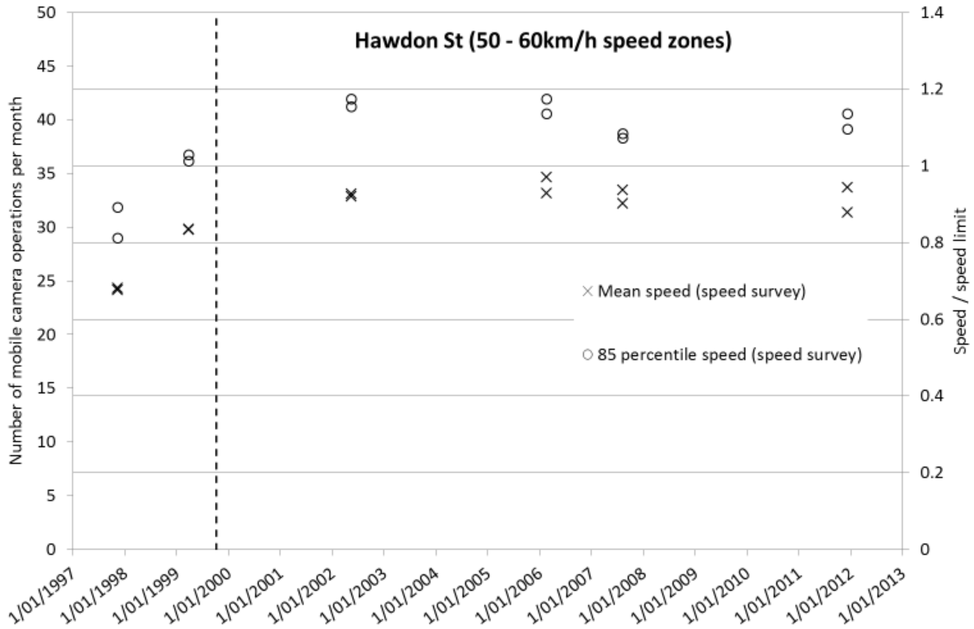
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hawdon St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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25
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35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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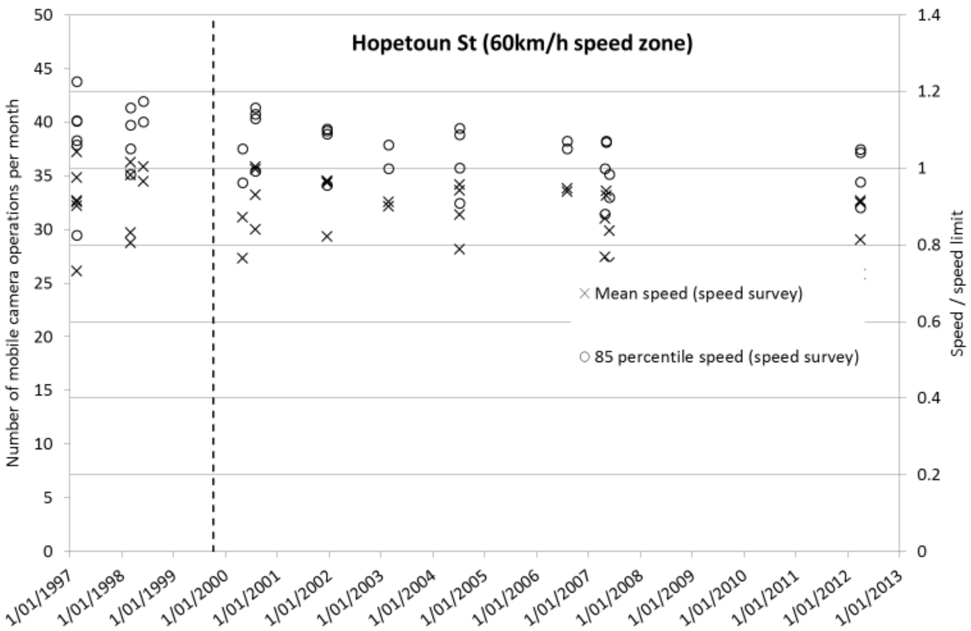
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Hopetoun St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
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35
30
25
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10
5
0
1.4
1.2
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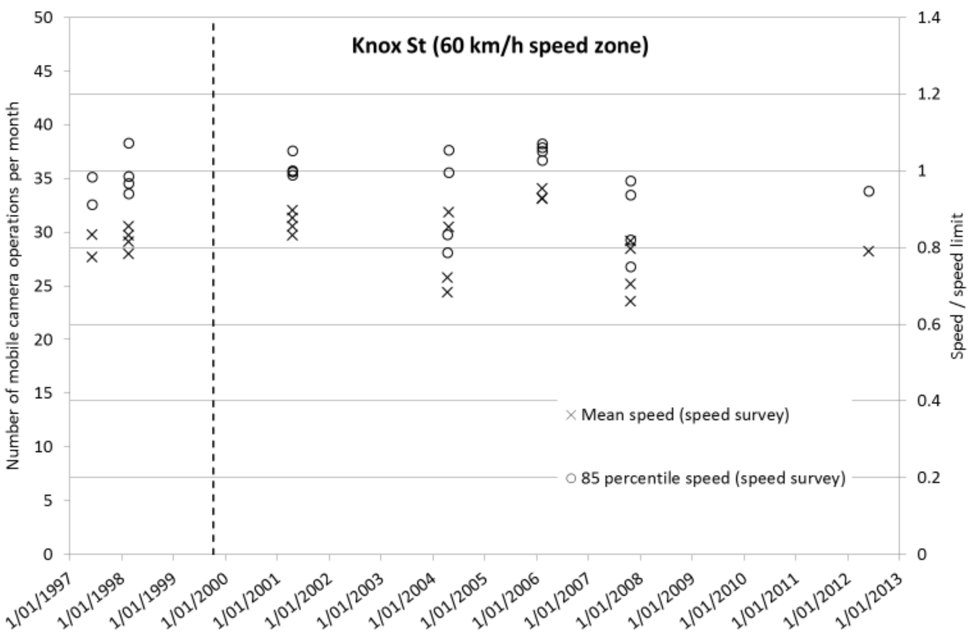
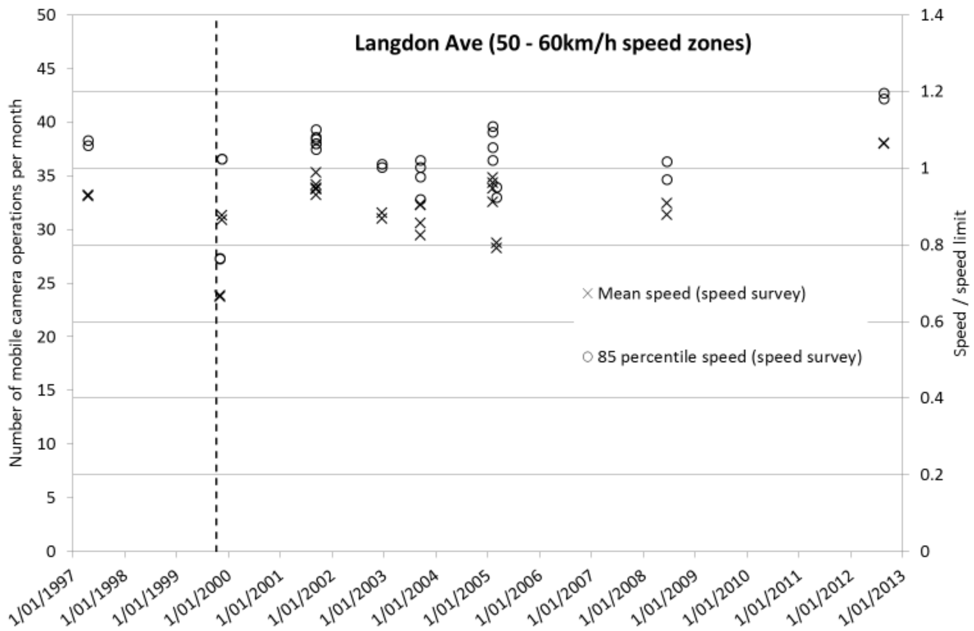
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Knox St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Langdon Ave (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
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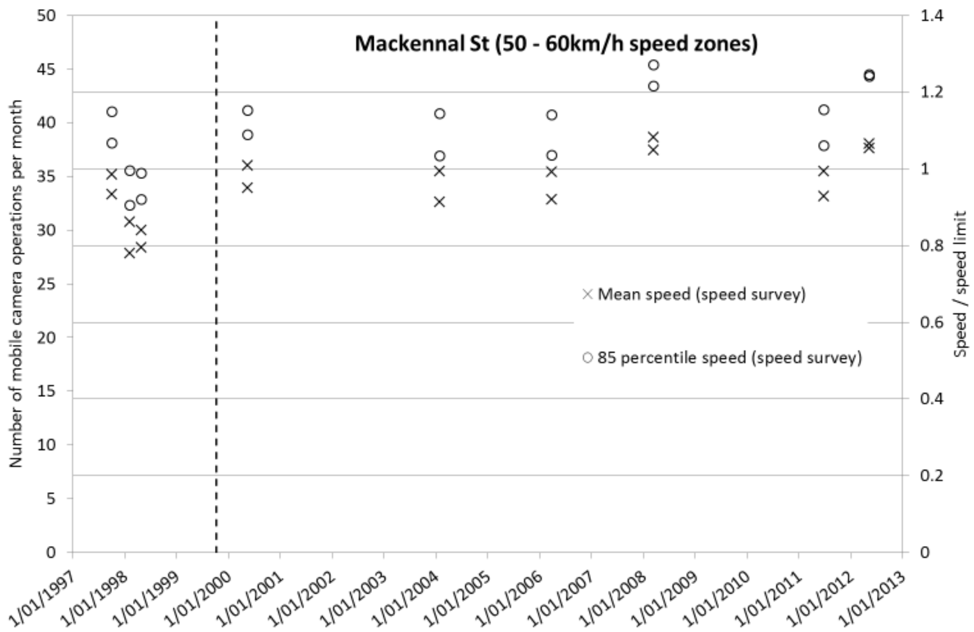
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Mackennal St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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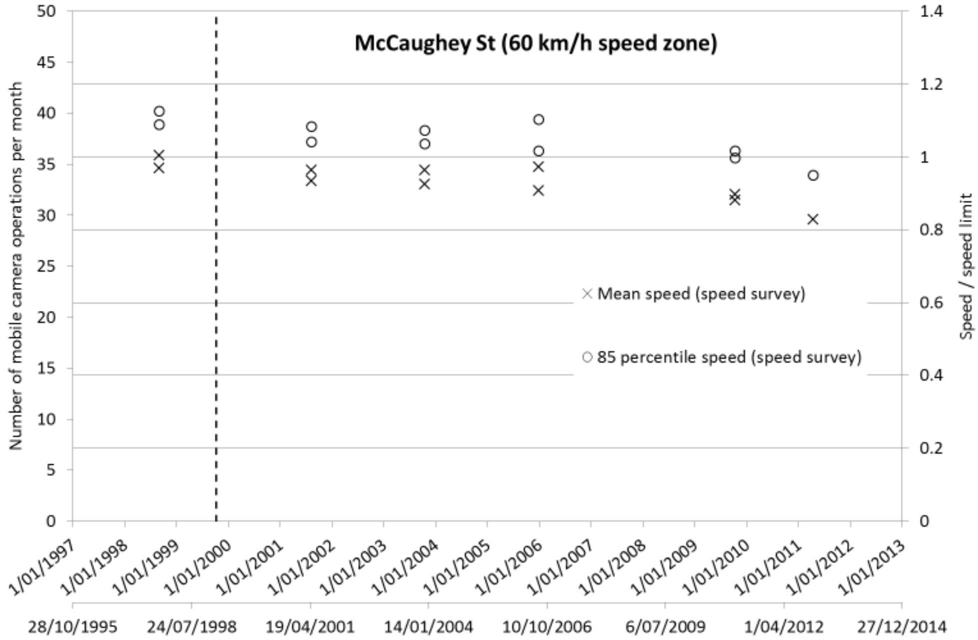
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


McCaughey St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
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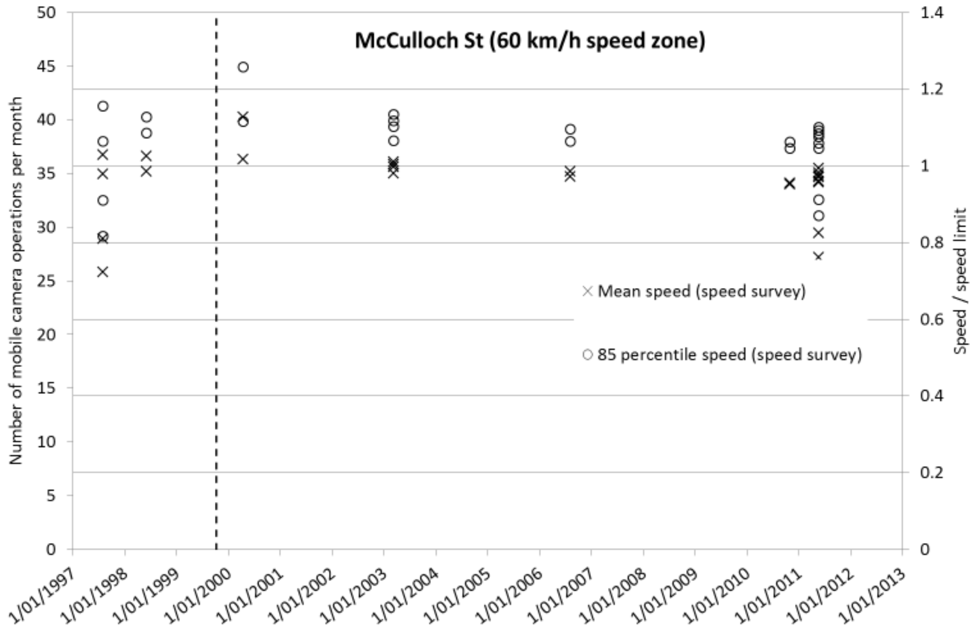
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014


McCulloch St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
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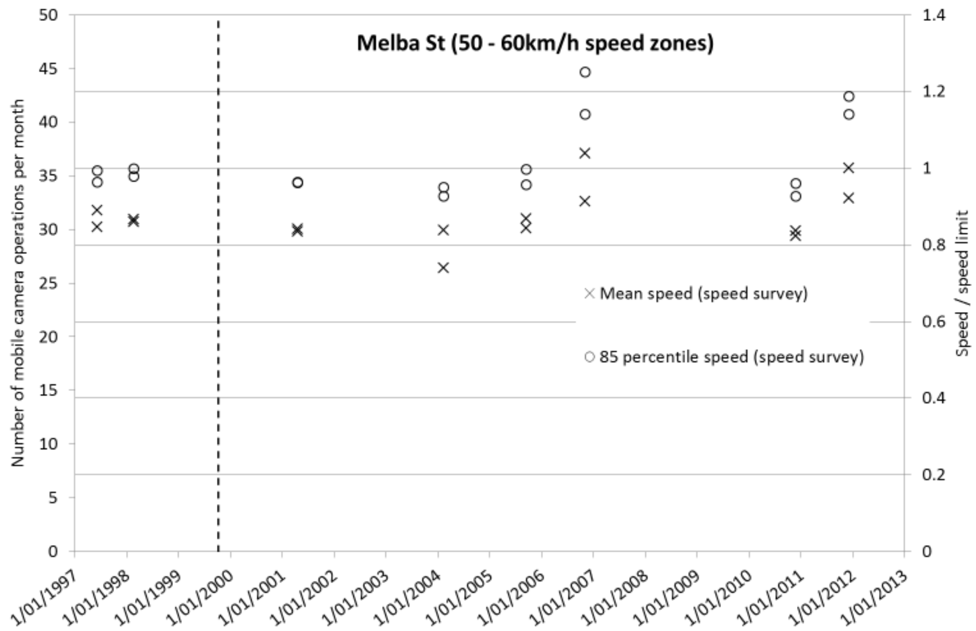
1/01/2012
1/01/2013


Melba St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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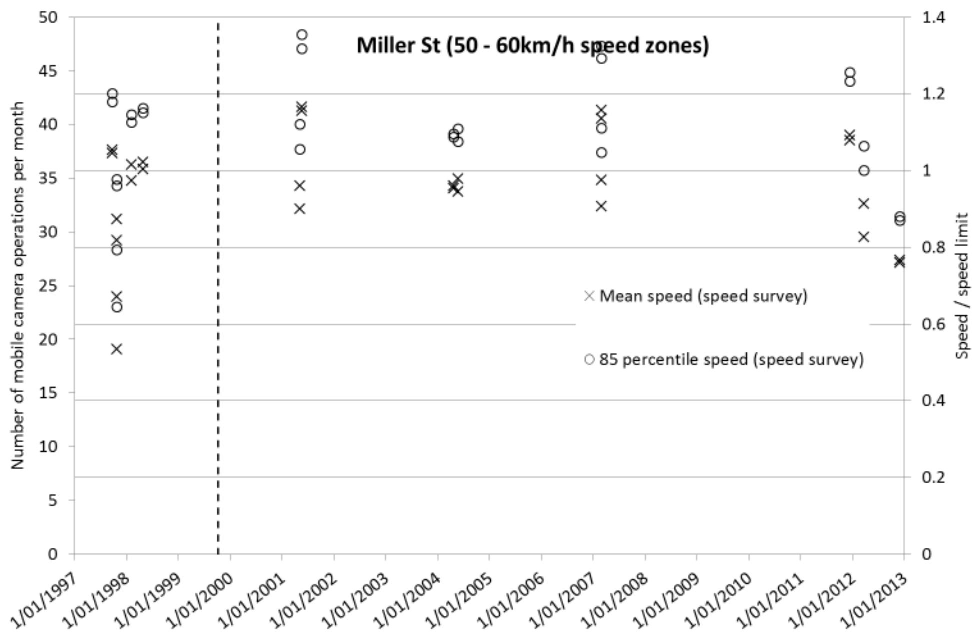
1/01/2011
1/01/2012
1/01/2013


Miller St (50 - 60km/h speed zones)
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
Number of mobile camera operations per month
Speed / speed limit
50
45
40
35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
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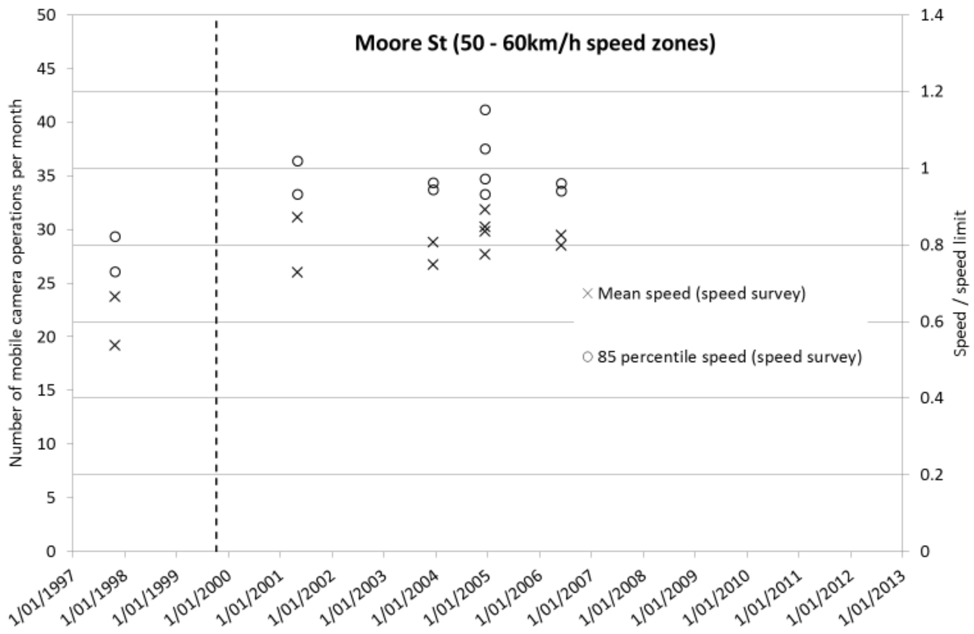
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Moore St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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15
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25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
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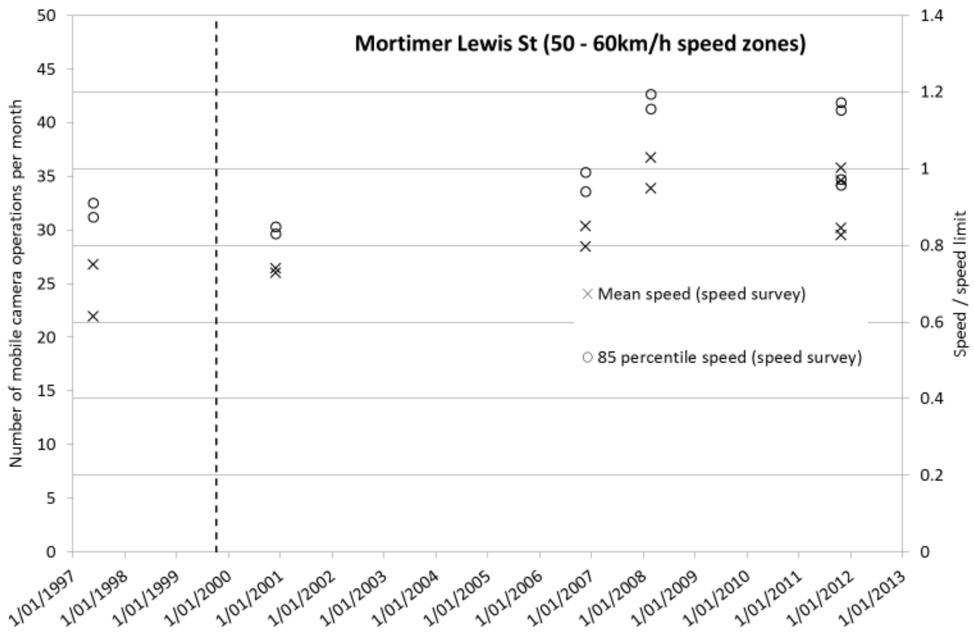
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Mortimer Lewis St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
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35
40
45
50
0
0.2
0.4
0.6
0.8
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1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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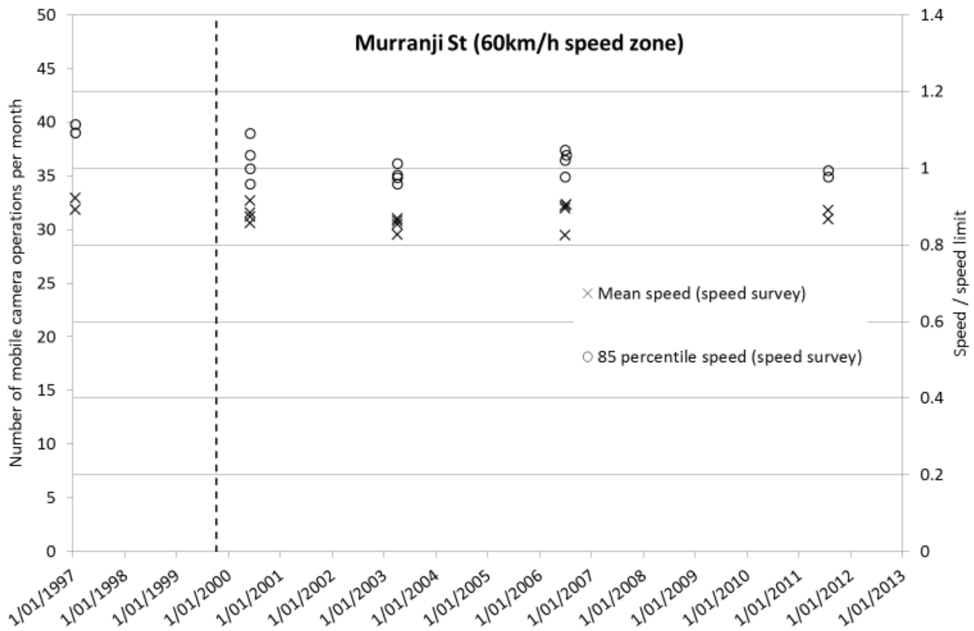
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Murranji St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
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35
30
25
20
15
10
5
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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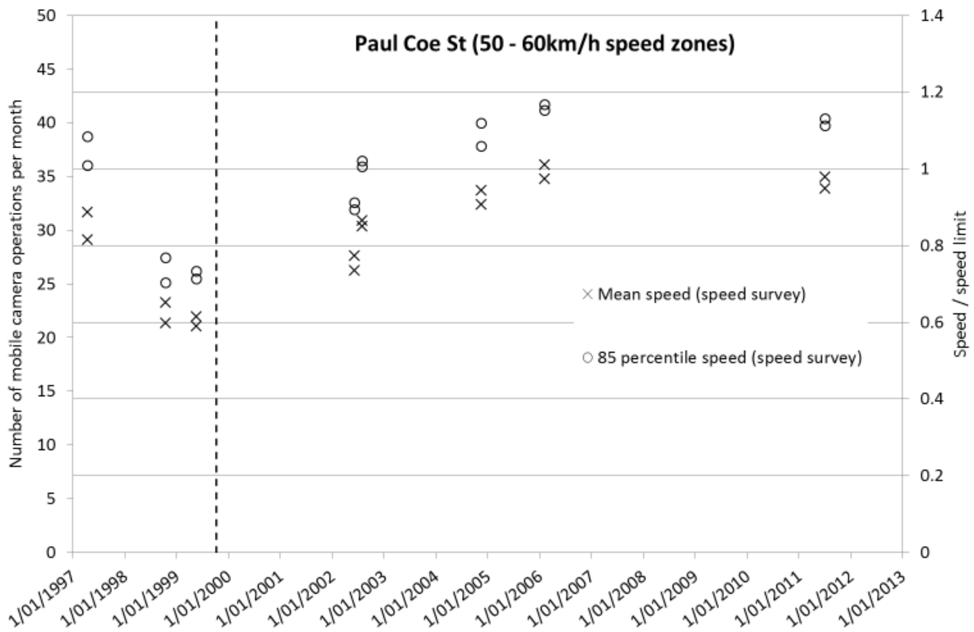
1/01/2011
1/01/2012
1/01/2013


Paul Coe St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
50
45
40
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15
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5
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1.4
1.2
1
0.8
0.6
0.4
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
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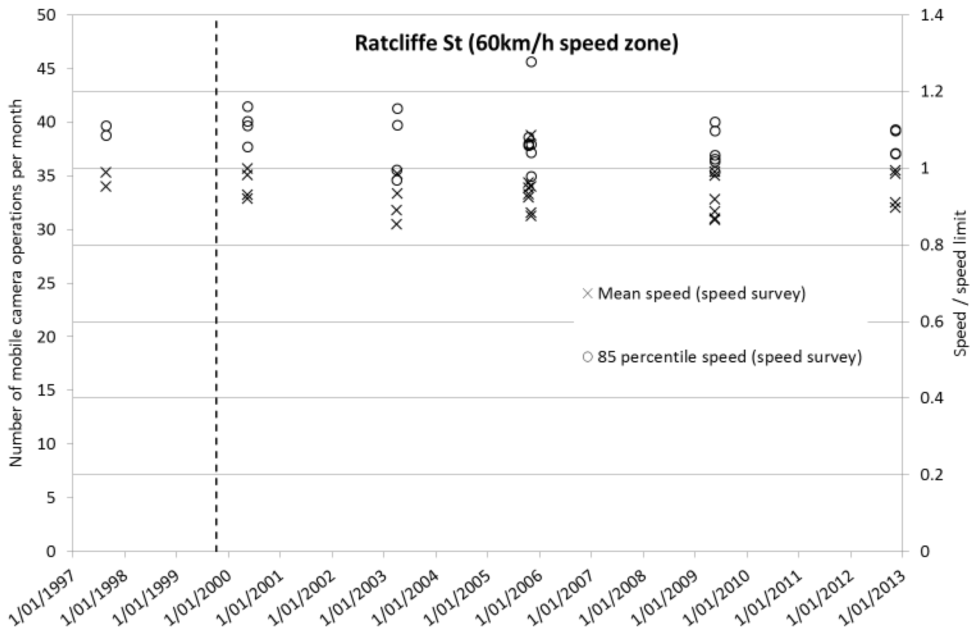
1/01/2012
1/01/2013


Ratcliffe St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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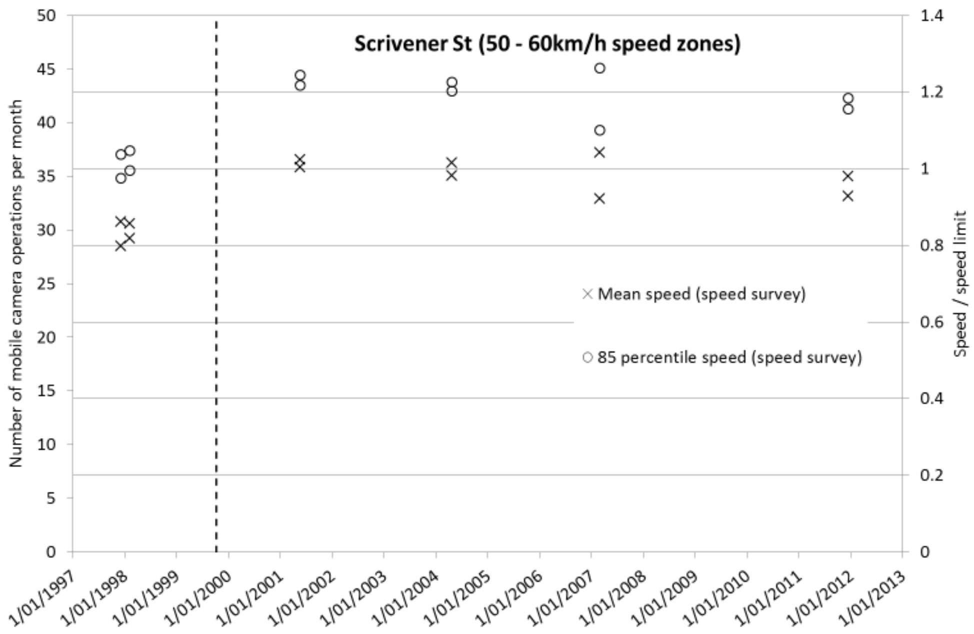
1/01/2012
1/01/2013


Scrivener St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
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1/01/2008
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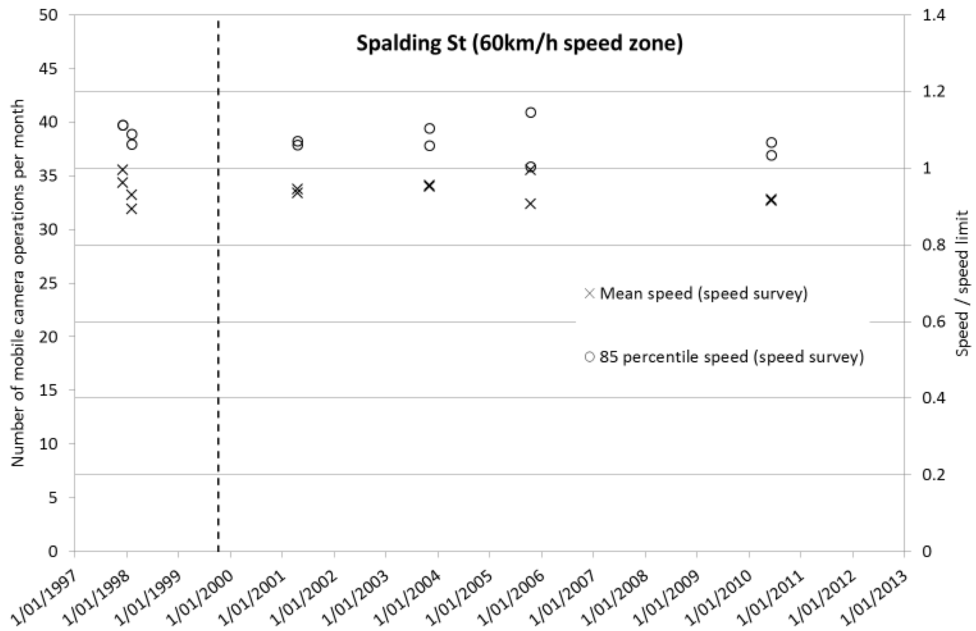
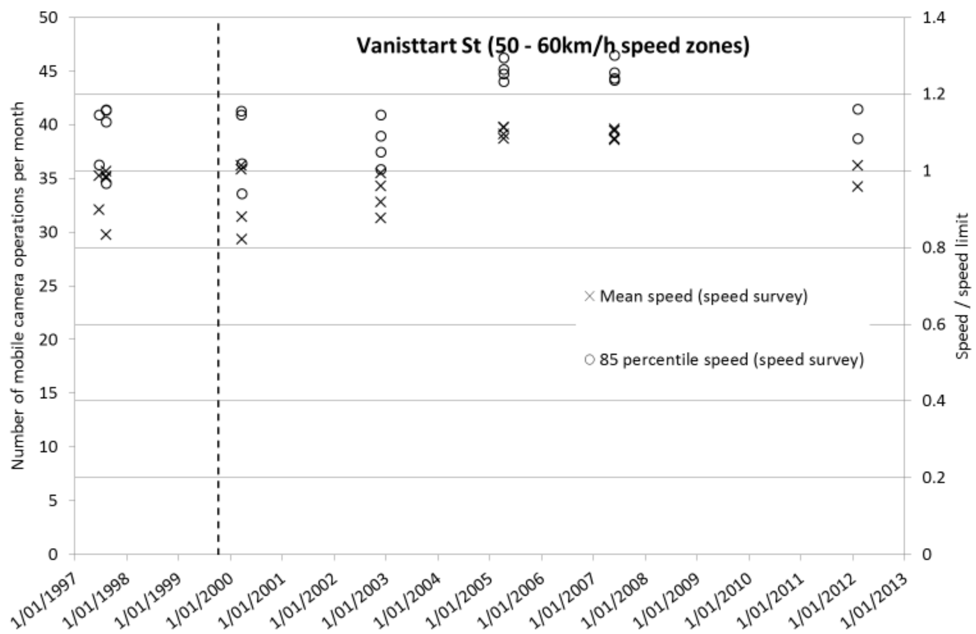
1/01/2012
1/01/2013


Spalding St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Vanisttart St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
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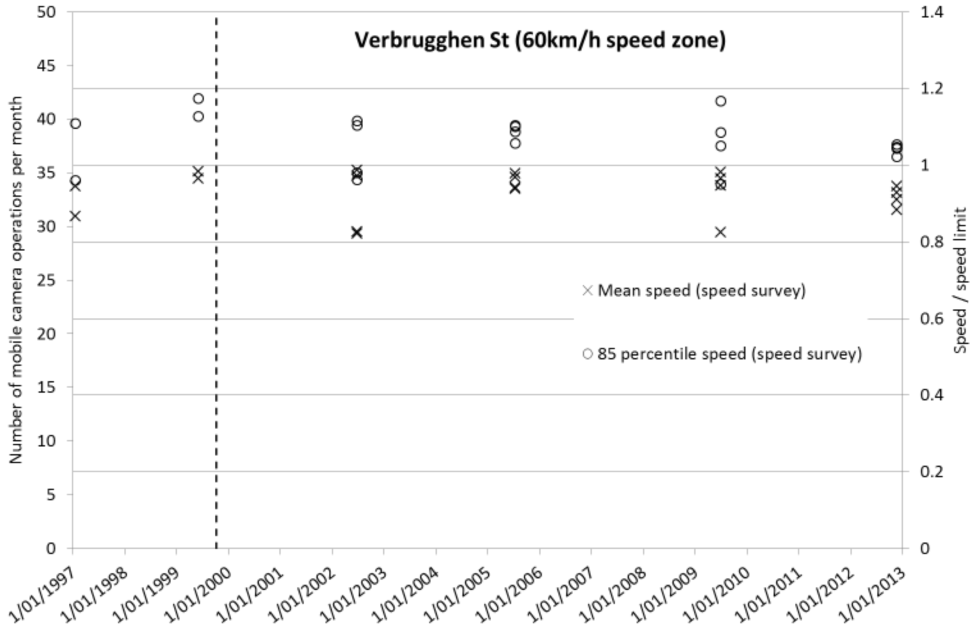
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Verbrugghen St (60km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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1/01/2002
1/01/2003
1/01/2004
1/01/2005
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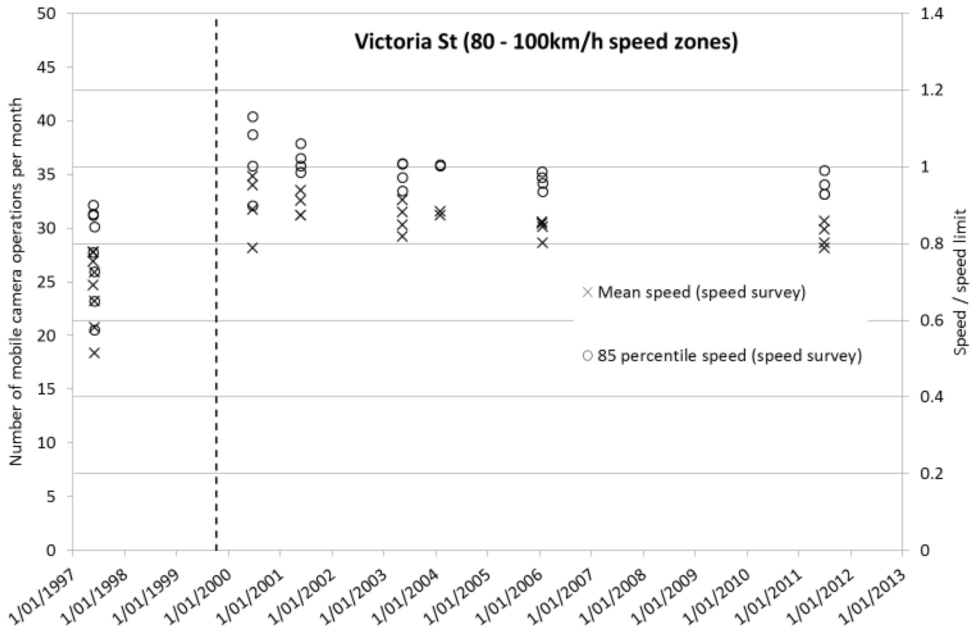
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Victoria St (80 - 100km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
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1/01/1997
1/01/1998
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1/01/2000
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1/01/2005
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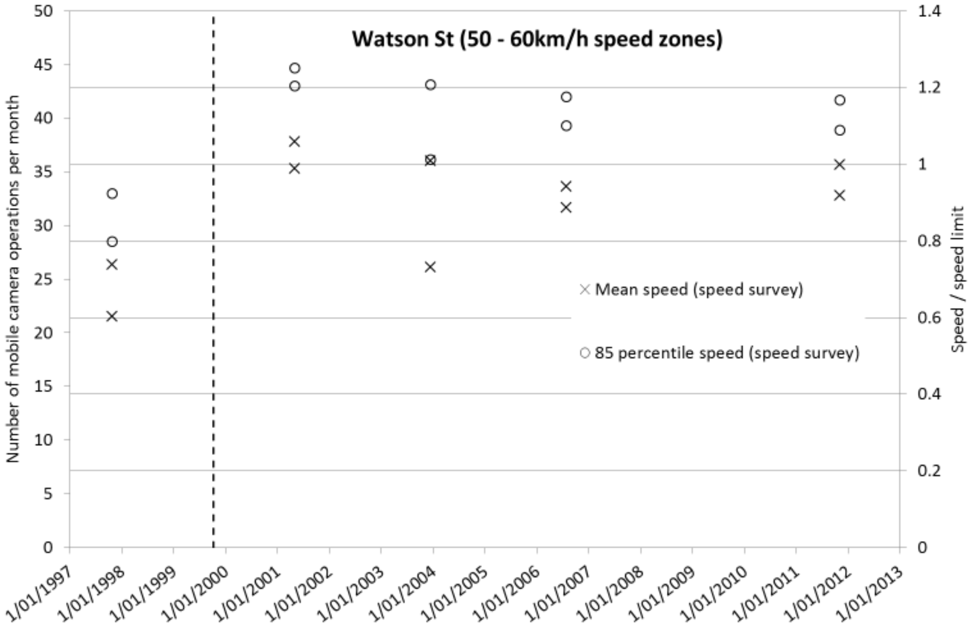
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Watson St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
10
15
20
25
30
35
40
45
50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/1997
1/01/1998
1/01/1999
1/01/2000
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1/01/2005
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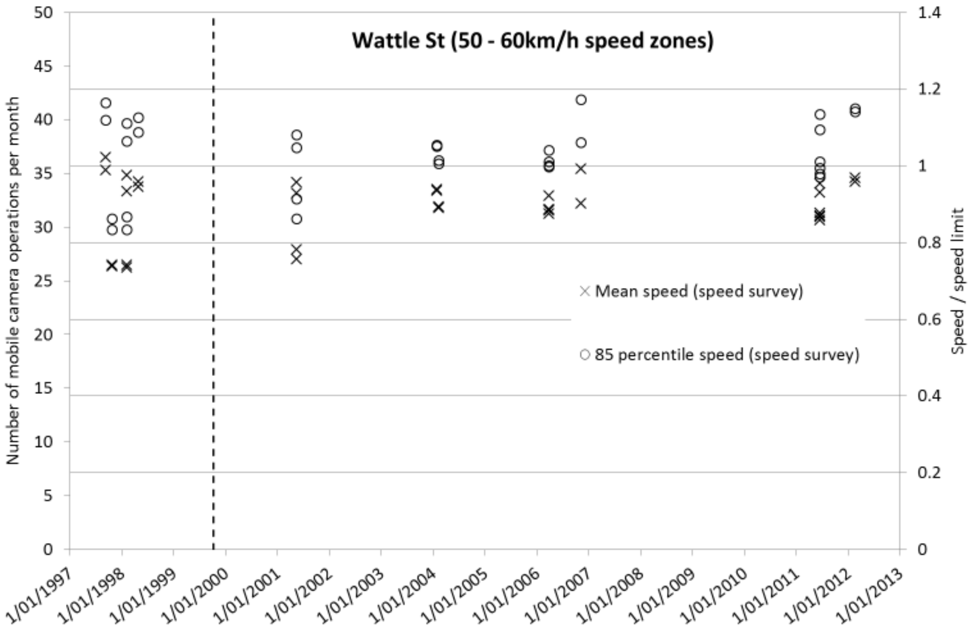
1/01/2010
1/01/2011
1/01/2012
1/01/2013


Wattle St (50 - 60km/h speed zones)
Number of mobile camera operations per month
Speed / speed limit
× Mean speed (speed survey)
○ 85 percentile speed (speed survey)
0
5
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0.2
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1/01/2000
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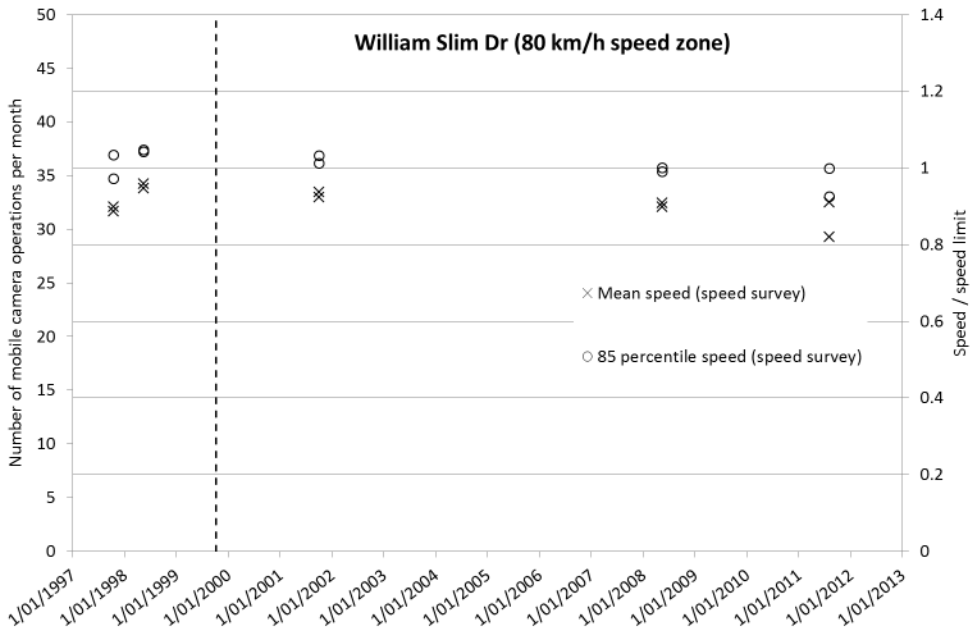
1/01/2010
1/01/2011
1/01/2012
1/01/2013


William Slim Dr (80 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
5
10
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0
0.2
0.4
0.6
0.8
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1.2
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1/01/1997
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1/01/2008
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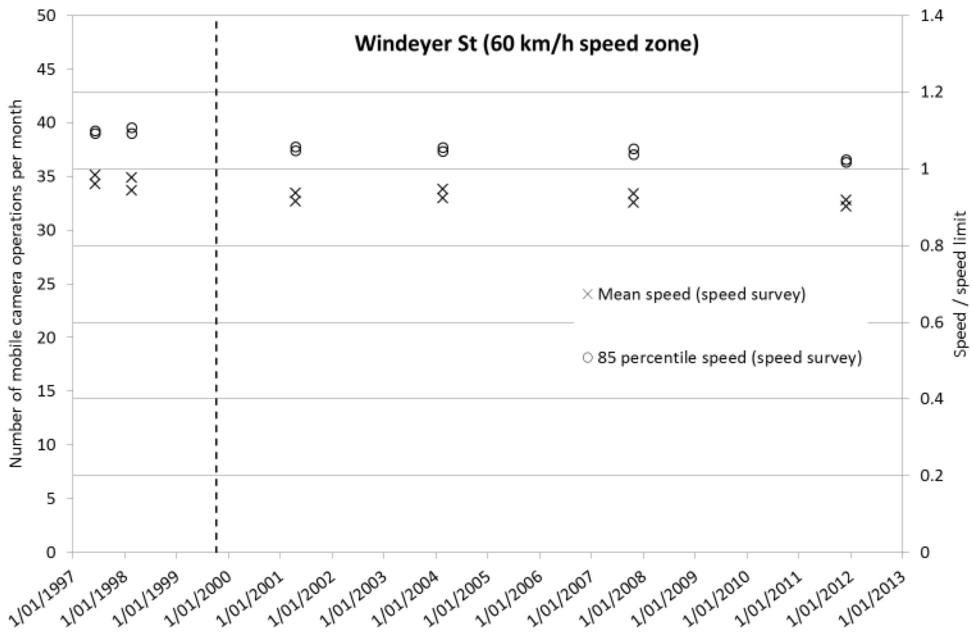
1/01/2011
1/01/2012
1/01/2013


Windeyer St (60 km/h speed zone)
Number of mobile camera operations per month
Speed / speed limit
Mean speed (speed survey)
85 percentile speed (speed survey)
0
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0.2
0.4
0.6
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1
1.2
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1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
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1/01/2010
1/01/2011
1/01/2012
1/01/2013

Appendix E: Detailed statement of requirements

Evaluation scope

The evaluation is to assess the impact of the ACT's Road Safety Camera Program, which includes mobile, fixed mid-block, point to point and red light/speed cameras, on the road safety objectives of:

(a) reducing crashes;

(b) reducing speeding (and thereby reducing crash risk).

The evaluation is to utilise:

(c) available ACT data, including crash data, speed surveys, and infringement data;

(d) relevant research and findings of other jurisdictions' evaluations of the effectiveness of road safety cameras and road safety camera programs; and

(e) any other relevant data, studies, evaluations or information.

The evaluation is to, as far as possible, having regard to the available data and information:

(f) assess the impact of the ACT Road Safety Camera Program as a whole;

(g) assess the contribution and impact of the various types of cameras used as part of the ACT Road Safety Camera Program; and

(h) assess the governance arrangements for the ACT Road Safety Camera Program.

The evaluation is to identify:

(i) potential opportunities to gain improved road safety effectiveness from the existing resources of the ACT Road Safety Camera Program;

(j) future opportunities to maximise the road safety effectiveness of the ACT Road Safety Camera Program, in relation to both network resources and governance; and

(k) an appropriate ongoing evaluation framework to support an effective ACT Road Safety Camera Program.

From: Davidson, Geoffrey
To: Mike Bambach
Subject: RE: Fixed camera Locations
Date: Thursday, 8 May 2014 4:47:00 PM

Hi Mike

Sorry – yes.

The change in the total number of operations per month was due to vans being out of service for maintenance as a result of aging equipment. There were also periods of high turnover of staff.

GEoff

Geoffrey Davidson | Manager, Road Safety
Legislation, Policy & Programs | Justice and Community Safety Directorate | **ACT Government**
Level 2, 12 Moore Street, CANBERRA CITY ACT 2601 | GPO Box 158, CANBERRA ACT 2608
Telephone (02) 620 77195 | Facsimile (02) 620 50937

From: Mike Bambach [mailto:
Sent: Thursday, 8 May 2014 9:43 AM
To: Davidson, Geoffrey
Subject: FW: Fixed camera Locations

Hi Geoff, any response regarding the below?
Mike

From: Mike Bambach
Sent: Monday, 5 May 2014 2:32 PM
To: 'Davidson, Geoffrey'
Subject: RE: Fixed camera Locations

Hi Geoff,
Could you please pass the following question on to the appropriate person, thanks.

In the mobile camera operations data there seems to be a marked change in the total number of operations per month in late 2006. After this time monthly operations continued at a lower rate than prior to 2006.
Could I be provided with a brief narrative of mobile operations over time generally, particularly the changes in late 2006?
I would like to include this in the report, which I presume will become a public document, so please only include information you are happy to become public.
Thanks!

Mike

From: Davidson, Geoffrey [mailto:Geoffrey.Davidson@act.gov.au]
Sent: Tuesday, 29 April 2014 8:43 AM
To: Mike Bambach
Subject: FW: Fixed camera Locations

Here you go Mike. These appear to match up to the data sent.

Geoffrey Davidson | Manager, Road Safety
Legislation, Policy & Programs | Justice and Community Safety Directorate | **ACT Government**
Level 2, 12 Moore Street, CANBERRA CITY ACT 2601 | GPO Box 158, CANBERRA ACT 2608
Telephone (02) 620 77195 | Facsimile (02) 620 50937

From: Stone, Gordon
Sent: Monday, 28 April 2014 3:44 PM
To: Davidson, Geoffrey
Subject: Fixed camera Locations

Hi Geoff,

Attached is a list of locations they are also in they are also in the Road Transport (Safety & Traffic Management) Regulations 2000. http://www.legislation.act.gov.au/sl/2000-10/current/pdf/2000-10.pdf Part 1.2 .

Regards

Gordon

Gordon Stone
Manager
ACT Traffic Camera Office
Transport Regulation | Justice and Community Safety Directorate | ACT Government
13 – 15 Challis St, DICKSON ACT 2602 | PO Box 582, DICKSON ACT 2602
Telephone (02) 6207 5770 | Facsimile (02) 6207 7287

From: Davidson, Geoffrey
Sent: Monday, 28 April 2014 2:28 PM
To: Stone, Gordon
Subject: FW: data

Hi Gordon

Are you able to assist?

Geoff

Geoffrey Davidson | Manager, Road Safety
Legislation, Policy & Programs | Justice and Community Safety Directorate | **ACT Government**
Level 2, 12 Moore Street, CANBERRA CITY ACT 2601 | GPO Box 158, CANBERRA ACT 2608
Telephone (02) 620 77195 | Facsimile (02) 620 50937

From: Mike Bambach [mailto:
Sent: Monday, 28 April 2014 2:10 PM
To: Davidson, Geoffrey
Subject: RE: data

Thanks Geoff,
Can you please send a list of the locations corresponding to the numeric codes used for the fixed cameras?
Thanks,
Mike

This email, and any attachments, may be confidential and also privileged. If you are not the intended recipient, please notify the sender and delete all copies of this transmission along with any attachments immediately. You should not copy or use it for any purpose, nor disclose its contents to any other person.
