Economic Development Committee

Inquiry into the road safety benefits of fixed speed cameras

Submission 29

NSW Centre for Road Safety

RTA

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Ms Lyndel Bates
The Research Director
Economic Development Committee
Parliament House
George Street
BRISBANE QLD 4000

Dear Ms Bates

Thank you for letter regarding the inquiry into the road safety benefits of fixed speed cameras in Queensland.

Fixed speed cameras have operated in NSW for around 10 years. There are currently 172 speed cameras located at 141 locations throughout NSW. An independent evaluation of the NSW Fixed Speed Camera Program conducted by ARRB Group revealed at camera sites the number of vehicles exceeding the speed limit was reduced by 71 per cent leading to a 90 per cent reduction in fatal crashes and more than a 20 per cent decrease in injury crashes at fixed speed camera locations. I have attached a copy of the evaluation for your information.

In NSW fixed speed cameras operate with three prominent warning signs on the approach to the camera. A study by the RTA in 2006 found that, unsurprisingly, drivers decrease speed on approach to and on passing the cameras then increase speed again on departure from the cameras. Thus, the specific deterrent value and safety benefits of the speed cameras, because they operate only at one point, are limited to a total length of approximately 500 metres around each camera. This makes them an excellent treatment for a crash blackspot where speeding occurs.

Should you have any further enquiries regarding the NSW Fixed Speed Camera Program, please contact Mr Evan Walker, Senior Policy Manager (Speed) on (02) 8588 5825.

Yours sincerely

R F. Soames Job 22/4/10

Dr Soames Job
Director
NSW Centre for Road Safety

Roads and Traffic Authority ABN 64 480 155 255

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Evaluation Report

Evaluation of the Fixed Digital Speed Camera Program in NSW

by *ARRB Group Project Team*

for Roads & Traffic Authority, NSW

RC2416 – May 2005

arrb
consulting

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Contents

Executive summary

Introduction

In July 2000, the NSW Roads and Traffic Authority (RTA) commissioned ARRB Group Ltd (ARRB Group) to conduct a detailed evaluation of the Fixed Digital Speed Camera Program in NSW. The evaluation comprised crash analyses, speed surveys, community questionnaire surveys and an economic analysis. Initially, 20 fixed digital speed camera sites were selected for inclusion in the evaluation. In October 2002, eight more camera sites were added to the sample.

Selection of sites for fixed digital speed camera use in New South Wales

A set of criteria was developed by the RTA, in consultation with NSW Police and NRMA Motoring and Services, for selection of fixed digital speed camera sites (the camera length). The criteria assess crash rates and vehicle speeds over a length of road of between one and 3.3 kilometres (the camera length or blacklength) where the camera is intended to reduce speeding and crashes.

The crash analysis involves a review of the rates of crashes occurring over a length of road relative to the traffic volume, the severity of the crashes and the travel speed of the prevailing traffic. The crashes are compared with predetermined rates for three road type categories: rural, urban and freeway/motorway. If the length demonstrates characteristics that exceed the defined criteria then that section of road is considered for speed analysis.

If speed survey data demonstrate vehicle speeds in excess of the criteria thresholds, investigations are conducted into the physical site requirements including site configuration, safety barrier requirements, power requirements and telecommunication availability. Prior to the selection of the fixed digital speed camera sites, an initial investigation is carried out at each of the candidate sites. The investigation seeks to identify potential treatments, as an alternative to the use of fixed digital speed cameras that would improve the safety at each of the sites. If no viable alternative treatment is identified the site is then considered as a fixed digital speed camera site.

After the RTA has collected and analysed the crash and speed data and inspected the proposed site to ensure that the criteria are met, the proposed site and all relevant details are forwarded to NSW Police for formal endorsement of the site.

Signage

Each fixed digital speed camera has three large prominently placed signs on both approaches informing motorists that the camera is in operation. As a motorist approaches the camera the sign messages are firstly, *Speed cameras 24 hours*, secondly, *Speed camera ahead*, and thirdly, *Heavy fines, loss of licence* and each sign incorporates a regulatory speed limit display (the limit in digits surrounded by a red circle).

The operation of the fixed digital speed cameras in NSW

A typical fixed digital speed camera installation includes two posts with metal boxes mounted on the top of each. One box contains the camera and computer and the other box the flash unit. It should be noted that each of the camera boxes contains a fixed digital speed camera and that cameras are not rotated out of any of the installation sites.

Fixed digital speed cameras detect the speed of vehicles by using piezo-electric detectors embedded into the road surface. These piezo detectors deflect slightly when a vehicle is driven over them and this causes them to emit signals, which then trigger an electronic device that accurately measures the speed of the vehicle. If the speed of the vehicle exceeds the legal limit then a digital picture is taken of the offending vehicle which is stored along with all the other necessary data.

If a vehicle is detected speeding, a digital image of the vehicle and associated data are recorded onto a disk from which all details regarding the speeding vehicle can be extracted. The image clearly shows the colour, type, make and number plate of the vehicle, as well as site details. The fixed digital speed cameras in this evaluation all measured speeds of vehicles in one direction only. A speeding vehicle can be detected and photographed even if it is within a group of vehicles because there are separate piezo detectors for each lane. The angle at which the cameras are set enables pictures to be taken of the offending vehicle even if another vehicle is in close proximity.

The original recorded images and related data are stored electronically on a WORM (Write Once Read Many) disk, which cannot be overwritten or erased and existing data cannot be altered. A security indicator is also produced when the file is written to the disk and should any attempt be made to tamper with the image at any stage, a change in the security indicator will result and this will be obvious to the technician viewing the image.

All images and the data relating to them (such as speed, time, date and location) are encrypted. Thus, the image cannot be viewed without the appropriate encryption key.

The Office of State Revenue's Infringement Processing Bureau (IPB) manages the processing and issuing of traffic infringements from fixed digital speed cameras. The IPB issues the traffic infringement notice that details the incurred traffic offence penalty.

Where cases go to court the original image forms the basis of the evidence produced in court. In line with legislative requirements, the photographs from fixed digital speed cameras can be tendered as evidence in court, together with appropriate evidentiary certificates signed by an authorised technician.

The registered owner of a vehicle that has been detected by a fixed digital speed camera is considered to be responsible for the designated offence unless the owner supplies a statutory declaration containing the name and address of the person who was in charge of the vehicle at the time of the offence.

Penalties

If an individual's vehicle is detected speeding by a fixed digital speed camera the registered operator of the vehicle, or the driver nominated by the owner via a statutory declaration will incur a fine and licence demerit points. There are automatic licence suspension periods, or in the case of matters that are defended in court, minimum disqualification periods, for exceeding the speed limit by more than 30 km/h (three months), and by more than 45 km/h (six months).

To ensure that the Fixed Digital Speed Camera Program delivers optimal safety benefits to the community, it is essential that the impact of the cameras be identified and evaluated in terms of driver speed behaviour, road trauma, economic value, and community awareness and understanding of the use of fixed digital speed cameras as a road safety tool. Knowledge of the ongoing performance of the Program will provide the opportunity to examine the implementation and operation strategy, and if so required, revise the Program so as to optimise the safety benefits.

Evaluation methodology

Initially, the Fixed Digital Speed Camera Program consisted of 25 fixed digital speed cameras. The evaluation was designed to encompass 20 of these 25 camera sites to maximise the range of road environment features from the various sites. At this point it was not envisaged that the number of fixed digital speed cameras would grow to 111 (as it has). When the evaluation commenced not all 25 camera sites had been selected, however, these sites were finalised after the sample of 20 sites was identified. In October 2002, when there was a total of 81 cameras installed, a further eight sites were added to the sample bringing the total sample size to 28.

Once a camera length is approved adjacent lengths are identified, each typically 1 – 2 kilometres in length. The adjacent lengths are positioned before and after the camera length and directly abut the camera length. The adjacent lengths generally contain the same traffic that travels through the camera length. Not all camera lengths have an adjacent length either side.

The objective of the evaluation was to identify and measure the impact of 28 unattended fixed digital speed cameras at urban and rural locations in NSW. The lengths of road either side of the camera length were defined as either 'upstream' or 'downstream'. It is important to note that the direction of the traffic determined whether a section of road was defined as either upstream or downstream. In other words, vehicles travelling in the direction that the camera was aimed first travelled through the upstream length, then the camera length (length in which camera was based) and then the downstream length. Similarly, vehicles travelling in the opposite direction to which the camera was aimed first travelled through the upstream length (which is adjacent to the downstream length for the vehicles travelling in the direction of the camera) then the camera and finally through the downstream length (which is adjacent to the upstream length for the vehicles travelling in the direction of the camera). Figure A shows the typical layout of a camera site.

The effectiveness of the Program was measured in terms of:

a) Changes in driver speed behaviour (ie. proportion of motorists 'speeding' above pre-determined thresholds, mean speeds and 85th percentile speeds) occurring at the fixed digital speed camera locations and the upstream and downstream lengths.

b) Changes in the incidence and severity of road crashes at fixed digital speed camera locations (ie. camera length), and in locations within close proximity to these sites (ie. described as the upstream and downstream lengths, located either side of the speed camera location).

c) Economic value of the Program to the community.

d) Community attitudes, knowledge, beliefs and reported behaviours in relation to the Program and changes in these over time.

Site details

In this evaluation the fixed digital speed camera site was defined as the 'camera length'; the blacklength section of road in which the camera was located. The cameras covered only one direction of travel and were not rotated (ie there was always a camera in each installation).

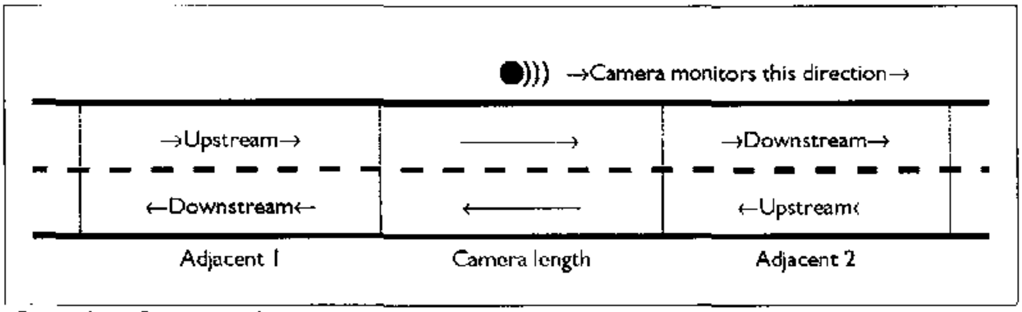

Figure A: Camera site layout

Speed survey analysis

Speed surveys were carried out at the 20 initially-selected fixed digital speed camera locations. Surveys were conducted prior to the commencement of operation of the cameras, and compared with speed surveys carried out at six months, 12 months and 24 months following the commencement of operation of the cameras. To determine the possible effect of the cameras on vehicle speeds in advance and beyond the camera locations, speed surveys were also carried out in the adjacent road sections. The analysis compared the following:

- Percentage of vehicles exceeding the speed limit.
- Percentage of vehicles exceeding the speed limit by at least 10 km/h, 20 km/h and 30 km/h.
- Mean and 85th percentile speed.

Two separate statistical analyses of the speed data were performed for the evaluation, namely the descriptive statistical analysis and the inferential statistical analysis, with the latter providing a more accurate determination of the impact of the fixed digital speed cameras on vehicle speeds.

The descriptive statistical analysis was carried out at intervals throughout the course of the study to provide an indication of the effect of the fixed digital speed cameras on vehicle speeds, while the inferential statistical analysis was carried out during the latter stages of the evaluation. Contrasting with the descriptive statistical analysis the inferential statistical analysis entailed carrying out of statistical methods that are able to be used to draw inferences about all fixed digital speed camera sites from a data set drawn from a representative group of fixed digital speed camera sites.

Speed surveys were also conducted at the eight additional sites. For each of the eight camera sites two series of speed surveys were conducted. These surveys were carried out at two of the 12 month, 18 month or 30 month points after the time the cameras became operational. It should be noted that because the sites were added to the study after the cameras located at these sites were commissioned, there were no pre-installation speed survey data available upon which to draw any comparisons. The speed survey data obtained, however, did allow the speed profiles to be investigated at each of the camera sites, and allowed the longer-term impact on speeds to be determined at the sites through the comparison of the two sets of surveys at each of the locations.

To account for any changes in vehicle speeds that may have resulted from other factors speed data from 'matched' non-speed camera locations (ie. control sites) were used in the analyses.

a) Inferential statistical analysis of speeds (20 initial sites)

Mean speed

At the **camera lengths** there was a statistically significant ($p<0.0001$) reduction in mean speed of 6.3 km/h and 5.8 km/h 12 months and 24 months 'after' respectively. While there were generally no changes in speed in the **adjacent lengths**, a small but statistically significant ($p=0.0192$) increase of 1.5 km/h was detected in the upstream length at the 24-month 'after' survey.

Percentage of vehicles exceeding the speed limit

The 12 month 'after' speed data revealed statistically significant ($p<0.0001$) reductions across all lengths of 5.3 per cent (**upstream length**), 70 per cent (**camera length**) and 20.9 per cent (**downstream length**).

While the 24-month 'after' data show that statistically significant ($p<0.0001$) reductions were maintained along the camera length (71.8%) and the downstream length (5.1%), the upstream length increased to a statistically significant ($p<0.0001$) degree of 3.4 km/h.

Percentage of vehicles exceeding the speed limit by at least 10 km/h

Statistically significant ($p<0.0001$) reductions of 85.6 per cent and 87.9 per cent were achieved along the **camera lengths** 12 months and 24 months after the cameras became operational.

After 12 months the **downstream** proportion reduced by 8.2 per cent while the **upstream** length increased by 7.6 per cent, 24 months 'after' there were increases of 24.8 per cent in the upstream length and 10.5 per cent in the downstream length. In all cases the changes were statistically significant ($p<0.0001$).

Percentage of vehicles exceeding the speed limit by at least 20 km/h

Statistically significant ($p<0.0001$) reductions of 85.6 per cent and 86.5 per cent were achieved along the **camera lengths** 12 months and 24 months after the cameras began operating.

After 12 months, the proportions of vehicles exceeding the limit by at least 20 km/h in the **upstream and downstream lengths** increased by 21.9 per cent and 22.1 per cent respectively. Twenty-four months 'after' there were increases of 36.9 per cent in the upstream length and 41 per cent in the downstream length. In all cases the changes were statistically significant ($p<0.0001$).

Percentage of vehicles exceeding the speed limit by at least 30 km/h

Statistically significant ($p<0.0001$) reductions of 83.9 per cent and 79.5 per cent were achieved along **the camera lengths** 12 months and 24 months after the cameras began operating.

After 12 months, the proportions exceeding the limit by at least 30 km/h in the **upstream and downstream lengths** increased by 23.2 per cent and 29.6 per cent respectively. Twenty-four months 'after' there were increases of 13.6 per cent in the upstream length and 29.4 per cent in the downstream length. In all cases the changes were statistically significant ($p<0.0001$).

Summary

The data reveal that substantial reductions were achieved in mean speeds along the fixed digital speed camera sites. Mean speeds fell by approximately 6 km/h, 12- and 24-months after the cameras became operational while adjacent length mean speeds changed by relatively small amounts.

When considering the percentage of vehicles exceeding the speed limit, and exceeding the speed limit by 10 km/h, 20 km/h and 30 km/h the analysis revealed that very large reductions were achieved along the 'high crash' camera lengths. Reductions achieved were in the range of 70 per cent to almost 90 per cent, far outweighing any increases detected in adjacent lengths.

b) Descriptive statistical analysis of speeds (28 sites)

85^{th} percentile speed

The 85^{th} percentile speed is the speed at or below which 85 per cent of all vehicles are observed under free flow conditions.

After taking account of control speed data **the following reductions** within the camera lengths were achieved:

- 7.3 km/h (11%) and 6.3 km/h (9%) **within 60 km/h speed zones** after 12 months and 24 months respectively.
- 8 km/h (10%) and 8.4 km/h (11%) **within 70 km/h** speed zones after 12 months and 24 months respectively.
- 11 km/h (13%) and 12 km/h (13%) **within 80 km/h speed zones** after 12 months and 24 months respectively.
- 22.4 km/h (20%) and 22.3 km/h (20%) **within 90 km/h speed zones** after 12 months and 24 months respectively.

- 4.4 km/h (4%) and 7.3 km/h (7%) **within 100 km/h speed zones** after 12 months and 24 months respectively.
- 12.6 km/h (10%) **within the 110 km/h speed zone** after 12 months. It should be noted that no 24-month 'after' speed data were recorded for this site.

Standard deviation

The standard deviation is a statistic that can be used as a measure of the distribution of speeds amongst the traffic flow. It is considered that other things being equal, a reduction in the standard deviation will be associated with a more uniform traffic flow thus reducing the need for overtaking movements. This will be expected to consequently result in improved safety for the moving traffic.

After taking account of control speed data the following **reductions** within the camera length were achieved:

- 1.4 km/h (18%) and 1.7 km/h (22%) **within 60 km/h speed zones** after 12 months and 24 months respectively.
- No change and 1.0 km/h (15%) **within 70 km/h speed zones** after 12 months and 24 months respectively.
- 1.8 km/h (22%) and 2.1 km/h (27%) **within 80 km/h speed zones** after 12 months and 24 months respectively.
- 4.1 km/h (40%) and 4.6 km/h (40%) **within 90 km/h speed zones** after 12 months and 24 months respectively.
- 1.8 km/h (18%) and 3.8 km/h (34%) **within 100 km/h speed zones** after 12 months and 24 months respectively.
- 0.5 km/h (17%) **within the 110 km/h speed zone** after 12 months. It should be noted that no 24-month 'after' speed data were recorded for this site.

Crash analysis

The crash analysis was conducted, on all 28 sites, to identify whether the changes in crashes at the camera sites were beyond chance fluctuation, that is, statistically significant, while at the same time taking into account any influence of other factors. Thus, any statistically significant changes can be considered as 'real' effects that are due to the cameras.

The inferential statistical analysis provided the following key findings after two years of camera operation:

- There was a statistically significant reduction (p=0.0001) in **all reported crashes** along the **camera lengths** of 19.7 per cent.
- For the **combined lengths** there was a total reduction in **all reported crashes** of 7.6 per cent, which is borderline to being statistically significant (p=0.056).
- For the **camera lengths** there was a statistically significant reduction (p=0.0051) in **casualty crashes** (ie fatal plus injury crashes) of 22.8 per cent.
- For the **combined lengths** there was a non-statistically significant reduction of 7.8 per cent in **casualty crashes**.
- There was a statistically significant (p=0.012) reduction of 16.9 per cent in **tow-away crashes** along the **camera lengths**.
- Across the **combined lengths** there was a non-statistically significant reduction of 6.6 per cent in **tow-away crashes**.
- There was a statistically significant (p=0.0164) reduction of 20.1 per cent in the **injury crashes** along the **camera length**.
- For the **combined lengths** there was a non-statistically significant reduction of 6.2 per cent in **injury crashes**.
- There was a 89.8 per cent reduction in **fatal crashes** in the **camera lengths** during the two years after the cameras became operational. This estimate was statistically significant (p=0.014). The 95 per cent confidence limits on this estimated effect ranged from 22.1 per cent reduction to 98.7 per cent reduction.
- There was a 57.6 per cent reduction in **fatal crashes** in the **combined lengths** during the two years after the cameras became operational. This estimate was borderline to being statistically significant (p=0.054). The 95 per cent confidence limits on this estimated effect ranged from 1.3 per cent increase in fatal crashes to 82.3 per cent reduction.

Economic analysis

Overall, the 28 camera sites have positive social benefits corresponding to positive net present values. The crash reductions achieved through the Fixed Digital Speed Camera Program contribute to its high degree of economic merit.

Net present value

For the total 28 fixed digital speed camera sites, the net present value over a project horizon of 18 years is $109.1 million and $113.4 million for all road lengths and the camera lengths respectively. Over a project horizon of six years, the net present value shows a similar trend; $50.9 million and $53 million for all road sections and the camera section respectively.

Overall, the 28 camera sites have positive social benefits corresponding to positive net present values. This indicates that the Fixed Digital Speed Camera Program has a high degree of economic merit.

Benefit Cost Ratio

The economic analysis of the project estimates a **benefit cost ratio** of 3.4 over a project horizon of six years or 3.5 for a project horizon of 18 years. This indicates that the Fixed Digital Speed Camera Program will perform competitively with other road safety programs over its time of operation.

Community questionnaire surveys

Four waves of community questionnaire surveys were conducted over two years. The surveys collected information on motorists' knowledge, attitudes, beliefs and reported behaviours in relation to fixed digital speed cameras, speeding behaviour and speeding enforcement.

In the two-year period of the four waves of the community attitude survey, the number of fixed digital speed cameras increased from 10 to 35 across NSW. From the beginning of the evaluation community awareness of fixed digital speed cameras was high and continued to rise with increased implementation of fixed digital speed cameras.

The community had a generally positive attitude towards fixed digital speed cameras with respondents more likely to associate the fixed digital speed cameras and their locations with speeding, crashes and road safety rather than revenue-raising. The use of fixed digital speed cameras received strong acceptance from the respondents with a preference for them in higher rather than lower speed zones.

The Fixed Digital Speed Camera Program appears to have had an impact on influencing driver behaviour with most respondents slowing down at the fixed digital speed camera sites. This conclusion is reinforced by the increase in the incidence of respondents (across the four waves) claiming most other drivers reduce their speed below the limit on sighting fixed digital speed camera warning signs. This is also apparent in the speed survey results, which show that all sites experienced substantial reductions in vehicle speeds.

The bulk of respondents perceived fixed digital speed cameras as having a legitimate role as a road safety countermeasure particularly in reducing speeding and preventing crashes. These findings revealed that with greater exposure to the fixed digital speed cameras respondents' perceptions of the fixed digital speed cameras improving road safety increased.

Conclusions

This evaluation has shown that after the installation of 28 fixed digital speed cameras across various sites in New South Wales, significant reductions were achieved in vehicle speeds, speeding rates and crashes. Statistical analysis of speed and crash data has shown that significant reductions in speed parameters and crash numbers are attributable to the presence of the fixed digital speed cameras.

The speed data revealed that substantial reductions were achieved in mean speeds along the speed camera sites. Mean speeds fell by approximately 6 km/h at 12 and 24 months 'after' while adjacent mean speeds changed by relatively small amounts. The analysis also revealed large reductions in the percentage of vehicles exceeding the speed limit, and exceeding the speed limit by 10 km/h, 20 km/h and 30 km/h along the 'high crash' camera lengths. Reductions achieved were in the order of 70 per cent to almost 90 per cent, far outweighing any increases detected in adjacent lengths.

Overall reported crashes fell by almost 20 per cent along the road segments that had demonstrated high crash risk (camera lengths). Casualty crashes fell along the camera lengths by 23 per cent, injury crashes by 20 per cent and fatal crashes by nearly 90 per cent.

When accounting for changes in crashes along the combined camera lengths, large reductions in crashes continued to be achieved: 7.6 per cent in all reported crashes, 7.8 per cent in casualty crashes, 6.2 per cent in injury crashes and 57.6 per cent in fatal crashes.

For the total 28 fixed digital speed camera sites, the net present value over a project horizon of 18 years is $109.1 million and $113.4 million for all road sections and the camera section respectively. Over a project horizon of six years, the net present value shows a similar trend; $50.9 million and $53 million for all road sections and the camera section respectively.

The economic analysis of the project estimates a benefit cost ratio of 3.4 over a project horizon of six years or 3.5 for a project horizon of 18 years. This indicates that the Fixed Digital Speed Camera Program competes well with other road safety countermeasures.

Overall, respondents had positive community attitudes towards the Fixed Digital Speed Camera Program, were well aware of the initiative, had realistic expectations of the Program and believed the cameras were an effective road safety countermeasure.

In summary the key findings of the evaluation were that:

- Vehicle operating speeds (ie 85th percentile speeds) fell markedly along the camera lengths;
- Crashes fell in a highly statistically significant manner in the camera length;
- Crash reductions achieved through the Fixed Digital Speed Camera Program contribute to its high degree of economic merit.

The above findings show that lowering speeds is a mediating factor in crash reduction within camera sites. This is consistent with the findings of other research that indicate speeding is associated with increases in road trauma (Federal Highway Administration 1998; Fildes and Lee 1993; Kloeden, McLean & Glonek, 2002; RTA 2000; Sliogeris, 1992, Taylor et al, 2002).

On this basis of the benefits achieved by the Fixed Digital Speed Camera Program it would be appropriate to extend the Program across a wider area of NSW at suitably selected locations.

Acknowledgments

Acknowledgment is given to the role of the Fixed Digital Speed Camera Evaluation Steering Committee. Members of the Committee included Gill Browne (MAA), Tasha Prabhakar (NRMA Motoring and Services), Dave Evans (NSW Police), Don Carseldine/Rosemary Rouse (RTA) and David Walsh (David Walsh and Associates Pty Ltd on behalf of the RTA).

ARRB Group would like to further acknowledge and thank the following RTA personnel for their assistance in conducting the evaluation.

Roads & Traffic Authority, New South Wales (RTA) – Project Management Team

- Dr Don Carseldine — Manager, Speed Management
- David Walsh (David Walsh and Associates Pty Ltd) — Manager, Speed Camera Evaluation Project
- Rosemary Rouse — Manager, Road User Safety
- Greg Allsop — Speed Management Officer, Speed Management

Other significant contributions were made by the following RTA staff:

- Mike Adams — Manager, Data Provision, Information
- Emma Shearer — Data Management Officer, Information

ARRB Group Project Team

- Michael Tziotis (Project Manager)
- Ray Taylor (Quality Manager)
- Philip Roper
- Dr Dimitris Tsolakis and Katrina Preski (economic analysis), and Fiona Green, Thanuja Gunatillake, Lisa Boschert (project team assistance)

Associates:

- Barry Elliott, Research and Communications Psychologist, and NCS Australasia (attitudinal surveys)
- Sam White TCS Instruments, and Palle Johansen, Palle Johansen and Associates (speed surveys)
- Max Cameron and Stuart Newstead, Camcomp Partners Pty. Ltd. (statistical analysis and reporting of final speed and crash data).

1 Introduction

In July 2000, the NSW Roads and Traffic Authority (RTA) commissioned ARRB Transport Research Ltd (ARRB Group) to conduct an extensive evaluation of the Fixed Digital Speed Camera Program in NSW. The evaluation comprised crash analyses, speed surveys, community questionnaire surveys and an economic analysis. Initially 20 fixed digital speed camera sites were selected, and in October 2002, eight more cameras were added to the sample.

1.1 Background

Speeding has been identified as a major factor in the occurrence and severity of road crashes. Speeding is the most common contributing factor to road trauma on NSW roads. In the five-year period 1999 – 2003 there were 1,171 people killed and 23,888 people injured in speed-related crashes. The cost to the community was in excess of $6.2 billion (RTA).

The NSW Roads and Traffic Authority (RTA) reports that in 2003 speed was a factor in 36 per cent of all fatal crashes, 41 per cent of fatal crashes on country roads and in 29 per cent on metropolitan roads (RTA).

Research has also shown that as vehicle speeds increase so does the risk of a crash occurrence, and the severity level (Federal Highway Administration 1998; Fildes and Lee 1993; Kloeden, McLean & Glonek, 2002; RTA 2000; Sliogeris, 1992, Taylor et al, 2002).

A number of evaluations of speed cameras internationally have also demonstrated substantially reduced crashes in locations where fixed speed cameras had been installed, including Elvik (1997) and PA Consulting (2004).

In an endeavour to reduce crash risk and crash severity at hazardous road locations, the RTA initiated a Fixed Digital Speed Camera Program across a select group of high-crash locations in urban and rural areas of NSW.

1.1.1 Selection of sites for fixed digital speed camera use in New South Wales

A set of criteria was developed by RTA, in consultation with NSW Police and NRMA Motoring and Services, for selection of fixed digital speed camera sites (the camera length). The criteria assess crash rates and vehicle speeds over a length of road (the camera length or blacklength) where the camera is considered to have an effect.

The crash analysis involves a review of the rates of crashes occurring over a length of road relative to the traffic volume, the severity of the crashes and the travel speed of the prevailing traffic. The crashes are compared with predetermined rates for road type categories, rural, urban and freeway/motorway. If the length demonstrates characteristics that exceed the defined criteria then that section of road is considered for speed analysis.

If speed survey data demonstrate vehicle speeds in excess of the thresholds set out in the criteria, investigations are conducted into the physical site requirements including site configuration, guardrail requirements, power requirements and telecommunication availability. Prior to the selection of the fixed digital speed camera sites, an initial investigation is carried out at each of the candidate sites. The investigation seeks to identify potential treatments, as an alternative to the use of fixed digital speed cameras, that would improve the safety at each of the sites. If no viable alternative treatment is identified the site is then considered as a fixed digital speed camera site.

After the RTA has collected and analysed the crash and speed data and inspected the proposed site, the proposed site and all relevant details are forwarded to NSW Police for formal endorsement of the site.

1.1.2 Signage

Each fixed digital speed camera has three large prominently placed signs on both approaches informing motorists that the camera is in operation. As a motorist approaches the camera the sign messages are firstly, *Speed cameras 24 hours*, secondly, *Speed camera ahead*, and thirdly, *Heavy fines, loss of licence* and each sign incorporates a regulatory speed limit display (the limit is in digits surrounded by a red circle).

1.1.3 Fixed digital speed cameras

A typical fixed digital speed camera installation includes two posts, each with a metal box mounted at the top. One box contains the camera and computer and the other box the flash unit.

Fixed digital speed cameras detect the speed of vehicles by using piezo-electronic detectors embedded into the road surface. The piezo detectors deflect slightly when a vehicle is driven over them, and this then triggers an electronic device that accurately measures the speed of the vehicle. If the speed of the vehicle exceeds the legal limit then a digital picture is taken of the offending vehicle.

If a vehicle is detected speeding, a digital image of the vehicle is recorded onto a disk from which all details regarding the speeding vehicle can be extracted. The image clearly shows the colour, type, make and number plate of the vehicle. A speeding vehicle can be detected and photographed even if it is within a group of vehicles. The angle at which the cameras are set enables pictures to be taken even if another vehicle is in close proximity.

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1.1.4 Penalties

If a vehicle is detected speeding by a fixed digital speed camera the registered operator of the vehicle, or the driver nominated by the owner via a statutory declaration driver will incur a fine and licence demerit points. There are automatic licence suspension periods, or in the case of matters that are defended in court, minimum disqualification periods, for exceeding the speed limit by more than 30 km/h (three months), and by more than 45 km/h (six months).

To ensure that the Fixed Digital Speed Camera Program delivers optimal safety benefits to the community, it is essential that the impact of the cameras be identified and evaluated in terms of driver speed behaviour, road trauma, economic value, and community awareness and understanding of the use of fixed digital speed cameras as a road safety tool. Knowledge of the ongoing performance of the Program will provide the opportunity to examine the implementation and operation strategy, and if so required, revise the Program so as to optimise the safety benefits.

1.2 Evaluation methodology

1.2.1 Objectives

Initially the Fixed Digital Speed Camera Program consisted of 25 fixed digital speed cameras. The evaluation was designed to encompass 20 of these 25 camera sites to maximise the range of road environment features from the various sites. At this point it was not envisaged that the number of fixed digital speed cameras would grow to 111 (as it has). When the evaluation commenced not all 25 camera sites had been selected, however, these sites were finalised the sample of 20 sites was identified. In October 2002, when there was a total of 81 cameras installed, a further eight sites were added to the sample bringing the total sample size to 28.

Once a camera length is approved adjacent lengths are identified, each typically one to two kilometres in length. The adjacent lengths are positioned before and after the camera length and directly abut the camera length. The adjacent lengths generally contain the same traffic that travels through the camera length. Not all camera lengths have an adjacent length either side. The lengths of road either side of the camera length were defined as either 'upstream' or 'downstream'. It is important to note that the direction of the traffic determined whether a section of road was defined as either upstream or downstream. In other words, vehicles travelling in the direction that the camera was aimed first travelled through the upstream length, then the camera length (length in which camera was based) and then the downstream length. Similarly, vehicles travelling in the opposite direction to which the camera was aimed first travelled through the upstream length (which is adjacent to the downstream length for the vehicles travelling in the direction of the camera) then the camera and finally through the downstream length (which is adjacent to the upstream length for the vehicles travelling in the direction of the camera).

The objective of the evaluation was to identify and measure the impact of 28 unattended fixed digital speed cameras at urban and rural locations in NSW. The effectiveness of the Program was measured in terms of the:

a) Changes in driver speed behaviour (ie. proportion of motorists 'speeding' above pre-determined thresholds, mean speeds and 85th percentile speeds) occurring at the fixed digital speed camera locations and the upstream and downstream lengths.

b) Changes in the incidence and severity of road crashes at fixed digital speed camera locations (ie. camera length), and in locations within close proximity to these sites (ie. described as the upstream and downstream lengths, located either side of the speed camera location).

c) Economic value of the Program to the community.

d) Community attitudes, knowledge, beliefs and reported behaviours in relation to the Program and changes in these over time.

1.3 Scope of the project

The influence of the cameras on traffic speed, crash rates (per year and per kilometre.year) and community attitudes and reported behaviours, as well as the economic merit of the cameras, were the subject of the evaluation.

Speed data were collected for each site before the cameras were installed and then at six, 12 and 24 months after the commencement of operation of the cameras for the 20 initial sites. Other survey periods up to 30 months were used in various combinations for the additional eight sites. The speed data were assessed to determine changes in driver behaviour across the sites, and in the lengths of road preceding and following each site, for the duration of the study.

Crash records were analysed for a period of up to five years for each site, comprising three years before the commencement of operation of the cameras of the camera and up to two years 'after'. Cameras at different sites began operation on different dates and the crash data were filtered to ensure the correct durations of pre- and post-installation periods.

Results of the crash analysis together with known costs of camera installation and operation were used to estimate the magnitude of any economic benefit of the 28 cameras.

Community questionnaire surveys were conducted at four stages during the evaluation in order to track public perceptions of, and responses to, the Fixed Digital Speed Camera Program.

1.4 Key Tasks

The project consisted of the following key tasks:

1. Mapping and site maps — To assist in the evaluation of the Fixed Digital Speed Camera Program, maps were prepared for each site (ie. camera and control sites). Each of these maps included the camera length, upstream and downstream lengths. The start and end of each of these lengths was also geocoded. Other information provided on the site maps included:

    - All intersecting roads.

- Scale of the map and a symbols legend.
- Crash locations.

Digital images were captured at each of the 28 camera locations (ie. camera length, upstream and downstream lengths, and at the control sites).

2. **Speed surveys and analysis**

To determine the impact on vehicle (cars and heavy vehicles) speed profiles (ie. mean speeds, 85th percentile and proportions of motorists speeding above pre-determined thresholds), surveys were undertaken to complement speed data already collected by RTA at camera and non-camera (ie. control) locations. Pre- and post-installation speed data were analysed and compared to measure the effects of the camera on driver speed behaviour.

Speed survey data were collected from a representative sample of 28 fixed digital speed camera locations.

To measure any halo effect of the cameras, speed measurements were also collected adjacent to the fixed digital camera sites. A further element of the speed data analysis was to determine whether the effect on driver speed behaviour varied over time. Consequently speed surveys, for the initial 20 sites, were undertaken at a series of intervals during the evaluation period (ie. six months, 12 months and 24 months). For the additional eight sites, combinations of 12 and 18 months (five), 12 and 24 months (two) and 24 and 30 months (one) were used due to the varying stages at which they were included and the date at which they were commissioned.

3. **Crash data analysis**

The evaluation examined in detail the impact on crashes associated with the Fixed Digital Speed Camera Program. Before and after commencement of camera operation crash analysis was undertaken in progressive quarterly periods up to a two-year post-camera operation period and compared with a three-year pre-camera operation period.

The analysis applies to a representative sample of 28 fixed digital speed camera sites. Control data were collected for the sites to account for general changes in crash rates on the road network.

The analysis includes comparisons by actual crash numbers, crashes per year, crash rates (crashes/kilometre.year), crash severity and heavy vehicle involvement.

4. **Economic analysis**

The economic analysis was undertaken in accordance with the *RTA Economic Analysis Manual, Version 2, 2003*. The analysis investigates in detail the economic benefit associated with the Fixed Digital Speed Camera Program.

5. **Community questionnaire surveys**

To determine the community's attitudes, beliefs, knowledge and reported behaviours in relation to the operation of the Fixed Digital Speed Camera Program, telephone surveys were undertaken covering a random sample of residents from specifically defined geographic locations in NSW, along with a booster sample of 50 professional drivers. Sampling comprised categories of residents living in areas that are exposed and not exposed to the influence of the fixed digital speed cameras.

To measure long-term changes in community attitudes, beliefs, knowledge and reported behaviours, surveys were conducted in September 2000 (Wave I), March/April 2001 (Wave II), September 2001 (Wave III) and September 2002 (Wave IV).

Information was collected using a 27-item questionnaire (that was developed in collaboration with RTA and subjected to pre-testing and piloting), and telephone surveys.

2 Evaluation method

2.1 Mapping and site maps

All New South Wales crash data for the period January 1996 to June 2003 were supplied to ARRB Group as annual database files. Each year's database consisted of a file of crash identification numbers and their associated location co-ordinates and a file containing full details of each crash.

RTA staff created shapefiles[1] for each camera site and for all of the site-specific control sites. These shapefiles were supplied to ARRB Group to enable extraction of relevant crash data from the database.

There were 28 locations included in the analysis. Table 1 lists each of the 28 treatment locations.

Camera sites in the Sydney and Hunter RTA regions were controlled with crash figures from their relevant local government areas (LGAs). Sites in other RTA regions were controlled with crash data from specific lengths of road. These road lengths were selected according to various criteria to ensure that they represented similar road environments to their respective camera sites.

Digital still photographs and details of the road environment were collected for all 28 treatment sites by ARRB Group staff and RTA staff. Those responsible for taking the photos also drove the length of the camera, upstream and downstream lengths to collect the road environment details, such as speed zone changes and the locations of signs.

Co-ordinates from each crash location file were mapped on the shapefiles of the camera and control sites to extract only the crash identification numbers that occurred on those particular lengths of road. The resultant lists of crash identification numbers were then matched to the full details for each crash from the crash details file for each year. The output of this process was a database of all crashes that had occurred at the camera sites, and a separate database of crashes at control sites and in control LGAs.

[1] Shapefile is a term used by the electronic mapping software used in this evaluation. The shapefiles used were a collection of data points representing the physical layout of the lengths of road occupied by speed camera sites. The mapping software combined the crash data with the shapefiles to determine which crashes occurred at camera sites.

Table 1: Camera, upstream and downstream length distances for all 28 sites in the evaluation

No.	Installation Date	Road Name	Suburb	Camera length (km)	Upstream (km)	Down-stream (km)
1	28/1/2000	Hume Hwy	Tarcutta	2.5	6.0	2.8
2	24/12/1999	Woy Woy Rd	Kariong	2.5	2.5	2.5
3	6/1/2000	Delhi Rd	Macquarie Park	1.0	1.7	1.0
4	24/12/1999	Pacific Hwy	Herons Creek	1.0	3.7	6.3
5	24/12/1999	New England Hwy	Tilbuster	1.1	6.9	4.1
6	19/4/2000	Cowpasture Rd	Green Valley	2.2	1.6	0.7
7	30/5/2000	Pacific Hwy	Gateshead	1.3	2.1	1.3
8	23/5/2000	Bells Line of Rd	Kurrajong Heights	1.0	1.3	2.5
9	13/6/2000	Princes Hwy	Wollongong	1.1		0.9
10	31/7/2000	Eastern Arterial Rd	Gordon	1.1	1.4	1.9
11	29/6/2000	Newcastle Rd	Lambton	1.1	1.1	1.2
12	19/6/2000	The Entrance Rd	Bateau Bay	2.7	2.4	2.7
13	30/6/2000	Richmond Rd	Berkshire Park	1.0	3.3	1.9
14	4/12/2000	Henry Lawson Dr	Picnic Point	1.6	1.5	1.2
15	10/7/2000	Elizabeth Dr	Bonnyrigg	1.4	1.2	1.2
16	3/7/2000	Gibson Ave	Padstow	1.0	0.4	
17	24/7/2000	Concord Rd	Concord West	1.3	1.4	
18	6/12/2000	Great Western Hwy	Hartley	2.3	2.75	2.7
19	1/9/2000	Princes Hwy	Bulli	1.2	3.3	
20	20/3/2001	Pacific Hwy	Woodburn	1.9	3.84	4.4
			8 sites added to the study			
21	6/11/2000	The Spit Rd (southbound)	The Spit	1.2	1.3	1.2
22	31/10/2001	Princes Hwy	Bulli (southbound)	3.3		1.3
23	8/3/2001	The Spit Rd (northbound)	Beauty Point	1.2	1.3	1.2
24	23/3/2001	Pacific Hwy	Urunga	1.4	1.6	1.5
25	24/10/2001	M4 Motorway	South Wentworthville (eastbound)	1.1	2.0	3.0
26	31/10/2001	M4 Motorway	South Wentworthville (westbound)	1.1	2.0	3.0
27	1/11/2001	F3 Freeway	Ourimbah	1.2	2.5	2.8
28	30/10/2001	New South Head Rd	Edgecliff	1.0		

2.2 Speed surveys and analysis

Each camera site was surveyed (using a six-second headway[3]) before the installation of the cameras and follow-up surveys were conducted at various times after the cameras commenced operation. Follow-up surveys for the 20 initial sites were carried out at six, 12 and 24 months after the cameras began operation. The eight additional sites were surveyed at different follow-up points, 12, 18, 24 and 30 months, due the different times at which the cameras were installed.

Separate speed surveys were conducted in each of the camera, upstream and downstream lengths for each site to provide an indication of the changing speed behaviour of drivers as they approached, travelled through and left the camera sites.

Control speed data were taken from the Statewide speed database which contains annual speed data for a large number of survey sites. These sites were matched controls for the camera sites based on speed limit, number of lanes and road cross-section (divided/undivided).

2.2.1 Descriptive and inferential statistical analyses of speed data

Two separate statistical analyses of the speed data were performed for the evaluation, namely the descriptive statistical analysis and the inferential statistical analysis, with the latter providing a more accurate determination of the impact of the fixed digital speed cameras on vehicle speeds.

The descriptive statistical analysis was carried out throughout the course of the study to provide an indication of the effect of the fixed digital speed cameras on vehicle speeds, while the inferential statistical analysis was carried out during the latter stages of the evaluation. Contrasting with the descriptive statistical analysis the inferential statistical analysis entailed carrying out of statistical methods that are able to be used to draw inferences about all fixed digital speed camera sites from a data set drawn from a representative group of fixed digital speed camera sites.

It should be noted, however, that the inferential statistical analysis of vehicle speeds was only carried out for the initial 20 sites. The reason for excluding the additional eight sites from this part of the analysis is that the full range of speed data required for that analysis was not available for the additional 8 sites. Further, it should be noted that the inferential statistical analysis was not suitable to analyse the 85th percentile speed or the standard deviations.

The descriptive statistical analysis was therefore used to describe the impact of the fixed digital speed cameras at the 28 sites for both the 85th percentile speed and the standard deviation.

2.3 Crash data analysis

The crash data output from the mapping process were queried in Microsoft Access to produce lists of crashes for each site across the relevant time periods. The crashes were individually tabulated for each length of each site and were disaggregated by severity (tow-away, injury, fatal). Crash numbers were summed, for each site, for the three-year period prior to the

[3] A six-second headway is used in the analysis so that only free vehicle speeds are included. A free vehicle speed occurs when a vehicle is at least six seconds behind the vehicle in front. The RTA used a six-second headway because the Australian Standard (A1742, 1999) requires at least a four-second headway for surveys when setting speed limits, and therefore six seconds further reduces any chance of error. A six-second headway has been RTA practice for the past 25 years.

commencement of camera operation (excluding the last two weeks before the camera began operation) and for the two-year period after camera operation commenced (excluding the first two weeks after the camera began operation). From these periods a crash rate in units of crashes per year was calculated.

Crashes at the 14 camera sites in the Sydney RTA Region and the four camera sites in the Hunter RTA Region were controlled by crashes in the same LGA as the camera site. This equates to 13 LGAs and four LGAs respectively for the two Regions. Crashes at the 10 camera sites in other Regions were controlled by crashes on 13 other specific lengths of road with similar characteristics to the camera sites.

2.4 Economic analysis

The economic analysis of the cameras used crash data disaggregated by severity to estimate the reduction in social cost achieved by reducing the rate of crashes. The crash rate reductions used were the results of the controlled, inferential statistical analysis.

All costs involved in the installation, maintenance and operation of the fixed digital speed cameras, including administration costs of processing infringements, were included in the economic analysis. The benefits included estimated reductions in social costs from the reductions in crash rates projected over the lifetime of the cameras. The fines resulting from camera operation were treated as a transfer, not a benefit, and therefore did not enter into the calculations.

2.5 Community questionnaire survey

Four waves of community questionnaire surveys were conducted over two years. The survey collected information on motorists' knowledge, attitudes, beliefs and reported behaviours in relation to fixed digital speed cameras, speeding behaviour and speeding enforcement. The surveys were conducted in four waves: September 2000 (Wave I), late March/early April 2001 (Wave II), September 2001(Wave III) and in September 2002 (Wave IV).

Telephone surveys were undertaken covering a random sample of residents from specifically defined geographic locations in NSW, along with a booster sample of 50 professional drivers. Sampling comprised categories of residents living in areas that are exposed and not exposed to the influence of the fixed digital speed cameras. Information was also collected using a 27-item questionnaire (that was developed in collaboration with RTA and subjected to pre-testing and piloting).

3 Results: Speed survey analysis

The impact of the Fixed Digital Speed Camera Program on measured speeds is based on the changes observed in each of the speed characteristics from the pre-installation surveys and the follow up surveys at six, 12, 18 (three sites), 24 months and 30 months (one site only).

The changes observed between the speed surveys include the following characteristics of speed:

- Mean speed, $\bar{x}$ (km/h).
- 85th percentile speed, P^{85} (km/h)*.

- Standard deviation, SD (km/h)*.
- Percentage of vehicles travelling above the speed limit (%).
- Percentage of vehicles travelling at least 10 km/h above the speed limit (%).
- Percentage of vehicles travelling at least 20 km/h above the speed limit (%).
- Percentage of vehicles travelling at least 30 km/h above the speed limit (%).

The 85^{th} percentile speed and standard deviation of speeds were not assessed in the inferential statistical analysis but have been addressed in the descriptive statistical analysis. Refer to Section 3.3 for further information.

3.1 Interpreting speed surveys

Figure 1 depicts two hypothetical (standard normal) distributions of speed. The solid line shows the original speed distribution whilst the dashed line represents the speed distribution following the introduction of a successful countermeasure to speeding. However, it should be noted that the distinctions between the two distributions are likely to be more subtle than the changes depicted.

In Figure 1 the following legend applies:

$\bar{x}_{0,1}$ = mean speed (km/h).

$P_{0,1}^{85}$ = 85^{th} percentile speed (km/h).

$SD_{0,1}$ = standard deviation (km/h).

0 = baseline data, prior to the introduction of the countermeasure (solid line) .

1 = post- camera commencement – introduction of countermeasure (dashed line).

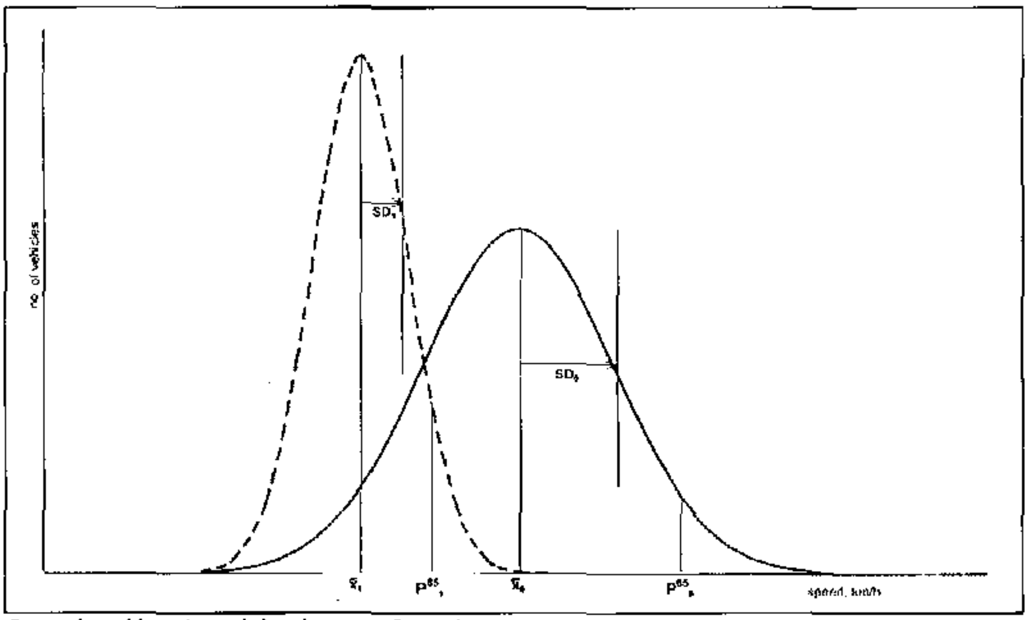


Figure 1: Hypothetical distributions of speed

The speed analysis is based on data collected at four or six locations at and around the camera site. The data are separated into traffic flows in the direction monitored by the fixed digital speed camera and the opposite direction at each of the survey locations.

Figure 2 illustrates an example of a road segment with a fixed digital speed camera installed. The three surveys are conducted in the three segment lengths: camera length; upstream and downstream (although some sites, due to site conditions, lack either an upstream or a downstream length). The results of the speed analysis can then be categorised into the direction of traffic, towards the camera site or away from the camera site. Hence, for every speed characteristic mentioned previously there are six values (or sometimes two or four)[3] for each wave of speed survey.

Figures 3 (a) and (b) illustrate which surveys are upstream and which are downstream depending on the direction of traffic flow past the camera (ie direction being monitored, or the opposite direction).

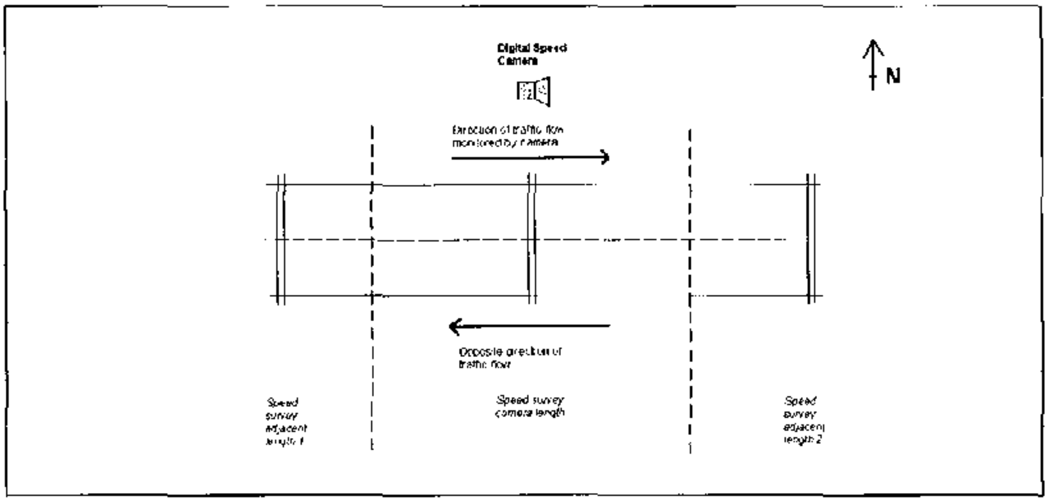
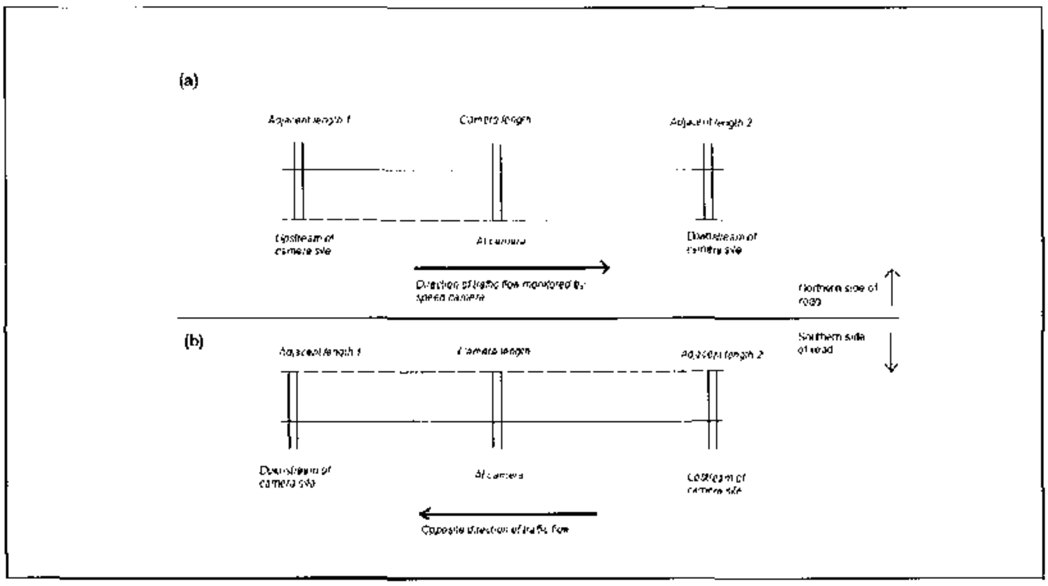


Figure 2: Example of a camera site used in the speed analysis

[3] There will be fewer values if the site does not have both upstream and downstream adjacent lengths



Figures 3 (a) and (b): **Example of a camera site used in the speed analysis by direction of traffic flow**

3.2 Inferential statistical analysis – 20 sites

3.2.1 Speed data

Speeds had been measured at each of the first 20 camera sites before the cameras began operating and at six, 12 and 24 months after the cameras began operating. The six-month survey results could not be included in the statistical analysis because of the absence of comparable control site speed data collected at an appropriate time (see below). Cameras were progressively installed at these 20 sites during the period December 1999 to March 2001.

Control sites were chosen from the RTA's statewide program of speed monitoring, for the purpose of measuring trends and changes in speeds on comparable NSW roads as would be expected to have occurred at the camera sites had there been no Fixed Digital Speed Camera Program. The statewide speed survey program had covered an extensive range of sites in May/June 1999, June 2001 and August–October 2002. No suitable speed surveys were conducted during 2000, hence the May 1999 surveys were used to measure speeds at the control sites at a time corresponding to the pre-camera operation surveys at the camera sites.

Groups of control sites were chosen to match the camera sites in each speed zone class (and road class, where sites were available), except in rural areas where there were insufficient statewide program sites to cover the full range of speed zones at camera sites. In country locations 100 km/h zones were used as the controls for all treatment sites except for one 80 km/h treatment site that was matched to two 80 km/h control sites.

The matched control sites by speed zone, region, road class and the like was not considered to be a difficulty for the analysis because the role of the control sites was to indicate general trends in speeds over the period of the study, due to global factors affecting speeds in NSW. For this purpose, it was most critical that there was an adequate number of control sites to measure trends over the period. Data from 33 control sites were made available for analysis in conjunction with speed data from the 20 initial camera sites. One of the global factors affecting speeds was the progressive introduction of 50 km/h speed limits on former 60 km/h limit, two-lane roads in urban areas[4]. Twelve of the 23 control sites initially with 60 km/h limits experienced a reduction in limit between June 1999 and June 2001.

In the evaluation of the effects of 50 km/h limits on streets in the first 26 local councils in NSW (Cameron and Newstead, 2000), it was found that there were very substantial reductions in the proportions of vehicles exceeding 60, 70 and 80 km/h, respectively (but relatively little reduction in mean speeds). Hence it was expected that the proportions of vehicles exceeding the speed limit by fixed amounts (ie 0, 10, 20 and 30 km/h) would remain essentially the same (apart from any general trend) at the 60 km/h control sites, no matter whether the speed limit was subsequently reduced to 50 km/h or remained unchanged. Cameron and Newstead (2000) also found that the 50 km/h limits had little effect on mean speeds, so it was expected that mean speeds would be unaffected at the control sites.

A detailed examination of the estimated effects at the camera sites dependent on the use of urban 60 km/h control sites, some of which experienced the reduction in limit, confirmed that these expectations were reasonable ones and that the mixed 60 km/h controls did not distort the estimated effects (see discussion in Section 3.2.3 below).

3.2.2 Analysis of speed data

The analysis compared the changes in the speed distribution parameters at the speed camera sites with the changes in the same parameters measured at the control sites. The changes at the control sites were considered to measure the changes at the camera sites had the Fixed Digital Speed Camera Program not been implemented. The change from the period before camera operation to each of the periods after the cameras began operating were considered to be of interest, the first indicating the effect of the cameras after 12 months and the second indicating the changes in speeds which might be expected in the longer term (24 months and beyond).

The mean speed was analysed using a log-normal model (McCullagh and Nelder 1989), with the standard deviation of each mean value calculated from the sample standard deviation divided by the square root of the sample size. The factors included in the log-normal model were the period [(1) pre- v. 12 months post-camera commencement, or (2) pre- v. 24 months post-camera commencement], camera v. control site, and the interaction between these two factors. The interaction term is a measure of whether the change in the mean speed at the camera sites was greater than the change at the control sites. The net change measures the effect of the fixed digital speed cameras on the speed parameter. The analysis included a test of the statistical significance of the net change to judge whether the observed change represented a real change in the speed distribution or could have been due to chance.

The proportions exceeding the speed limit and by at least 10, 20 and 30 km/h, respectively, were each analysed separately using a Poisson regression model with the sample size as the off-set value (Aitkin et al 1989, SAS Institute 1993). The factors included in the model were the same as for the analysis of the mean speed, as was their interpretation. The Poisson regression model is an appropriate method to analyse counts of vehicles exceeding certain speeds, whereas the log-normal model is not.

[4] NSW introduced the 50 km/h Urban Speed Limit progressively, Local Government Area by Local Government Area

The key output from the analysis was the estimated reduction in mean speed (km/h) or the estimated percentage net reduction in the speed distribution parameter (proportion exceeding the speed limit by a specific amount) at the camera sites relative to the control sites. The significance probability associated with each of these estimates was also calculated to provide a basis of whether there was evidence of a real effect on the speed parameter. The calculated probabilities were those associated with a two-tail test of whether the true speed parameter had increased or decreased.

Analysis of speed changes was conducted for observations made in the camera length, and also for speed observations made in the upstream and downstream lengths (where the proportions were relative to the speed limit in the road length, which was different from the speed limit at the camera site in some circumstances). Integrated models of the effects at the camera site and in each adjacent length were fitted, taking into account the speed observations at the control site and comparing the control site changes with each of the three sets of camera site observations.

The principal analysis considered the speeds of all types of vehicles, but secondary analyses considered the speeds of rigid trucks and semi-trailers separately. It should be noted that there were substantially fewer observations of truck speeds and hence the statistical significance tests were less powerful compared with the analysis of all vehicle speeds, that is, a given change in a speed parameter is less reliable and less likely to be statistically significant.

The speed surveys conducted at camera sites before cameras commenced operation, at 12 months and at 24 months after cameras commenced operation, in each of the site lengths (upstream, camera and downstream lengths), covered a total of at least one million vehicles (except for the upstream length pre-commencement of camera operation, where about 840,000 vehicles were surveyed). Of these surveyed vehicles, at least 40,000 were semi-trailers and at least 45,000 were rigid trucks on each occasion.

3.2.3 Results (initial 20 evaluation sites)

Mean speeds

Twelve months after the cameras commenced operation there were statistically significant reductions in mean speeds at the fixed digital speed camera sites in nearly all speed zones, and 6.3 km/h reduction overall ($p<0.0001$), but generally no changes in the adjacent lengths (Table 2). This effect was essentially maintained in the camera lengths at 24 months after the cameras began operating (5.8 km/h reduction, statistically significant ($p<0.0001$)), but by that time the mean speeds in the upstream lengths had increased overall by 1.5 km/h to a statistically significant ($p=0.0192$) extent (Table 3).

Table 2: Change in mean speeds at and adjacent to the initial 20 evaluation sites 12 months after commencement of camera operation (negative values indicate reductions)

Speed Zone	Upstream		Camera Length		Downstream	
	Change (km/h)	Stat. sig.	Change (km/h)	Stat. sig.	Change (km/h)	Stat. sig.
60 km/h	1.07	0.1404	-6.88	<0.0001	0.01	0.9854
70 km/h	1.37	0.5455	-4.79	0.0348	-5.39	0.0177
80 km/h	0.45	0.8420	-9.26	<0.0001	3.32	0.1442
90 km/h	-0.94	0.6245	-8.98	<0.0001	-1.54	0.4227
100 km/h	-0.32	0.786	-2.09	0.0784	0.72	0.5429
All	**0.67**	**0.2974**	**-6.27**	**<0.0001**	**-0.16**	**0.7953**

Table 3: Change in mean speeds at and adjacent to the initial 20 evaluation sites 24 months after commencement of camera operation (negative values indicate reductions)

Speed Zone	Upstream		Camera Length		Downstream	
	Change (km/h)	Stat. sig.	Change (km/h)	Stat. sig.	Change (km/h)	Stat. sig.
60 km/h	1.82	0.0119	-6.22	<0.0001	1.06	0.1245
70 km/h	1.78	0.4331	-4.31	0.0577	-0.74	0.7461
80 km/h	1.00	0.6590	-9.18	<0.0001	3.51	0.1219
90 km/h	-0.89	0.6430	-6.67	0.0005	-1.59	0.4082
100 km/h	1.79	0.1307	-2.74	0.0211	2.52	0.0335
All	**1.52**	**0.0192**	**-5.82**	**<0.0001**	**1.21**	**0.0579**

Proportion exceeding the speed limit

The proportion of vehicles exceeding the speed limit at camera sites was reduced to a statistically significant degree in all speed zones; by 70 per cent overall ($p<0.0001$) after 12 months and by 72 per cent ($p<0.0001$) after 24 months (Table 4 and Table 5). There was an overall statistically significant ($p<0.0001$) reduction of 5 per cent in the proportion speeding upstream from the camera sites, and 21 per cent ($p<0.0001$) reduction downstream, 12 months after commencement of camera operation. However, after 24 months, the proportion speeding upstream had changed from a reduction to a statistically significant increase of 3 per cent ($p<0.0001$) and the reduction downstream had eroded to only 5 per cent, but this was still a statistically significant reduction ($p<0.0001$).

While the pattern of changes in the camera lengths was reasonably consistent across speed zones, the pattern varied substantially in the adjacent lengths depending on the zone limit. This may be indicative of real behavioural differences related to specific speed zones, or may indicate that the results are reliable only for the changes averaged across all speed zones.

Table 4: **Changes in proportion exceeding the speed limit at and adjacent to the initial 20 evaluation sites sites 12 months after commencement of camera operation (negative values indicate reductions)**

Speed	Upstream		Camera Length		Downstream	
Zone	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	-5.22	<0.0001	-71.32	<0.0001	-16.99	<0.0001
70 km/h	17.05	<0.0001	-54.07	<0.0001	-68.27	<0.0001
80 km/h	-6.84	<0.0001	-90.05	<0.0001	35.76	<0.0001
90 km/h	-26.18	<0.0001	-83.49	<0.0001	-46.17	<0.0001
100 km/h	-17.82	<0.0001	-49.84	<0.0001	-13.59	<0.0001
All	-5.30	<0.0001	-69.95	<0.0001	-20.86	<0.0001

Table 5: **Changes in proportion exceeding the speed limit at and adjacent to the initial 20 evaluation sites 24 months after commencement of camera operation (negative values indicate reductions)**

Speed	Upstream		Camera Length		Downstream	
Zone	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	3.22	<0.0001	-72.29	<0.0001	-6.84	<0.0001
70 km/h	21.23	<0.0001	-57.65	<0.0001	-7.85	<0.0001
80 km/h	4.34	0.0005	-87.80	<0.0001	40.13	<0.0001
90 km/h	-31.55	<0.0001	-72.44	<0.0001	-53.18	<0.0001
100 km/h	-4.91	<0.0001	-60.69	<0.0001	11.52	<0.0001
All	3.39	<0.0001	-71.84	<0.0001	-5.12	<0.0001

Proportion exceeding speed limit by at least 10 km/h

The proportion of vehicles exceeding the speed limit by at least 10 km/h was reduced to an even greater extent than the proportion speeding, averaging 86–88 per cent over all speed zones at the times of the post-commencement surveys (in the camera lengths) (See Table 6 and Table 7). However, the proportion of vehicles speeding to this degree had increased in both the upstream and downstream lengths 24 months after commencement of camera operation, and there was a trend in this direction in the upstream length 12 months after commencement of camera operation.

Table 6: **Changes in proportion exceeding the speed limit by at least 10 km/h at and adjacent to the initial 20 evaluation sites 12 months after commencement of camera operation (negative values indicate reductions)**

Speed	Upstream		Camera Length		Downstream	
Zone	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	8.22	<0.0001	-86.52	<0.0001	-1.64	0.0016
70 km/h	4.99	0.0644	-71.32	<0.0001	-79.13	<0.0001
80 km/h	-4.46	0.0701	-98.01	<0.0001	27.52	<0.0001
90 km/h	-19.35	<0.0001	-92.47	<0.0001	-52.49	<0.0001
100 km/h	14.57	<0.0001	-67.73	<0.0001	-14.92	<0.0001
All	7.58	<0.0001	-85.62	<0.0001	-8.19	<0.0001

Table 7: Changes in proportion exceeding the speed limit by at least 10 km/h at and adjacent to the initial 20 evaluation sites 24 months after commencement of camera operation (negative values indicate reductions)

Speed Zone	Upstream		Camera Length		Downstream	
	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	23.44	<0.0001	-88.26	<0.0001	12.79	<0.0001
70 km/h	38.97	<0.0001	-72.15	<0.0001	-22.18	<0.0001
80 km/h	19.72	<0.0001	-98.17	<0.0001	36.22	<0.0001
90 km/h	-38.16	<0.0001	-79.80	<0.0001	-53.95	<0.0001
100 km/h	59.55	<0.0001	-81.84	<0.0001	28.42	<0.0001
All	**24.78**	**<0.0001**	**-87.94**	**<0.0001**	**10.47**	**<0.0001**

Proportion exceeding speed limit by at least 20 km/h

The proportion of vehicles exceeding the speed limit by at least 20 km/h was reduced substantially by 85.6 per cent in the camera lengths (statistically significant, p<0.0001). This impact was maintained 24 months 'after' (ie. at 86.5%). However, it was noted that there were substantial increases in this proportion in the adjacent lengths (Table 8 and Table 9). After 12 months the proportion had increased by 22 per cent in both lengths, and after 24 months it had increased by 37 per cent upstream and by 41 per cent downstream (both statistically significant, p<0.0001).

Table 8: Changes in proportion exceeding the speed limit by at least 20 km/h at and adjacent to the initial 20 evaluation sites 12 months after commencement of camera operation (negative values indicate reductions)

Speed Zone	Upstream		Camera Length		Downstream	
	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	21.80	<0.0001	-86.25	<0.0001	28.31	<0.0001
70 km/h	-0.38	0.9591	-65.14	<0.0001	-67.50	<0.0001
80 km/h	14.33	0.0255	-98.33	<0.0001	100.51	<0.0001
90 km/h	-6.84	0.3643	-93.79	<0.0001	-52.32	<0.0001
100 km/h	45.89	<0.0001	-71.56	<0.0001	-9.05	0.0243
All	**21.92**	**<0.0001**	**-85.56**	**<0.0001**	**22.12**	**<0.0001**

Table 9: Changes in proportion exceeding the speed limit by at least 20 km/h at and adjacent to the initial 20 evaluation sites 24 months after commencement of camera operation (negative values indicate reductions)

Speed Zone	Upstream		Camera Length		Downstream	
	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	35.11	<0.0001	-87.87	<0.0001	46.33	<0.0001
70 km/h	44.57	<0.0001	-70.98	<0.0001	-15.99	0.0067
80 km/h	24.66	<0.0001	-98.24	<0.0001	86.60	<0.0001
90 km/h	-35.07	<0.0001	-45.08	<0.0001	-29.48	0.0237
100 km/h	151.53	<0.0001	-85.54	<0.0001	24.27	<0.0001
All	**36.92**	**<0.0001**	**-86.52**	**<0.0001**	**41.03**	**<0.0001**

Proportion exceeding speed limit by at least 30 km/h

The reductions in the proportion exceeding the speed limit by at least 30 km/h in the camera lengths were similar to, but a little smaller than, the reductions in extreme speeding described above, averaging 83.9 per cent over all speed zones 12 months after commencement of camera operation and 79.5 per cent after 24 months (Table 10 and Table 11). The increase in this proportion upstream averaged 23.2 per cent after 12 months, but diminished to 13.6 per cent after 24 months. However, the overall increase in the proportion exceeding the limit by 30 km/h remained almost the same at 29.6 and 29.4 per cent in the downstream lengths at 12 and 24 months respectively. All the changes mentioned here were statistically significant ($p<0.0001$).

Table 10: **Changes in proportion exceeding the speed limit by at least 30 km/h at and adjacent to the initial 20 evaluation sites 12 months after commencement of camera operation (negative values indicate reductions)**

Speed	Upstream		Camera Length		Downstream	
Zone	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	22.07	<0.0001	-84.19	<0.0001	36.29	<0.0001
70 km/h	-14.59	0.3365	-64.53	<0.0001	-49.64	<0.0001
80 km/h	46.49	0.0027	-99.44	<0.0001	123.04	<0.0001
90 km/h	6.87	0.769	-94.06	<0.0001	-70.35	0.0563
100 km/h	48.96	0.0005	-75.37	<0.0001	-1.59	0.8584
All	23.16	<0.0001	-83.86	<0.0001	29.63	<0.0001

Table 11: **Change in proportion exceeding the speed limit by at least 30 km/h at and adjacent to the initial 20 evaluation sites 24 months after commencement of camera operation (negative values indicate reductions)**

Speed	Upstream		Camera Length		Downstream	
Zone	Change (%)	Stat. sig.	Change (%)	Stat. sig.	Change (%)	Stat. sig.
60 km/h	9.44	0.0096	-86.59	<0.0001	34.06	<0.0001
70 km/h	21.60	0.2457	-68.42	<0.0001	-24.46	0.0471
80 km/h	70.98	<0.0001	-95.68	<0.0001	135.02	<0.0001
90 km/h	-8.93	0.6822	-140.25	<0.0001	13.05	0.7615
100 km/h	165.09	<0.0001	-87.81	<0.0001	9.29	0.3102
All	13.58	<0.0001	-79.51	<0.0001	29.36	<0.0001

Summary of mean speeds and percentages of vehicles exceeding the speed limit.

Tables 12-16 summarise changes in speed characteristics for each of the five speed zones (60, 70, 80, 90 and 100 km/h) along the speed camera lengths.

Table 12: **Changes in speed characteristics for those of the initial 20 evaluation sites that were zoned 60 km/h, in the camera length**

Speed characteristics	Baseline – 12-month		Baseline – 24-month	
	Change	Statistical significance	Change	Statistical significance
Mean speed, $\bar{x}$ (km/h)	-6.88 km/h	<0.0001	-6.22 km/h	<0.0001
Percentage above speed limit	-71.32%	<0.0001	-72.29%	<0.0001
Percentage at least 10 km/h above speed limit	-86.52%	<0.0001	-88.26%	<0.0001
Percentage at least 20 km/h above speed limit	-86.25%	<0.0001	-87.87%	<0.0001
Percentage at least 30 km/h above speed limit	-84.19%	<0.0001	-86.59%	<0.0001

Table 13: **Changes in speed characteristics for those of the initial 20 evaluation sites that were zoned 70 km/h, in the camera length**

Speed characteristics	Baseline – 12-month		Baseline – 24-month	
	Change	Statistical significance	Change	Statistical significance
Mean speed, $\bar{x}$ (km/h)	-4.79 km/h	0.0348	-4.31 km/h	0.0577
Percentage above speed limit	-54.07%	<0.0001	-57.65%	<0.0001
Percentage at least 10 km/h above speed limit	-71.32%	<0.0001	-72.15%	<0.0001
Percentage at least 20 km/h above speed limit	-65.14%	<0.0001	-70.98%	<0.0001
Percentage at least 30 km/h above speed limit	-64.53%	<0.0001	-68.42%	<0.0001

Table 14: Changes in speed characteristics for those of the initial 20 evaluation sites that were zoned 80 km/h, in the camera length

Speed characteristics	Baseline – 12-month		Baseline – 24-month	
	Change	Statistical significance	Change	Statistical significance
Mean speed, $\bar{x}$ (km/h)	-9.26 km/h	<0.0001	-9.18 km/h	<0.0001
Percentage above speed limit	-90.05%	<0.0001	-87.80%	<0.0001
Percentage at least 10 km/h above speed limit	-98.01%	<0.0001	-98.17%	<0.0001
Percentage at least 20 km/h above speed limit	-98.33%	<0.0001	-98.24%	<0.0001
Percentage at least 30 km/h above speed limit	-99.44%	<0.0001	-95.68%	<0.0001

Table 15: Changes in speed characteristics for those of the initial 20 evaluation sites that were zoned 90 km/h, in the camera length

Speed characteristics	Baseline – 12-month		Baseline – 24-month	
	Change	Statistical significance	Change	Statistical significance
Mean speed, $\bar{x}$ (km/h)	-8.98 km/h	<0.0001	-6.67 km/h	0.0005
Percentage above speed limit	-83.49%	<0.0001	-72.44%	<0.0001
Percentage at least 10 km/h above speed limit	-92.47%	<0.0001	-79.80%	<0.0001
Percentage at least 20 km/h above speed limit	-93.79%	<0.0001	-45.08%	<0.0001
Percentage at least 30 km/h above speed limit	-94.06%	<0.0001	-140.25%	<0.0001

Table 16: Changes in speed characteristics for those of the initial 20 evaluation sites that were zoned 100 km/h, in the camera length

Speed characteristics	Baseline – 12-month		Baseline – 24-month	
	Change	Statistical significance	Change	Statistical significance
Mean speed, $\bar{x}$ (km/h)	-2.09 km/h	0.0784	-2.74 km/h	0.0211
Percentage above speed limit	-49.84%	<0.0001	-60.69%	<0.0001
Percentage at least 10 km/h above speed limit	-67.73%	<0.0001	-81.84%	<0.0001
Percentage at least 20 km/h above speed limit	-71.56%	<0.0001	-85.54%	<0.0001
Percentage at least 30 km/h above speed limit	-75.37%	<0.0001	-87.81%	<0.0001

3.3 Descriptive statistical analysis of speed

In the absence of an inferential analysis of all 28 sites (see Section 3.2), a descriptive analysis is presented in Section 3.4. The descriptive statistical analysis evaluates the 85th percentile speeds and standard deviations, the two parameters that were not part of the inferential statistical analysis.

The inferential analysis covered mean speeds and the proportions of vehicles exceeding the limit, and exceeding the limit by at least 10, 20 and 30 km/h. Two additional parameters that could not be accommodated by the design of the inferential analysis were:

- *85th percentile speed.* The 85th percentile speed is the speed at or below which 85 per cent of all vehicles are observed under free flow conditions.
- *Standard deviation of speed.* The standard deviation is a measure of the spread of vehicle speeds across the vehicles surveyed. A reduction of the standard deviation, as experienced, will be expected to reduce the level of lane changing and overtaking manoeuvres, as traffic is travelling at more uniform speed. As a result fewer conflicts and therefore fewer crashes will be expected.

The descriptive analysis has been completed in two ways:

1. Combined data for pre-, six-, 12-, 18-, 24- and 30-month post-camera commencement surveys by speed zone (18- and 30-month were not conducted for all sites – the eight additional sites used 18- or 30-month in place of 12- or 24-month surveys).
2. Comparison of speed characteristics by individual sites in the direction monitored by the camera and in the camera length <u>only</u>.

These analyses are expected to be most revealing about the influence of the fixed digital speed cameras on speeds at and around the camera sites.

3.3.1 Application of control ratios

For 85th percentile speed and standard deviation in the analysis methods listed above, control data have been used to create control ratios. The control ratios were applied to the baseline data from each controlled site (ie sites with control sites) to generate 'expected' values for those parameters at follow-up surveys. Actual follow-up data from controlled sites were then compared with expected values to determine how much of any change in the parameter can be attributed to the presence of the treatment (fixed digital speed cameras).

For example, if Site A recorded a baseline 85th percentile speed figure of 60 km/h and a first follow-up figure of 54 km/h, this would be a reduction of 10 per cent if control data were ignored. However, if Site A's corresponding control site recorded a drop from 62 km/h to 57 km/h (8%) in the same time, a 'control ratio' of 92 per cent would then be allocated to Site A because if the treatment had not been installed at Site A, then, all other factors being equal, the speed at the follow-up survey could be expected to be 92 per cent of the speed at the baseline survey.

Applying the control ratio of 92 per cent to Site A's baseline of 60 km/h produces an expected follow-up figure of 55.2 km/h. As Site A's actual follow-up figure was 54 km/h, the reduction in speed attributable to the treatment is only 1.2 km/h (55.2 minus 54), which equates to a reduction of 2.2 per cent.

3.4 Trends in speed characteristics in the direction monitored by the camera for all 28 sites (descriptive statistical analysis)

3.4.1 Introduction

It should be noted that annual speed data collected by the RTA were used as the baseline control data, and that these data were only available for application for the 12-month and 24-month after periods.

Section 3.4.2 provides a comparison of recorded speeds at 6, 9, 12, 24 and 30 months after camera installation with the pre-camera installation baseline speed data. As the speeds have not been adjusted by control data to account for changes in speed that may have occurred because of other non-speed camera factors, they should be treated with caution.

Section 3.4.3, however, provides a comparison of speeds 12 and 24 months after fixed digital speed camera installation, taking account of speed control data. This therefore provides a more accurate descriptive assessment of the impact of the fixed digital speed cameras.

3.4.2 Comparisons of <u>recorded</u> 85th percentile speeds and standard deviations by speed zone – all vehicles

The tables in this section (3.4.2) describe the speed characteristics during each series of speed surveys for all sites within each speed zone: 60, 70, 80, 90, 100 and 110 km/h in the camera length in the direction being monitored by the camera at all 28 treatment sites. This section presents recorded values obtained in speed surveys. No adjustments due to controls are shown in this section for the 85th percentile speed and standard deviation.

It should be noted that the number of sites in each speed zone varies:

- 60 km/h – 17 sites (Macquarie Park, Gateshead, Kurrajong Heights, Wollongong, Gordon, Bateau Bay, Picnic Point, Bonnyrigg, Padstow, Concord West, Bulli, Woodburn, Bulli (southbound), Beauty Point, Edgecliff, The Spit (southbound) and Urunga).
- 70 km/h – 2 sites (Lambton, Green Valley).
- 80 km/h – 2 sites (Kariong, Berkshire Park).
- 90 km/h – 3 sites (Hartley, South Wentworthville (two sites – east- and westbound)).
- 100 km/h – 3 sites (Tarcutta, Herons Creek, Tilbuster).
- 110 km/h – 1 site (F3 Ourimbah).

Not all sites were scheduled to have surveys at all intervals due to the differing periods at which the fixed digital speed cameras were installed.

Overall, there were speed reductions in all speed zones between the baseline and follow-up speed surveys (Table 17). It is notable that the reductions achieved between the baseline and six-month follow-up speed surveys were maintained at the 12-month speed surveys in all speed zones. These reductions were further maintained in the 18-month, 24-month and 30-month follow-up periods (where applicable). Some of the greatest changes following the introduction of the cameras were achieved in 60, 80 and 90 km/h speed zones.

The 24-month results indicate that the reductions in mean and 85th percentile speed, standard deviation and the incidence of speeding at the camera sites have been maintained, not only in the short term, but over a period of two years following installation of fixed digital speed cameras at these sites. It should be noted that the 30-month figures represent a single site and should not be seen as representative of all 60 km/h sites.

(i) Average 85th percentile speeds

The average reduction in 85th percentile speed (See Table 17), after six months of camera operation ranged from 5.7 km/h (5.2%) in 100 km/h zones to 22.3 km/h (20.1%) in 90 km/h zones. By the 24-month point the range was from 8.3 km/h (7.7%) in the 100 km/h zones to 23.3 km/h (21.0%) in the 90 km/h zones.

(ii) Standard deviation of speed

Table 18 lists the average standard deviations of speed, by speed zone, in the camera length. The reductions in standard deviations ranged from 0.9 km/h (8.1%) in 100 km/h zones to 4.1 km/h (36.2%) in 90 km/h zones after six months of camera operation. After 24 months the range was from a low of 2.0 km/h (26.5%) in the 70 km/h speed zones to a high of 4.6 km/h (40.5%) in the 90 km/h speed zones.

Table 17: Change in 85th percentile speeds, by speed zone, in the camera length only (28 evaluation sites)

Speed zone km/h	Baseline km/h	6-month follow-up km/h	12-month follow-up km/h	18-month follow-up km/h	24-month follow-up km/h	30-month follow-up km/h	Change between baseline and 6-month follow-up		Change between baseline and 12-month follow-up		Change between baseline and 18-month follow-up		Change between baseline and 24-month follow-up		Change between baseline and 30-month follow-up	
							km/h	(%)	km/h	(%)	km/h	(%)	km/h	(%)	km/h	(%)
60	71.3	63.0	60.9	58.0	60.6	60.0	-8.3	*-11.6*	-10.4	*-14.5*	-13.3	*-18.6*	-10.7	*-15.0*	-11.3	*-15.8*
70	79.5	69.0	71.5		68.0		-10.5	*-13.2*	-8.0	*-10.1*			-11.5	*-14.5*		
80	91.0	79.0	77.0		78.0		-12.0	*-13.2*	-14.0	*-15.4*			-13.0	*-14.3*		
90	111.3	89.0	87.7	88.0	88.0		-22.3	*-20.1*	-23.7	*-21.3*	-23.3	*-21.0*	-23.3	*-21.0*		
100	108.3	102.7	102.7		100.0		-5.7	*-5.2*	-5.7	*-5.2*			-8.3	*-7.7*		
110	122.0		108.0	107.0					-14.0	*-11.5*	-15.0	*-12.3*				

Table 18: Change in standard deviation, by speed zone, in the camera length only (28 evaluation sites)

Speed zone km/h	Baseline km/h	6-month follow-up km/h	12-month follow-up km/h	18-month follow-up km/h	24-month follow-up km/h	30-month follow-up km/h	Change between baseline and 6-month follow-up		Change between baseline and 12-month follow-up		Change between baseline and 18-month follow-up		Change between baseline and 24-month follow-up		Change between baseline and 30-month follow-up	
							km/h	(%)	km/h	(%)	km/h	(%)	km/h	(%)	km/h	(%)
60	8.4	6.7	6.2	5.9	6.0	6.9	-1.7	*-20.3*	-2.2	*-25.9*	-2.5	*-29.2*	-2.4	*-28.2*	-1.5	*-17.7*
70	7.6	5.8	6.8		5.6		-1.8	*-23.8*	-0.8	*-10.6*			-2.0	*-26.5*		
80	8.5	6.3	6.1		5.8		-2.2	*-25.4*	-2.4	*-28.4*			-2.7	*-32.0*		
90	11.4	7.3	6.3	6.1	6.8		-4.1	*-36.2*	-5.2	*-45.2*	-5.4	*-47.1*	-4.6	*-40.5*		
100	11.1	10.2	8.2		7.2		-0.9	*-8.1*	-2.8	*-25.6*			-3.8	*-34.6*		
110	9.3		7.9	7.6					-1.4	*-15.1*	-1.7	*-18.3*				

3.4.3 Comparisons of 85th percentile speed and standard deviation by speed zone (using control data) – all vehicles

The information in Table 19 has been calculated using control data as described in Section 3.3.1. Appendix A provides the detail of the information summarised in the table below.

Table 19: Changes in 85th percentile and standard deviation for the 28 evaluation sites, by speed zone, in all survey lengths, in the direction being monitored by the camera (negative values indicate reductions)

Speed characteristics	Upstream				Camera				Downstream			
	12-month		24-month		12-month		24-month		12-month		24-month	
	km/h	%	km/h	%	km/h	%	km/h	%	km/h	%	km/h	%
60 km/h zones												
85th percentile speed, (km/h)	0.8	1.3	1.1	1.7	-7.3	-10.7	-6.3	-9.4	1.9	2.9	4.2	6.6
Standard deviation, SD (km/h)	0.3	5.0	-0.1	-1.8	-1.4	-17.9	-1.7	-22.3	0.9	12.3	1.0	13.7
70 km/h zones												
85th percentile speed, (km/h)	-8.0	-10.4	-2.0	-2.7	-8.0	-10.1	-8.4	-11.0	-2.0	-2.9	0.7	1.1
Standard deviation, SD (km/h)	-0.9	-9.7	0.3	3.0	-0.0	-0.1	-1.0	-15.4	-0.1	-1.3	0.9	9.6
80 km/h zones												
85th percentile speed, (km/h)	-	-	-	-	-11.0	-12.5	-12.0	-13.3	5.8	7.0	3.9	4.7
Standard deviation, SD (km/h)	-	-	-	-	-1.8	-22.4	-2.1	-27.1	0.7	9.8	0.4	5.6
90 km/h zones												
85th percentile speed, (km/h)	-2.8	-2.8	-4.1	-4.0	-22.4	-20.3	-22.3	-20.2	-1.8	-1.8	-0.0	0.0
Standard deviation, SD (km/h)	-0.2	-2.2	-0.4	-4.1	-4.1	-39.6	-4.6	-40.2	1.1	12.4	0.8	7.9
100 km/h zones												
85th percentile speed, (km/h)	1.0	1.2	0.8	0.9	-4.4	-4.1	-7.3	-6.8	-0.7	-0.6	0.0	0.0
Standard deviation, SD (km/h)	-1.6	-19.5	-2.7	-29.7	-1.8	-18.1	-3.8	-34.2	0.7	7.8	-0.5	-5.7
110 km/h zone												
85th percentile speed, (km/h)	-	-	-	-	-12.6	-10.4	-	-	-	-	-	-
Standard deviation, SD (km/h)	-	-	-	-	-0.5	-6.5	-	-	-	-	-	-

These figures are derived from control ratios and are not based on the inferential statistical analysis. The inferential statistical analysis does not refer to 85th percentile speed or standard deviation and only refers to the initial 20 sites *(i) Average 85th percentile speeds*

The data reveal that the 85th percentile speeds, 12 months 'after', fell within the **speed camera length** across all speed zones. The 85th percentile speeds reduced from between 4.4 km/h (4.1%) within the 100 km/h speed zones to 22.4 km/h (20.3%) within the 90 km/h speed zones (Table 19). Twenty-four months 'after', the speed reductions were generally maintained, ranging from 6.3 km/h (9.4%) in the 70 km/h speeds zones to 22.3 km/h (20.2%) within the 90 km/h speed zones.

Within the **upstream lengths** the 85th percentile speeds remained relatively unchanged 12 and 24 months 'after' within the 60 km/h and 100 km/h speed zones, while within the 70 km/h and 90 km/h speed zones they fell by 8.0 km/h (10.4%) and 2.8 km/h (2.8%) respectively. Twenty-four months 'after', the reductions, when compared with the baseline speeds, fell within the 70 km/h and 90 km/h speed zones by 2.0 km/h (2.7%) and 4.1 km/h (4.0%) respectively (Table 19).

Within the **downstream lengths**, 12 months 'after', the 85th percentile speeds decreased in some speed zones while increasing in others. The variations fluctuated between a reduction of 2 km/h (2.9%) within 70 km/h speed zones and an increase of 5.8 km/h (7.0%) within 80 km/h speed zones (Table 19). Twenty four months 'after', relative to the baseline speeds, the 85th percentile speeds remained relatively unchanged within the 70, 90 and 100 km/h speed zones, while within the 60 and 80 km/h speed zones they increased by 4.2 km/h (6.6%) and 3.9 km/h (4.7%) respectively.

(ii) Standard deviation of speed

Within the **speed camera lengths**, 12 months 'after', the standard deviations fell across nearly all of the speeds zones. The reductions ranged from between 4.1 km/h (39.6%) within the 90 km/h speed zones to 0.5 km/h (6.5%) within the 110 km/h speed zone (Table 19). There was no change in the standard deviation within the 70 km/h speed zones, and no speed zone experienced an increase in standard deviation. Twenty-four months 'after', all standard deviations continued to reduce relative to the baseline data. The reductions ranged from between 4.6 km/h (40.2%) within the 90 km/h speed zones to 1.0 km/h (15.4%) within the 70 km/h speed zones.

Within the **upstream lengths**, 12 months 'after', standard deviations fell across nearly all of the speeds zones. The reductions ranged from between 1.6 km/h (19.5%) within the 100 km/h speed zones to 0.2 km/h (2.2%) within the 90 km/h speed zones. Within the 60 km/h speed zones the standard deviation increased by 0.3 km/h (5%). Twenty-four months 'after', compared with the baseline data, the standard deviations remained relatively unchanged, with the exception of 100 km/h speed zone where the standard deviation fell by 2.7 km/h (29.7%).

Within the **downstream lengths**, 12 months 'after', standard deviations increased in all speed zones with the exception of the 70 km/h speed zones, which remained relatively unchanged. Increases ranged from between 1.1 km/h (12.4%) within the 90 km/h speed zones to 0.7 km/h (7.8%) within 100 km/h speed zones (Table 19). Twenty-four months 'after', compared with the baseline data, the standard deviations fell within 100 km/h speed zones by 0.5 km/h (5.7%) while increasing within the 60 km/h speed zone by 1.0 km/h (13.7%), the 70 km/h speed zone by 0.9 km/h (9.6%) and the 90 km/h 0.8 km/h (7.9%).

4 Results: crash analysis

4.1 Statistical analysis

The crash analysis aims to measure whether the changes in crashes at the camera sites were beyond chance fluctuation, that is, statistically significant, while at the same time taking into account any influence of other factors. Thus, any statistically significant changes can be considered as 'real' effects that are due to the cameras.

4.1.1 Analysis

The numbers of crashes were analysed separately for each of the following types of crashes (some of which are sub-sets of the broader types):

- All reported crashes (casualty plus tow-away crashes)
- Casualty crashes (fatal plus injury crashes)
- Tow-away (non-injury) crashes
- Injury crashes

To account for changes that may have occurred as a result of other factors, crashes at control sites were also taken into consideration in the analysis. All 28 sites were broken down separately by camera and adjacent lengths, and combined lengths (ie. adjacent lengths plus camera length).

The method of analysis was a log-linear regression model applied to a quasi-experimental design framework. This method is based on the appropriate assumption that crashes have a Poisson-type statistical distribution. This avoids the assumption of the Normal distribution of crash frequencies, which is inherent in simple linear regression analysis of crashes. The method is an extension of that developed by Bruhning and Ernst (1985). It has been applied by Newstead et al (1999) to evaluate the Random Road Watch enforcement program in Queensland and the method has been peer-reviewed for publication in the journal *Accident Analysis and Prevention* (Newstead et al 2001). It was also used in the evaluation of the crash effects of the 50 km/h speed limit in New South Wales (ARRB Transport Research 2000).

In the analysis model, the natural logarithms of crashes in each period are a linear function of a constant depending on whether from a camera or control area/site, a step function at the commencement of the camera operation period, and an interaction term to indicate whether the steps differ between the camera and control areas/sites.

The effect of the fixed digital speed cameras on crashes was measured by the difference in the steps estimated for the camera and control areas/sites in the period after the cameras became operational. The result is expressed as a percentage reduction in the crashes of the type analysed. The statistical significance of the interaction term (described in the previous paragraph) is an indication of whether the measured reduction is real or could be due to chance. Very low values of the significance probability indicate that is very unlikely that the pattern of crashes could have been observed due to chance if the fixed digital speed cameras had no effect on crashes. In these circumstances it is reasonable to conclude that the cameras had an effect, and that the calculated percentage reduction is the best estimate of that effect.

4.1.2 Results

The following results summarise the detailed analysis of the estimated effects of the fixed digital speed cameras on crashes. It was not possible to analyse the effect of the fixed digital speed cameras on fatal crashes at a level of detail other than for all 28 camera sites combined, so only overall estimates of effect are given below. It should be noted that percentage values need to be treated with great caution. They are NOT additive nor can comparisons of percentage be made between upstream, camera and downstream lengths. By way of example, as the camera lengths had a history of relatively high crash numbers (compared with the adjacent lengths), substantial changes in crash occurrence along these lengths may yield moderate percentage value changes. Yet in adjacent lengths the same changes in crash numbers may produce large percentage value changes (because of the relatively low baseline crash numbers).

4.1.2.1 Reference levels of crash frequencies

Table 20 provides the average value of the crash frequency per speed camera site per year, measured during the period before the cameras became operational at the 28 camera sites. This table is provided to assist the interpretation of the results in Tables 21 to 30. For example, the estimated 19.7 per cent reduction in reported crashes in the camera lengths during the 24 months after cameras became operational (Table 21) could alternatively be expressed as a reduction from 13.9 (as shown in Table 20) to 11.2 (ie 13.9 minus 19.7% of 13.9) reported crashes per site per annum, or a reduction of 2.7 crashes per site per annum due to each camera.

Table 20: Average crash frequency per site per year in the upstream, camera and downstream lengths at fixed digital speed camera sites during the period before the cameras became operational

Crash Type	Upstream	Camera	Downstream
Fatal	0.07	0.24	0.09
Injury	2.66	4.92	3.16
Casualty	2.74	5.16	3.25
Tow-away	5.61	8.75	4.98
All Reported	8.35	13.91	8.23

4.1.2.2 Effects on all reported crashes (casualty plus tow-away crashes)

There was a statistically significant 19.7 per cent reduction (p=0.0001) in reported crashes in the camera length of road during the two years after the fixed digital speed cameras became operational (See Table 21). The magnitude of the reduction varied with the speed zone in which the camera was situated, with the effects at camera sites in 70, 100 and 110 km/h speed zones being relatively large and individually statistically significant or close to significant.

There were no statistically significant reductions in reported crashes in the upstream or downstream lengths adjacent to the fixed digital camera site lengths.

Table 21: Estimated changes in all reported crashes in the camera, upstream and downstream lengths at fixed digital speed camera sites up to two years after the cameras became operational (negative values indicate reductions)

Speed Zone	Upstream			Camera			Downstream		
	Change		Stat. sig.	Change		Stat. sig.	Change		Stat. sig.
	No.	%		No.	%		No.	%	
60 km/h	8.11	6.01	0.4848	-24.88	-10.17	0.1082	7.94	7.35	0.4203
70 km/h	4.73	13.61	0.5118	-29.01	-48.34	0.0004	-10.17	-19.68	0.3361
80 km/h	0.00	-14.35	0.6153	-5.12	-27.49	0.1973	-1.30	-34.14	0.0784
90 km/h	1.48	7.03	0.7194	-8.82	-26.87	0.1292	-8.02	-23.57	0.1747
100 km/h	-1.02	-4.17	0.9127	-6.97	-53.74	0.0510	9.78	80.04	0.1132
110 km/h	0.36	3.50	0.9342	-4.38	-59.34	0.0889	-6.05	-44.66	0.2494
All Sites	**-19.82**	**8.72**	**0.2088**	**-75.55**	**-19.66**	**0.0001**	**-6.04**	**-2.60**	**0.7047**

Note: 1. Percentage values are not additive across speed zones or upstream, camera and downstream lengths.
2. Percentage changes should be considered with caution. By way of example, as the camera lengths had a history of relatively high crash numbers (compared with the adjacent lengths), substantial changes in crash occurrence along these lengths may yield moderate percentage value changes. Yet in adjacent lengths the same changes in crash numbers may produce large percentage value changes (because of the relatively low baseline crash numbers).

When considering the combined lengths for all 28 sites there was a borderline significant (p=0.056) reduction of 7.6 per cent in all reported crashes (See **Table 22**).

Table 22: Estimated changes in *all reported crashes* in the combined lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions in crashes)

Speed Zone	Combined lengths		
	Change		Stat. sig.
	No.	%	
60 km/h	-7.87	-1.62	0.7353
70 km/h	-38.09	-25.38	0.0410
80 km/h	-6.15	-27.78	0.0451
90 km/h	-12.49	-14.70	0.2609
100 km/h	-4.33	-7.75	0.7642
110 km/h	-10.00	-32.35	0.2520
All Sites	**-64.06**	**-7.57**	**0.0559**

Note: Percentage values are not additive across speed zones.

4.1.2.3 Effects on casualty crashes (fatal plus injury crashes)

Across all 28 sites there was a statistically significant (p=0.0051) reduction of 22.8 per cent in the number of casualty crashes along the camera lengths (See Table 23). Across the combined lengths there was a non-statistically significant (p=0.22) reduction of 7.8 per cent (See Table 24).

Table 23: **Estimated changes in casualty crashes in the camera, upstream and downstream lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions)**

Speed Zone	Upstream			Camera			Downstream		
	Change		Stat. sig.	Change		Stat. sig.	Change		Stat. sig.
	No.	%		No.	%		No.	%	
60 km/h	7.55	14.67	0.3093	-9.21	-9.33	0.3608	-4.63	-9.62	0.4676
70 km/h	6.16	54.30	0.1895	-15.91	-52.32	0.0091	-9.99	-34.45	0.2150
80 km/h	0.00	-11.10	0.8078	-4.68	-53.94	0.0651	-0.02	-2.01	0.9578
90 km/h	3.59	51.85	0.2069	-2.34	-23.78	0.4610	-0.23	-2.45	0.9403
100 km/h	-2.41	-27.03	0.5819	-4.94	-71.19	0.0510	2.28	27.71	0.6479
110 km/h	2.05	83.33	0.4304	-0.64	-38.89	0.6085	-0.23	-8.33	0.9309
All Sites	**18.56**	**22.57**	**0.0606**	**-36.39**	**-22.79**	**0.0051**	**-8.64**	**-8.90**	**0.3991**

Note: 1. Percentage values are not additive across speed zones or upstream, camera and downstream lengths.
2. Percentage changes should be considered with caution. By way of example, as the camera lengths had a history of relatively high crash numbers (compared with the adjacent lengths), substantial changes in crash occurrence along these lengths may yield moderate percentage value changes. Yet in adjacent lengths the same changes in crash numbers may produce large percentage value changes (because of the relatively low baseline crash numbers).

Table 24: **Estimated changes in casualty crashes in the combined lengths at fixed speed camera sites up to two years after (28 evaluation sites, negative values** indicate reductions in crashes)

Speed Zone	Combined lengths		
	Change		Stat. sig.
	No.	%	
60 km/h	-6.59	-3.32	0.6594
70 km/h	-19.27	-27.42	0.1416
80 km/h	-1.91	-27.68	0.2122
90 km/h	1.57	6.16	0.8094
100 km/h	-9.19	-32.61	0.3247
110 km/h	1.02	14.58	0.8336
All Sites	**-26.29**	**-7.76**	**0.2195**

Note: Percentage values are not additive across speed zones.

4.1.2.4 Effects on tow-away (non-injury) crashes

Across all 28 sites there was a statistically significant (p=0.012) reduction of 16.9 per cent in the number of tow-away crashes along the camera lengths in the 24 months after the cameras became operational (See Table 25). Across the combined lengths, there was a non-statistically significant reduction of 6.6 per cent in tow-away crashes (Table 26).

Table 25: **Estimated changes in tow-away crashes in the camera, upstream and downstream lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions)**

Speed Zone	Upstream			Camera			Downstream		
	Change		Stat. sig.	Change		Stat. sig.	Change		Stat. sig.
	No.	%		No.	%		No.	%	
60 km/h	1.78	2.17	0.8417	-13.82	-9.64	0.2367	12.33	20.50	0.1014
70 km/h	1.23	5.91	0.8182	-13.21	-44.47	0.0188	-2.29	-9.24	0.7535
80 km/h	0.00	-15.57	0.6730	-0.29	-3.01	0.9236	-1.31	-46.67	0.0408
90 km/h	-1.28	-9.66	0.6598	-6.42	-28.01	0.1879	-8.09	-32.25	0.1170
100 km/h	3.40	24.98	0.6769	-2.43	-37.83	0.3567	6.88	148.85	0.0811
110 km/h	-1.38	-18.75	0.6785	-3.77	-65.33	0.0960	-5.72	-53.57	0.2009
All Sites	**4.33**	**3.05**	**0.7240**	**-37.82**	**-16.94**	**0.0116**	**2.10**	**1.55**	**0.8640**

Note: 1. Percentage values are not additive across speed zones or upstream, camera and downstream lengths.
2. Percentage changes should be considered with caution. By way of example, as the camera lengths had a history of relatively high crash numbers (compared with the adjacent lengths), substantial changes in crash occurrence along these lengths may yield moderate percentage value changes. Yet in adjacent lengths the same changes in crash numbers may produce large percentage value changes (because of the relatively low baseline crash numbers).

Table 26: **Estimated changes in tow-away crashes in the combined lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions in crashes)**

Speed Zone	Combined lengths		
	Change		Stat. sig.
	No.	%	
60 km/h	1.03	0.36	0.9536
70 km/h	-17.06	-21.85	0.1993
80 km/h	-4.17	-27.49	0.1244
90 km/h	-13.69	-23.13	0.1279
100 km/h	5.36	19.76	0.6219
110 km/h	-10.68	-45.11	0.1377
All Sites	**-33.41**	**-6.64**	**0.1953**

Note: Percentage values are not additive across speed zones.

4.1.2.5 Effects on injury crashes

Across all 28 sites there was a statistically significant (p=0.016) 20.1 per cent reduction in injury crashes in the camera lengths (See Table 27). However, across the combined lengths there was a non-statistically significant reduction of 6.2 per cent in injury crashes (See Table 28).

Table 27: **Estimated changes in injury crashes in the camera, upstream and downstream lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions)**

Speed Zone	Upstream			Camera			Downstream		
	Change		Stat.	Change		Stat.	Change		Stat.
	No.	%	sig.	No.	%	sig.	No.	%	sig.
60 km/h	6.87	13.31	0.3557	-7.30	-7.58	0.4660	-4.84	-10.11	0.4519
70 km/h	6.33	59.39	0.1675	-14.19	-49.46	0.0177	-9.19	-33.18	0.2379
80 km/h	0.00	-10.60	0.8175	-4.17	-51.04	0.0922	-0.02	-1.67	0.9652
90 km/h	3.31	49.44	0.2313	-1.82	-19.57	0.5598	0.05	0.54	0.9870
100 km/h	-1.82	-21.87	0.6750	-3.96	-66.43	0.0996	1.90	23.45	0.6997
110 km/h	3.14	229.99	0.1558	-0.36	-26.67	0.7513	0.23	10.00	0.9256
All Sites	**18.55**	**22.97**	**0.0591**	**-30.81**	**-20.06**	**0.0164**	**-8.49**	**-8.90**	**0.4050**

Note: 1. Percentage values are not additive across speed zones or upstream, camera and downstream lengths.
2. Percentage changes should be considered with caution. By way of example, as the camera lengths had a history of relatively high crash numbers (compared with the adjacent lengths), substantial changes in crash occurrence along these lengths may yield moderate percentage value changes. Yet in adjacent lengths the same changes in crash numbers may produce large percentage value changes (because of the relatively low baseline crash numbers).

Table 28: **Estimated changes in injury crashes in the combined lengths at fixed speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions in crashes)**

Speed Zone	Combined lengths		
	Change		Stat. sig.
	No.	%	
60 km/h	-5.61	-2.86	0.7087
70 km/h	-16.33	-24.62	0.2027
80 km/h	-1.71	-25.49	0.2626
90 km/h	2.09	8.58	0.7418
100 km/h	-6.69	-26.55	0.4605
110 km/h	2.91	57.15	0.5062
All Sites	**-20.43**	**-6.20**	**0.3365**

Note: Percentage values are not additive across speed zones .

4.1.2.6 Effects on fatal crashes

There was a 89.8 per cent reduction in fatal crashes in the camera lengths of road during the two years after the fixed digital speed cameras became operational (See Table 29). The 95 per cent confidence limits on this estimated effect ranged from 22.1 per cent reduction to 98.7 per cent reduction. The estimate was statistically significant (p=0.014) and unlikely to be due to chance fluctuation in the relatively small number of fatal crashes in these road lengths.

In contrast, the estimated effects on fatal crashes in the road lengths adjacent to the speed camera site lengths were not statistically significant and could have been due to chance. The confidence limits on the estimated reductions range from high positive values to very high negative values.

Table 29: Estimated changes in fatal crashes (with 95% confidence limits) in the camera, upstream and downstream lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions)

	Upstream		Camera		Downstream	
Speed Zone	% Change	Stat. Sig.	% Change	Stat. sig.	% Change	Stat. sig.
All Sites	**-3.13**	**0.483**	**-89.80**	**0.014**	**-16.96**	**0.396**
Lower 95% CL	-76.55		-98.67		-79.23	
Upper 95% CL	300.14		-22.09		231.97	

When the crashes were analysed for the combined lengths, there was a 57.6 per cent reduction in fatal crashes during the two years following installation of the fixed speed cameras (See Table 30). This estimate was borderline to being statistically significant ($p=0.054$). The 95 per cent confidence limits on this estimated effect ranged from 1.3 per cent increase in fatal crashes to 82.3 per cent reduction.

Table 30: Estimated changes in fatal crashes (with 95% confidence limits) in the combined lengths at fixed digital speed camera sites up to two years after the cameras became operational (28 evaluation sites, negative values indicate reductions in crashes)

Speed Zone	Upstream, Camera and Downstream combined		
	No.	% Change	Stat. sig.
All Sites	**-4.76**	**-57.62**	**0.054**
Lower 95% CL	-16.24	-82.27	
Upper 95% CL	0.00	1.34	

5 Economic evaluation

This component of the evaluation uses the results of the controlled inferential statistical analysis to compute the economic performance of each site.

5.1 Data

The data were classified by site, road section and crash severity. Not all estimates were statistically significant. Nevertheless estimates were used in the absence of more detailed data. In the case of fatalities in particular, the sample size was insufficient to permit a statistically significant percentage reduction for individual sites to be determined. Instead, a single estimate was made for all sites in aggregate, which was used in the computations pertaining to all individual sites.

The unit costs of different types of road crashes, as used by the RTA (*RTA Economic Analysis Manual Version 2, 2003*) are:

- Fatal crash $1,711,620
- Injury crash $126,630
- Towaway crash $7,150

5.2 Benefits

The benefits consist of reductions in the social cost of road trauma. The benefit pertaining to each site was given by the multiple of the pre-Program annual crash rate, the percentage reduction, and the unit cost of road trauma. The fines resulting from camera operation were treated as a transfer – not a benefit – and so did not enter into the calculations.

5.3 Costs

The costs consist of:

- Initial camera installation.
- Camera replacement.
- Recurrent cost of camera operation.
- Re-sheeting (resurfacing of the road where the camera sensors are embedded).
- Processing of Traffic Infringement Notices (TINs).

Initial camera installation costs were provided by the RTA. This cost is incurred once only, when each camera is installed.

Camera replacement. According to the RTA, cameras are replaced at a cost of $100,000 every five to eight years. Conservatively, it is assumed that the cameras will need to be replaced every six years.

Recurrent costs of camera operation were provided by the RTA. This cost is incurred in every year of the project.

Re-sheeting. According to the RTA, re-sheeting costs $12,000 per lane, and is required every three years.

Processing of TINs. NSW Police (the agency that operated the Infringement Processing Bureau at the time of the evaluation) provided information on the cost of processing TINs over a specified period for each site. These were converted into annual rates. This cost is incurred in every year of the project.

5.4 Method

Cash flow streams consisting of the costs, detailed in Section 5.3, and benefits were constructed for each camera site. A notional project horizon of 18 years was chosen, which is three full camera lives of six years each.

No allowance has been made for traffic growth, although it is noted that this will improve economic performance for those sites where crashes were predicted to fall.

For each site, the net present value and benefit cost ratio were calculated at a 7 per cent real discount rate per annum.

Fines were excluded from the analysis on the grounds that they are not an economic cost generated by the project but a transfer.

5.4.1 Scenarios

Two scenarios were analysed, each characterised by cash flow streams for each site consisting of the above costs and benefits.

- **Scenario A**: a notional project horizon of 18 years, being three full camera lives of six years each.
- **Scenario B**: a notional project horizon of six years, being one full camera life of six years.

The analysis was further divided into two combinations of road sections:

- **All road sections**: comprises crashes in all road sections—upstream, downstream and 'camera'.
- **'Camera' section only**: comprises crashes in the 'camera' road section only.

5.5 Results

The results of the economic analysis are summarised in Table 31 below.

Table 31: Results summary

	All lengths				Camera length only			
	Scenario A		Scenario B		Scenario A		Scenario B	
	NPV# ($mil)	BCR⌀	NPV# ($000)	BCR⌀	NPV# ($000)	BCR⌀	NPV# ($mil)	BCR⌀
All 28 sites	109,087	3.50	50,885	3.37	113,447	3.60	52,951	3.46

\# Net present value

⌀ Benefit cost ratio

5.5.1 Net present value

For the total 28 fixed digital speed camera sites, the net present value over a project horizon of 18 years is $109.1 million and $113.4 million for all road sections and the camera section respectively. Over a project horizon of six years, the net present value shows a similar trend; $50.9 million and $53 million for all road sections and the camera section respectively.

Overall, the 28 camera sites have positive social benefits corresponding to positive net present values. This indicates that the Fixed Digital Speed Camera Program has a high degree of economic merit.

5.5.2 Benefit cost ratio

The numerator of the benefit cost ratio consisted of the social cost saving; and the denominator, the camera-related costs (including that of processing TINs, which is not borne by the RTA).

For the Fixed Digital Speed Camera Program the benefit cost ratio is high: 3.5 for a project horizon of 18 years and 3.4 for a project horizon of six years.

6 Community questionnaire survey

6.1 Objectives of the community questionnaire survey

The purpose of the survey was to:

- Establish community knowledge perceptions and attitudes.
- Measure the incidence of attitudes, beliefs and reported behaviours.
- Identify changes in the above over time.
- Establish differences if they exist between urban and non-urban motorists, and between motorists exposed versus not exposed to the cameras.

The survey results presented in this report were designed specifically to track changes in motorists' attitudes, knowledge, beliefs and reported behaviours in those geographic areas likely to be exposed to fixed digital speed cameras. Accordingly, motorists were identified as having been exposed or not exposed to parts of the road system in which fixed digital speed cameras operate.

6.2 Findings of community questionnaire survey

The community questionnaire surveys were conducted in four waves: September 2000, late March/early April 2001, September 2001 and in September 2002.

Likelihood of detection for speeding

The perceived likelihood of detection for speeding was quite low. Motorists were asked to put aside fixed speed cameras and think about your driving in day and night time, how would you rate the risk of getting caught by the Police for exceeding the speed limit by 10 km/h? (using a scale from 1 to 10)'. Across all four waves this measure remained relatively stable. The mean risk score remained at slightly less than five out of 10. The mean score for the random sample decreased at Wave III (4.69 from 4.58 in Wave I) and remained at that for Wave IV, while the booster sample's mean decreased at Wave II (4.78) and increased at Waves III (5.17) and IV (5.38).

Most drivers claimed to 'usually' drive on the limit or just over and non-metropolitan drivers were more likely to claim to drive on the limit or under the limit. The incidence of claiming to drive over the speed limit in metropolitan areas since Wave I (44%) remained static (42%) in Wave IV.

Exposure to fixed digital speed cameras

Exposure to fixed digital speed cameras, measured in terms of having driven in the last two months along roads at sites where they are located, was greatest in metropolitan areas rising from 84 per cent in Wave I to 97 per cent in Wave IV; the non-metropolitan sample increased from 75 per cent in Wave I to 88 per cent in Wave IV. For the booster sample of Sydney professional drivers exposure increased from 90 per cent in Wave I to 96 per cent in Waves III and IV with their exposure pattern mirroring the random sample but with higher levels at all metropolitan sites.

Awareness of fixed digital speed cameras

Awareness of fixed digital speed cameras grew substantially from 64 per cent in Wave I to 84 per cent in Wave IV. Over this period awareness in the Booster sample grew from 72 per cent to 94 per cent.

The incidence of motorists reporting that they were aware of speed limit signs near the fixed digital speed cameras increased substantially from 51 per cent in Wave I to 69 per cent in Wave II but the increases in Waves III and IV were only minor, 73 and 76 per cent respectively. Similar gains occurred in the booster sample (Wave I 42%, Wave II 63%, Wave III 74%, Wave IV 83%).

Driver reaction to fixed digital speed cameras

Drivers' reactions on sighting a warning sign remained largely unchanged across all four Waves. A majority claim to drive 'at the limit' (Wave I 60%, Wave II 58%, Wave III 50% and in Wave IV 62%), or 'below the limit' (22-25%). The minority who drive slightly over the limit has declined from 15 per cent in Wave I, to 19 in Wave IV. Between Waves II and IV the percentage claiming to drive slower than the limit increased from 25 per cent to 37 per cent.

In Wave I, 51 per cent of drivers believed most other drivers still exceeded the speed limit upon sighting the warning signs. This fell to 39 per cent in Wave IV.

In Wave I, 19 per cent of drivers claimed to personally 'speed up a bit' after having passed a fixed digital speed camera. In Wave IV this increased to 27 per cent. However, a much higher percentage said that most other drivers speed up a bit (52% in Wave I and 59% in Wave IV) having passed a speed camera.

Perceptions of fixed digital speed cameras

Respondents perceived fixed digital speed cameras as having a legitimate role. Unprompted responses included 'reduce speeding' (55%), 'reduce crashes' (30%), and 'improve road safety' (31%) and each of these responses remained relatively static for the four waves. The incidence of respondents who associated fixed digital speed cameras with revenue-raising was small and rather stable for the four survey waves (15 – 25%).

The perception of speeding tickets issued (as a result of fixed digital speed cameras) as primarily revenue-raising, rather than a road safety countermeasure, changed only slightly over the four waves, hovering around 45 per cent (Wave I 45%, Wave II 47%, Wave III 44%, Wave IV 45%). Similarly, the incidence of 'uncertain' responses showed little change. At Wave I the booster sample of professional drivers was most likely to believe speeding tickets resulting from fixed digital speed cameras were primarily revenue raising (76%). This finding declined to 56 per cent for Wave II and remained at this level for Waves III and IV. Only a relatively small proportion of respondents was likely to spontaneously associate fixed digital speed cameras with revenue-raising (15 – 25%), but when asked directly if speeding tickets issued as a result of fixed digital speed cameras are primarily for revenue-raising rather than as a road safety countermeasure, approximately 45 per cent of respondents in each wave reported 'revenue-raising'.

Respondents' expectations of the cameras, in relation to reducing crashes, increased significantly between Waves I and II (50 – 49%) and Waves III and IV (55 – 57%) believing the cameras would have a 'big' or 'medium' impact on crashes.

Respondents who indicated that fixed digital speed camera tickets were 'primarily for revenue-raising' were asked 'out of every five speeding tickets issued from permanent speed cameras, how many are for revenue-raising (rather than in the interests of road safety)'. The results indicated a slight decrease between Wave I and Wave II with the average declining from 3.40 to 3.27 tickets, but in Wave III it had risen to 3.88. In Wave IV it returned to almost baseline level (Wave I 3.42 versus Wave IV 3.4).

In order not to be seen as revenue-raising, most motorists who attributed revenue-raising said that there should be a speed tolerance level. The distribution remained bi-modal[5] at 10 km/h (41% Wave I, 38% Wave II, 34% Wave III and 38% Wave IV) and up to 5 km/h (35% Wave I, 28% Wave II, 36% Waves III and IV). Overall, the average tolerance expected to avoid revenue-raising fell slightly at each Wave from 8.5 km/h in Wave I to 8.0 km/h in Wave IV.

Awareness of 'anybody' booked by fixed digital speed cameras continued to increase marginally each Wave from 42 per cent in Wave I, 47 per cent in Wave II, 53 per cent in Wave III and 55 per cent in Wave IV. More people attributed the booking to road safety (47%) than revenue-raising (38%).

Level of acceptance of fixed digital speed cameras

The level of acceptance for the use of fixed digital speed cameras on 40 and 50 km/h roads increased from 59 per cent in Wave I, to 68 per cent in Wave IV, but remains below the levels on roads with higher limits. Between Wave I and Wave IV, acceptance remained static on 60 to 80 km/h roads (75%) and on 90 to 110 km/h roads (72 – 73%).

Just over half in all four Waves (53%) had been booked for speeding and this number remained constant, as did the number booked for speeding in the last six months (7 – 8%). Most caught were aware of the speed limit and the incidence saying that they were not aware of the speed limit remained static at 27 – 30 per cent. The incidence of those caught for speeding in the last six months was also related to lack of exposure.

Over the four Waves only 5–7 per cent chose not to volunteer at least one advantage for fixed digital speed cameras. The most frequently cited advantages were reducing speeding (in Wave I 59% and in Wave IV 60%), preventing crashes, (28% to 27%) improving safety (9% up to 20%) and revenue-raising (12% up to 15%).

In Wave I, 47 per cent saw no drawbacks to fixed digital speed cameras. In Wave IV this fell to 38 per cent. The most often mentioned drawbacks were the same across all four Waves (fine/loss of points 8%, drive slow then speed up 7%, revenue raising 9%, people know locations 7%, slows traffic flow 5%).

Impact of fixed digital speed cameras

The main impact of the cameras on drivers' own behaviour was to reduce speed for some distance in the vicinity of the camera and this increased from 34 per cent in Wave I to 40 per cent in Wave IV.

The impact on nearby roads without fixed digital speed cameras is seen to be somewhere between 'slight' and 'quite' effective and these results remained unchanged over the four Waves.

The overall assessment of the impact of fixed digital speed cameras on speeds also remained largely unchanged as did the assessment of the impact on crashes. Across all four Waves the impact was expected to be greater on speeds than on crashes.

Over time (Waves II – IV) the incidence of motorists believing that mobile speed cameras operated by Police were more likely to detect or reduce speeding than were fixed digital

[5] 'Bi-modal' means that there were two peaks in the data. In this case the peaks were at 10 km/h and up to 5 km/h, meaning that a large number of respondents suggesting that the tolerance level of the speed cameras be 10 km/h, and also a large number (though not necessarily the same number) suggested that the tolerance should be up to 5 km/h.

speed cameras increased from 68 per cent Wave II to 80 per cent in Wave IV (detection); 66 per cent in Wave II to 71 per cent in Wave IV (influence speeding).

Speeding penalties continued to be more associated with fines (80% in Wave I, to 83% in Wave IV) than demerit points (61% in Wave I, 64% in Wave IV), loss of licence (19% in Wave I and IV) or gaol sentence (4% in Waves I & IV).

Loss of licence for speeding offences was seen as appropriate only for speeds in excess of 15 km/h over the limit, and this remained relatively constant over all four Waves. The incidence claiming that loss of licence is only appropriate for a repeat offender increased with each Wave from 1 per cent to 11 per cent. A slight majority (53 – 54%) was also in favour of a gaol sentence for excessive or repeated speeding.

7 Major findings

7.1 Speed survey analysis

7.1.1 Inferential statistical analysis (20 sites)

Mean speed

At the camera lengths there was a statistically significant ($p<0.0001$) reduction in mean speed of 6.3 km/h and 5.8 km/h 12 months and 24 months 'after' respectively. While there were generally no changes in speed in the adjacent lengths, a small but statistically significant ($p=0.0192$) increase of 1.5 km/h was detected in the upstream length during the 24-month 'after' period.

Percentage of vehicles exceeding the speed limit

The 12-month 'after' speed data revealed statistically significant ($p<0.0001$) reductions across all lengths of 5.3 per cent (upstream length), 70 per cent (camera length) and 20.9 per cent (downstream length).

While the 24-month 'after' data show that statistically significant ($p<0.0001$) reductions were maintained along the camera length (71.8%) and the downstream length (5.1%), the proportion in the upstream length increased to a statistically significant ($p<0.0001$) degree of 3.4 km/h.

Percentage of vehicles exceeding the speed limit by at least 10 km/h

Statistically significant ($p<0.0001$) reductions of 85.6 per cent and 87.9 per cent were achieved along the camera lengths at 12 months and 24 months 'after'.

After 12 months of the cameras in operation the downstream proportion reduced by 8.2 per cent while the upstream length increased by 7.6 per cent. At 24 months 'after' there were increases of 24.8 per cent in the upstream and 10.5 per cent in the downstream. In all cases the changes were statistically significant ($p<0.0001$).

Percentage of vehicles exceeding the speed limit by at least 20 km/h

Statistically significant ($p<0.0001$) reductions of 85.6 per cent and 86.5 per cent were achieved along the camera lengths at 12 months and 24 months 'after'.

After 12 months the proportion in the upstream and downstream lengths increased by 21.9 per cent and 22.1 per cent respectively. Twenty-four months 'after' there were increases of 36.9 per cent in the upstream length and 41 per cent in the downstream length. In all cases the changes were statistically significant ($p<0.0001$).

Percentage of vehicles exceeding the speed limit by at least 30 km/h

Statistically significant ($p<0.0001$) reductions of 83.9 per cent and 79.5 per cent were achieved along the camera lengths 12 months and 24 months 'after'.

After 12 months, the upstream and downstream proportion increased by 23.2 per cent and 29.6 per cent respectively. Twenty-four months 'after' there were increases of 13.6 per cent in the upstream length and 29.4 per cent in the downstream length. In all cases the changes were statistically significant ($p<0.0001$).

7.1.2 Descriptive statistical analysis (28 sites)

85th percentile speed

The 85th percentile speed is the speed at or below which 85 per cent of all vehicles are observed under free flow conditions.

After taking account of control speed data the following **reductions** within the camera length were achieved:

- 7.3 km/h (11%) and 6.3 km/h (9%) **within 60 km/h speed zones** after 12 months and 24 months respectively.
- 8 km/h (11%) and 8.4 km/h (11%) **within 70 km/h speed zones** after 12 months and 24 months respectively.
- 11 km/h (13%) and 12 km/h (13%) **within 80 km/h speed zones** after 12 months and 24 months respectively.
- 22.4 km/h (20%) and 22.3 km/h (20%) **within 90 km/h speed zones** after 12 months and 24 months respectively.
- 4.4 km/h (4%) and 7.3 km/h (7%) **within 100 km/h speed zones** after 12 months and 24 months respectively.
- 12.6 km/h (10%) **within the 110 km/h** speed zone after 24 months. It should be noted that no 24-month 'after' speed data were recorded for this site.

Standard deviation

Standard deviation is a statistic that can be used as a measure of the distribution of speeds within the traffic flow. It is considered that other things being equal, a reduction in the standard deviation will be associated with a more uniform traffic flow thus reducing the need for overtaking movements. This will be expected to consequently result in improved safety for the moving traffic.

After taking account of control speed data the following **reductions** within the camera length were achieved:

- 1.4 km/h (18%) and 1.7 km/h (22%) **within 60 km/h speed zones** after 12 months and 24 months respectively.
- No change and 1.0 km/h (15%) **within 70 km/h speed zones** after 12 months and 24 months respectively.
- 1.8 km/h (22%) and 2.1 km/h (27%) **within 80 km/h speed zones** after 12 months and 24 months respectively.
- 4.1 km/h (40%) and 4.6 km/h (40%) **within 90 km/h speed zones** after 12 months and 24 months respectively.
- 1.8 km/h (18%) and 3.8 km/h (34%) **within 100 km/h speed zones** after 12 months and 24 months respectively.
- 0.5 km/h (7%) **within the 110 km/h speed zone** after 12 months. It should be noted that no 24-month 'after' speed data were recorded for this site.

7.2 Crash data analysis

The evaluation revealed that substantial reductions were achieved in road trauma across the 28 fixed digital speed camera locations. The reductions were achieved along the speed camera lengths (ie. the length of road along which the fixed digital speed camera operated) and the combined length of road that included the camera length and the adjacent lengths either side.

The inferential statistical analysis provided the following key findings:

- There was a statistically significant reduction (p=0.0001) in **all reported crashes** along the **camera lengths** of 19.7 per cent in the 24 months after the cameras became operational.
- For the **combined lengths** there was a total reduction in **all reported crashes** of 7.6 per cent, which is borderline to being statistically significant (p=0.056).
- For the **camera lengths** there was a statistically significant reduction (p=0.0051) in casualty crashes (ie fatal plus injury crashes) of 22.8 per cent.
- For the **combined lengths** there was a non-statistically significant reduction of 7.8 per cent in **casualty crashes**.
- There was a statistically significant (p=0.012) reduction of 16.9 per cent in **tow-away crashes** along the **camera lengths**.
- Across the **combined lengths** there was a non-statistically significant reduction of 6.6 per cent in **tow-away crashes**.
- There was a statistically significant (p=0.0164) reduction of 20.1 per cent in the **injury crashes** along the **camera lengths**.
- For the **combined lengths** there was a non-statistically significant reduction of 6.2 per cent in **injury crashes**.
- There was a 89.8 per cent reduction in **fatal crashes** in the **camera lengths** during the two years after the cameras became operational. This estimate was statistically significant (p=0.014). The 95 per cent confidence limits on this estimated effect ranged from 22.1 per cent reduction to 98.7 per cent reduction.
- There was a 57.6 per cent reduction in **fatal crashes** in the **combined lengths** during the two years after the cameras became operational. This estimate was borderline to being statistically significant (p=0.054). The 95 per cent confidence limits on this estimated effect ranged from 1.3 per cent increase in fatal crashes to 82.3 per cent reduction.

7.3 Economic analysis

Overall the 28 camera sites have positive social benefits corresponding to positive net present values. This indicates that the measured crash reductions contribute to the Fixed Digital Speed Camera Program having a high degree of economic merit.

The net present value over a project horizon of 18 years is $109.1 million and $113.4 million for the combined lengths and the camera lengths respectively. Over a project horizon of six years, the net present value shows a similar trend; $50.9 million and $53 million for the combined lengths and the camera lengths respectively.

The benefit cost ratio of the Fixed Digital Speed Camera Program is high: 3.5 for a project horizon of 18 years and 3.4 for a project horizon of six years. If the camera lengths of the sites are considered without their adjacent lengths, the benefit cost ratio increases to 3.6 for a project horizon of 18 years and 3.5 for a project horizon of six years.

7.4 Community questionnaire surveys

Over the two-year period of the four waves of community questionnaire survey, fixed digital speed camera installations increased from 10 to 35. Community awareness of the cameras was high at the beginning of the study and continued to rise with increased implementation of the cameras.

The community has a generally positive attitude towards fixed digital speed cameras with respondents more likely to spontaneously associate the fixed digital speed cameras and their locations with speeding, crashes and road safety rather than revenue-raising.

The use of fixed digital speed cameras received strong acceptance from the respondents with a preference for them in higher rather than lower speed zones.

The Fixed Digital Speed Camera Program appears to have had an impact on influencing driver behaviour with most respondents reporting that they slow down at the fixed digital speed camera sites. These responses are consistent with the results of the speed surveys, which showed that vehicles had slowed down at all of the fixed digital speed camera sites during the two years after the installation of the cameras.

The majority of respondents perceived fixed digital speed cameras as having a legitimate role as a road safety countermeasure, in particular in reducing speeding and preventing crashes. These findings revealed that with greater exposure to the fixed digital speed cameras, respondents' perceptions of the fixed digital speed cameras improving road safety increased.

8 Conclusions

This evaluation has shown that after the installation of 28 fixed digital speed cameras across various sites in New South Wales, significant reductions have been measured in vehicle speeds, speeding rates and crashes.

The **speed** data revealed that substantial reductions were achieved in mean speeds along the speed camera sites. Mean speeds fell by about 6 km/h, 12 and 24 months 'after' while adjacent mean speeds changed by relatively small amounts. The analysis also revealed large reductions in the percentage of vehicles exceeding the speed limit, and exceeding the speed limit by 10 km/h, 20 km/h and 30 km/h along the 'high crash' camera lengths. Reductions achieved were in the order of 70 per cent to almost 90 per cent, far outweighing any increases detected in adjacent lengths.

Overall reported **crashes** fell by almost 20 per cent along the road segments (camera lengths) that had demonstrated high crash risk. Casualty crashes had also fallen markedly along the camera lengths by 23 per cent, injury crashes by about 20 per cent and fatal crashes by nearly 90 per cent.

When accounting for changes in crashes along the adjacent camera lengths, substantial reductions in crashes continued to be achieved: 7.6 percent in all reported crashes, 7.8 per cent in casualty crashes, 6.2 per cent in injury crashes and 57.6 per cent in fatal crashes.

For the total 28 fixed speed camera sites, the **net present value** over a project horizon of 18 years is $109.1 million and $113.4 million for all road lengths and the camera length respectively. Over a project horizon of six years, the net present value shows a similar trend: $50.9 million and $53 million for the combined lengths and the camera length respectively. This indicates that the Fixed Digital Speed Camera Program can be expected produce a social benefit in reduced crashes over its time of operation.

The economic analysis of the project estimates a **benefit cost ratio** of 3.4 over a project horizon of six years or 3.5 for a project horizon of 18 years. This indicates that the Fixed Digital Speed Camera Program will produce a social benefit in reduced crashes over its time of operation.

Overall, respondents had positive **community attitudes** towards the Fixed Digital Speed Camera Program, were well aware of the initiative, had realistic expectations of the Program and believed the cameras were an effective road safety countermeasure.

In summary the key findings of the evaluation are that:

- vehicle operating speeds (ie mean and 85^{th} percentile speeds) fell markedly along the camera sites.
- crashes fell in a highly statistically significant manner in the camera lengths.
- crash reductions achieved through the Fixed Digital Speed Camera Program contribute to its high degree of economic merit.

The above findings show that reduced speeding is a mediating factor in the measured crash reduction within camera sites. This is consistent with the findings of numerous other lines of research that indicate that speeding is associated with increases in road trauma (Federal Highway Administration 1998; Fildes and Lee 1993; Kloeden, McLean & Glonek, 2002; RTA 2000; Sliogeris, 1992, Taylor et al, 2002).

This evaluation has shown that the approach adopted for deploying fixed digital speed cameras in NSW, which involves selecting sites based on a particular speed and crash history and prominently sign-posting them, has proven successful. The evaluation provides support for extending the Program across other similarly selected locations in NSW.

References

Aitkin, M., Anderson, D., Francis, B., and Hinde, J.; *Statistical modelling in GLIM.* Oxford: Oxford Science Publications; 1989.

ARRB Transport Research. Evaluation of the 50 km/h urban speed limit in New South Wales; 2000.

Bruhning, E. and Ernst, G.; *Log-linear models in effectiveness studies – an application to simultaneous before-after comparisons with control group.* International meeting on the evaluation of local traffic safety measures; 1985.

Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record 1595.* pp14-19.

Fildes, B. and Lee, S.; *The speed review: Road environment, behaviour, speed limits, enforcement and crashes.* Federal Office of Road Safety.; 1993.

Federal Highway Administration (FHWA). Synthesis of Safety Research Related to Speed and Speed Management. July 1998.

Kloeden, CN., McLean, AJ., & Glonek, G. *Reanalysis of Travelling Speed and the Risk of Crash Involvement in Adelaide South Australia.* Department of Transport and Regional Services Australian Transport Safety Bureau; 2002

McCullagh, P., and Nelder, J. A.; *Generalized linear models.* London: Chapman and Hall; 1989.

Newstead, S., Cameron, M. and Leggett, M.; *Evaluation of the Queensland Random Road Watch Program.* Monash University Accident Research Centre, Report Number 149, Melbourne, Australia; 1999.

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

Nilsson, G.; *Reduction in the speed limit from 100 km/h to 90 km/h during summer 1989: effects on personal injury accidents, injuries and speeds.* Linkoping, Sweden: Swedish Road and Traffic Research Institute; Report Number 358A; 1990.

PA Consulting Group. (2004) *The National Safety Camera Program.* Available from the Department for Transport, UK.

RTA NSW. *Speeding, Hp. 26th September 2000. [last update].* On-line. Roads and Traffic Authority. Available: http://www.rta.nsw.gov.au/safety/c15_c.htm 17/09/2001.

RTA NSW. *Speed: Speed Problem Definition and Countermeasure Summary.* Road and Traffic Authority. August 2000.

RTA NSW Roads and Traffic Authority Crash Statistics.

RTA NSW Economic Analysis Manual, Version 2, 1999 (and revisional updates Nos 1 to 8).

SAS Institute Inc.; *SAS Technical Report P-243 SAS/STAT Software: The GENMOD Procedure.* Cary, North Carolina, USA; 1993.

Sliogeris, J. *110 kilometre per hour limit – evaluation of road safety effects.* VicRoads 1992

Taylor, MC, Baruya, A and Kennedy, JV (2002) *The relationship between speed and accidents on rural single-carriageway roads.* Prepared for Road Safety Division, Department of Transport, Local Government and the Regions TRL Report TRL511

Appendix A

AI: Changes in 85th percentile and standard deviation for the 28 evaluation sites, by speed zone, in the camera lengths, in the direction being monitored by the camera (negative values indicate reductions)

	Camera										
		12-month					24-month				
	Baseline	Expected	Actual	Control ratio	Difference		Expected	Actual	Control ratio	Difference	
	km/h	km/h	km/h	%	km/h	%	km/h	km/h	%	km/h	%
60 km/h zones											
85th percentile speed, (km/h)	71.3	68.3	60.9	0.96	-7.3	-10.7	66.9	60.6	0.94	-6.3	-9.4
Standard deviation, SD (km/h)	8.4	7.6	6.2	0.90	-1.4	-17.9	7.8	6.0	0.92	-1.7	-22.3
70 km/h zones											
85th percentile speed, (km/h)	79.5	79.5	71.5	1.00	-8.0	-10.1	76.4	68.0	0.96	-8.4	-11.0
Standard deviation, SD (km/h)	7.6	6.8	6.8	0.89	-0.0	-0.1	6.6	5.6	0.87	-1.0	-15.4
80 km/h zones											
85th percentile speed, (km/h)	91.0	88.0	77.0	0.97	-11.0	-12.5	90.0	78.0	0.99	-12.0	-13.3
Standard deviation, SD (km/h)	8.5	7.8	6.1	0.92	-1.8	-22.4	7.9	5.8	0.93	-2.1	-27.1
90 km/h zones											
85th percentile speed, (km/h)	111.3	110.1	87.7	0.99	-22.4	-20.3	110.3	88.0	0.99	-22.3	-20.2
Standard deviation, SD (km/h)	11.4	10.4	6.3	0.91	-4.1	-39.6	11.4	6.8	0.99	-4.6	-40.2
100 km/h zones											
85th percentile speed, (km/h)	108.3	107.1	102.7	0.99	-4.4	-4.1	107.3	100.0	0.99	-7.3	-6.8
Standard deviation, SD (km/h)	11.1	10.0	8.2	0.91	-1.8	-18.1	11.0	7.2	0.99	-3.8	-34.2
110 km/h zone											
85th percentile speed, P^{85} (km/h)	122.0	120.6	108.0	0.99	-12.6	-10.4	-	-	0.99	-	-
Standard deviation, SD (km/h)	9.3	8.4	7.9	0.91	-0.5	-6.5	-	-	0.99	-	-

* These figures are derived from control ratios and are not based on the inferential statistical analysis. The inferential statistical analysis does not refer to 85th percentile speed or standard deviation and only refers to the initial 20 sites

A2: **Changes in 85th percentile and standard deviation for the 28 evaluation sites, by speed zone, in the upstream lengths, in the direction being monitored by the camera (negative values indicate reductions)**

	Upstream										
		12-month					24-month				
	Baseline	Expected	Actual	Control ratio	Difference		Expected	Actual	Control ratio	Difference	
	km/h	km/h	km/h	%	km/h	%	km/h	km/h	%	km/h	%
60 km/h zones											
85th percentile speed, (km/h)	66.0	63.2	64.0	0.96	0.8	1.3	61.9	63.0	0.94	1.1	1.7
Standard deviation, SD (km/h)	7.6	6.9	7.2	0.90	0.3	5.0	7.0	6.9	0.92	-0.1	-1.8
70 km/h zones											
85th percentile speed, (km/h)	77.0	77.0	69.0	1.00	-8.0	-10.4	74.0	72.0	0.96	-2.0	-2.7
Standard deviation, SD (km/h)	10.4	9.3	8.4	0.89	-0.9	-9.7	9.0	9.3	0.87	0.3	3.0
80 km/h zones											
85th percentile speed, (km/h)	91.0	88.0	77.0	0.97	-	-	90.0	78.0	0.99	-	-
Standard deviation, SD (km/h)	8.5	7.8	6.1	0.92	-	-	7.9	5.8	0.93	-	-
90 km/h zones											
85th percentile speed, P^{85} (km/h)	102.0	100.8	98.0	0.99	-2.8	-2.8	101.1	97.0	0.99	-4.1	-4.0
Standard deviation, SD (km/h)	10.7	9.7	9.5	0.91	-0.2	-2.2	10.6	10.2	0.99	-0.4	-4.1
100 km/h zones											
85th percentile speed, (km/h)	84.0	83.0	84.0	0.99	1.0	1.2	83.2	84.0	0.99	0.8	0.9
Standard deviation, SD (km/h)	9.3	8.4	6.8	0.91	-1.6	-19.5	9.2	6.5	0.99	-2.7	-29.7
110 km/h zone											
85th percentile speed, (km/h)	122.0	120.6	108.0	0.99	-	-	-	-	0.99	-	-
Standard deviation, SD (km/h)	9.3	8.4	7.9	0.91	-	-	-	-	0.99	-	-

* These figures are derived from control ratios and are not based on the inferential statistical analysis. The inferential statistical analysis does not refer to 85th percentile speed or standard deviation and only refers to the initial 20 sites

A3: **Changes in 85th percentile and standard deviation for the 28 evaluation sites, by speed zone, in the downstream lengths, in the direction being monitored by the camera (negative values indicate reductions)**

	Downstream										
		12-month					24-month				
	Baseline	Expected	Actual	Control ratio	Difference		Expected	Actual	Control ratio	Difference	
	km/h	km/h	km/h	%	km/h	%	km/h	km/h	%	km/h	%
60 km/h zones											
85th percentile speed, (km/h)	68.0	65.1	67.0	0.96	1.9	2.9	63.8	68.0	0.94	4.2	6.6
Standard deviation, SD (km/h)	7.9	7.1	8.0	0.90	0.9	12.3	7.3	8.3	0.92	1.0	13.7
70 km/h zones											
85th percentile speed, (km/h)	70.0	70.0	68.0	1.00	-2.0	-2.9	67.3	68.0	0.96	0.7	1.1
Standard deviation, SD (km/h)	10.3	9.2	9.1	0.89	-0.1	-1.3	8.9	9.8	0.87	0.9	9.6
80 km/h zones											
85th percentile speed, (km/h)	85.0	82.2	88.0	0.97	5.8	7.0	84.1	88.0	0.99	3.9	4.7
Standard deviation, SD (km/h)	7.2	6.6	7.3	0.92	0.7	9.8	6.7	7.1	0.93	0.4	5.6
90 km/h zones											
85th percentile speed, (km/h)	104.0	102.8	101.0	0.99	-1.8	-1.8	103.0	103.0	0.99	-0.0	0.0
Standard deviation, SD (km/h)	9.6	8.7	9.8	0.91	1.1	12.4	9.5	10.3	0.99	0.8	7.9
100 km/h zones											
85th percentile speed, (km/h)	112.0	110.7	110.0	0.99	-0.7	-0.6	111.0	111.0	0.99	0.0	0.0
Standard deviation, SD (km/h)	9.5	8.6	9.3	0.91	0.7	7.8	9.4	8.9	0.99	-0.5	-5.7
110 km/h zone											
85th percentile speed, (km/h)	122.0	120.6	108.0	0.99	-	-	-	-	0.99	-	-
Standard deviation, SD (km/h)	9.3	8.4	7.9	0.91	-	-	-	-	0.99	-	-

* These figures are derived from control ratios and are not based on the inferential statistical analysis. The inferential statistical analysis does not refer to 85th percentile speed or standard deviation and only refers to the initial 20 sites