EVALUATION OF THE ROAD SAFETY BENEFITS OF THE QUEENSLAND CAMERA DETECTED OFFENCE PROGRAM (CDOP) IN 2016

by

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Abstract:
The Queensland Camera Detected Offence Program (CDOP) covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras, and has been expanded over recent years to include point to point cameras and combined speed and red light cameras at intersections. Use of mobile speed cameras since April 2010 has also involved some use of cameras covertly which has been confined to up to 30% of deployments in urban areas. Furthermore, changes to the process for camera site selection as well as camera scheduling have also occurred in recent years. The broad objective of this study was to measure crash frequency, severity and social costs to the community in Queensland associated with the ongoing operation of the CDOP over the year 2016. The evaluation framework developed by Newstead and Cameron (2012) was used and incorporated estimation of the impacts of different camera types, and articulated the use of available speed monitoring data as an intermediate measure of CDOP effectiveness.

In 2016 the CDOP was associated with an overall reduction in police reported serious casualty crashes of 11%, and minor injury crash reductions of 6%. These estimates are less than for previous years in prior applications of the framework but reflect a much higher coverage of the crash population by the mobile camera program resulting from expansion in the number of sites enforced in 2016. Translation of percentage crash savings to absolute crash savings in 2016 estimated saving of around 2,500 casualty crashes of which around 1,650 were fatal and serious injury crashes. Conversion of the estimated crash savings into (2016) cost savings estimated savings associated with the CDOP of around $1.5B using Willingness to Pay estimates or $0.7B using Human Capital crash costs. About 90% of the total cost savings stem from savings in fatal and serious injury crashes. Estimated savings for the CDOP in 2016 are similar to those estimated for the previous 3 years suggesting recent multiple changes to the operation of the mobile speed camera program, including a new scheduler, increased hours of operation and the addition of new sites for enforcement, have not had a significant additional impact on its effectiveness which remains high. Simultaneous introduction of the changes, limited available crash history after the changes and limitations in the evaluation framework meant it was not possible to assess the individual impacts of each specific change. Despite the expansion of the number of fixed cameras in use under the CDOP 98% of the savings associated with the program derive from the mobile speed camera program, which is the CDOP technology that covers by far the largest proportion of the crash population in Queensland.

Key Words:
CDOP, mobile speed, fixed speed, red light speed, Queensland, red light cameras, Quasi-experimental, time series

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Preface

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Stuart Newstead:	Study design, evaluation framework design, and report editing/writing
Laurie Budd:	Crash data analysis and report preparation
Max Cameron	Study design, evaluation framework design, manuscript review

Ethics Statement

Ethics approval was not required for this project.

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Contents

GLOSSARY OF ABBREVIATIONS AND TERMS

Term / Abbreviation	Meaning
CDOP	Camera Detected Offence Program.
GIS	Geographical Information System – a computer program which maps and relates information spatially.
Human capital crash cost	A method of determining the cost of a road crash to the community based on the actual cost of all the associated events (property damage, medical costs, lost productivity etc.).
Negative Binomial regression	A form of statistical regression analysis used to model count data and contingency tables. It assumes the response variable has a Negative Binomial distribution and assumes the natural logarithm of the response variable can be modelled by a linear combination of a set of independent variables.
Poisson regression	A form of statistical regression analysis used to model count data and contingency tables. It assumes the response variable has a Poisson distribution and assumes the natural logarithm of the response variable can be modelled by a linear combination of a set of independent variables.
PtP	Point to Point Speed Camera System – an automated enforcement system designed to measure average speed over a length of road.
Quasi experiment	A scientific study design similar to the randomised controlled trial except selection of participants to receive the intervention is not random.
Relative Risk	The risk of an outcome in one situation or group relative to another (e.g. in males relative to females).
Simpson's Paradox	A situation in statistical analysis where the outcome effects of an action are estimated incorrectly (and more typically in the wrong direction) due to the failure of the analysis to account for the effect of another factor effecting the outcome but associated with the factor of interest.
SLA	Statistical Local Area – local geographical areas defined by the Australian Bureau of Statistics.
Speed bins	Ranges of speed into which individual speed observations are classified for analysis (e.g. 0-5kph, 5-10kph etc.).
Speed enforcement tolerance	The amount over the speed limit a motorist can travel before a traffic offence notice will be issued.
Test of homogeneity	A statistical test to establish whether a countermeasure has achieved the same outcome effect over multiple sites.
TMR	Transport and Main Roads – a Queensland Government department.
Traffic/crash migration	When implementation of a countermeasure causes traffic, and resulting crashes, to move to another site.
Willingness to Pay crash cost	A method of determining the cost of a road crash to the community based on a survey of the population's opinion of what it would be willing to pay to prevent a crash and associated injury outcome.

EXECUTIVE SUMMARY

The Queensland Camera Detected Offence Program (CDOP) covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras, and has been expanded over recent years to include point to point cameras and combined speed and red light cameras. Use of mobile speed cameras since April 2010 has also involved some use of cameras covertly which has been confined to up to 30% of deployments in urban areas.

The broad objective of this study was to measure crash frequency, severity and social costs to the community in Queensland associated with the ongoing operation of the CDOP over the year 2016. The evaluation framework developed by Newstead and Cameron (2012) was used and incorporated estimation of the impacts of different camera types. Where possible, the effects of each camera type in operation were estimated in terms of crash frequency and severity. From this, the effects of the CDOP on crash frequency and costs were able to be estimated both by police region and for Queensland as a whole.

Police reported data for minor, serious and fatal injury crashes were available up to June 2017 for the evaluation although only data to the end of 2016 were analysed. Non-injury crash data has not been collected in Queensland past the end of 2010 therefore this analysis was confined to casualty crashes only. Camera installation and operations data were provided by Queensland Police Service. Evaluation methodology followed that specified in the development of the evaluation framework (Newstead and Cameron, 2012) which used a quasi-experimental design measuring the change in crash rates at camera sites from before to after camera deployment relative to changes over the same time period at suitable chosen comparison sites similar in characteristics to the matched camera sites.

Statistically reliable crash reduction estimates were obtained for red light cameras, mobile speed cameras and the spot speed cameras in the Clem 7 tunnel. The evaluation also produced crash reduction estimates for red light cameras (referenced to no camera periods), upgrades of red light cameras to red light speed cameras, point-to-point speed cameras, fixed speed cameras in the Airport Link tunnels and fixed spot speed cameras in other locations. Whilst estimates were generally indicative of crash reduction effects associated with these CDOP camera types, they were not statistically reliable due to either a small number of cameras installed, limited after installation crash data available for evaluation or a combination of both. Further evaluation of these camera types in the future when additional cameras have been installed and a longer post installation crash history has accumulated is likely to yield more statistically robust estimates of associated crash effects.

Figure E1 shows the relative risk estimates and 95% confidence intervals for each of the fixed CDOP speed camera types and for the mobile speed camera program in 2016 as well as in 2012-2015 for comparison. Separate estimates for serious casualty and all casualty crashes are shown. The lower the relative risk estimate, the larger the estimated crash reduction associated with the camera type. A 95% confidence limit not overlapping the red line indicates a statistically reliable estimate; reliable estimates were only associated with mobile speed, tunnel spot speed cameras and red light cameras.

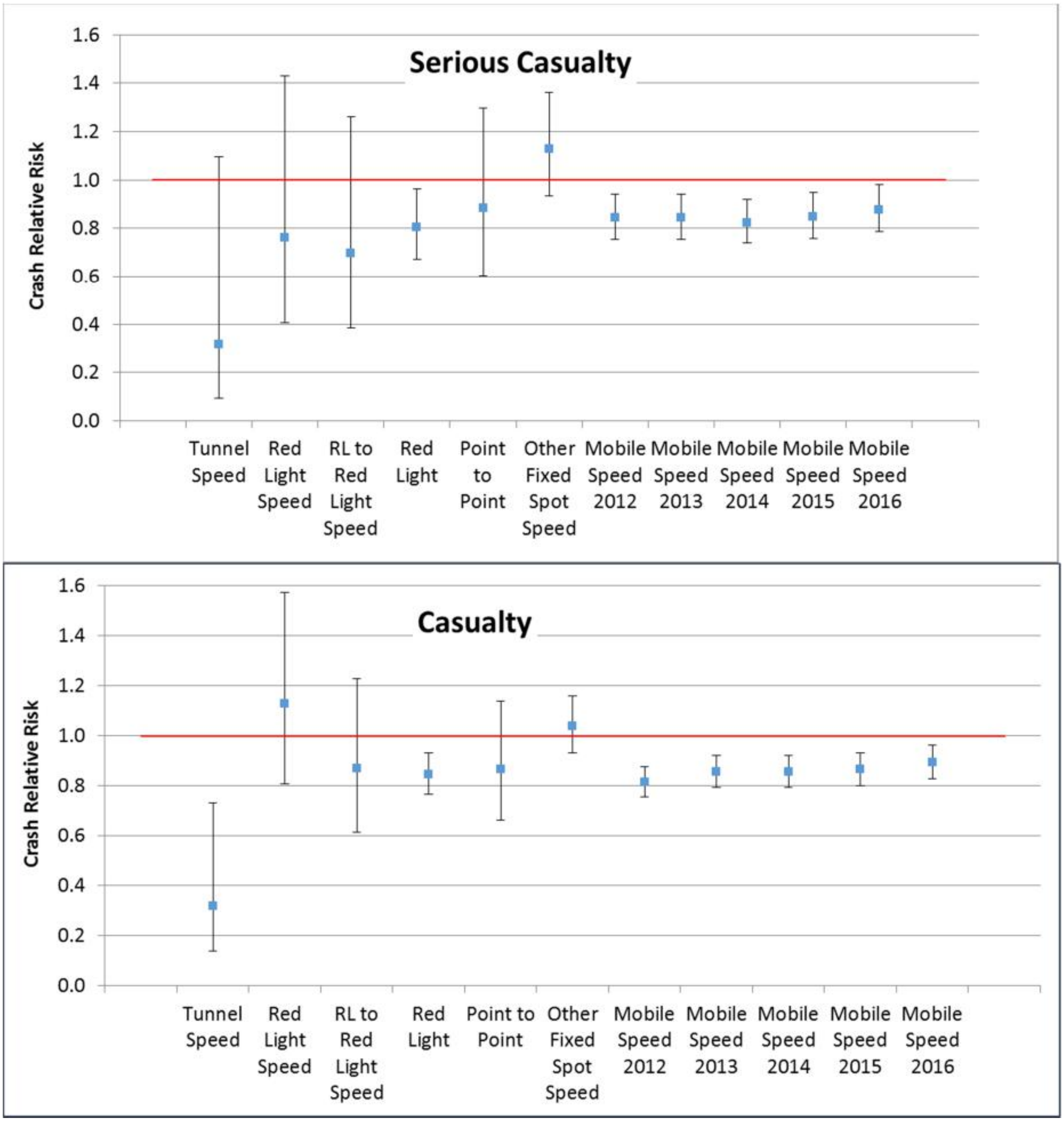


***Figure E1:** State-wide relative risk estimates for each CDOP camera type*

The overall crash reductions associated with CDOP in 2016 was 11% for serious casualty crashes and 6% for all casualty crashes reflecting largely the crash reductions associated with the mobile speed camera program which produces the bulk of measures crash effects for the CDOP. Percentage crash reductions for 2016 associated with the CDOP are smaller than those from previous years estimated in prior evaluations. This was a result of the higher proportion of the crash population in the evaluation design used covered by mobile camera operations. This was a result of progressive increases in the cumulative number of mobile camera sites that have been enforced over the history of the program. Weighted average crash reductions associated with the CDOP across the years 2013-2016 were slightly greater than for 2016 suggesting a small decrease in effectiveness of the CDOP program in recent years although, within statistical confidence levels, the effectiveness of the program has been constant for the past 4 years. Decreases in associated CDOP crash reductions were suggested to have come primarily from the rural mobile speed camera programs. Across the 16 years since 2000 a trend to steadily decreasing effectiveness was observed for mobile cameras in rural areas. However, the statistical evidence of this trend is weak due to the paucity of rural crash data.

Translation of the percentage crash savings into absolute crash saving was achieved by applying the estimated percentage crash savings to the observed crashes at camera sites in 2016. It was estimated that CDOP was associated with absolute casualty crash savings of 2,488 in 2016 of which 1,647 were fatal or serious injury savings. Conversion of the estimated crash savings into (2016 $) cost savings estimated annual savings of around $1.5B in 2016 associated with the program valued using Willingness to Pay estimates or $0.7B using Human Capital crash costs. About 90% of the total savings stem from savings in fatal and serious injury crashes which is similar to previous evaluations of CDOP. Estimated savings for the CDOP in 2016 are similar to those estimated for the previous 3 years suggesting recent changes to the operation of the mobile speed camera program have not had a significant impact on its effectiveness which remains high although it was not possible to assess the individual impacts of each specific change. Despite the expansion of the number of fixed cameras in use under the CDOP 98% of the savings associated with the program derive from the mobile speed camera program, which is the CDOP technology that covers by far the largest proportion of the crash population in Queensland.

There was significant variation in estimated CDOP effects between regions of Queensland. Estimated program effects were smallest in the rural areas of Northern and South Eastern regions and stronger in urban areas generally. The bulk of the crash and economic savings from the program stem from the highest populated areas of Brisbane, Central and South Eastern regions. These areas are also predominantly urban highlighting the greater potential for speeding and the greater role of speed in crash causation in urban areas.

Difficulties in application of the existing evaluation framework to estimate the crash effects of the mobile speed camera program were encountered due to the significant expansion in the number of sites enforced over the history of the program. These difficulties were largely overcome in producing the estimates of overall CDOP crash effects in this evaluation update. However, limitations in the current framework meant that explicit consideration of the individual crash impacts of recent changes to operation of the mobile camera program, including the introduction of the new scheduler in 2016, increases in deployment hours and changes in the number of sites enforced, all of which occurred around the same time, could not be made. As a package, these changes appeared to have little impact on the overall crash effects associated with the mobile speed camera program in 2016. However, the period of available data for this evaluation after implementation of these changes was short, further limiting the opportunity to assess their long term effects. Modifications to the mobile speed camera evaluation framework for future updates of the CDOP evaluation are recommended to allow more specific consideration of the impact of changes to the mobile camera component of the CDOP.

1. BACKGROUND AND AIMS

The Queensland Camera Detected Offence Program (CDOP) is jointly managed by the Department of Transport and Main Roads (TMR) and the Queensland Police Service (QPS) and covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras and in recent years has been expanded to include point to point cameras and combined speed and red light cameras at intersections. Some significant change have been made to the mobile speed camera program in recent years in with the objective of increasing its effectiveness in reducing crashes. Originally mobile speed cameras in Queensland were operated only in overt mode. Since April 2010, up to 30% of urban mobile speed camera operations have been deployed in covert mode. Changes in the spatial partitioning of Queensland to identify new sites for mobile camera enforcement occurred during 2016 and the number of site available for enforcement and actually enforced has also changed progressively over time. In concert, changes the scheduling of mobile camera operations also occurred in May 2016 designed to increase compliance with the randomisation regime.

The broad objective of this project was to apply the developed evaluation framework (Newstead & Cameron, 2012) to crash data and speed survey data to estimate the effects of the CDOP during 2016. Development of the evaluation framework for the assessment of the overall impact of the Queensland CDOP on road trauma outcomes in Queensland considered the likely mechanisms and scope of influence for each camera type in relation to the most appropriate evaluation designs and statistical analysis techniques identified in literature. The evaluation framework developed included a methodology to estimate the effectiveness of each CDOP element on the key outcomes, the three key outcomes being:

- percentage crash savings;
- absolute crash savings per year; and
- social costs of the estimated absolute crash savings.

The evaluation framework design also considered measurement of the effectiveness of other activities associated with the CDOP including: speed related public education programs, high profile media announcements and public statements and changes to the supporting legislation or operational policy. The design also included control of the effects of non CDOP related factors known to influence road trauma outcomes, for example: other road safety programs, socio-economic, environmental and travel exposure. Figure 1 provides a schematic of all the considerations that went into designing the evaluation framework.

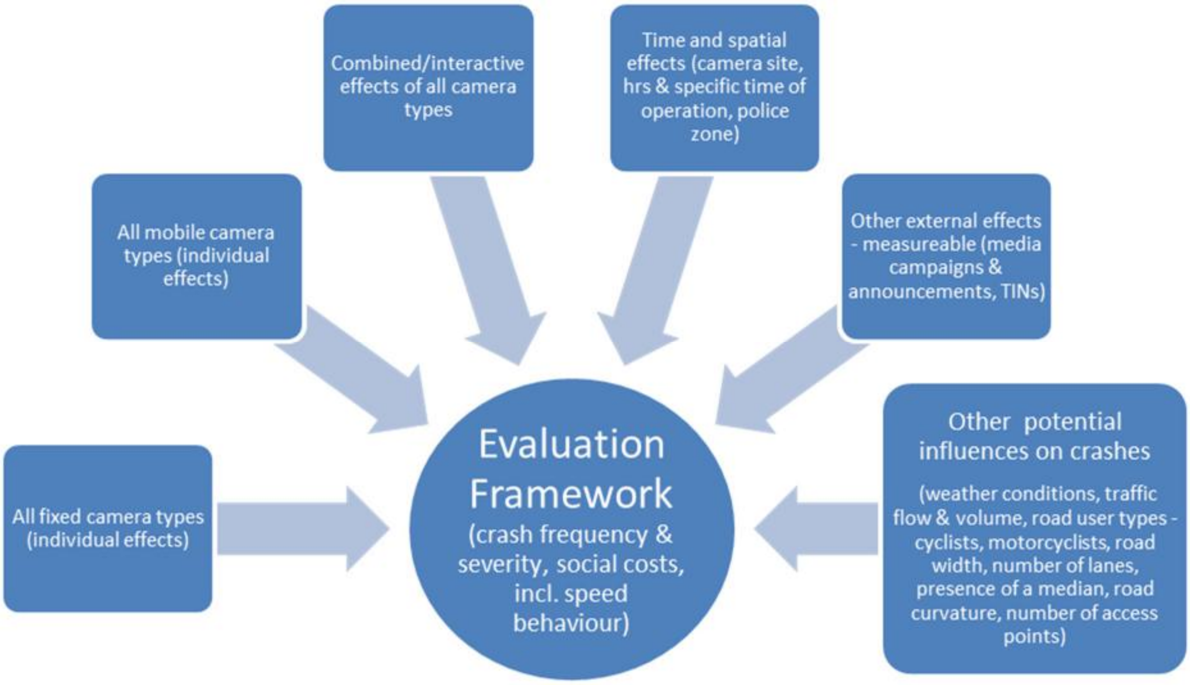


Figure 1 *Elements included in the CDOP evaluation framework design*

Consistent with the evaluation framework specifications, application of the framework in this study estimated crash outcomes associated with the CDOP both in aggregate and by crash severity level. Percentage crash savings were converted to absolute crash savings and subsequently into social cost savings per annum using both Willingness to Pay (WTP) and Human Capital (HC) crash costs provided by Queensland TMR. Furthermore, estimates of the effectiveness of individual program elements were brought together to arrive at aggregate effectiveness estimates both within specific police regions as well as across the whole of Queensland. This involved consideration of the crash population covered by each mode of enforcement. Trends in speed monitoring data were considered in prior applications of the evaluation framework to provide a more causal link between camera operation and estimated crash outcomes. Serious concerns with the quality, completeness and representativeness of the speed survey data meant that further analysis of this data was not conducted as part of this evaluation update.

Based on the overall evaluation results, a secondary aim of the evaluation was to assess whether the changes to scheduling mobile speed camera operations in Queensland to increase compliance with the randomisation regime had measurable impacts of the crash effects of the CDOP.

2. DATA

2.1. CRASH DATA

The Data Analysis Unit within TMR supplied MUARC with crash data covering the period from January 1992 to June 2017 inclusive. Property damage only crashes were reported to the end of 2010. The data covered all crashes reported to police in Queensland with each unit record in the data representing a unique crash. A total of 483,518 crash records were contained in the data. The data included the following fields pertaining to the crash:

- Unique identification number
- Date of occurrence

- Severity (fatal, hospitalisation, medically treated injury, other injury, no injury)
- Police region
- Statistical Local Area
- Speed limit
- Street on
- Intersecting street
- Traffic control
- DCA code (Definition for Classifying Accidents)
- Roadway feature (intersection geometry, bridge, etc.)
- Divided/undivided carriageway
- Number of lanes
- Speed related crash indicator
- Number of traffic units involved in crash
- Sector ID, activation date, urban/rural status and urban centre name for crash
- Distance from 5 closest mobile speed camera sites and the unique site identifiers for the 5 closest mobile speed camera areas of possible influence including: sites, sectors, weighting areas and zones, all of which are further defined in the next section.
- Distance from the 3 closest fixed spot speed camera sites and the unique site identifiers for the 3 closest fixed spot speed camera sites
- Distance from the closest combined speed and red light camera site and the unique site identifier for the closest combined speed and red light camera site
- Distance from the closest average speed camera site and the unique site identifier for the closest average (point-to-point) speed camera site
- GDA latitude and longitude for the crash
- Willingness to Pay 2016 Crash cost
- Human Capital 2016 Crash cost

In addition, for certain road segments where available, average annual daily traffic volume was provided and for some intersections where available, an intersection ID was provided.

2.1.1. Changes to Mobile Speed Camera Site Selection

From the commencement of the Queensland mobile speed camera program in 1997, zones for mobile camera operation were defined as a 1 kilometre (urban) or 5 kilometre (rural) diameter circle which was approved enforcement based on priori crash or speeding history or public reporting of a road safety problem. Once a zone was identified for potential mobile speed camera enforcement, Queensland Police would undertake an operational assessment to identify locations within the zone for mobile speed camera sites based on safe operation of the camera. They were able to pick multiple sites within the zone if necessary or reject the zone as not suitable. Previous evaluation of the mobile speed camera program in Queensland has defined the area of influence of the mobile speed camera program relative to the centre of the zone of operation.

During 2016, Queensland TMR changed to a new methodology for partitioning Queensland into areas for consideration of mobile speed camera enforcement. Previously areas for enforcement were based on circular zones which left gaps in areas of the road network considered. Transition to square sectors allowed all of Queensland to be considered for mobile camera enforcement. All areas of Queensland were divided up into square sectors of

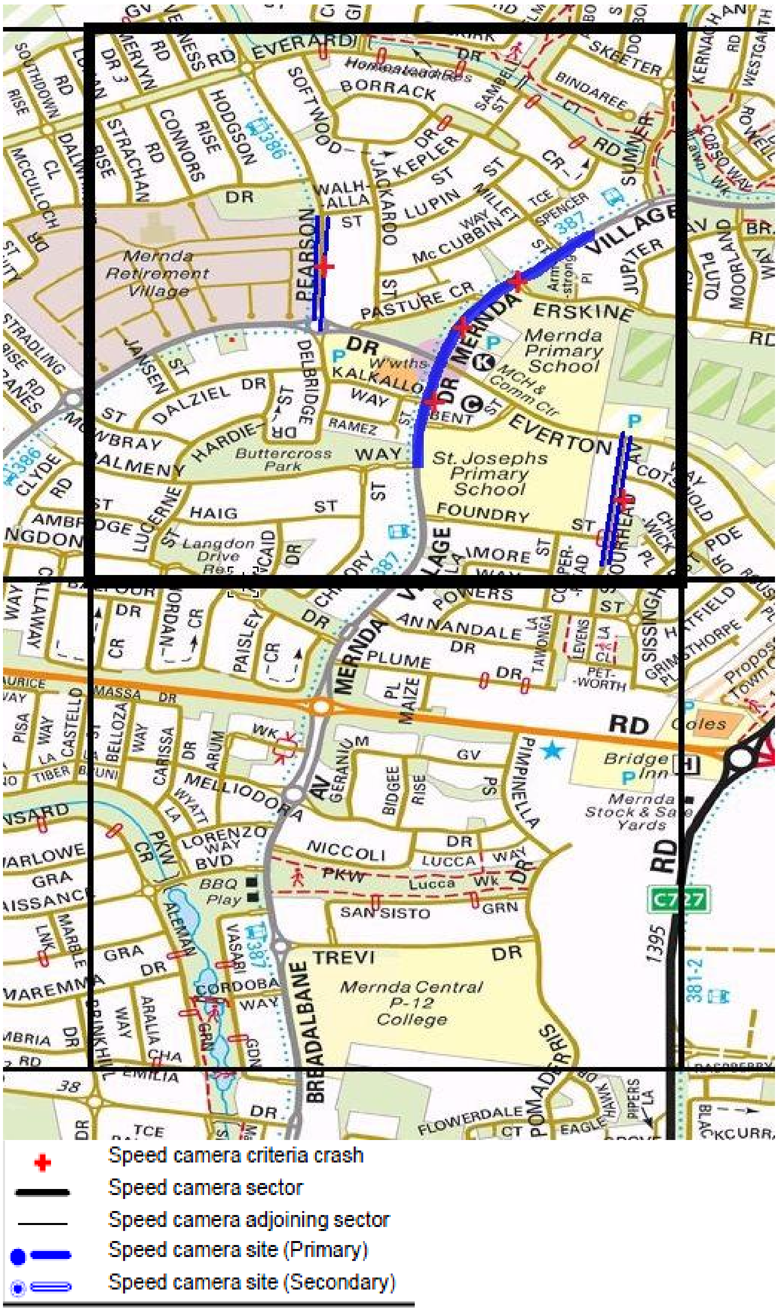
1km side length in urbanised (built up) areas and 5km side length in rural areas. Each sector was then assessed for enforcement and sites chosen for enforcement within the sector based on operational and safety criteria. Around each enforcement site a segment of the same road on which the site is located was defined as having influence by the camera. Crashes within the segment of influence are used to weight camera visitation frequency. Sites previously selected for enforcement under the previous site selection criteria have been retained for enforcement in der the new regime. The concepts of sectors, segments and sites are illustrated in Figure 2. Sectors and sites within sectors for potential mobile camera enforcement were chosen based on the number and severity of crashes as previously used for the circular zone based partitioning methodology.

Reflecting the new basis for partitioning Queensland for selection of mobile speed camera enforcement areas, analysis crash data for this evaluation was related spatially to a number of potential definitions of areas of camera influence including:

- Within the defined segment of influence on the same road
- Within a 1km or 5km radius from the site location for urban and rural crashes respectively
- Within a 1km or 5km radius from the zone centroid location for urban and rural crashes respectively
- Within a 1km or 5km radius from the sector centroid location for urban and rural crashes respectively

In practice, crashes designated to be within the hypothesised area of influence of a mobile speed camera operation varied little depending on whether the distance from the site, zone centroid or sector centroid was considered. For consistency with previous evaluations of the Queensland mobile camera program, the zone centroid was used as the basis for defining crashes influenced by the program. Using the segment of influence defined a much narrower set of influenced crashes and produced relative crash reductions similar to the broader areas of influence considered suggesting the segment definition of influence was too narrow for the purposes of the evaluation hence excluding its further consideration. Comparison crashes in the evaluation design were chosen outside of any of the hypothesised areas of mobile camera operations influence.

A consequence of changing the mobile camera site selection process has been a significant increase in the number of sites enforced from around 2500 to 3500 by mid-2017. For the evaluation, this has had the impact of limiting the number of crashes in the comparison set which has impacted the evaluation results as will be described further on in the report.



A sector is a rectangular (or polygon) block which may contain sites where mobile speed camera operations are carried out. To the left is a bolded block with examples of primary and secondary speed camera sites and speed camera criteria crashes (illustrative only and not from the Queensland program). A speed camera site may be defined as a point, or a segment of road (blue line), which is called a "weighting area" in the crash data. The actual site of the scheduled operation may occur anywhere along this segment. Such a block would be defined as a treatment block in the evaluation. Under this block is another sector which has no mobile camera sites which would be used as a comparison or control site in the evaluation.

A zone is defined as a circle with a 1 km radius in urban areas and a 5km radius in rural areas. The centre of the zone is the site/area centroid.

Figure 2 *The new format for the identification of mobile speed camera operations*

2.2. CAMERA DATA

2.2.1. Red Light Cameras

Data on 140 red light camera locations at 126 intersections were provided. Eight intersections had 2 camera sites (40/60, 43/52, 67/68[1], 153/483153, 157/158, 460/462, 110/119 & 69/500). Three cameras were sited in different points at the intersection of Kessels and Mains roads (5, 76 &77). Four cameras were positioned at different sites at the junction of the gateway arterial and Old Cleveland road in Belmont (62-65). The crashes indicated as within 100 metres of site 115 (Gold Coast Highway & Government Road,

[1] Decommissioned RLC #2 is very near this intersection so this site was combined with the 67/68 intersection rather than used as a control intersection.

Labrador) were in fact located at site 110/119, so were analysed as a third site at this intersection (Kumbari Avenue and Smith Street, Southport).

Six of the cameras (each of which were also at unique intersections) were upgraded to red light speed cameras and were analysed as such with the crash and economic effects of the upgrade being estimated. This meant that 120 RLC only intersections were available for analysis of the crash reduction effects of red light cameras (without speed enforcement) in Queensland.

In addition to the 140 red light camera sites described, information was provided for a further twelve red light camera sites (2, 33, 51, 81, 107, 111, 120, 127, 201, 251, 303 and 352), each at unique and different intersections. Cameras at these sites were indicated as being decommissioned during the period 1992 to 2015. Furthermore, the crash data provided did not indicate any of these thirteen camera sites to have crashes located within 100 metres of them so they were not considered further in the analysis.

In addition to the twelve decommissioned cameras, information was provided for an additional intersection where red light cameras were stated to have gone live during the study period and are currently either still live or parked awaiting digital conversion (#255, George Street, Rockhampton City at the intersection with Albert Street). No crash data was associated with this camera so it was not further considered as a red light camera site.

All red light cameras were made active prior to July 2014, so all have at least 18 months of '*after go-live*' crash data.

During the study period (1992-2017) all intersections with red light cameras and associated crash data had at least one camera site at the intersection upgraded to, or installed as, a digital red light or red light speed camera (6 sites as listed) with the following exception:

- over the period September 2014 to May 2015, red light camera sites (203, 301, 351, and 355) at four unique intersections were parked awaiting digital upgrade.

For all red light cameras considered in the study, it was assumed that all posts and camera housing remained in place so that effective deterrence remained plausible from the '*go live*' date to the middle of 2017. Cameras with less than three years of crash data prior to the '*go live*' date for the intersection, were excluded from the analysis. There were 63 intersections (with associated crash data) that went live prior to 1995; three of these became red light speed camera sites (2005, 2006 and 2007) and three were multi-site intersections (62-65, 153/483153 and 5/76/77). Although the crash effects at these red light camera sites were not able to be estimated, provided that the site was identified in the crash data, the overall contribution of these sites to road trauma outcomes in Queensland were considered by assuming the average crash effects estimates for the sites evaluated applied equally to the sites not evaluated.

2.2.2. Intersection and mid-block fixed speed cameras

As of December 2015, there were seven digital red light speed cameras operating in Queensland: one at each of the location numbers 2001 to 2007. Seven additional red light speed cameras, at six intersections, went live in 2016 and 2017; four of these intersections previously housed red light cameras. With less than one year of available crash data, the decision was made not to use these sites in the analysis of red light speed cameras; crashes in the 'live' period for the combined speed and red light camera upgrade was excluded from the analysis. It was also decided to use the four intersections which previously housed red light cameras in the analysis of red light cameras.

Of the 7 analysed speed and red light camera intersections, only one (2002) previously did not house a red light camera. Three of the red light speed cameras which were previously red light (RL) cameras had RL cameras installed prior to 1995 and thus would have been excluded from analysis due to inadequate pre-installation crash data. For the other three sites, the RL cameras went live from between 2000 to early in 2002. As a result, the decision was made to analyse both the effect of a RLS *upgrade* (for all but 2002) and the effect of a RLS camera referenced against no camera. In the combined fixed camera regression analysis:

- cameras identified as 2001, 2002, 2003 and 2004 contributed to the measured effects associated with the installation of red light speed cameras (where a 'no camera' reference period was used – i.e. the period prior to the installation of the RL camera);
- in addition, cameras at the intersections of 2001, 2003 and 2004 (during the RL period) contributed to the measured effects associated with red light cameras; and
- the crash reduction benefits at the RLS camera intersections which had no period without a camera (2005, 2006 and 2007) contributed to an upgrade only effect from RL to RLS.

As with RL cameras, the overall contribution of all RLS camera sites to road trauma outcomes in Queensland were considered by assuming the average crash effects estimates for the sites evaluated applied equally to the sites not evaluated.

There were 9 analogue fixed spot speed cameras (1 per site) made active prior to 2012. Two of these were decommissioned during the observation period. However, on the assumption that the hosting structure and signage have remained in place, they were assumed to continue to remain an effective deterrent and as such the post-activation observation periods for these two cameras were considered to continue to the end of 2016.

There were 40 fixed spot digital speed cameras at 16 locations that were activated prior to December 2016:

- 5, on the PtP section of the Bruce Highway, (3 at one end, 2 at the other end - these still operate as fixed spot speed cameras when the PtP system is down)
- 10 in the Airport-Link Tunnel (at four locations)
- 6 in the Legacy Way Tunnel (at two locations)
- 8 in the Clem 7 tunnel (at four locations)
- 4 at location number 1002 (with 1 in each of 4 lanes)
- 5 at location 1012 (with 1 in each of 5 lanes)
- 1 at location 1011 (Nambour) and
- 1 at location number 1001 (Nudgee)

The average speed point to point camera system, operating on a segment of the Bruce Highway between Landsborough and the Glass House Mountains, began operation 5 months after the fixed spot speed cameras operating at each end of the average speed camera system on this road section went live.

A summary of fixed speed camera sites available for evaluation is presented in Section 8.2 of the Appendix. From this it may be seen that there was insufficient post-period crash data to analyse the Legacy Way Tunnel cameras, so these cameras were excluded from the analysis. The next shortest post-activation observation periods are for RLS cameras.

The pre-activation period for all fixed spot, average and red light speed cameras exceeded the suggested three year minimum period for minimisation of regression to the mean effects by providing an accurate base estimate of the underlying crash rates at each camera site. It is not known whether this period is coincident with the time period used to identify each site as a candidate for enforcement. However, using a long pre- installation evaluation time period maximises the chance that this time period is not fully coincident with the selection period hence further minimising regression to the mean prospects.

The post-activation period of crash data has made it possible to consider analysis of digital fixed spot speed and red light camera effects disaggregated by Police region. However, due to low crash counts reflecting the relatively few cameras and the very specific halos of influence, statistical power was insufficient to draw conclusions with statistical significance from this analysis. Hence overall estimates of average camera effectiveness were the focus of the analysis.

2.2.3. Mobile Cameras

Data on the hours and locations of mobile camera operations were provided by QPS with the locations subsequently matched to crash data to determine the spatial distribution of crashes in relation to camera locations.

Data was also aggregated into tables summarising the hours of deployment and number of operations by quarter, deployment type, police region, sector urbanisation (urban or rural), schedule type (system generated or not/unknown) and covert/overt status. Notable features of mobile camera deployment included:

- Deployment hours increases in January and July 2013 and July 2014 (see Figure 3)
- A reduction in the enforcement thresholds staggered by speed zone over the period July 2013 to June 2014
- A steady increase in the use of portable speed cameras with a trial of the Poliscan system in the second half of 2014 (see Figure 3).
- Removal of the requirement for signage of mobile speed cameras in July 2015.
- New Scheduler in May 2016 (see Figure 4)

Figure 3 shows the number of hours of mobile speed camera operations per quarter year by mobile camera type. It shows the increase in camera hours in July 2013 and July 2014 as well as the introduction of both covert camera operations and the commencement and growth of use of the portable speed cameras. Figure 4 shows the percentage of speed camera operations complying with the operations schedule generated by the mobile camera scheduling program. It demonstrated the large increase in compliance with the scheduler from around 60% to over 90% resulting from introduction of the new scheduler in May 2016.

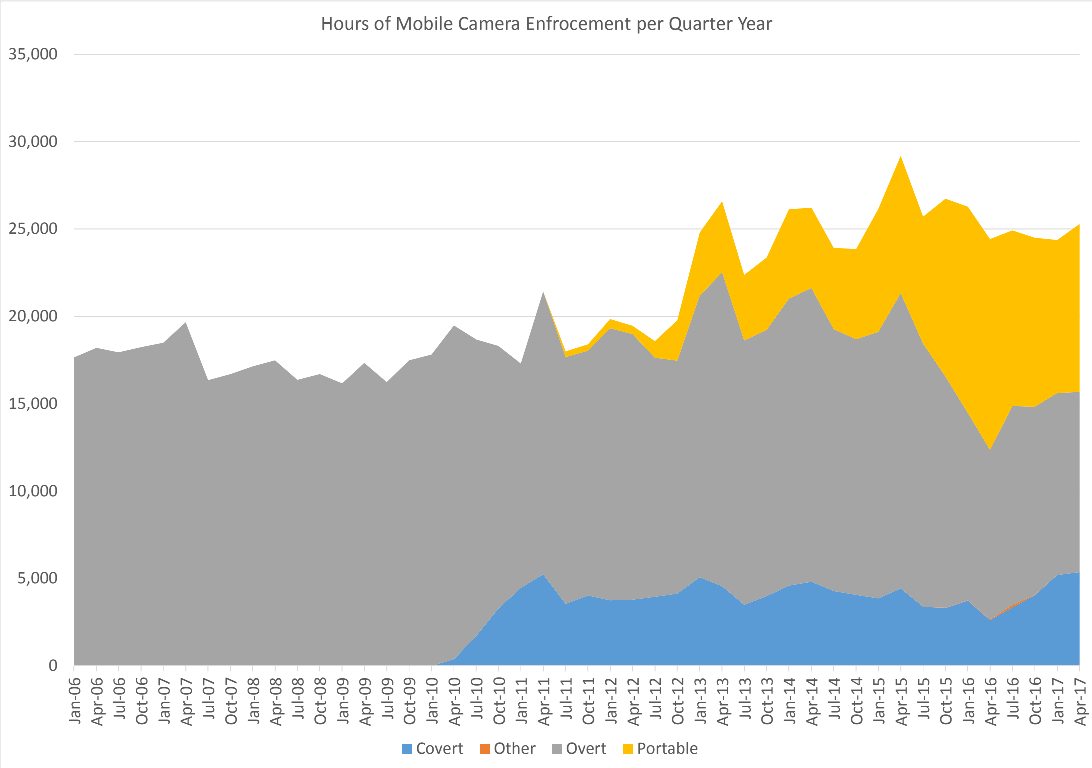


Figure 3 *Quarterly mobile speed camera hours by mobile camera type*

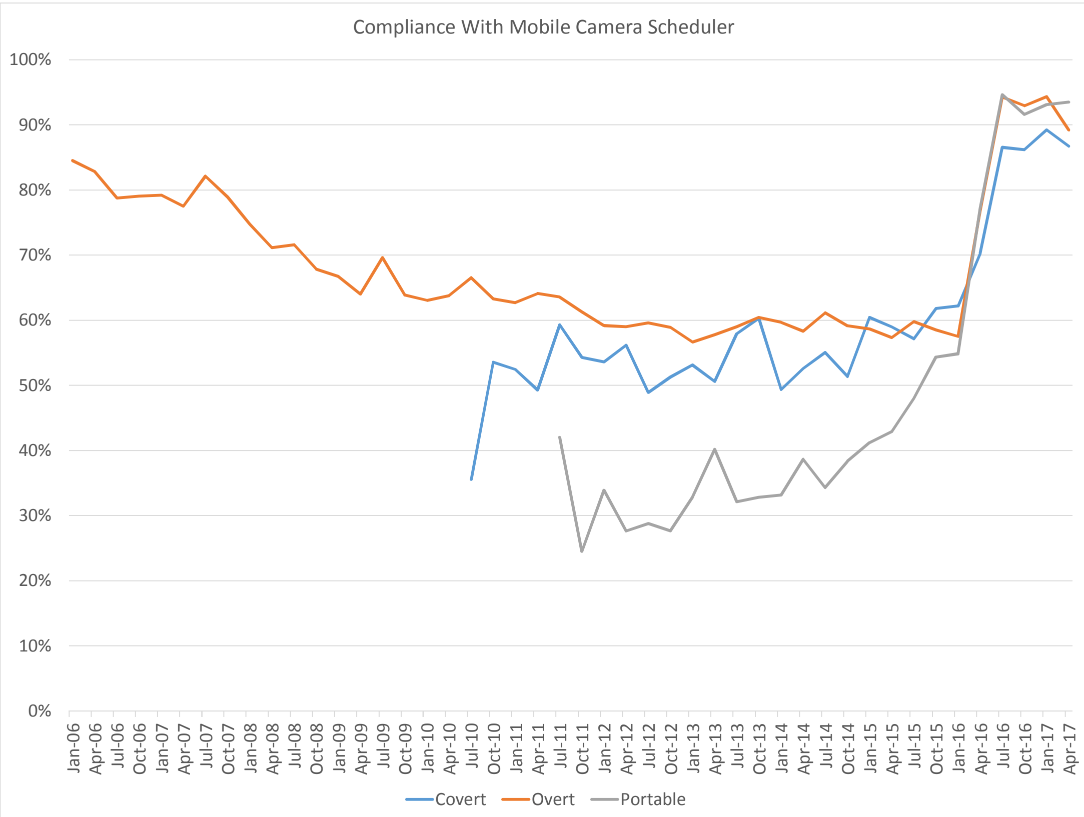


Figure 4 *Percentage compliance with the mobile camera scheduler by mobile camera type*

2.3. CRASH COSTS

Human Capital and Willingness to Pay crash costs for use in the economic evaluation were provided by TMR with the crash data (Table 1). The post-activation camera crash distribution by severity and police region (and speed category) was used to weight fatal, hospital, medically treated, other injury and no injury costs to produce serious injury (fatal + hospital) and minor injury (minor injury + medical treatment) unit costs (Table 2 and Table 3). For mobile cameras the crash population was further disaggregated by crash year (Table 38) for the years 2013 to 2017 although showed relative consistency across the years.

Table 1 2016 Willingness to Pay (WTP) and Human Crash (HC) Unit Costs by severity

	WTP	HC
Property Damage Only	$9,960	$12,833
Minor Injury	$41,708	$18,959
Medical Treatment	$127,778	$18,959
Hospitalisation	$645,276	$343,074
Fatal	$9,249,738	$3,443,635

Table 2 2016 WTP Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Serious Casualty Crashes	Minor Injury	All Casualty Crashes
Brisbane		$781,855	$109,813	$358,864
Central	Urban	$784,058	$108,566	$349,258
	Rural	$996,479	$108,436	$569,362
Northern	Urban	$805,893	$110,984	$340,729
South Eastern	Urban	$834,385	$110,723	$324,532
	Rural	$805,893	$112,408	$322,251
Southern	Urban	$805,893	$109,174	$360,785
	Rural	$989,454	$117,450	$548,986

Table 3 2016 HC Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Serious Casualty Crashes	Minor Injury	Casualty Crashes
Brisbane		$392,289	$18,959	$157,311
Central	Urban	$393,083	$18,959	$152,268
	Rural	$469,628	$18,959	$252,764
Northern	Urban	$400,951	$18,959	$182,494
South Eastern	Urban	$411,218	$18,959	$134,854
	Rural	$400,951	$18,959	$131,833
Southern	Urban	$400,951	$18,959	$156,767
	Rural	$467,096	$18,959	$240,654

Average fatal and hospitalisation (serious casualty) crash costs in Table 3 and 4 vary a relatively large amount between police regions due to the different mix of fatal and hospitalisation crashes in each region; the urban Central region had a higher rate of fatal crashes per hospitalisation crash. As there were no fatal crashes in the three-year period at the camera sites in South Eastern rural regions and in Northern and Southern urban regions, the average ratio of fatal to serious crashes was used in weighting the costs of serious injury crashes in these regions.

3. EVALUATION FRAMEWORK AND ANALYSIS METHODS

This evaluation used the framework developed specifically for the Queensland CDOP (Newstead & Cameron, 2012). The report documenting the evaluation framework for the CDOP provided evidence through literature review and established practices for the methodology used in this evaluation. It also established its efficacy for producing scientifically robust estimates of the crash effects of the Queensland CDOP through a trial run. It thoroughly discussed the design strengths and weaknesses, and may be referred to for further details. This section of the study (Section 3) only details the exceptions to the evaluation framework that were not used nor discussed in the initial test run.

This evaluation did not undertake analysis of the localised time-based effects of mobile speed cameras since no time-based effects were detected in the test run.

Newstead & Cameron (2012) proposed testing the use of negative binomial error distributions in the statistical analysis of CDOP crash count data. Ultimately (for this, the 2012 analysis, the 2016 analysis and the trial analysis,) Poisson distributions were not found to adequately represent the variability in the data reflecting the short after-activation fixed camera crash periods and low crash counts when mobile camera crash data were disaggregated by police region, treatment group and crash severity. In the fixed camera analyses, where possible, modelling with both negative binomial and Poisson distributions was compared in this analysis to validate the distribution chosen.

Regression analysis produced a relative risk estimate. The relative risk estimate is the measure of the risk of having a crash within the camera's hypothesised halo of influence after camera activation compared to before activation relative to the crash risk change in the comparison area over the same time period. The analysis design means that this relative risk is adjusted for the effects of non-camera related factors leading to changes in crash risk at the control site. Relative risks less than one indicate a crash reduction associated with camera operation. A net percentage crash reduction associated with the camera can be obtained by subtracting the relative risk from 1 and multiplying by 100%.

Regression analysis models were applied to crashes by severity: serious casualty, minor injury and all casualty crashes in aggregate. Non-injury crashes are not reported beyond 2010 in Queensland and hence cannot be considered in estimating effects of the program in 2016. It should be noted that estimated savings associated with *all casualty* crashes were determined from the respective regression model crash reduction estimates and not from the summation of savings associated with fatal, serious, minor injury and no-injury crashes. This provides more robust statistical assessment of camera effects on the aggregate crash groupings. In contrast, state-wide savings estimates presented in the results sections were calculated by summation of regional savings estimates.

3.1. EVALUATION OF FIXED CDOP ELEMENTS

3.1.1. Treatment and Control selection

A table summarising the treatment and control selection for fixed CDOP elements (fixed spot speed cameras (FSS), speed and red light intersection cameras (RLS), point-to-point cameras (PtP) is presented in Section 8.3 of the Appendix.

Both in this analysis and in the trial analysis the proposed matching of the control sites for RLS, PtP and fixed spot speed camera sites by number of lanes, crash history or traffic volume was not attempted. While the intersection identifier was provided, it was not sufficiently complete to allow broad control matching. An attempt using street names and GPS location was made to uniquely identify intersections of the control and RL/RLS camera sites. Once identified, a pre-period crash history was defined and used to trim the control intersections with an excessively different history[2]. Generally, there were insufficient control intersections available to do crash history matching with too much vigour. Traffic volume data, again could not practically be identified for many RLS and RL camera intersections which precluded this factor being used to match control sites. Traffic volume data, although provided for a number of major arterial roads, were not available for all control sections of road. By matching on other road geometry characteristics, speed limits (Table 4), intersection control type (signalisation), road dividedness and generally by the locality (SLA and similar surrounding SLAs), it was deemed that a sufficiently similar and sizeable set of control crash sites were identified that were likely to broadly represent traffic volume and crash history. To extend the numbers of control sites to enhance statistical power, control crashes for red light speed cameras were matched by SLA or the distance from the camera.

Control sites for fixed spot cameras were chosen from the same road, limited to 2km outside the hypothesised zone of camera influence (defined as 1km either side of the camera) and from the same locality (SLA) so it was also deemed unnecessary to further distinguish by lane number, crash history and crash volume. In addition, road dividedness was not used as a control matching variable due to the complications caused by the varying nature of reporting this variable along the road where the camera was placed. However, speed limit was used in the selection of these controls, but was broadened for five fixed speed camera control sections so that sufficient controls could be found hence providing adequate analysis power. The following gives the camera site number and the speed limit range used for matching controls:

- Site 1001: 80-100km/h
- Site 1011: 60-80km/h
- Site 3003: 90-100km/h
- Site 3004: 60-70km/h
- Site 3006: 80-90km/h

Both treatment and control crashes for fixed spot cameras were excluded from analysis if their location was listed as being on an entry or exit ramp to a motorway.

Table 4 Speed limits (km/h) associated with Fixed Speed Cameras

Red Light Speed ID	Speed limit	Fixed Spot ID	Speed Limit	Tunnel ID	Speed Limit
2001	60	1001	90	1003-1006	80
2002	80	1002	100	1007-1010	80
2003	60	1011	70	1013-1016	80
2004	60	1012	110		
2005	60	3001	100		
2006	60	3002	60		
2007	80	3003	100		
2010	60	3004	60	**Point to Point**	
2011	60	3005	60	4001	110
2012	60	3006	90		
2014	60	3007	100		
2015	unknown	3008	70		
2016	70	3009	100		
2017	60				
2018	unknown				

[2] If the pre-period history of the control was less than 0.025 or more than 1.975 times the pre-period crash history of the matched treatment site, the control intersection was excluded.

Direction of travel was not available as a variable in the data (since vehicles in a crash can have multiple directions of travel) so control crashes for the point to point average speed cameras had to be allocated on both outbound and inbound sections of divided road. The controls for this segment of road were chosen not by speed or road geometry but by using the lengths of road north and south of the outermost halo region for the cameras defined as 5km up and downstream of the system end points). The control section was equally split between the northern and the southern ends. Distances were measured along the Bruce Highway using the Google Earth "path" function and GIS mapped camera locations. Crashes were counted north or south of the latitude position (measured to seconds) of the outer control and halo points on the Bruce Highway section.

Table 5 Segment Distances and Location of Point to Point camera and control segments

Position	Latitude	Longitude	Distance (km)
Northern end of Control segment	26°42' S	153°00' E	7.2
Northern End of camera Halo	26°45' S	153°03' E	5.0
Northern Camera	26°47' S	153°03' E	14.8
Southern Camera	26°55' S	152°60' E	14.8
Southern End of camera Halo	26°58' S	152°59' E	5.0
Southern end of Control segment	27°01' S	152°59' E	7.2

The Airport-Link, Legacy Way and Clem 7 tunnels had no period without cameras since the cameras were installed before the roads were opened. There were also no suitable feeder roads to use as controls, so the Southern Cross Way and Port of Brisbane Motorway were chosen as control segments. The crash counts were then analysed with a volume and distance offset (an offset being a constant term included in the model) to give a comparison of relative crash rates per distance travelled across the treatment and control sections. The Inner City Bypass (ICB) was not chosen as traffic volume data were not available for all years and were recorded in a different manner to the state AADT surveys. Also, the ICB was complicated by having sections with varying speed limits and multiple exit/entry points. Crash counts, volume data, volume location and distances measured using Google Maps are shown in Table 7.

Table 6 Tunnel cameras, treatment and control road lengths and traffic volume

Road	Position of Volume Data	AADT 2013	AADT 2014	AADT 2015	AADT 2016	AADT 2017*	Distance (km)
Clem 7	U12A North of Ipswich Rd O'pass	124,435	125,445	126,115	127,310	63,655	6.84
Airport-Link	400m East of Sandgate Rd	43,272	45,946	63,881	69,580	34,790	6.7
Legacy Way	Western Arterial road S of Mt Cootha Roundabout			68,526	76,545	38,272	4.6
Southern Cross Way	913 Gateway Mwy Sth of Toombul Rd O'pass	41,351	41,588	43,516	43,516	21,758	7.15
Port of Brisbane Mwy	WiM site Lytton	12,164	12,834	13,161	13,161	6,080	7.07

*half year

The volume data for the Clem7 was collected just prior to the exit for the southern start of the Clem7 Tunnel on the South Eastern Arterial (M3). The Airport Link volume data was collected just east of the Tunnel, on the same road. Crash counts in each tunnel are summarised in Table 8. There were no crashes observed in the 2 years of observation for the Legacy Way Tunnel.

Table 7 Crash counts for treatment and control segments in the cross sectional analysis of the Clem 7 and Airport-Link tunnels

Road	Serious Casualty	Minor Injury	Casualty
Treatment			
Clem 7	3	6	9
Airport-Link	3	3	6
Control			
Southern Cross Way	6	3	9
Port of Brisbane Mwy	4	6	13

3.1.2. Analysis period

The analysis periods were defined by the 'go live' dates for each camera. For consistency, dates for the installation of signage were not used in the analysis because they were only available for the PtP cameras, 4 digital fixed speed cameras and the RLS cameras. However, due to the RLS cameras being previously RL cameras, sign installation dates were not relevant for RLS cameras. In addition, the fixed speed camera crash data were too few to attempt a two point after period effect (i.e. measuring the crash effects after camera placement but before activation, and then after activation).

3.1.3. Analysis by Crash Type

There was sufficient statistical power to analyse red light (RL) and red light speed (RLS) cameras by crash type (targeted, rear-end or speed related) when RL control groups were excluded with at least one of the crash types with no before camera, treatment crashes.

3.1.4. Crash History

Every attempt was made to balance control site proximity to the camera site and the size of the control crash group. However, in order to preserve the integrity of the crash location, so that traffic volume and local events are controlled, the control crash population did not always meet the preferred size. Newstead & Cameron (2012) suggested that the pre-activation control crash history should be within the 2 standard error range of treatment crashes indicating statistical compatibility. From Section 8.6 of the Appendix, which presents the crash history at red light camera treatment and control sites, it can be seen that although this condition has not been universally met, control site crash counts are generally of a similar magnitude to those of the treatment sites.

3.1.5. Crash savings for Fixed Camera program

The average annual crash counts at fixed camera treatment sites, after the camera went live, were first calculated by camera type, police region (and rural/urban status) and severity for the years 2013 to 2016. Absolute annual crash savings for each crash severity, police region (and speed category) and fixed speed camera type were determined from the application of crash reduction percentages (for each crash severity) determined from regression analysis to these average annual crash counts. Regression was carried out with all cameras combined except for the tunnel cameras, which, in having no pre-camera period, could not be analysed within the treatment-control, before-after quasi-experimental design.

Average annual absolute crash reductions were converted into community cost savings according to the process illustrated in the CDOP framework (Newstead & Cameron, 2012) by multiplying the estimated absolute crash savings at the crash severity level being considered by the per unit cost of each crash (Table 2 and Table 3) to derive the community cost savings related to the crash reductions.

3.2. EVALUATION OF THE MOBILE SPEED CAMERA PROGRAM

3.2.1. Police Regions and Control Selection

This study uses the Queensland Police Regions defined in 2015 (Brisbane, Central, Northern, South-Eastern and Southern) disaggregated by urban and rural status according to the sector in which the crash fell. However, the Brisbane region was defined as purely urban due to the paucity of crashes in rural areas in Brisbane. A table summarising the treatment and control selection is presented in Section 8.3.

As described previously and reflecting the old and new methods of enforcement site selection, there were four definitions of treatment crashes.

1. **Site.** Treatment area crashes (those within the influence of a mobile speed camera) were defined as crashes being within 1km of a mobile camera ***site*** in urban areas and within 5km of a mobile camera ***site*** in rural areas. The additional 1 km was added to the definition to make the *site* data compatible with the treatment data defined by *zones*.
2. **Area.** A yes/no indicator variable determined whether the crash was within a site weighting ***area*** (road segment). If "yes", then the crash was classified as treatment and not limited to the distance from the segment centroid. However, if the crash was within an urban sector, to maintain some comparability with the other three definitions, the distance of the crash from the *area* centroid was restricted to 1 km if the *area* was additionally classified as rural or a motorway.
3. **Zone.** Treatment area crashes were defined as crashes being within 1km of a mobile camera ***zone*** centroid in urban areas and within 5km of a mobile camera ***zone*** centroid in rural areas. Zones have a 5km radius in rural areas and a 1km radius in urban areas.
4. **Sector.** If the *sector* that a crash was within was classified in the crash data as active, and was found to be the closest sector, the crash was considered a treatment crash.

Urban and rural status were determined by the status of the sector in which the crash fell (which was provided in the crash data).

An initial feasibility analysis was conducted using control crashes defined as all crashes which were not identified as treatment crashes by any of the four definitions. This analysis found all four treatment definitions to produce very similar relative crash risks; however, it also found the estimates to have extremely wide confidence intervals primarily due to the small size of the comparison group. It was decided that the reduced set of comparison crashes led the analysis to be subject to potential bias and poor precision, so an alternative methodology was developed. Under the original comparison crash set definition, only 12% of police reported casualty crashes in Queensland (not already allocated as fixed camera *treatment* crashes) were outside a halo of influence of either a sector, area, zone or site.

Firstly, due to the similarity in the estimated crash risks and crash counts for 'treatment' crashes using the four different definitions, it was decided, in the interests of parsimony, to use a single definition of 'treatment' crashes. Secondly, all unallocated crashes that were previously 'treatment' crashes for the other definitions, were allocated as an extension to the comparison set. The *Zone* definition was chosen because, in addition to producing an almost identical *treatment* crash dataset to the *Site* and *Sector* definition, and noting that crash effects were the same within area and zone definitions suggesting the area definition of influence is too narrow, it was consistent with the treatment definition used in previous evaluations so enabling direct comparison of results. This defined 11,944 more casualty crashes in the comparison group and increased the analysis power notably.

Furthermore, fixed speed camera sites were excluded from both treatment and control areas for the mobile camera analysis.

3.2.2. Time Series

For the regression analysis, data were aggregated into a time series structure with each police region, urban / rural split, and treatment and control pair having its own periodic crash count time series for analysis.

It was found that, there was an overall reduction in the power of the analysis producing the risk estimates compared to previous evaluation updates. Analysis identified that this was due to continual increases over time to site coverage (reflecting the increased number of sites used under the program over time), and an extension of the radius of the rural zone of influence by 1 km.

Analysis identified a further problem with the evaluation design being employed also related to the increased site coverage. To understand this problem, it should be first noted that crashes for analysis were labelled as inside or outside the hypothesised area of influence of the mobile speed camera program through geographical relation to a camera site which has been used at any time during the history of the speed camera program from implementation. In the early years of the mobile speed camera program the number of sites in use grew rapidly, tripling in the period from 1997 to 2000. From 2000 onwards, the number of sites used increased much more slowly. Evidence from a preliminary analysis of crash trends at treatment and control sites over time suggested that crash history at the sites introduced at a later time in the mobile camera program were not consistent with crash trends at the sites used initially in the program, particularly in the early years of the program when the later sites were not being enforced. Whilst this problem has not impacted previous evaluations it has become more acute in the current evaluation due to the pool of control sites being further reduced as more sites are chosen for enforcement and potentially being less representative of unenforced trends in the early stages of the program hence impacting estimated program effects in the early years. Application of the analysis framework used previously to the current data produced estimates of historical effects of the program that were inconsistent with previous evaluation updates demonstrating the impact of the bias that had emerged in the framework.

To overcome this problem, a new basis year for estimation of the effects of the mobile speed camera program was chosen as the year 2000 when the rapid expansion of enforcement sites began to plateau. In choosing this base year, estimates of the mobile speed camera program no longer absolute relative to the start of the program. Instead they were relative to the effects of the program in the year 2000 which must be borne in mind when interpreting the results of the analysis model.

3.2.3. Analysis

The time series data for the mobile speed camera program were analysed using Equation 4-14 from the CDOP evaluation framework test run of Newstead and Cameron (2012) and could readily accommodate the change in base comparison year. The form of the model was:

$$\ln(y_{siptr}) = \delta_{st} + \beta_{si} + \phi_{rip} \ldots \text{(Equation 3-1)}$$

where

y	is the crash count per period and analysis stratum
i	is an indicator for treatment or control area
t	is a linear time period indicator variable
p	is the speed camera program post implementation time period indicator
s	is an indicator for analysis stratum
r	is the police region by urban/rural status (Brisbane, Central urban & rural, Northern urban & rural, South Eastern urban & rural or Southern urban & rural)
β, δ, ϕ	are parameters of the model

The factors in the model take the following values.

t	= 1 in the time period of data
	= 2 in the second time period of data etc.
i	= 0; control series (crashes as defined above)
	= 1; treatment series (crashes as defined above)
s	= 1 for crashes in the Police region of Brisbane
	= 2 for crashes in the Police region of Central in urban areas
	= 3 for crashes in the Police region of Central in rural areas
	= 4 for crashes in the Police region of Northern in urban areas
	= 5 for crashes in the Police region of Northern in urban areas
	= 6 for crashes in the Police region of South Eastern in urban areas
	= 7 for crashes in the Police region of South Eastern in rural areas
	= 8 for crashes in the Police region of Southern in urban areas
	= 9 for crashes in the Police region of Southern in rural areas

The speed camera program indicator, *p*, has been defined in a number of ways depending on whether effects of the speed camera program were being estimated across the total period after implementation or by year (or half-year or quarter) after implementation.

For annual, half-yearly or quarterly program estimates

p = *0* if crash month was in 2000

= *1* if crash month was in the first year (half-year or quarter) after December 2000

= *2* if month was in the second year (half-year or quarter) after introduction of speed camera program

etc.

To determine the program effect over all regions, the model was adapted to the form:

$$\ln(y_{sipt}) = \delta_s t + \beta_{si} + \phi_{ip} \ldots\text{(Equation 3-2)}$$

3.2.4. Absolute crash savings for the Mobile Camera program

The average yearly crash counts at mobile camera treatment sites, for years 2013 to 2016 were first calculated by crash year, police region and severity. Percentage reduction estimates from the regression analysis were then applied to the after-period average annual mobile camera treatment area crashes to produce absolute crash savings for each crash year.

Absolute crash reductions were converted into community cost savings according to the process illustrated in the CDOP framework (Newstead & Cameron, 2012) by multiplying the estimated absolute crash savings at the crash severity level being considered by the unit cost of each crash (Table 38) to derive the cost savings related to the crash reductions. Savings were calculated by Police region, crash severity and crash year.

3.3. COMBINED ESTIMATE OF STATE-WIDE CDOP CRASH EFFECTS

The final step of the evaluation framework development for measuring crash effects of the CDOP was to combine estimates of the effectiveness of individual program elements to arrive at aggregate effectiveness estimates both within specific police regions as well as across the whole of Queensland. This process involved consideration of the crash population covered by each mode of enforcement along with the estimated effectiveness of each camera type. The methodology used to combine state wide CDOP effects is described in Section 4.3 of the evaluation framework (Newstead & Cameron, 2012). Details specific to this analysis are described below.

In this report average annual crash savings were calculated by crash severity, police region and camera type groupings: red light cameras, red light speed cameras, mobile speed cameras, tunnel fixed cameras, all other fixed speed cameras (including average speed cameras). The state–wide CDOP annual absolute crash reductions and average annual crash cost savings were determined through regional summation over tunnel, other fixed (combined) and mobile camera type. The state-wide CDOP average crash reduction was weighted using the average annual *post-activation* base period crash counts.

3.4. ISSUES FACED IN THIS ANALYSIS, THE PREVIOUS ANALYSES AND THE TRIAL RUN

A number of data and design issues were identified in applying the evaluation framework. Most of these were identified in the development of the original evaluation framework but are worth noting here since they still apply.

Control Selection

- Traffic volume data were only available at a limited set of sites, meaning that it was still unavailable for use in broader control matching.
- Control road segments for the cross-sectional analysis of the Clem 7 and Airport-Link were not tunnels, so measured effects might be biased.

Data disaggregation

- There was insufficient data to produce significant relative risk estimates at each of the severity levels from the fixed speed camera analyses for some camera types. In this analysis significant crash reductions were found for red light cameras and the Clem 7 tunnel cameras but not for red light to red light speed camera upgrades or new red light speed cameras or for the point to point system or the fixed spot speed cameras.
- There was insufficient data to analyse fixed camera effectiveness varying over time although it is not expected that there will be significant time variation in effectiveness for these camera types.
- There was insufficient fatality data to estimate camera effects associated with fatal crashes alone with statistical reliability for any of the camera types considered.
- Although there were some significant differences in mobile speed camera crash effects measured between police regions, using regional based estimates by crash severity resulted in greater volatility in the crash and cost savings estimates reflected in the wider confidence limits on the regional estimated effects. If the primary objective of the evaluation framework were to only measure effectiveness of the CDOP mobile speed camera program on crashes in Queensland as a whole, using the average estimates of crash effects across all regions in calculating the crash savings and economic benefits would yield more accurate results. However, since the stated objective of the evaluation framework was to estimate CDOP crash effects on a region by region basis so a higher degree of statistical uncertainty in the estimates is expected.

Other

- Traffic migration issues in the evaluation were considered unlikely with the potential effects not readily assessed.
- It is also possible that the mobile speed camera program has produced generalised effects over space that cannot be readily detected by the evaluation framework employed.
- Challenges to the efficacy of the evaluation framework for the mobile speed camera program have been presented due to the increase in number of sites enforced and significant variation in which of those sites has been enforced over time. A work around to use the current framework was reached through the use of an alternative base comparison year for this evaluation however a re-design of the evaluation framework should be considered for future evaluation updates.

4. RESULTS

4.1. CRASH ANALYSIS

Results of the crash analyses are presented as relative risks, absolute annual crash savings and crash cost savings using the Willingness to Pay and the Human capital approaches (expressed in 2016 dollars).

Regression analysis models were applied to crashes by the defined crash severity groupings: serious casualty (fatal + hospitalisation), minor injury (medically treated + other injury), no injury, all severity and all casualty crashes (all severities excluding non-injury). Analysis focusses on the years 2013 to 2016 which do not include the years where non-injury crash data were available, therefore results for non-injury and combined all severity level crash analysis were not presented. Estimated savings associated with the aggregate category of *casualty* crashes were determined from the respective regression model crash reduction estimates and not from the summation of savings associated individually with fatal, serious and minor injury crashes.

In contrast, although state-wide effects were modelled, the presented crash reduction estimates for these models were not used to estimate state-wide savings. For consistency, state-wide savings estimates presented in the results sections were calculated by summation of regional savings estimates. State-wide regional estimates were the sum of the separately modelled tunnel speed camera, other fixed camera and mobile camera programs.

4.1.1. State-wide Estimates of CDOP Effectiveness

This section presents the crash and economic effects estimated to be associated with the CDOP in 2016. It should be noted that estimates for the mobile speed camera program are relative to the year 2000 for the reasons described previously. Results for all other camera types are estimates of their impact relative to the program not being in place. Results are presented for each crash severity grouping defined, by police region, status as urban or rural (as defined by the sector in which the crash fell), and by the broad camera type. The base camera-specific crash effect analysis, from which the overall crash and economic effects for each broad camera type are derived, is described in the sections immediately following this section (Sections 4.1.2 to 4.1.6).

Table 8 presents the regional average estimated relative crash risk associated with the CDOP in each year from 2013 to 2016 as well as in the year 2016 specifically. The relative crash risk estimates are the risk of a crash occurring with the CDOP in place compared to the fixed CDOP not being present or to the mobile camera program operating at year 2000 levels, adjusted for the effects of confounding factors represented in the control areas. For example, a relative risk of 0.80 for serious casualty crashes across all regions in 2016 indicates a state-wide 20% reduction in serious casualty crash risk associated with implementation of the CDOP. Average relative risk estimates by severity of crash, region and urban/rural status of the crash location, and over the entire state, were derived by combining estimates for tunnel, other fixed, mobile and camera types in each year after camera implementation. Averages were calculated through weighting the estimates for each camera type by the percentage of post-implementation crashes covered by the camera type.

Crash savings were also calculated for each region and urbanisation category by weighting the tunnel camera, all other fixed camera and mobile camera relative risk estimates for 2016 within region and speed category by the post activation period crash count associated with each in 2016. Crash effects estimates across all regions and speed zones for both the mobile speed camera and fixed camera program by crash severity grouping are also given in Table 8.

For the fixed CDOP camera types, yearly crash effect estimates were not available directly from the analysis due to the limited quantities of crash data associated with these sites. Instead, the average crash effects associated with each fixed camera types in their entire post implementation period were used to derive subsequent crash and crash cost savings. The average relative risk estimates for each fixed camera type as well as across all fixed cameras are reported in Table 9.

The Brisbane region relative crash risks associated with CDOP in Table 8 include the effects of the Clem 7 and Airport-Link fixed spot speed cameras however no contribution for the Legacy Way cameras could be calculated due to the lack of sufficient accumulated crash history. The fixed camera Central Rural region relative crash risks associated with CDOP in Table 8 are made up of the effects of the average point to point cameras and the fixed speed camera at The Sunshine Motorway, Mooloolaba. The fixed camera average estimates in Table 8 of the other two rural regions (South Eastern and Southern) are derived from five fixed speed camera sites only (two and three respectively).

Table 8 Estimated relative risk of crashes (with CDOP vs without CDOP) and crash savings associated with the Queensland CDOP by crash severity

		Average Relative Risks Ω			Estimated Crash Savings		
AVERAGE 2013-2016Ω		**Serious Casualty**	**Minor Injury**	**†All Casualty**			
All		0.86	0.93	0.88			
Brisbane‡		0.57	0.86	0.77			
Central	Urban	0.78‡	0.75‡	0.80			
	Rural‡	0.80	0.72	0.79			
Northern‡	Urban	0.93	0.88	0.91			
	Rural	1.15	1.37	1.20			
South-Eastern‡	Urban	0.70	0.74	0.77			
	Rural	1.35	1.09	1.36			
Southern‡	Urban	0.90	0.90	0.91			
	Rural	0.98	1.16	1.04			
Fixed Camerasβ‡		0.94	0.94	0.93			
Mobile Speed Cameras*‡		0.85	0.92	0.87			
2016Ω		**Serious Casualty**	**Minor Injury**	**†All Casualty**	**Serious Casualty**	**Minor Injury**	**†All Casualty**
All ‡		0.89	0.94	0.90	1,647	795	2,488
Brisbane		0.59	0.83‡	0.77	1,020	307	1,249
Central	Urban	0.77	0.76‡	0.80	177	138	329
	Rural‡	0.90	0.75	0.87	75	81	190
Northern‡	Urban	0.81	0.91	0.87	83	23	131
	Rural	1.18	1.38	1.22	-46	-47	-85
South Eastern	Urban	0.63	0.69	0.71	425	437	873
	Rural	1.71‡	1.58‡	1.79	-84	-91	-163
Southern‡	Urban	1.01	0.94	0.98	2	23	27
	Rural	1.02	1.28	1.10	-5	-77	-61
Fixed Camerasβ‡		0.94	0.94	0.93	11	19	30
Mobile Speed Cameras*‡		0.88	0.94	0.89	1,636	776	2,458

Ω 2013-2016 average risk is a weighted average of risks for each year, region and camera type (mobile, tunnel and other fixed). 2016 'ALL' risk is the weighted average of risks for each region and camera type.
† Estimated from an all casualty crash model
‡ Based on non-significant mobile camera relative risks; see Table 12 for the significance of fixed camera relative risks.
β Risk is from the model of all fixed cameras combined, which excluded tunnel cameras; crash savings is the difference of all region and mobile camera estimates and included the savings from the tunnel cameras.
* Risk is from models that estimated state-wide directly by year. A weighted average was used for 2013-2016 average. Crash savings is the sum of the regions for mobile cameras.

This 2016 evaluation was based on a reduced comparison (control) set of crashes for the mobile speed camera program evaluation compared to previous evaluations reflecting the increased coverage of crashes by additional enforcement sites and increased size of hypothesised rural zones of influence. This resulted in less precise estimates than for previous evaluations. The higher crash coverage of the mobile camera program additionally led to comparatively higher relative risks (lower estimated percentage crash savings) than estimated for previous mobile camera evaluations with an 18% reduction in serious casualty crashes estimated in the evaluation compared to a 26% reduction estimated for 2015 in the previous evaluation. Since the crash pool covered by the program is higher, total crash reductions attributable to the program are similar to previous years with the 1,647 serious casualty crashes saved comparable to the 1,661 estimated serious casualty savings from the program in 2015. This results also validates the use of the year 2000 as a comparison base year for the mobile camera program evaluation to overcome evaluation design issues caused by the significant expansion of sites enforced in recent years.

It should be noted that a number of the regional estimates presented in Table 8 have only limited statistical analysis power. For example, the only serious casualty crash risk reductions associated with mobile cameras in 2016 that were evidenced with a p-value of 0.05 or less were for Brisbane, Central Urban and South Eastern Urban; for minor injury crashes it was only South Eastern Urban.

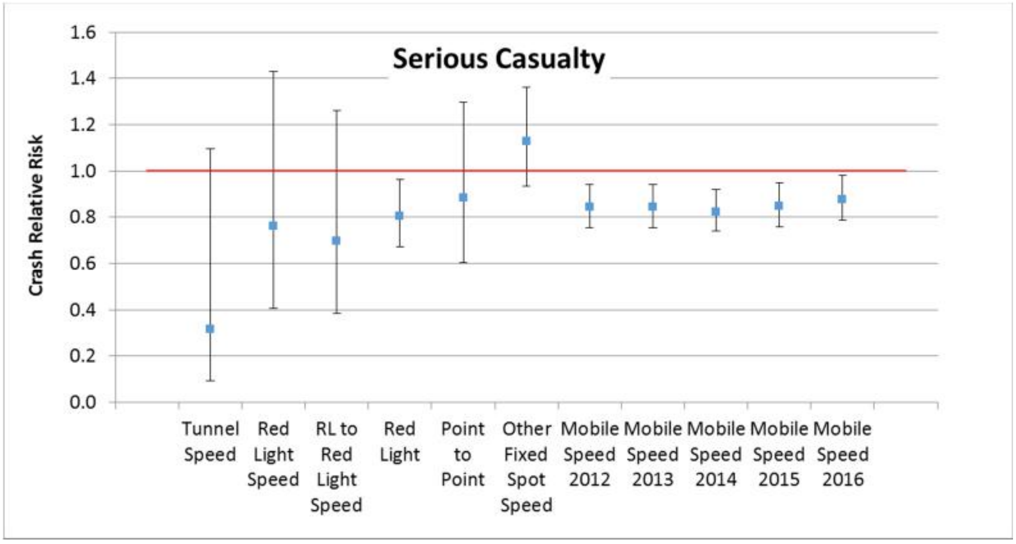
Estimated overall crash effects for CDOP as a whole were closely aligned to the estimates for the mobile camera program which has by far the highest coverage of reported crashes in Queensland of all the CDOP elements. Figure 5 compares the tunnel speed, red light speed, red light, point-to-point, other fixed speed and mobile camera state-wide relative risk estimates and 95% confidence intervals for 2012 to 2016, for serious casualty and all casualty crashes. The red line indicates the line of no program effect (a relative risk of 1). Estimates of the mobile speed camera program are shown for 2012-2015 as a benchmark for comparison of the mobile speed camera program crash effects over the year of interest, 2016.

Crash reduction estimates associated with various camera types showed red light cameras have the highest associated crash effects of all camera types albeit with a much smaller coverage of the total crash population than the mobile camera program. Hence the smaller influence of red light cameras on the overall CDOP effect. Estimated crash effects associated with fixed cameras other than the red light, red light speed, point-to-point and tunnel cameras should be treated with extreme caution since they were not statistically significant being based on a small number of cameras with short after installation time periods. Estimates of the average crash effects across all fixed camera types (except tunnel) were statistically reliable only for all casualty crashes (p=0.05, but 95% CI is 0.87 to 1.00), albeit with the estimates being somewhat aligned with the intersection cameras given the predominance of these cameras amongst all fixed camera types. The results for other fixed cameras will be discussed later in this report including the rationale for estimating their average effectiveness across the whole CDOP.

Table 9 Estimated relative risks and annual crash savings associated with the Queensland CDOP fixed camera types, by crash severity

Average Annual Effects Applied Over 2013-2016	Relative risks*: Serious Casualty	Relative risks*: Minor Injury	Relative risks*: Casualty†	Crash Savings*: Serious Casualty	Crash Savings*: Minor Injury	Crash Savings*: Casualty†
All Fixed (sum of below & tunnel)				18	22	37
All Fixed (except Clem & Airport) ‡	0.94	0.94	0.93	16	19	31
Red Light Camera	0.81	0.86	0.84	17	19	33
Red Light Speed Camera Ω ‡				2	-3	-2
Referenced to no camera	0.76	1.38	1.13			
Referenced to RL camera	0.69	0.62	0.64			
Tunnel Cameras	0.32	0.32	0.32	2	3	5
Clem 7 tunnel Cameras	0.15	0.25	0.21			
Airport Link Tunnel Camera‡	0.64	0.53	0.53			
PtP Avg/spot speed cameras‡	0.88	0.83	0.87	2	3	5
Other fixed speed cameras‡	1.13	1.00	1.04	-5	0	-5

Ω Only 2001, 2002, 2003 and 2004 had a no camera period, so estimate is based only on these 4 sites. Upgrade was calculated from sites 2005, 2006 and 2007 only. Crash savings applies (no camera ref) risk to all RLSC after period crashes.
‡based on non-significant relative risks,
*crash savings is the sum of regions; risks are from state-wide regression models.
† Estimated from an all casualty crash model



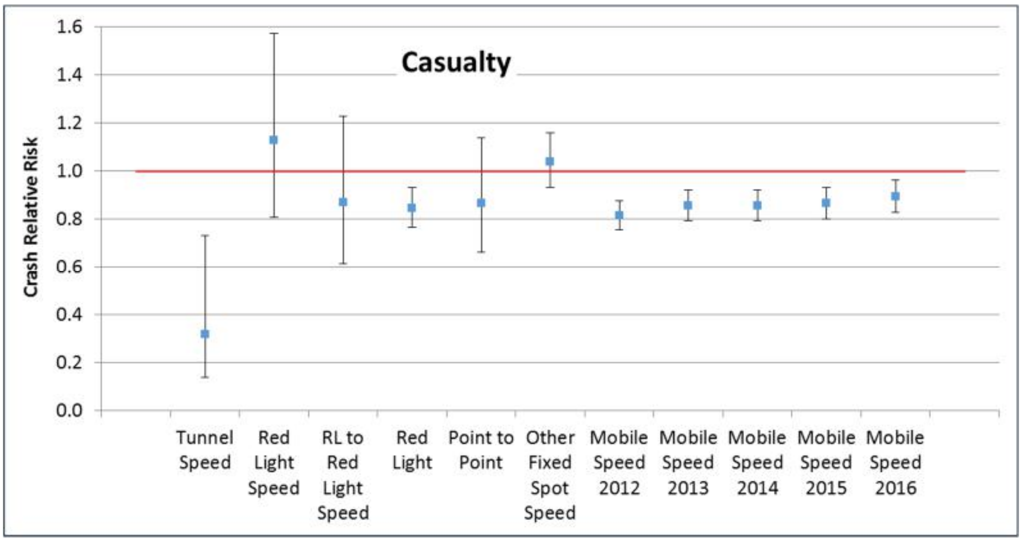


Figure 5 *State-wide relative risk estimates for each CDOP camera type*

Table 8 also presents the estimated absolute annual crash savings, associated with the CDOP by year, crash severity, police region, urbanisation and camera type. The estimated percentage reductions in crash risk in combination with the observed actual crash numbers in each hypothesised halo of influence for each camera type have been used to derive absolute crash savings in Table 8. This methodology produced the most conservative estimates of crash savings and subsequent crash cost savings as it assumes factors other than the CDOP act proportionately first. During 2016, CDOP was associated with an absolute saving of approximately 2,488 casualty crashes of which 1,647 serious casualty crashes.

Examining regional effects, the serious casualty crash reduction estimates were greatest in the Brisbane and South Eastern urban regions (as was seen in the previous evaluation) and eighty-five percent of the casualty crash savings come from these two regions. This reflects both the high proportion of the Queensland crash population in these regions and the high coverage of these crashes by the mobile speed camera program. The crash increases estimated for rural areas were based on non-significant relative risk estimates with wide confidence intervals produced from a small set of crashes, so are not cause for concern.

Overall it is evident that the vast majority of the estimated crash savings come from the operation of the mobile camera program, again reflecting its high coverage of the crash population. This is consistent with the findings of the 2008 evaluation reported in Newstead and Cameron (2012).

Table 10 presents the translation of crash savings into economic cost savings using the Human Capital and Willingness to Pay approaches respectively. Conversion of the estimated crash savings into cost savings estimated annual savings of $1.54B associated with the CDOP program valued using Willingness to Pay crash costs and $0.72M valued using Human capital estimates in 2016. Around 90% of the total casualty crash cost savings stem from savings in serious casualty crashes.

Table 10 Estimated annual economic savings associated with the Queensland CDOP, by crash severity: Human capital approach and Willingness to Pay (2016 million AUS$)

		WTP			HC		
2016		Serious Casualty	Minor Injury	†All Casualty	Serious Casualty	Minor Injury	†All Casualty
All*‡		$1,463	$88	$1,551	$709	$15	$724
Brisbane‡		$888	$35	$923	$433	$6	$439
Central	Urban	$155	$15	$170	$75	$3	$78
	Rural‡	$104	$9	$113	$46	$2	$48
Northern‡	Urban	$77	$3	$80	$37	$0	$37
	Rural	-$64	-$5	-$69	-$28	-$1	-$29
South Eastern	Urban	$378	$48	$426	$183	$8	$191
	Rural‡	-$69	-$10	-$79	-$34	-$2	-$36
Southern‡	Urban	$1	$3	$4	$1	$0	$1
	Rural	-$7	-$9	-$16	-$3	-$1	-$4
Fixed Speed Cameras*‡		$9	$2	$11	$5	$0.3	$5
Mobile Speed Cameras*‡		$1,453	$86	$1,539	$704	$15	$719

† Sum of serious casualty and minor injury savings
‡ Based on non-significant mobile camera relative risks; see Table 12 for the significance of fixed camera relative risks.
* Sum of the regions by for tunnel and all other fixed camera, sum of regions for mobile camera.

4.1.2. Red Light Cameras

Table 11 presents a summary of the estimated crash effects associated with CDOP Red Light cameras by region and crash severity grouping. The table presents the estimated relative risk, 95% statistical confidence limit on the estimate and statistical significance probability over the lines in each table block. Results of homogeneity tests indicated that there was no statistical evidence that the crash effects associated with the red light camera operation differed between police regions at any level of crash severity, thus whole state crash reductions associated with the different severities are the most informative with differences in estimates between police regions an artefact of random variation. However, given the significance of regional estimates, regional estimates were used in the estimation of savings, with the exception of the Northern region, where non-significant risk increases were observed for crashes. As this estimate was based on nine post period treatment casualty crashes per year (and fewer pre-period crashes) and was not significant, (with very large estimate confidence intervals) the all-region average red light camera reduction estimate (which included the Northern region) was used to estimates to Northern urban crash savings associated with red light cameras.

Table 11 Estimated crash risks associated with the red light camera sites relative to sites without red light cameras

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	0.81 (0.67, 0.96) 0.02	0.86 (0.76, 0.97) 0.01	0.84 (0.77, 0.93) 0.001
Brisbane	0.84 (0.64, 1.09) 0.19	0.90 (0.76, 1.07) 0.24	0.89 (0.77, 1.02) 0.10
Central	0.98 (0.59, 1.62) 0.94	0.79 (0.57, 1.09) 0.15	0.86 (0.66, 1.12) 0.26
Northern	1.51 (0.68, 3.37) 0.32	1.49 (0.86, 2.58) 0.16	1.53 (0.98, 2.4) 0.06
South Eastern	0.70 (0.5, 0.99) 0.04	0.70 (0.55, 0.88) 0.002	0.69 (0.57, 0.84) 0.0002
Southern	0.53 (0.29, 0.95) 0.03	1.03 (0.67, 1.58) 0.91	0.81 (0.57, 1.14) 0.23

† Estimated from an all casualty crash model

Individual statistically significant camera site crash reductions are presented in Table 12. Some presented very large reductions of 90% and higher, however, five sites presented statistically significant increases in crash rates: sites 45, 61, 2/67/68, 123 and 124. The control intersections for site 61 were dominated by the intersection of Moreton Bay and Redland bay roads. Both this and site 61 share the Birkdale Road route, and both these intersections experienced a much reduced after period crash count. In raw terms, the control sites crashes were reduced by a further 13 percentage points. The control intersection also had a 20% higher before period crash history. In terms of surveyed AADT traffic flow for the non-shared route number; route 112 for the treated site had post period flow of 34,399 and 35,128, and route 1102 for the major control site had a similar flow of 35,613. These flows were recorded in both the before and after periods within the crash data provided. Although the control site in question did not have a red light camera, there was one (#33) a short distance north on the corner of Dollery and Redland Bay roads which was decommissioned in 2006 and not identified in the crash data provided. As this camera was made operational in 1993 and the treatment camera in 2009, its effect would most likely have reduced the pre-crash history at site 61 and thus increase the measured treatment crash risk.

An increase in crash rates was significantly associated with the RL cameras on Lutwyche Road, Windsor (# 45) and near Gympie road at the intersection with Kedron Park Rd (#2/67/68) [3], which were made operational in 1999 and 2012 respectively. One camera, with no associated crash data was made operational in 1999 at an intersection along Lutwyche Road in a nearby suburb (#51). In addition, another three camera sites were operational and (#13, #59 and 69/500) nearby on Lutwyche Rd. Camera #13was made operational prior to 1992 so could not be evaluated, but #59, #51 and #69/#500 were all made operational around the same time or after #45, so are unlikely to have impacted its estimated effectiveness. The likely contributor is the greatly reduced crashes in controls such as those at Bowen Bridge and Herston road which were likely to have been reduced by changed traffic flows since 1999 due to construction of roads such as the Inner City Bypass and the Clem7 and Airport Link tunnels. Unfortunately, no traffic survey flows were available for comparison.

No explanation could be found for the observed risk increases at site #123 and #124[4]. Both fell on Bermuda Street. Two camera sites, (#121 and #113), operational in 1997 and April 2000 were operational at least one year prior to cameras #123 and #124, which may have improved the crash outcomes at the nearby comparison intersections. Also, an RLS camera was positioned in 2013 at site #124. The control sites for this camera site were mostly located on the Gold Coast Highway and the Burleigh Connection road, so perhaps roadworks or improved alternative routes provided lower flows or less crash risk in the control routes. It is interesting that significant increases in casualty crashes were also observed for the fixed spot speed camera on the Gold Coast Highway, Broadbeach. Again, traffic survey data provided had records with the exact same flows in both the before and after periods, so was able to provide no additional information.

The sensitivity of the overall CDOP crash effect estimates to sites #45, #61 and #123 was examined in the previous evaluation with the estimates not found to change within the bounds of statistical confidence demonstrating that these 3 anomalous sites did not have a major bearing on the overall analysis. A sensitivity analysis was not performed for this evaluation. It was assumed, that given the findings of the previous sensitivity analysis, the sensitivity to these five sites would result in only very small insignificant changes in the overall, regional and 'by camera' estimates.

[3] The 2009 decommissioned # 2 is at Stafford Road, Kedron (at i/s with Gympie Road), very near to #67 and was made operational in 1996.

[4] An RLS camera was positioned in 2013 at site 124.

Table 12 Statistically significant estimated CDOP fixed camera effects associated with individual fixed camera sites

Camera	Location	Serious Injury			Minor Injury			All casualty		
								Estimate	(95% CI)	p-value
Decrease	*Red Light*									
25	Newnham Road, Mount Gravatt East (at i/s with Broadwater	0.19	(0.07, 0.47)	0.0003	0.37	(0.18, 0.74)	0.005			
48	Mains Road, MacGregor (at i/s with Leadenhall Street)	0.04	(0.01, 0.24)	0.0004				0.42	(0.19, 0.91)	0.03
57	Rochedale Road, Rochedale South (at i/s with Underwood Road)				0.12	(0.04, 0.37)	0.0002			
58	Gympie Road, Aspley (at i/s with Zillmere Road)				0.38	(0.15, 0.97)	0.04	0.39	(0.18, 0.86)	0.02
75	Logan Road, Underwood (at i/s with Gunn Street)				0.41	(0.18, 0.9)	0.03	0.42	(0.22, 0.83)	0.01
94	Chermside Road, East Ipswich (at i/s with Brisbane Road)							0.50	(0.27, 0.91)	0.02
113	Bermuda Street, Broadbeach Waters (at i/s with Rudd Street)				0.36	(0.16, 0.83)	0.02	0.39	(0.19, 0.78)	0.01
114	Southport Nerang Road, Ashmore (at i/s with Currumburra Road)				0.38	(0.16, 0.87)	0.02			
461	Takalvan Street, Bundaberg West (at i/s with Bourbong Street)				0.50	(0.26, 0.99)	0.05	0.54	(0.3, 0.97)	0.04
503	Takalvan Street & Walker Street				0.33	(0.11, 1)	0.05	0.32	(0.13, 0.8)	0.01
505	Kumbari Avenue & Smith Street	0.30	(0.15, 0.6)	0.0007				0.52	(0.34, 0.79)	0.002
	Fixed Spot									
1011	Nambour Connection Road				0.12	(0.01, 0.91)	0.04			
3003	Pacific Motorway				0.57	(0.36, 0.9)	0.02			
3005	Gold Coast Highway,Labrador				0.48	(0.33, 0.7)	0.0002			
Increase	*Red Light*									
45	Lutwyche Road, Windsor (at i/s with Northey Street)							2.17	(1.02, 4.61)	0.04
61	Moreton Bay Road, Capalaba (at i/s with Old Cleveland Road and				2.41	(1.16, 5)	0.02			
67	Lutwyche Road, Kedron (at i/s with Kedron Park Road)				4.71	(1.64, 13.51)	0.004	4.26	(1.83, 9.91)	0.001
123	Bermuda Street, Burleigh Waters (at i/s with Christine Avenue)				3.29	(1.12, 9.67)	0.03	2.11	(1.08, 4.11)	0.03
124	Markeri Street, Clear Island Waters (at i/s with Bermuda Street)				2.43	(1.07, 5.55)	0.03	2.33	(1.24, 4.39)	0.01
	Fixed Spot									
1002	Pacific Motorway				1.80	(1.19, 2.71)	0.01	1.50	(1.07, 2.11)	0.02
3004	Gold Coast Highway,Broadbeach				1.48	(1.08, 2.03)	0.02	1.36	(1.05, 1.78)	0.02
	Red Light Speed									
2003	Markeri Street, Clear Island Waters (at i/s with Bermuda Street)				3.08	(1.15, 8.21)	0.02	2.59	(1.19, 5.64)	0.02
2004	Nathan Street, Aitkenvale (at i/s with Bergin Road)				5.28	(1.46, 19.13)	0.01			

For this evaluation, annual crashes, in the post-camera period, identified within the defined halo of influence of a red light camera (<100m from camera and recorded as at a signalised intersection) were tabled by severity and police region for 2013 to 2016. The average annual count (rounded to the nearest integer) over the period is given in Table 13 as an indication of the crash population covered by this camera type. Crash reductions by severity were applied to the annual counts to produce the absolute crash savings per year given in the main results (rounded to the nearest integer). Table 14 shows the average annual saving across 2013 to 2016 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 15 and Table 16 respectively.

Table 13 Average annual post-activation red light camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	All Casualty
All*	59	100	159
Brisbane	31	53	84
Central	8	13	20
Northern	5	4	9
South Eastern	10	21	31
Southern	6	8	14

*sum of regions

Table 14 Average annual absolute crash savings associated with red light cameras, by severity and Police region

	Serious Casualty	Minor Injury	All Casualty†
All*	17	19	33
Brisbane	6	6	11
Central	0	3	3
Northern‡	1	1	2
South Eastern	4	9	14
Southern	5	0	3

*sum of regions.

‡ Average reduction rate used for Northern region.

† All Casualty is modelled separately and is not the sum of serious and minor.

The casualty crash reductions of 16% (Table 11) associated with red light cameras translated to the average annual prevention of 33 casualty crashes, 17 of which were serious, saving society about $12 million per year using Willingness to Pay crash cost valuations or $5 million per annum using Human Capital crash cost valuation.

Table 15 Average annual savings associated with red light cameras, by severity and Police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty†
All*	$13,565,543	$2,080,843	$11,533,291
Brisbane	$4,720,047	$627,474	$3,876,805
Central	$124,301	$371,238	$1,190,132
Northern‡	$960,122	$81,297	$663,728
South Eastern	$3,604,533	$1,023,234	$4,603,602
Southern	$4,156,541	-$22,401	$1,199,023

*Sum of regions, rounding errors apply
‡ Average reduction rate used for Northern region.
† All Casualty is modelled separately and is not the sum of serious and minor.

Table 16 Average annual savings associated with red light cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty†
All*	$6,733,500	$358,972	$5,016,076
Brisbane	$2,368,245	$108,021	$1,700,972
Central	$62,161	$64,408	$517,306
Northern‡	$476,822	$13,940	$363,074
South Eastern	$1,762,024	$176,483	$1,914,110
Southern	$2,064,248	-$3,879	$520,615

*sum of regions, rounding errors apply
‡ Average reduction rate used for Northern region.
† All Casualty is modelled separately and is not the sum of serious and minor.

4.1.3. Red Light Speed Cameras

Six of the seven RLSC sites evaluated were previously RLC sites. Half of the six sites had red light cameras installed and operational in 1992 so there was no opportunity to use a period prior to any camera installations as the pre-treatment study period. Furthermore, defining a pre-treatment period so far in advance of the camera installation would draw questions about the representativeness of the comparison. Consequently, analysis for those three sites (2005-2007) focused on assessing the crash effects of upgrading RLC sites to RLSC with the before treatment period defined as the period where the RLC was installed and the post period the time from which the upgraded RLSC was installed. For all other sites[5] the effect of the red light speed camera for the site (during its operational period) was assessed against a no camera pre-period. Defining pre-RLS camera periods in these ways produced pre-periods of at least 8.5 years and operational periods of at least 4 years.

Table 17 presents a summary of the regression result estimates, no crash reductions achieved statistical significance. The overall analysis is based on only seven camera sites, with five

[5] Crashes during the RL camera periods at these RLS camera sites (2001, 2003 and 2004) were evaluated in the red light camera evaluation, using the same no camera pre-period and control intersections.

being from regions other than Brisbane and only one camera in the South East region. Of the two cameras in the Northern region, only one is analysed with a no-camera pre-period. Thus, the two regions with minor injury crash increase estimates are made up of only one camera each, lending the regional analysis to a greater potential influence of confounding bias and to reduced precision, which may be seen in the very large confidence intervals around these estimates. Combined, these factors mean that data is too limited to produce accurate and precise estimates of risk at this point in time. Consequently, estimates presented should be viewed with some caution, particularly those from the regional analyses.

Table 17 Estimated crash risks, (95% confidence interval and p-value) associated with the red light speed cameras

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
Referenced to no-camera period			
Combined: 2001, 2002, 2003 and 2004	0.76 (0.41, 1.43) 0.40	1.38 (0.92, 2.05) 0.12	1.13 (0.81, 1.57) 0.48
Brisbane (2001, 2002)	0.60 (0.27, 1.33) 0.21	0.90 (0.55, 1.48) 0.69	0.78 (0.51, 1.17) 0.23
Northern Urban (2004)	0.50 (0.07, 3.38) 0.48	**5.28** (1.46, 19.13) 0.01	2.57 (0.94, 7.05) 0.07
South Eastern Urban (2003)	1.86 (0.5, 6.85) 0.35	**3.08** (1.15, 8.21) 0.02	**2.59** (1.19, 5.64) 0.02
Referenced to Red Light camera period			
Combined: 2005, 2006 and 2007	0.69 (0.25, 1.86) 0.46	0.62 (0.27, 1.41) 0.25	0.64 (0.34, 1.2) 0.16
Central Urban (2005&2007)	0.51 (0.12, 2.24) 0.37	1.01 (0.34, 3.01) 0.99	0.77 (0.32, 1.84) 0.55
Northern Urban (2006)	0.89 (0.24, 3.25) 0.86	0.32 (0.07, 1.41) 0.13	0.52 (0.2, 1.35) 0.18

† Estimated from an all casualty crash model

The red light cameras at site 2003 and 2004 were associated with statistically significant minor injury crash increases. It must be noted that these estimates fall within very wide 95% confidence intervals, so their magnitude must be interpreted with caution. The issues associated with the control intersections for 2003 have already been discussed with respect to the RL camera analysis of #124.

The relative risk analyses (Table 17) were carried out for all fixed cameras combined (except for the tunnel cameras). Additionally, an analysis of just the red light speed cameras was carried out to examine the effects of RL to RLS camera upgrades to cameras at sites 2001, 2003, 2004, 2005, 2006 and 2007. The results of these analyses are found in Table 18.

It may be seen that, although crash increases were estimated when referenced against the no camera period, when referenced against the red light camera period, fatal and serious injury crash reductions were estimated at site 2003 in the South Eastern region.[6] Overall crash reductions were expected at red light speed camera sites in comparison with the prior red light camera only periods.

Table 18 Estimated crash risks, (95% confidence interval and p-value) associated with the upgrade of red light cameras to red light speed cameras (2001, 2003-2007)

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All except 2002	0.70 (0.38, 1.26) 0.23	0.99 (0.64, 1.51) 0.95	0.87 (0.62, 1.23) 0.42
Brisbane (2001)	0.55 (0.15, 2.03) 0.37	0.46 (0.14, 1.57) 0.22	0.50 (0.21, 1.22) 0.13
Central Urban (2005&2007)	0.51 (0.12, 2.24) 0.37	1.01 (0.34, 3.01) 0.99	0.77 (0.32, 1.84) 0.55
Northern Urban (2004&2006)	0.80 (0.28, 2.27) 0.68	1.01 (0.49, 2.09) 0.97	0.93 (0.52, 1.68) 0.82
South Eastern (2003)	0.84 (0.29, 2.42) 0.75	1.26 (0.63, 2.54) 0.51	1.11 (0.62, 1.99) 0.72

Results of homogeneity tests indicated that there was no statistical evidence that the crash effects associated with the upgrade of a RLC to a RLSC differed between sites at any level of crash severity although this analysis would also have limited statistical power. This indicates that the average crash reductions estimated across all sites associated could be considered to apply equally to all sites. As a demonstration, estimates by region were applied to derive absolute crash savings although again it is stressed that none of the results were statistically robust.

Average annual crashes identified within the defined halo of influence of a red light speed camera (<100m from camera and recorded as at a signalised intersection) were tabled by severity and police region across the period of focus, 2013 to 2016, and are given in Table 19. Crash reductions by severity were applied to the annual counts to produce the absolute crash savings per year given in the main results. Table 20 shows the average annual saving across 2013 to 2016 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 21.

[6] This observation adds more evidence to the hypothesized issues with the comparison no camera intersections (discussed for RLC #124).

Table 19 Average annual post-activation red light speed camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	Casualty
All*	4	12	16
Brisbane	1	6	7
Central	1	1	2
Northern	1	3	4
South Eastern	1	4	5

* Sum of regions

Table 20 Average annual absolute crash savings associated with red speed light cameras, by severity and Police region

	Serious Casualty	Minor Injury	Casualty†
All*	2	-3	-2
Brisbane	0.7	0.6	2.0
Central‡	0.3	0.8	1.2
Northern	1.1	-2.2	-2.3
South Eastern	-0.6	-2.4	-3.0

* Sum of regions
† Estimated from an all casualty crash model
‡Estimated for a RLC to RLSC upgrade

The casualty crash reductions of 22% (Table 17) associated with red light speed cameras in Brisbane translated to the average annual prevention of 2.0 casualty crashes, the majority of this being serious casualty crash savings, saving society about $0.7 million per year by the Willingness to Pay approach. These estimates should be seen as only illustrative given the lack of statistical significance in the underlying crash reduction estimates. It should be noted that the estimates for casualty crash savings in Tables 20-21 do not result from the summation of the serious casualty and minor injury models. A separate model was fitted to all casualty crashes which is likely to be more accurate than simply summing the serious casualty and minor injury crash models given it is based on greater crash numbers.

Table 21 Average annual savings associated with red light cameras, by severity and Police region

	Willingness to pay			Human Capital		
	Serious Casualty	Minor Injury	Casualty†	Serious Casualty	Minor Injury	Casualty†
All*	$944,996	-$432,852	-$1,160,299	$28,783	-$33,462	-$95,061
Brisbane	$573,191	$69,933	$733,806	$287,594	$12,039	$321,962
Central‡	$239,967	$83,720	$435,519	$120,004	$14,525	$189,304
Northern	$901,251	-$238,973	-$891,128	$447,585	-$40,978	-$487,466
South Eastern	-$529,445	-$263,812	-$1,002,976	-$258,812	-$45,501	-$417,023

*sum of regions, rounding errors apply
† Estimated from an all casualty crash model
‡Estimated for a RLC to RLSC upgrade

Crash Type Analysis for Red Light and Red Light Speed Cameras

After the exclusion from analysis of sites with none of at least one of the three crash types analysed[7] (rear-end, right through and other) in the pre- camera installation period, regression analysis was able to produce crash reduction estimates disaggregated by crash type. Right-through crashes were crashes at the intersection where one vehicle was turning right, or approaching at a right angle, and would cross the path of another vehicle travelling straight through the intersection.

Figure 6 displays the relative risk estimates with 95% confidence intervals for the red light cameras (RLC) and red light speed cameras (RLS) referenced to a period of no camera, as well as for the red light speed cameras, 2005 to 2007, referenced to a period of red light cameras (RLS from RLC). From this figure, some clear trends are evident:

- The risk of serious and casualty *rear-end* crashes is likely to be above unity for red light cameras.
- Risk of a *rear-end* injury crash is less for RLS than for RL cameras
- Both red light and red light speed cameras were likely to reduce *right-through* injury crashes. RL and RLS cameras were significantly associated with serious and casualty crash reductions.
- The *right-through* injury crash reductions trended to a greater reduction associated with RLS cameras.

Data further disaggregated into regions and urbanisation proved too unstable for regression analysis.

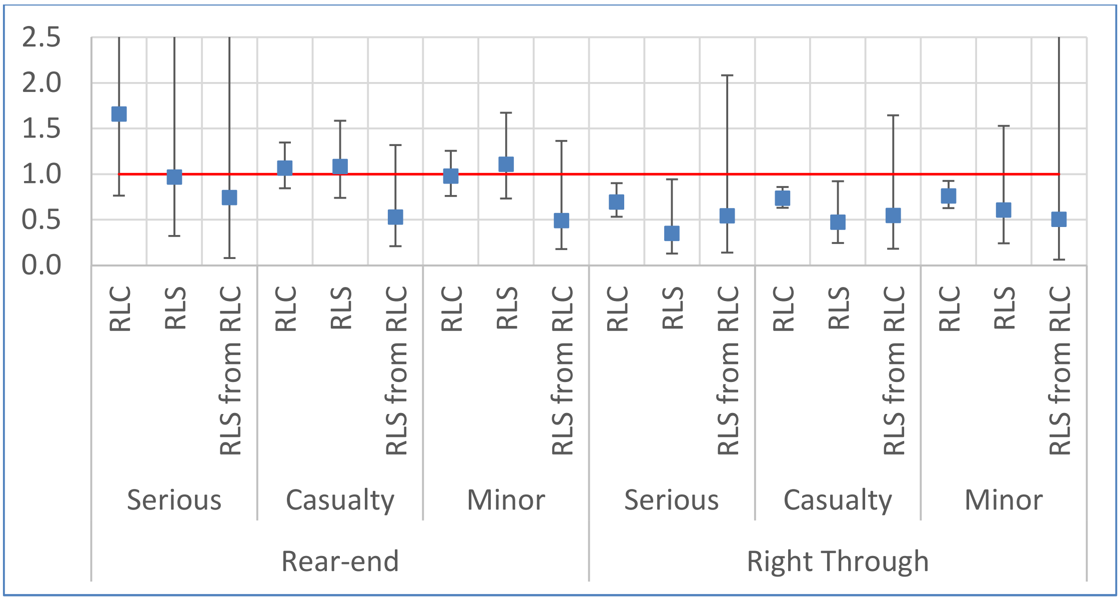


Figure 6 *State-wide relative risk estimates by crash type for each fixed intersection camera type*

[7] These were camera sites 41, 42, 46, 49, 50, 56, 57, 67, 75, 116, 122, 123, 126, 155, 206, 409, 503 and 508.

This evaluation supports the evidence suggesting that red-light cameras alone may result in an increase in the risk of a rear-end crash. A meta-analysis by Erke (2009) found a 40% increase in rear-end crashes associated with red light cameras. In this evaluation, red light cameras were associated with non-significant fatal and serious *rear*-end injury crash *increases* estimated at 66% (-24%, 2.61%).

Research by MUARC (Budd, Scully and Newstead, 2011) found red light speed cameras to be associated with a 44% reduction in right-through casualty crashes. Results in this evaluation found reductions in *right-through* associated with RLS cameras of

- 53% (95% CI: 8% to 76%, p=0.03) for casualty crashes
- 65% (95% CI: 6% to 87%, p=0.04) for fatal and serious injury crashes and
- 39% (95% CI: -53% to 76%, p=0.29) for minor injuries;

and with RL cameras of

- 26% (95% CI: 14% to 37%, p<0.0001) for casualty crashes
- 31% (95% CI: 10% to 47%, p=0.006) for fatal and serious injury crashes and
- 24% (95% CI: 8% to 37%, p= 0.006) for minor injuries.

4.1.4. Fixed Speed Cameras

The estimated effectiveness of fixed speed cameras is presented in three groups: the effects of the point to point speed camera system (site 4001), the combined effects of the tunnel speed cameras (sites 1003 to 1010 and 1013 to 1016) and by region and overall effects of all other fixed speed cameras (sites 1001, 1002, 1011, 1012 and 3001 to 3009). Table 22 and Table 23 present a summary of the fixed speed camera effectiveness estimates, all of which, except the Clem 7 Tunnel cameras in Table 23, and one other estimate were not statistically significant. There were no fixed speed cameras in the Northern region, nor in the urban Southern region.

The estimated 50% increase (Table 22) in fatal and serious injury crashes associated with the Brisbane fixed spot speed cameras was found significant. Although, according to the 95% confidence interval for this estimate, the increase may have been as low as 1%.

Estimated crash risks at Clem 7 and Airport-Link camera sites were relative to the chosen above ground comparison routes: Port of Brisbane Motorway and Southern Cross Way and were determined from Cross-sectional Treatment-Control analysis. A statistically significant reduction in risk was associated with the tunnel cameras, largely stemming from the Clem 7 tunnel result which was statistically significant on its own for each crash severity considered. To some degree these estimates should be treated with caution because the control roads, although adjusted for traffic volume and distance, were not tunnels. However, the results do indicate that the road safety environment created in the tunnels whether partially or wholly through the use of fixed speed cameras, is much safer than that observed at comparable above ground motorways.

Table 22 Estimated relative crash risks associated with fixed spot speed cameras (excluding point-to-point and tunnel cameras)

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	1.13 (0.93, 1.36) 0.21	1.00 (0.88, 1.15) 0.95	1.04 (0.93, 1.16) 0.50
Brisbane	1.50 (1.01, 2.22) 0.04	0.83 (0.63, 1.08) 0.16	0.99 (0.8, 1.24) 0.94
Central Urban	1.29 (0.73, 2.27) 0.38	1.09 (0.73, 1.63) 0.67	1.13 (0.82, 1.56) 0.46
Central Rural	1.10 (0.57, 2.12) 0.78	0.77 (0.42, 1.39) 0.38	0.86 (0.56, 1.34) 0.51
South Eastern Urban	0.85 (0.59, 1.23) 0.39	0.92 (0.72, 1.17) 0.50	0.90 (0.73, 1.1) 0.30
South Eastern Rural	0.96 (0.6, 1.53) 0.85	1.41 (1.03, 1.92) 0.03	1.26 (0.97, 1.63) 0.08
Southern Rural	1.36 (0.81, 2.29) 0.25	1.08 (0.89, 1.31) 0.42	1.28 (0.91, 1.79) 0.16

† Estimated from an all casualty crash model

Table 23 Estimated relative crash risks associated with Point to Point spot and average speed, and Tunnel fixed speed cameras

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All Tunnel	0.32 (0.09, 1.1) 0.07	0.32 (0.1, 0.98) 0.05	0.32 (0.14, 0.73) 0.01
Clem 7	*0.15* *(0.04, 0.55)* *0.004*	*0.25* *(0.09, 0.67)* *0.006*	*0.21* *(0.1, 0.45)* *<.0001*
Airport Link	*0.64* *(0.15, 2.68)* *0.54*	*0.53* *(0.13, 2.13)* *0.51*	*0.53* *(0.2, 1.42)* *0.21*
Point to point	0.88 (0.6, 1.3) 0.53	0.83 (0.57, 1.23) 0.36	0.87 (0.66, 1.14) 0.30

† Estimated from an all casualty crash model

Annual crashes identified within the defined halo of influence of a fixed speed camera (≤1000m in either direction on the same road) were tabled by severity and police region for 2013 to 2016. The average annual count over the period is given in Table 24 as an indication of the crash population covered by this camera type. Note that the crash reductions by severity were applied to the actual annual counts to produce the absolute crash savings per year given in the main results. Table 25 shows the average annual saving across 2013 to 2016 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 26 and Table 27 respectively.

Table 24 Average annual post-activation fixed speed camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	Casualty
All Tunnel	1	1	2
Point to Point	18	15	33
All other fixed*	41	76	117
Brisbane	11	17	28
Central Urban	5	10	14
Central Rural	4	4	8
South Eastern Urban	8	20	28
South Eastern Rural	7	19	26
Southern Rural	6	6	11

*sum of regions, rounding errors apply.

Table 25 Average annual absolute crash savings associated with fixed speed cameras, by severity and Police region

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	2	3	5
Point to Point	2	3	5
All other fixed*	-5	0	-5
Brisbane	-4	4	0
Central Urban	-1	-1	-2
Central Rural	-0	1	1
South Eastern Urban	1	2	3
South Eastern Rural	0	-5	-5
Southern Rural	-1	-0	-2

*sum of regions, rounding errors apply. † Estimated from an all casualty crash model

Table 26 Average annual savings associated with fixed speed cameras, by severity and Police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	$1,867,484	$315,657	$1,897,133
Point to Point	$2,304,622	$330,900	$2,884,095
All other fixed*	-$4,120,364	-$9,870	-$1,718,908
Brisbane	-$2,950,925	$396,370	$85,590
Central Urban	-$829,261	-$89,225	-$585,119
Central Rural	-$361,594	$145,670	$752,191
South Eastern Urban	$1,201,566	$194,975	$1,081,201
South Eastern Rural	$272,567	-$608,518	-$1,731,600
Southern Rural	-$1,452,716	-$49,142	-$1,321,171

*sum of regions † Estimated from an all casualty crash model

Table 27 Average annual savings associated with fixed speed cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	$936,995	$54,341	$832,379
Point to Point	$1,086,138	$57,854	$1,280,284
All other fixed*	-$2,028,779	$1,287	-$720,138
Brisbane	-$1,480,603	$68,236	$37,553
Central Urban	-$414,703	-$15,480	-$254,329
Central Rural	-$170,415	$25,469	$333,907
South Eastern Urban	$587,368	$33,628	$449,547
South Eastern Rural	$135,364	-$102,634	-$707,713
Southern	-$685,791	-$7,933	-$579,104

*sum of regions, rounding errors apply † Estimated from an all casualty crash model

The non-statistically significant casualty crash effects associated with fixed spot speed cameras translated to the net average annual savings of 5 casualty crashes saving society about $3.1 million per year by the Willingness to Pay approach. These estimates should be seen as only illustrative given the lack of statistical significance in the underlying crash reduction estimates for fixed speed cameras other than those in tunnels or the point to point system.

4.1.5. Homogeneity of fixed camera type and site

As has been reported throughout the results for fixed cameras, analysis was conducted to estimate whether there was statistical evidence to support differing (non-homogeneous) crash effects between different camera types and individual cameras. Analysis is based on a chi-squared test of the difference in model fit between a model estimating average effects across all cameras and a model fitting effects specific to each camera type. A significant result indicated non-homogeneous crash effects associated with different camera types or specific cameras.

Tests of homogeneity of camera and regional crash effects were undertaken for the three injury severity groups across the four fixed camera types: (i) Red light, (ii) red light speed from no camera (2001-2004), (iii) red light speed from red light camera (2004-2007) and (iv) fixed speed and point to point. The tunnel cameras were analysed separately so were excluded from this study of homogeneity. Results indicate whether camera effectiveness varies by fixed camera type or police region across all fixed camera crashes and if camera effectiveness at specific sites or within police regions varies within a specific camera type. The significance values for the tests of homogeneity of camera types are presented in Table 28 with a low significance value indicating non-homogeneous crash effects across cameras. Evaluation of homogeneity for red light speed cameras have been carried out on just the cameras with a no-camera period, as well as for all RL to RLS camera upgrades.

There was no statistical evidence to support differential regional effects within a camera type for RL, fixed and RLS upgrades from RL. In contrast, there was strong statistical evidence to show that crash effects were different for different fixed spot camera types. There is no evidence to support heterogeneity of crash effects across red light speed camera sites, when considering the RL to RLS camera upgrades, however there is strong evidence to suggest that the crash effects of red light cameras is dependent upon the site of the camera within Queensland.

Table 28 Significance probabilities from tests of homogeneity by injury severity for fixed camera analyses: (X^2, *d.f.*)

	Serious Casualty	Minor injury	Casualty
Camera Type	0.12	0.01	0.004
	(8.7,5)	(14.7, 5)	(17.1,5)
Camera sites	<0.0001	<0.0001	<0.0001
	(138.1,73)	(173.9, 73)	(213.0,73)
Red Light †	*<0.0001*	*<0.0001*	*<0.0001*
	(111.4,52)	*(106.1,52)*	*(149.9,52)*
Red Light Speed †			
(2001-2004, from no camera)	*0.23*	*0.01*	*0.02*
	(4.2,3)	*(10.5,3)*	*(10.4,3)*
(2001,2003-2007, upgrade)	*0.26*	*0.16*	*0.10*
	(6.5,5)	*(7.9,5)*	*(9.2,5)*
Fixed Speed †	*0.61*	*<0.0001*	*<0.0001*
	(11.0,13)	*(49.2,13)*	*(41.3,13)*
Regions	0.84	0.22	0.32
	(1.4,4)	(5.6,4)	(4.7,4)
Red Light †	*0.30*	*0.21*	*0.08*
	(4.88,4)	*(5.8,4)*	*(8.2,4)*
Red Light Speed †			
(2001-2004, from no camera)	*0.31*	*0.006*	*0.005*
	(2.3,2)	*(10.2,2)*	*(10.4,2)*
(2001,2003-2007, upgrade)	*0.18*	*0.21*	*0.06*
	(6.1,4)	*(5.8,4)*	*(9.2,4)*
Fixed Speed †	*0.15*	*0.29*	*0.51*
	(5.3,3)	*(3.8,3)*	*(2.3,3)*

† Within model of one camera type

4.1.6. Mobile Speed Cameras

Table 29 shows the proportion of total crash numbers in Queensland as a whole and by police region that fell into the hypothesised halos of influence of the mobile speed camera *Zones* from 2016. For the purposes of this and the previous analyses, crashes identified at the intersections of red light and red light speed cameras and crashes within the zones of influence of other fixed speed cameras, were excluded from the analysis of mobile speed cameras because the fixed cameras, present all of the time, were considered the greater influence on driver behaviour at these sites. Table 29 shows the proportions with the crashes with fixed camera sites excluded.

84% of all police reported casualty crashes in Queensland (excluding crashes at fixed camera sites) were inside the *Zone* halo of influence. This is broadly consistent with the high coverage of crashes by the mobile speed camera program, however because of the additional coverage, it exceeds those observed within the halo for the previous evaluation[8]. There was some variation in crash coverage of the mobile camera treatment areas by crash severity and police region. Police regions with higher proportions of rural roads had smaller coverage of crashes since crashes on rural roads are spatially diffuse meaning a smaller number of crashes will be near to each camera site. This is also the reason for the lower coverage of

[8] Previously urban casualty was 79% and rural casualty was 60% within the halos of influence.

serious casualty crashes which are over represented on high speed rural roads which predominate in the more rural areas.

For analysis, annual aggregate crash counts were derived for each speed zone in each region as a time series of treatment and control data covering the years 2000 to 2016. The mobile speed camera program commenced operation early in 1997, however, this did not define the before and after periods for the evaluation analysis; instead the year 2000 was used as the reference year for the relative risk estimates.

Table 29 Percentage of all reported crashes in Queensland within defined mobile speed camera halos of influence (2016)

		Serious Casualty	Minor Injury	Casualty
Brisbane		96	97	96
Central	Urban	72	75	74
	Rural	68	73	71
Northern	Urban	80	85	83
	Rural	62	68	65
South Eastern	Urban	90	91	91
	Rural	87	89	88
Southern	Urban	80	83	82
	Rural	56	63	60
All	Urban	87	90	89
	Rural	65	71	68

Relative risks (the risk of a crash in a mobile speed camera zone compared to outside the zone relative to this difference in the year 2000) by crash severity and year of the mobile speed program, for all regions combined are presented in Table 30 for the year of focus in this study, 2016 plus the three previous years for comparison. Most of the relative risk estimates for the minor injury crashes are not statistically significant, however, significant reductions in casualty crashes associated with the annual mobile speed camera program of between 11% and 15% were estimated. Estimated minor injury crash reductions associated with the program were slightly smaller; and estimated serious casualty crash associations with the program were slightly higher.

When program effects were estimated by half year, or by quarter year, and additionally disaggregated by police region, there is reduced analytical power and hence many of the results are not statistically significant. This is why program effects presented in Section 4.1.1 are based on the annual estimates by region (and urbanisation). When analysed by quarter and half year, trends seen in the annual estimates continue to be seen as demonstrated by the quarter-year estimates presented in Figure 7 both overall and by urbanisation. The reduced proportion of control crashes in this evaluation has meant that quarterly plots by region and urbanisation were too noisy to interpret, so Figure displays only the disaggregated casualty crash risk. As with previous evaluations, decreasing trends in associated crash risk were more pronounced in urban regions, although crash risk in urban regions has overall been fairly stable for the past six years. In contrast, there appears to be a long-term trend for a small rise in crash risk associated with the rural mobile speed camera program.

Table 30 Estimated net relative crash risks, significance values and 95% confidence limits associated with the Queensland mobile speed camera program by year from 2013 to 2016: average over all police regions.

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
2013	0.84 (0.76, 0.94) 0.002	0.90 (0.81, 0.99) 0.04	0.85 (0.79, 0.92) <.0001
2014	0.82 (0.74, 0.92) 0.001	0.92 (0.83, 1.02) 0.10	0.86 (0.79, 0.92) <.0001
2015	0.85 (0.76, 0.95) 0.004	0.91 (0.82, 1.01) 0.07	0.86 (0.80, 0.93) 0.0001
2016	0.88 (0.79, 0.98) 0.02	0.94 (0.85, 1.04) 0.22	0.89 (0.83, 0.96) 0.003

† Estimated from an all casualty crash model

Previous evaluations of the Queensland mobile speed camera program have found the crash reductions associated with the camera program have grown over time as a result of steady increases in the number of sites that are actively enforced each year along with increases over time in the number of hours of mobile speed camera enforcement undertaken each year. Trends in the improvement in crash risk over time have been greater in urban regions. Since 2010 (53rd quarter) increased effectiveness may also be as a result of covert use of the mobile camera program commencing. Figure and the corresponding estimates in Table 30 suggest that the mobile speed camera program has been effective in reducing crash risk for each severity grouping of crashes analysed, with evidence of greater reductions in urban areas. By severity, slightly greater reductions were observed for serious and fatal injury crashes. This is in agreement with the previous evaluations. Figure 7 shows an estimated serious casualty crash reduction associated with the mobile speed camera program urban operations within the *zone* defined halos of influence in the order of 20% in recent years.

For the most part, annual estimates by region are evidenced by p-values in excess of 0.05 accompanied by wide confidence intervals. Thus, the estimated crash increases highlighted in red in the following tables should not be cause for concern.

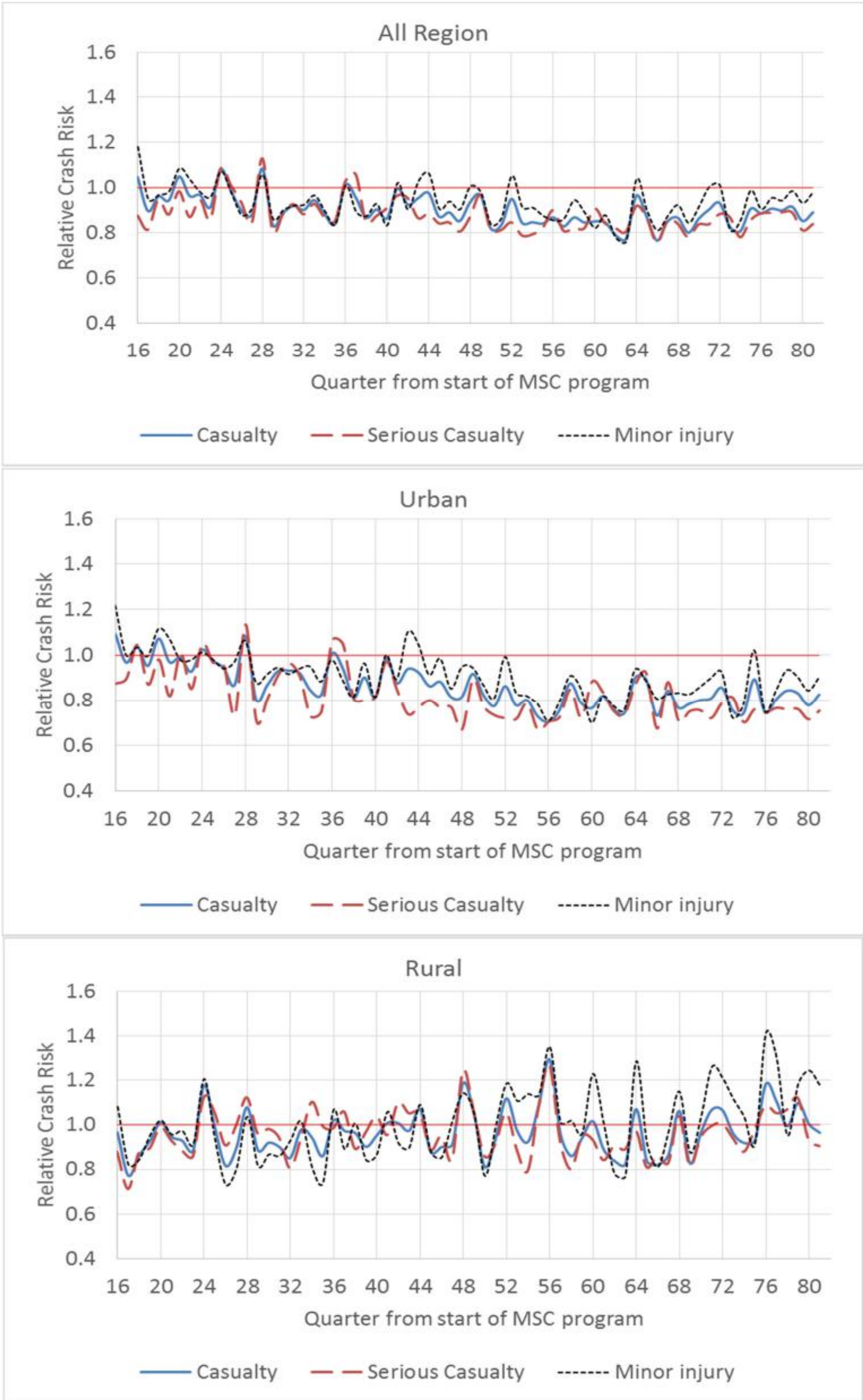


Figure 7 *Relative risks associated with the Queensland mobile speed camera program by quarter-year after January 2001 by crash severities, across all Police regions*

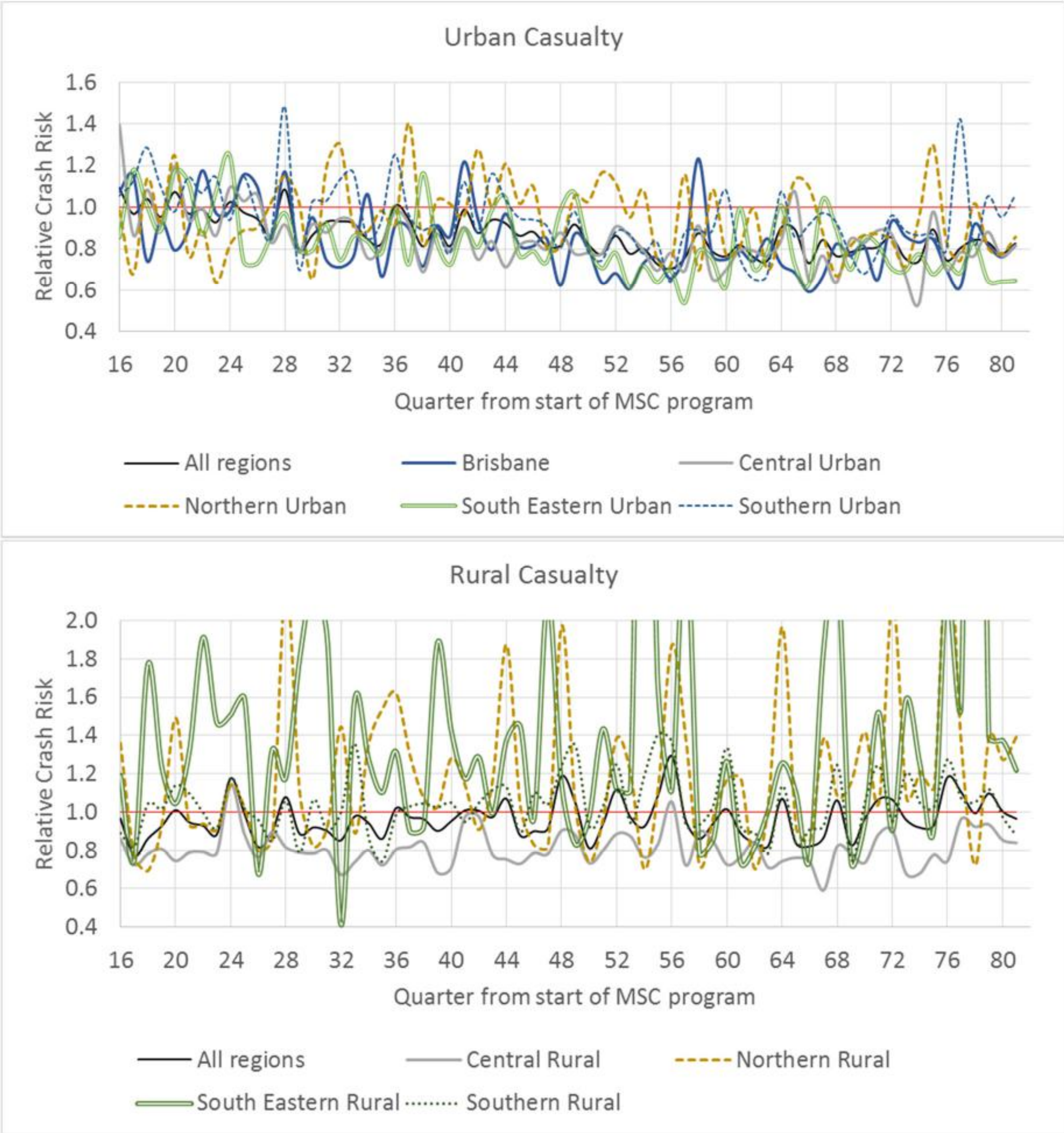


Figure 8 *Relative risks associated with the Queensland mobile speed camera program by quarter-year after January 2001 by Police region for casualty crashes*

Using the same process as demonstrated for the fixed spot speed and red light cameras, absolute crash savings and crash cost savings were estimated for the mobile speed camera program. Calculations were made for the years 2013 to 2016 using data disaggregated by crash year, police region (and urbanisation) and crash severity. These are presented in Table 39 and Table 40 in Section 8.5 of the Appendix present the 'by year' analysis. Table 31 through to Table 35 below present annual estimates for the year 2016 to illustrate the crash population and crash savings associated with the 2016 mobile speed camera program.

The 2016 casualty crash savings associated with the Queensland mobile speed camera program was 2,458 of which around 1600 were serious casualty crashes. This translates to a cost savings to the community of $0.72 billion (2016) using a Human Capital approach or $1.54 billion using the willingness to pay costs. The bulk of the savings come from fatal and serious injury crashes.

Table 31 2016 casualty crash counts in mobile speed camera zones of influence by crash severity and Police region and urbanisation

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		1,406	2,458	3,864
Central	Urban	564	639	1,203
	Rural	643	397	1,040
Northern	Urban	348	420	768
	Rural	294	168	462
South Eastern	Urban	704	1287	1,991
	Rural	198	164	362
Southern	Urban	450	728	1,178
	Rural	471	289	760
All Regions*	**All**	**5,078**	**6,550**	**11,628**

*sum of regions

Table 32 2016 Average relative casualty crash risks associated with the Queensland mobile speed camera program by police region and urbanisation

Region		Serious Casualty	Minor Injury	Casualty†
Brisbane		0.58	0.89	0.76
Central	Urban	0.76	0.83	0.79
	Rural	0.90	0.84	0.85
Northern	Urban	0.81	0.94	0.85
	Rural	1.18	1.38	1.23
South Eastern	Urban	0.63	0.75	0.70
	Rural	1.74	2.08	1.77
Southern	Urban	1.01	0.97	0.98
	Rural	1.01	1.36	1.08
All Regions*	**All**	**0.88**	**0.94**	**0.89**

*From model that estimated state-wide directly † Estimated from an all crash/ all casualty crash model

Table 33 Estimated absolute casualty crash savings associated with the Queensland mobile speed camera program by Police region and urbanisation in 2016

Region		Serious Casualty	Minor Injury	Casualty†
Brisbane		1,016	294	1,231
Central	Urban	177	135	327
	Rural	74	76	183
Northern	Urban	84	25	134
	Rural	-46	-47	-85
South Eastern	Urban	421	430	862
	Rural	-84	-85	-158
Southern	Urban	-3	23	24
	Rural	-4	-76	-59
All Regions*	**All**	**1,636**	**776**	**2,458**

*sum of regions † Estimated from an all crash/ all casualty crash model

Table 34 Estimated *Willingness to Pay* 2016 savings associated with the Queensland mobile speed camera program by Police region and urbanisation, *2016 AUS$*

Region		Serious Casualty	Minor Injury	Casualty†
Brisbane		$885,561,865	$33,115,317	$918,677,182
Central	Urban	$155,012,789	$15,007,619	$170,020,408
	Rural	$102,084,280	$8,603,095	$110,687,375
Northern	Urban	$77,198,887	$2,799,396	$79,998,283
	Rural	-$64,074,693	-$5,261,101	-$69,335,794
South Eastern	Urban	$374,612,597	$47,426,013	$422,038,610
	Rural	-$69,096,643	-$9,446,607	-$78,543,250
Southern	Urban	-$2,669,884	$2,571,958	-$97,926
	Rural	-$5,570,361	-$8,401,268	-$13,971,629
All Regions*	All	**$1,453,058,838**	**$86,414,423**	**$1,539,473,261**

*sum of regions † Estimated from an all crash/ all casualty crash model

Table 35 Estimated Human Capital 2016 savings associated with the Queensland mobile speed camera program by Police region and urbanisation, *2016 AUS$*

Region		Serious Casualty	Minor Injury	Casualty†
Brisbane		$431,416,263	$5,574,994	$436,991,257
Central	Urban	$75,462,895	$2,558,476	$78,021,371
	Rural	$44,955,930	$1,445,736	$46,401,666
Northern	Urban	$37,122,569	$470,436	$37,593,005
	Rural	-$28,126,283	-$883,321	-$29,009,604
South Eastern	Urban	$181,536,991	$8,160,032	$189,697,023
	Rural	-$34,224,379	-$1,613,732	-$35,838,111
Southern	Urban	-$1,254,729	$443,112	-$811,617
	Rural	-$2,437,639	-$1,437,513	-$3,875,152
All Regions*	All	**$704,451,617**	**$14,718,220**	**$719,169,837**

*sum of regions † Estimated from an all crash/ all casualty crash model

5. DISCUSSION AND CONCLUSIONS

Application of the CDOP evaluation framework involved separate evaluation of each of the CDOP elements over the history of their implementation, then using the results of these specific evaluations to infer the average annual crash effects of the program in 2016. Capitalising on the mutual exclusivity of the evaluation elements in the framework, the individual results were then combined to give a picture of the effects of the CDOP as a whole on crashes in Queensland.

5.1. OVERALL IMPACTS

The overall crash reductions associated with CDOP in 2016 was 11% for serious casualty crashes and 6% for all casualty crashes reflecting largely the crash reductions associated with the mobile speed camera program which produces the bulk of measures crash effects for the CDOP. As noted, percentage crash reductions for 2016 associated with the CDOP are smaller than those from previous years estimated in prior evaluations. This was a result of the higher proportion of the crash population covered by mobile camera operations as a result of recent major expansions of the number of sites enforced. Weighted average crash reductions associated with the CDOP for 2013-2016 were slightly greater than for 2016 suggesting a small decrease in effectiveness of the CDOP program in recent years although, within statistical confidence levels, the effectiveness of the program has been constant for the past 4 years. Decreases in associated CDOP crash reductions were suggested to have come primarily from the rural mobile speed camera programs. Across the 16 years since 2000 a trend to steadily decreasing effectiveness was observed for mobile cameras in rural areas (Figure). However, the statistical evidence of this trend is weak due to the paucity of rural crash data.

Translation of the percentage crash savings into absolute crash saving was achieved by applying the estimated percentage crash savings to the observed crashes at camera sites in 2016. This method assumes the camera program is last in order of factors reducing crashes, operating after other non-camera based factors represented by the analysis control sites. As noted, this gives the most conservative estimates of absolute crash savings associated with CDOP but is the most defensible since it does not rely on projecting road trauma in the absence of all other factors including CDOP. Using this methodology, it was estimated that CDOP was associated with absolute casualty crash savings of 2,488 in 2016 of which 1,647 were fatal or serious injury savings. Conversion of the estimated crash savings into (2016 $) cost savings estimated annual savings of around $1.5B in 2016 associated with the program valued using Willingness to Pay estimates or $0.7B using Human Capital crash costs. About 90% of the total savings stem from savings in fatal and serious injury crashes which is similar to previous evaluations of CDOP.

There was significant variation in estimated CDOP effects between regions of Queensland. Estimated program effects were smallest in the rural areas of Northern and South Eastern regions and stronger in urban areas generally. The bulk of the crash and economic savings from the program stem from the highest populated areas of Brisbane, Central and South Eastern regions. These areas are also predominantly urban highlighting the greater potential for speeding and the greater role of speed in crash causation in urban areas.

5.2. IMPACTS BY CAMERA TYPE

5.2.1. Intersection Cameras

The red light camera element of the CDOP has been in operation in Queensland for over 20 years meaning there was a large number of sites and extensive crash data on which to base the analysis. Consequently, the evaluation results for the 126 unique red light cameras intersections are likely to be highly robust. The test run of the evaluation framework by Newstead and Cameron (2012) showed particularly strong associated effects for targeted intersection crashes: RR 0.58 (0.48-0.69, $p<0.00005$) and, in contrast to previous studies, the test run evaluation showed no increase in rear end crashes. This might be as a result of the close proximity of each of the red light camera sites to a mobile speed camera site, hence ensuring general speed compliance at red light camera enforced intersections which could prevent rear end crashes. Unfortunately, the absence of red light cameras not in close proximity to a mobile speed camera site prevented explicit assessment of the overlay effects of the mobile camera site on red light camera crash effects. Estimated effects of red light cameras from this updated evaluation were less that previous estimates ($RR_{casualty} = 0.84$, 95% CI: 0.77 to 0.93), however when only the targeted (right-through) crashes were examined the casualty relative risk associated with red light cameras was not statistically different from the 2012 estimate at 0.74 (0.63 to 0.86, $p<0.0001$).

Despite the large number of sites on which the red light camera evaluation was based, even the extended crash data available for this evaluation were insufficient to allow estimation of yearly crash effects associated with the program. Consequently, only average crash effects over the post implementation period were estimated and it was assumed that the average crash effects applied equally over each post intervention year in estimating the 2016 crash effects associated with the red light cameras. This assumption is probably not unreasonable given red light cameras are a static and generally highly visible technology which should achieve stable crash effects after an initial short familiarisation period. The estimated crash effects translated to a savings of 33 casualty crashes associated with red light cameras per year of which 17 were serious casualty crashes, translating to an annual saving to society of around $7M (HC) or $13M (WTP).

Seven red light speed cameras, the majority being upgrades of previous red light camera only sites, and 9 analogue fixed speed cameras were made active during the period of observed crash data (prior to December 2015). In addition, the point to point speed camera system (also operating in spot speed mode) on a segment of the Bruce Highway between Landsborough and the Glass House mountains, fixed speed digital cameras in the Clem 7, Legacy Way and Airport-Link tunnels and digital fixed speed cameras in four additional locations were made active. The Legacy Way cameras could not be evaluated because insufficient crashes have been recorded there in the available data for this evaluation post camera installation. The fixed spot digital cameras had at least 2 years of post-activation casualty crash data. However, the limited number of sites and the relatively short after installation period of crash data available meant that the associated crash estimates obtained from the combined analysis of fixed spot speed cameras were not statistically reliable. With more observation time, a further full evaluation of the effectiveness of fixed spot speed cameras is likely to be more reliable given the similarity of evaluating these CDOP elements to the successful red light camera evaluation. As evidence, the analysis was able to produce significant relative risks for the South Eastern urban region based only on sited 3005.

An evaluation of casualty crash types specifically targeted by intersection cameras identified significant reductions in target crash types associated both with red light and red light-speed cameras. Red light speed cameras were associated with a 53% reduction ($p=0.03$) in targeted (right-through) casualty crashes and a 65% (p=0.04) reduction in fatal and serious targeted crashes. These reductions are double that associated with red light camera installations alone when considering the target crash types.

5.2.2. Tunnel and Mid-block Speed Cameras

A cross sectional comparison of the Clem 7 and the Airport-Link routes with the Port of Brisbane Motorway and the Southern Cross Way was undertaken. These control sections, although not tunnels, had suitable crash volume data available, were similarly located, had similar speed limits and freeway traffic characteristics. However, the comparability of these sites was questionable given that they are not tunnels. Based on the comparisons made, the Clem 7 and Airport-link cameras were found to be associated with a substantial (68%) reduction in casualty crashes in the tunnels. This is likely to reflect high speed compliance in the tunnels related the likely extensive knowledge of the cameras by drivers. To some degree, the crash reductions might also reflect the tunnel environment which is perceptually different to regular motorways due to being enclosed. Regardless of the cause, analysis suggests the operating environment in the tunnels has achieved a high level of safety. Whether this is entirely due to the speed cameras is unknown but these are likely to play an important part. Despite this, the total contribution of the tunnel cameras in terms of casualty crashes saved per year is only 5. So regardless of the effectiveness of the Clem 7and Airport Link cameras, their contribution to state-wide crash savings will always be small: e.g. 0.2% of all casualty crash savings.

TMR has noted that for all fixed speed camera modes there is sometimes a significant delay between installation of the camera and its activation when enforcement commences. Presented results are based only on activation date because installation date data were only available for a selection of fixed digital speed cameras and consequently associated crash data in the installation to activation period was limited. As noted, there may be some unaccommodated crash effects in the period between installation and activation which may have contaminated the defined pre-activation data period. Consequently, crash effects for the fixed camera elements to which this delay applies may be slightly under estimated. This under-estimation is likely to be small given the proportion of time that the ‘installation to operation’ period makes of the total, extensive, pre-activation period. Installation dates were not provided for analogue fixed speed cameras and could not be used for red light speed cameras. The installation to activation period for the 5 digital speed camera sites analysed, not in tunnels, ranged from only one to two months, which is less than 1% of the before-activation observation time. Activation and signage were coincident for the tunnel digital cameras.

5.2.3. Mobile Speed Cameras

As observed in previous evaluations of CDOP and reconfirmed in this evaluation update, 98% of casualty crash savings associated with CDOP were derived from the mobile speed camera program. This is because mobile speed cameras are the CDOP technology that covers by far the largest proportion of the crash population in Queensland. The mobile cameras were found to produce strong crash effects localised in space with 2016 casualty crash reductions estimated at 13% state-wide rising to 15% for serious casualty crashes. This translated to around 2,458 casualty crashes per year, saving society $0.72 billion (HC) or $1.54 billion (WTP).

Explicit Analysis of the direct impacts of the new mobile speed camera scheduler on crash effects associated with the mobile camera program was not possible for two key reasons. Firstly, as illustrated in Figure 3, introduction of the new scheduler has coincided with an increase in hours of operation of the mobile camera program along with a shift to using portable devices. It is also possible that there have been changes to the site coverage of the mobile camera program and potentially the density of enforcement across sites occurring at a similar time to the scheduler changes. Figure 9 plots the number of active speed camera sites available for enforcement from 2007 to 2016 as reported by Queensland Police Service. It also plots the number of unique sites used according to mobile camera operations reporting on a session by session basis from 2006 to 2016. Somewhat curiously, the operations data analysis suggests slightly more sites were enforced than were active which points to a potential inconsistency in either site labelling in the operations data or inaccuracies in the QPS summary data. Which is more likely is not clear but the reasons for the differences need to be understood for future research, particularly that investigating the influence of mobile camera program operations on program crash effects. Notwithstanding the data problems, there appears to have been a narrowing in the difference between the number of active mobile camera sites and the number actually enforced over time which will confound the measurement of changes to the scheduler on program crash effects. The confounding effects of potential multiple changes being introduced around the same time makes it difficult to estimate the individual effects of each of these changes at a state-wide level. One available mechanism to estimate the individual impact of the new scheduler and other program changes would be to look for variation in introduction and level of these changes between regions. As is discussed in the next section, limitations in the current evaluation framework mean that regional based estimates of program effectiveness have low statistical confidence. Consequently, attempts to assess regional variation in effectiveness against regional variation in the introduction of the program changes also lacked statistical power and was uninformative when attempted.

The only available means making comment on the potential impact of the new scheduler on mobile speed camera program effectiveness is to examine the estimates of program crash effects over recent years. Figure 5 summarises the overall crash effects of the mobile speed camera program over the years 2012 to 2016 shows very consistent levels of estimated crash reductions associated with the program. This provides no evidence that the package of recent changes to the use of mobile cameras, including covert operation, increases in deployment hours, removal of signage, expansion of sites used and introduction of a new scheduler, has significantly changed the overall effectiveness of the program in reducing crashes. This is perhaps unexpected given that previous evaluation of the mobile speed camera program in Queensland (Newstead and Cameron, 2003) has suggested that increased adherence with the randomised scheduler and increased enforcement hours are associated with greater crash reductions from the program.

Figure 10 below shows that, although the number of speed camera hours has increased, the number of sites actually enforced (as opposed to active sites) has potentially increased at a greater rate leading to a plateauing or decrease in the average hours of enforcement per site in recent years. This may potentially explain the plateauing of estimated crash effects associated with the mobile camera program. As noted due to the limited statistical power of the analysis for the mobile camera program undertaken in this update, the confounding influence of multiple changes to the mobile camera program occurring simultaneously, and the lack of sufficient time after the implementation of recent changes to the program, it was not possible to assess the impact of the individual changes to understand the reasons behind the lack of detected change in effectiveness of the program in 2016. Modification to the current evaluation framework would be necessary to consider the individual impacts of these changes.

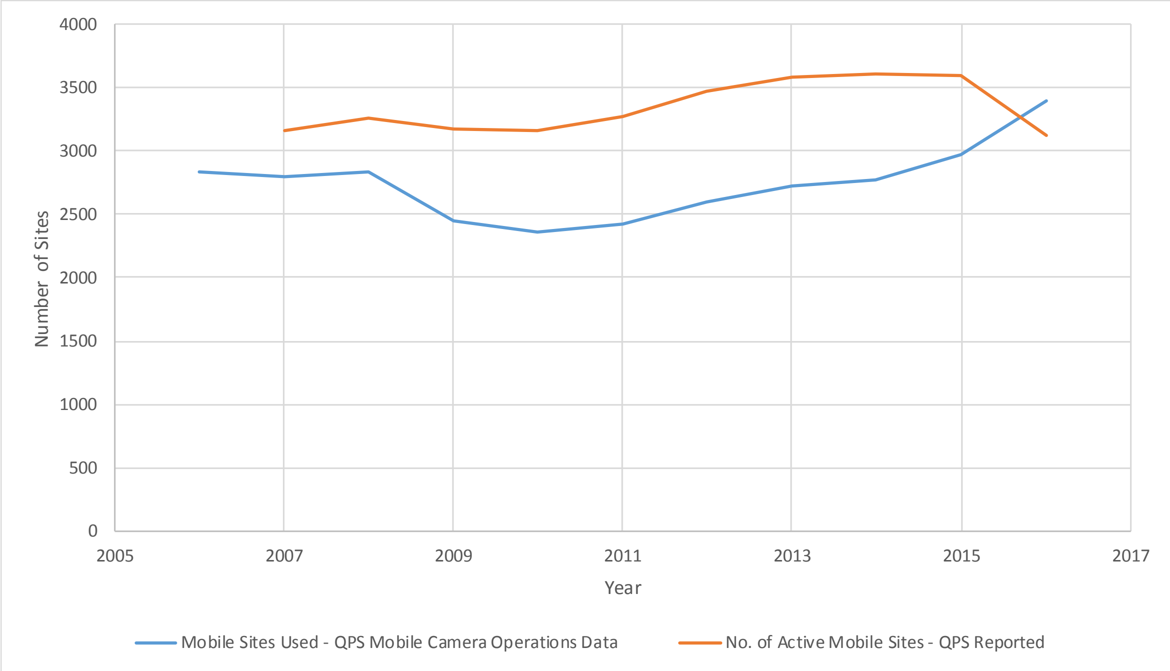


Figure 9 *Number of active mobile speed camera sites in Queensland by year*

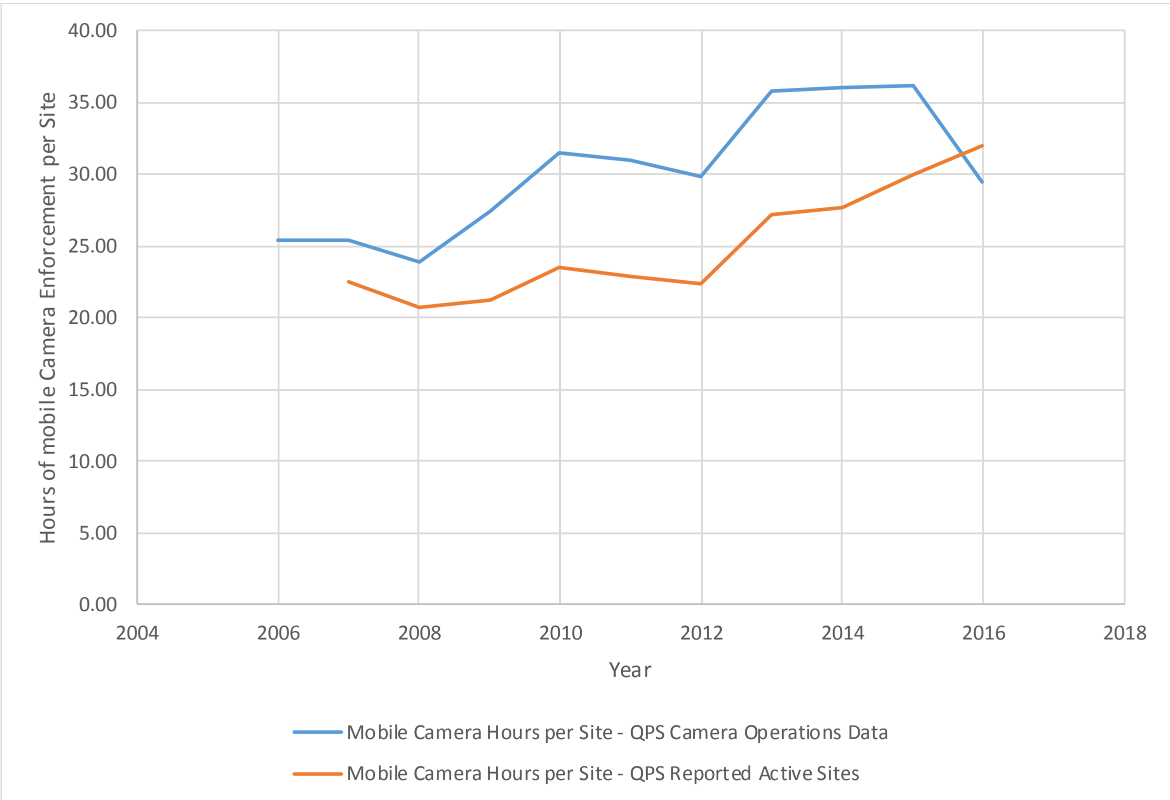


Figure 10 *Average hours of mobile speed camera enforcement per active enforcement site*

5.3. LIMITATIONS OF THE EVALUATION FRAMEWORK AND POTENTIAL SOLUTIONS

Limitations of the current evaluation framework for the assessing the mobile speed camera program have led to reduced analysis power and a need to change the reference point from the introduction of the mobile program to the year 2000 when the number of sites in use had expanded sufficiently. Many of the evaluation design problems have stemmed from the further expansion of the number of sites used for the mobile speed camera program resulting from the change in the way in which sites for mobile speed enforcement are chosen based on the partitioning of all of Queensland into sectors for assessment of crash history. The recent addition of around 1000 new sites for mobile enforcement has meant that nearly 90% of all crashes in Queensland have occurred within areas of influence of a mobile camera site that has been used at some time during the program. It should be noted that the current evaluation framework identifies sites as influenced by camera operations based on sites that have been used at any time during the program. A difficulty for the evaluation framework is that many of the newly chosen sites have only been enforced in recent years and were not active at the beginning of the mobile program. This means that most mobile camera sites which have been identified as 'treatment' sites in the current evaluation framework were not being enforced in the early years of the program. Crash rates at these unenforced sites may have continued to increase with population growth in Queensland population and travel sites making the program appear to have been ineffective in these early years. It was this possibility that forced the change in reference year for the mobile camera program evaluation. However, this has limited the evaluation to measuring relative effects compared to the year 2000 rather than measuring absolute effects of the program. Added to this is the related loss in statistical analysis power for the mobile program.

Despite the potential problems, efforts to overcome some of the mobile camera evaluation design issues by changing the reference year to 2000 seems to have been generally successful. Consistency between serious casualty crash savings estimated for the 2015 program year in this evaluation update compared to the last evaluation update provide evidence of this. Despite this, it is clear that the evaluation framework would benefit from some revision to better measure the crash effects at site actually being enforced at each time period rather than simply estimating crash effects across any site that has been enforced across the program history regardless of its usage status at each time point. Due to the limited analysis power now stemming from the high number of sites enforced, it was not possible to derive region and time specific crash reduction estimates that were reliable enough to be able to compare to camera operations data and hence allow deeper understanding of the characteristics of camera operations important in determining crash reductions estimated. This meant that explicit consideration of the impacts of recent changes to site selection and the corresponding changes in enforcement density per site along with changes to scheduling and covert enforcement usage could not be adequately explored using the current evaluation framework. Modifying the evaluation framework in this way would potentially allow these specific changes in the mobile program operations to be considered more explicitly.

Based on the problems identified with the mobile camera program evaluation framework, it is recommended that any further future evaluation of the Queensland mobile camera program consider a revised evaluation design. A revision of the evaluation design should reflect the areas of Queensland that are being enforced by the mobile camera program at each point in time and measure crash rates in the actual enforced areas compared to areas unenforced at each time point. This point is further noted in the Future Research Requirements section of this report.

5.4. CONCLUSION

In summary, this evaluation of the Queensland CDOP has shown sustained crash reductions associated with the program through the year 2016 with correspondingly large economic benefits to the community accruing from its operation. Both fixed and mobile elements of the program produced significant crash reductions. Crash effects associated with red light cameras and tunnel cameras estimated in the evaluation were robust. In contrast, the evidence of effectiveness for some of the more recently implemented fixed camera types, including point to point cameras, spot speed cameras and intersection speed and red light cameras, remains weak due to insufficient post implementation history. Despite the expansion of the number of fixed cameras in use under the CDOP, the mobile camera program continues to produce the vast majority of the measured benefits reflecting the high proportion of the crash population it covers.

Effectiveness of the CDOP program has remained relatively consistent over recent years of the program including 2016. This is largely driven by consistency in the effectiveness of the mobile program which provides the majority of crash savings associated with the program. Crash effects of the mobile speed camera program in Queensland have remained constant over recent years despite a number of changes to the program including introduction of the new mobile speed camera scheduler, increases in deployment hours and potential changes to the number of sites enforced. It was not possible to estimate the specific crash effects of each of these changes due to them being introduced at a similar time and because of limitations in the evaluation framework being used. Furthermore, the period of available data for this evaluation after implementation of these changes was short, further limiting the opportunity to assess their long term effects. Crash effects of the changes to the mobile speed camera program need to continue to be monitored in the future.

A number of recommendations are made in the next section to enhance the future application of the evaluation framework.

6. FUTURE RESEARCH REQUIREMENTS

Based on a number of issues identified in developing and applying the evaluation framework for the Queensland CDOP, a number of recommendations related to the future application of the CDOP evaluation framework were made by Newstead and Cameron (2012). Those that still remain relevant have been updated in the list below and the list expanded based on experience in the current evaluation update.

1. Review of the evaluation framework used to assess the crash effects of the mobile speed camera program component of the CDOP is required. Significant growth in the number of sites enforced under the program has occurred over the mobile program history along with significant variation in the set of sites actually enforced within each time period, in particular sites introduced later in the program not being enforced in the early year of the program. A new evaluation framework needs to be designed for the mobile camera program that measures the crash effects at sites operational at each time point in the program (for example each year) against those not operational. This is essentially a type of case-crossover design. Applying such a framework would allow a more specific understanding of the crash impacts of the mobile camera program to be ascertained which would potentially allow better understanding of the impacts of key changes to the operation of the mobile camera program. It would also have the likely advantage of improving the analysis power of the evaluation framework.

2. *Continued periodic application of the framework to monitor CDOP crash effects:* This report has detailed the application of the CDOP evaluation framework to estimate casualty and serious casualty crash effects of the CDOP program in 2016. A number of results for fixed cameras did not reach statistical significance due to limited data available after camera installation. Further future evaluation of fixed spot speed cameras, the point to point camera system, upgrades of red light cameras to speed and red light cameras and installation of new intersection speed and red light cameras would enhance the accuracy of estimated crash effects. Future application of the framework is likely to be informative, particularly with a revised approach to evaluation of the mobile speed camera component.

3. *Data Enhancements*: Development of a signalised intersection GIS layer to link to crash data would enhance the ability to match control data for the intersection camera analysis. Like the CDOP camera layers, the signalised intersection layer could be used to identify crashes within proximity of various intersection for the accurate selection of control sites. This will allow individual intersections to be reliably identified without the need to use road names which can be variable.

7. REFERENCES

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8. APPENDICES

8.1. CAMERA TYPES

The authors again ask the reader to refer to Newstead and Cameron (2012) for a detailed literature survey of camera modes of operation, effectiveness and scope. This section contains a brief summary of camera types as presented in or summarised from Newstead & Cameron (2012).

8.1.1. Red light cameras

Red Light cameras have been operational in Queensland since 1991. Prior to December 2012, the majority of fixed red light cameras operated on wet film technology. They are designed to detect vehicles infringing a red traffic signal at an intersection. They can enforce both through traffic as well as right turning traffic where there is full or partial control of the right turn phase by the signals. Installation of the camera is such that it generally only enforces one leg of the intersection driven by the need for the traffic signals to be in view of the camera for evidentiary reasons with 2 photographs of the infringing vehicle being taken to verify it is moving.

Sites for camera placement are understood to be chosen on the basis of high rates of red light infringing characterised by specific crash types related to these infringements such as right turn against and right-angle crashes. Red light cameras are placed and operated in an overt manner with the cameras being clearly visible on pole mountings on the roadside. In Queensland there is no accompanying signage to alert motorists of the presence of the camera (apart from eight trial sites). Infringement notices issued from the cameras also clearly denote the location at which the infringement occurred.

The effects of the cameras on crashes are likely to be highly localised to the sites where the cameras are placed. Whether the effects of the camera are localised to the intersection leg on which it is placed or spill over to the whole intersection are not clear. The spill over effects may be related to the use of accompanying signage on other legs warning of the presence of a camera, as is used in Victoria, or the visibility of the cameras from other legs. Primary mechanisms of deterrence associated with red light cameras identified in the evaluation studies are the overt physical presence of the camera and accompanying signage and the receipt of a traffic infringement by offending motorists. Given the overt nature of the program, the former is likely to be stronger.

8.1.2. Fixed spot-speed cameras

Fixed speed cameras are generally used as a black spot type treatment at locations where speeding has been identified as a primary driver of identified elevated crash risk. Effects of fixed spot cameras used in conjunction with high visibility signage have been estimated as highly localised to within 3km of the camera site. High visibility signage has been speculated as the primary mechanism of deterrence and infringement notices issued act as a secondary deterrence for infringing drivers.

Halo effects are expected within 1 km either side of a CDOP fixed camera. CDOP fixed camera signage is preferably within one kilometre of the camera and preferably includes two (but at least one sign) on all routes to the camera. Extra signage is used when other factors affect the visibility of the signs. The signs are installed in the following order:

1. ‘FIXED SPEED CAMERA AHEAD FOR ROAD SAFETY’ (placed furthest from the camera site)
2. ‘FIXED SPEED CAMERA 24 HOURS FOR ROAD SAFETY’ (placed closest to the camera site)

8.1.3. Combined red light speed cameras

Red light Speed Cameras at signalised intersections detect both red-light running and speeding infringements. The principal reason for installing these combination cameras is to reduce red-light running crashes and also to reduce the risk and severity of the remaining crashes, particularly rear end crashes which have been found in some studies to elevate when using only red light enforcement. The first objective is the same as for traditional red-light cameras whilst it could also be expected that the threat of detection for speeding by the cameras may encourage a proportion of motorists to travel at lower speeds through the intersection. As such the cameras appear to be consistent in objective with both the red light and fixed spot-speed cameras. Geographical reach in effectiveness and likely deterrence mechanism is likely to be similar to both single function camera types.

It was considered likely that the effects of the combined red light and speed cameras will be highly localised to the intersection and perhaps the leg on which the camera is installed. Possible halo effects on other intersection legs and up and down each intersecting road for some distance are also possible. Spread of the halo might be related to the use of accompanying signage. TMR advised that the fixed digital speed and red light cameras are signed where it is safe and practical to do so. Thus, CDOP crash effects are expected to be localised to the site with deterrence driven by both the camera presence and the issuing of infringement notices.

8.1.4. Point to Point Cameras

Point-to-point (PtP) camera technology uses a number of cameras mounted at staged intervals along a particular route. The cameras are able to measure the average speed between two points and/or the spot speed at an individual camera site.

Compared with traditional spot-speed fixed cameras, which have a site-specific effect, the point-to-point camera system has a link-long influence on drivers and their speeds, despite enforcement being visible only at the start and end of the enforced road length. It is likely that the CDOP PtP cameras provide deterrence along the full length of road between the PtP start and end gantries.

Point to point camera systems are signed in Queensland: with one prominent sign installed in the direction of enforcement within approximately one kilometre of the first camera in the point-to-point system and a second prominent sign installed in the direction of enforcement within approximately one kilometre of reaching the last camera in the point-to-point system. The presence of signage will most likely localise the effects of the PtP system to within the signed area with possible halo effects downstream of the covered link.

8.1.5. Mobile Speed Cameras

The mobile speed camera program in Queensland first commenced in May 1997. The use of mobile speed cameras in Queensland can generally be described as overt or covert with overt cameras operating from marked vehicles and signs advising motorists that they have passed a speed camera posted within 10 meters of the camera; and covert deployments operating from a variety of unmarked vehicles. Covert mobile speed cameras operate in urban areas.

The operation of cameras at particular locations is determined using a randomised scheduling procedure with some scope for variation. Locations for the deployment of cameras meet strict criteria, with crash history being the primary criterion used to identify sites. Other factors which contribute to the selection process include areas of high risk speeding behaviour that have been checked and referred to the relevant committee, including consideration of Workplace Health and Safety issues for workers at locations where roadwork is in progress.

The general effect might in fact be an aggregate of localised effects in space over a wide number of locations that target the Queensland crash population. There is a strong spatial correlation with the mobile camera zones of operation with the bulk of crash effects being measured in areas within 2 kilometres of the operational camera zone centroids.

Another key development in the Queensland CDOP is the introduction of covert mobile camera operations in 2010. Based on the combined covert and overt operation of the Queensland mobile speed camera program, a range of likely mechanisms and distributions of effects might be expected. They include effects generalised and localised in space related to the mode of operation as well as effects generalised and localised in time related to both the presence of a camera and/or the receipt of an infringement notice.

8.2. FIXED SPEED CAMERA LOCATIONS AND OPERATIONAL DATA

Table 36 Fixed Speed Camera location and operational data

		ID	Red Light Camera Go-Live Date	Speed Camera Go-Live Date	Before Period (years)	RL to RLS period	After Period (years)
Fixed Spot Speed Cameras							
Analogue	Bruce Hwy, Burpengary	3001		14/12/2007	16.0		9.5
	Main Street, Kangaroo Point	3002		14/12/2007	16.0		9.5
	Pacific Mwy, Tarragindi	3003		22/02/2008	16.1		6.8
	Gold Coast Hwy, Broadbeach	3004		31/08/2010	18.7		7.5
	Gold Coast Hwy, Southport	3005		29/09/2009	17.7		7.8
	Warrego Hwy, Redwood	3006		31/08/2010	18.7		6.8
	Warrego Hwy, Muirlea	3007		24/12/2009	18.0		7.5
	Nicklin Way, Warana	3008		30/06/2010	18.5		7.0
	Sunshine Mwy, Mooloolaba	3009		24/02/2010	18.2		7.4
Digital	Gateway Mwy, Nudgee	1001		2/08/2011	19.6		5.9
	Pacific Mwy, Loganholme	1002		2/08/2011	19.6		5.9
	Nambour Connection Road (Northbound), Woombye	1011		10/01/2013	21.0		4.5
	Pacific Mwy, Gaven	1012		28/03/2013	21.2		4.3
Clem 7 tunnel		1003-1006		6/04/2010	18.3		7.2
Airport-Link tunnel		1007-1010		25/07/2012	20.6		4.9
Legacy Way Tunnel		1013-1016		25/06/2015	23.5		2.0
Point to Point (fixed spot and average speed cameras) Bruce Hwy between Landsborough and the Glass House Mountains		4001		2/08/2011	19.6		5.9
Red Light Speed Cameras							
	Waterworks Rd, Ashgrove (at i/s with Jubilee Tce)	2001	12/02/2002	2/08/2011	10.1	9.5	5.9
	Beaudesert Rd, Calamvale (at i/s with Compton Rd)	2002		2/08/2011	19.6		5.9
	Markeri St, Clear Island Waters (Bermuda St) - Gold Coast	2003	11/04/2001	1/07/2013	9.3	12.2	4.0
	Nathan St, Aitkenvale (at i/s with Bergin Rd) - Townsville	2004	26/06/2000	8/07/2013	8.5	13.0	4.0
	Musgrave St, Berserker (at i/s with High St) - Rockhampton	2005	10/11/1992	31/07/2013	0.9	20.7	3.9
	Mulgrave Rd, Mooroobool (at i/s with McCoombe St) - Cairns	2006	10/08/1992	11/07/2013	0.6	20.9	4.0
	Bruce Hwy, Mount Pleasant (at i/s with Sams Rd) - Mackay	2007	01/11/1992	15/07/2013	0.8	20.7	4.0
	James Street, South Toowoomba (at i/s with Neil Street)	2010	10/01/1992	25/07/2016	0.0	24.5	0.9
	James Street, South Toowoomba (at i/s with Pechey Street)	2011	10/01/1992	25/07/2016	0.0	24.5	0.9
	James Street, Rangeville (at i/s with MacKenzie Street)	2012	05/09/1997	25/07/2016	5.7	18.9	0.9
	Bridge Street, Wilsonton (at i/s with McDougall Street)	2014	01/06/2000	25/07/2016	8.4	16.2	0.9
	Logan Road, Upper Mount Gravatt (at i/s with Newnham Rd)	2016		24/01/2017	25.1		0.4
	Morayfield Road, Morayfield (at i/s with Devereaux Drive)	2017		24/01/2017	25.1		0.4

8.3. CONTROL AND TREATMENT CRASH SELECTION

Table 37 Treatment and control Selection Criteria

<table>
<tr><th></th><th>Treatment Crash coded as:</th><th>Control Crash coded as:</th></tr>
<tr><td>Red Light cameras</td><td>Signalised Intersection
≤100m from camera
Not a FSSC, AvSpeed nor RLSC treatment crash
Not at a nearby or underground intersection</td><td>Signalised intersection >100m from camera, not a RLC, RLSC or FSSC treatment crash and
Matched to camera site by:
• Intersection configuration (T, Y or X)
• SLA and if needed surrounding SLA
• Speed limit
• Divided or undivided road
• Pre-period Crash History ranging 2.5% to 197.5% of treatment site
Not a RLSC control. Uniquely identified control intersections labelled with more than 1 SLA, speed limit or dividedness were only assigned to one control group.</td></tr>
<tr><td>Red Light speed Cameras</td><td>Signalised Intersection
≤100m from camera
Not a FSSC, AvSpeed nor RLC treatment crash
Not at a nearby or underground intersection</td><td>Signalised intersection >100m from camera, not a RLC, RLSC or FSSC treatment crash and
Matched to camera site by:
• Intersection configuration (T, Y or X)
• SLA and if needed surrounding SLA
• Speed limit
• Divided or undivided road
• Pre-period Crash History ranging 2.5% to 197.5% of treatment site
Not a RLC control. Uniquely identified control intersections labelled with more than 1 SLA, speed limit or dividedness were only assigned to one control group.</td></tr>
<tr><td>Fixed Spot Speed Cameras (except those at PtP site and tunnel sites)</td><td rowspan="2">On same road and not a ramp
≤1000m from camera
Not a RLC, AVSpeed or RLSC treatment crash</td><td>On same road and not a ramp
>1000m from camera
Not a RLC, RLSC or FSS treatment crash
And
Matched to camera site by:
• SLA or <2 km from camera
• On same road
• Speed limit, but widened if 70, 90 or 110
RLC and RLSC control crashes may be on the same length of road as the potential FSSC control crash pool. These could not be FSSC control crashes.</td></tr>
<tr><td>Clem 7 and Airport-Link tunnels</td><td>Not a ramp,
Not a RLC, RLSC or FSS treatment crash
On Southern Cross Way or on Port of Brisbane Motorway</td></tr>
<tr><td>Average Speed cameras and FSS at the same site</td><td>On same road and not a ramp
Between average speed cameras and 5 km along road North and South of them.
Not a FSSC, RLC or RLSC treatment crash.</td><td>On same road and not a ramp
>100m from camera
Not a RLC, RLSC or FSS treatment crash
And
Matched to camera site by:
• On same road
• 7.2 km North/South of treatment section</td></tr>
<tr><td>Mobile Speed Cameras</td><td>≤1km from camera in urban sectors and
≤5km from camera in rural sectors
Not a RLC, FSS, AvSpeed or RLSC treatment crash
See details in Section 3.2 for zones, sectors and areas.</td><td>Not a MSC, RLC, RLSC, AvSpeed or FSS treatment crash
And control sites defined as
>1km from camera in urban sectors and
>5km from camera in rural sectors. See details in Section 3.2 for zones, sectors and areas.
And matched to Police Region. All crashes in the Brisbane region were considered urban</td></tr>
</table>

8.4. CRASH COSTS BY SEVERITY YEAR AND POLICE REGION

Table 38 2016 Average crash costs by severity, crash year and Police region according to the distribution of mobile camera crashes (treatment definition=zone)

		Willingness to pay 2016			Human Capital 2016		
		Serious Injury Crash	Minor Injury Crash	Casualty Crash	Serious Injury Crash	Minor Injury Crash	Casualty Crash
Brisbane	2013	$786,155	$110,675	$384,803	$393,839	$ 18,959	$171,095
	2014	$782,804	$110,737	$363,377	$392,631	$ 18,959	$159,428
	2015	$824,004	$115,072	$370,181	$407,477	$ 18,959	$158,768
	2016	$871,709	$112,616	$388,828	$424,668	$ 18,959	$166,585
	2017	$810,992	$109,904	$355,485	$402,789	$ 18,959	$153,409
Central Urban	2013	$1,427,500	$111,392	$895,267	$624,943	$ 18,959	$379,884
	2014	$1,231,944	$112,275	$739,860	$554,476	$ 18,959	$319,121
	2015	$1,262,959	$115,801	$787,499	$565,652	$ 18,959	$339,066
	2016	$1,381,272	$112,819	$897,064	$608,285	$ 18,959	$383,321
	2017	$1,618,774	$105,154	$1,028,833	$693,867	$ 18,959	$430,818
Central Rural	2013	$897,524	$108,613	$466,097	$433,970	$ 18,959	$207,016
	2014	$880,210	$108,651	$447,836	$427,731	$ 18,959	$198,659
	2015	$893,141	$114,683	$453,386	$432,391	$ 18,959	$198,841
	2016	$874,118	$111,211	$468,883	$425,536	$ 18,959	$209,574
	2017	$876,047	$105,523	$451,067	$426,231	$ 18,959	$201,602
Northern Urban	2013	$1,297,129	$110,719	$819,986	$577,965	$ 18,959	$353,147
	2014	$1,338,253	$109,067	$869,020	$592,784	$ 18,959	$373,730
	2015	$1,499,620	$107,846	$939,372	$650,931	$ 18,959	$396,536
	2016	$1,406,215	$112,921	$935,926	$617,273	$ 18,959	$399,704
	2017	$1,362,315	$107,393	$903,785	$601,454	$ 18,959	$388,619
Northern Rural	2013	$771,195	$116,342	$436,354	$388,448	$ 18,959	$199,520
	2014	$745,096	$107,348	$417,584	$379,043	$ 18,959	$194,124
	2015	$954,948	$113,433	$527,275	$454,662	$ 18,959	$233,230
	2016	$917,256	$112,818	$477,329	$441,080	$ 18,959	$210,233
	2017	$1,048,610	$106,502	$595,380	$488,413	$ 18,959	$262,567
South Eastern Urban	2013	$1,307,158	$115,284	$824,176	$581,579	$ 18,959	$353,589
	2014	$1,103,502	$111,158	$645,254	$508,193	$ 18,959	$282,273
	2015	$1,333,633	$115,213	$798,622	$591,119	$ 18,959	$339,882
	2016	$819,104	$110,984	$498,298	$405,712	$ 18,959	$230,498
	2017	$1,505,722	$103,601	$808,578	$653,130	$ 18,959	$337,816
South Eastern Rural	2013	$877,515	$112,136	$426,693	$426,760	$ 18,959	$186,558
	2014	$769,081	$108,244	$357,177	$387,686	$ 18,959	$157,856
	2015	$773,128	$112,122	$347,746	$389,145	$ 18,959	$150,916
	2016	$889,721	$110,189	$385,825	$431,158	$ 18,959	$164,709
	2017	$851,234	$104,574	$381,442	$417,290	$ 18,959	$166,663
Southern Urban	2013	$1,657,566	$108,950	$971,026	$707,846	$ 18,959	$402,445
	2014	$1,483,373	$107,093	$878,745	$645,077	$ 18,959	$370,010
	2015	$1,374,166	$112,181	$893,257	$605,725	$ 18,959	$382,124
	2016	$1,430,821	$110,802	$928,867	$626,140	$ 18,959	$395,251
	2017	$1,200,403	$109,902	$791,858	$543,110	$ 18,959	$346,742
Southern Rural	2013	$826,249	$111,513	$434,317	$408,287	$ 18,959	$194,795
	2014	$809,797	$109,416	$435,596	$402,358	$ 18,959	$197,514
	2015	$865,903	$112,545	$415,702	$422,576	$ 18,959	$181,377
	2016	$1,008,576	$110,044	$453,286	$473,987	$ 18,959	$192,781
	2017	$856,861	$110,072	$416,834	$419,317	$ 18,959	$183,416

Table 38 continued

		Willingness to pay 2016			Human Capital 2016		
		Serious Injury Crash	Minor Injury Crash	Casualty Crash	Serious Injury Crash	Minor Injury Crash	Casualty Crash
All regions	2013	$1,012,217	$111,194	$530,137	$475,299	$ 18,959	$231,141
	2014	$948,633	$109,573	$482,767	$452,387	$ 18,959	$211,737
	2015	$1,003,210	$113,797	$499,992	$472,053	$ 18,959	$215,698
	2016	$1,035,002	$111,628	$514,870	$483,509	$ 18,959	$221,830
	2017	$1,026,376	$107,742	$506,465	$480,401	$ 18,959	$219,243
All Urban	2013	$1,125,069	$110,766	$598,750	$515,964	$ 18,959	$258,070
	2014	$1,057,621	$110,506	$542,183	$491,660	$ 18,959	$234,407
	2015	$1,104,101	$114,519	$565,650	$508,409	$ 18,959	$242,089
	2016	$1,116,636	$112,426	$578,622	$512,925	$ 18,959	$248,279
	2017	$1,128,812	$108,985	$564,136	$517,313	$ 18,959	$241,376
All Rural	2013	$852,114	$111,717	$440,335	$417,607	$ 18,959	$195,895
	2014	$803,121	$108,447	$407,772	$399,952	$ 18,959	$183,123
	2015	$858,680	$112,950	$416,115	$419,973	$ 18,959	$181,985
	2016	$915,988	$110,726	$434,398	$440,623	$ 18,959	$188,445
	2017	$893,867	$106,304	$436,404	$432,652	$ 18,959	$192,355

8.5. MOBILE CAMERA CRASH SAVINGS CALCULATIONS

Table 39 Annual crash counts, relative risks and crash savings in mobile speed camera zones of influence by crash severity and Police region, after introduction: 2013-2017 (treatment definition=zone)

		Post-period Crashes			Relative Risk			Crash Savings		
Region		**Serious Injury Crash**	**Minor Injury Crash**	**Casual-ty Crash**	**Serious Injury Crash**	**Minor Injury Crash**	**Casual-ty Crash**	**Serious Injury Crash**	**Minor Injury Crash**	**Casualty Crash**
Brisbane	2013	1588	2325	3913	0.83	0.96	0.84	317	101	729
	2014	1439	2389	3828	0.89	1.20	0.99	178	-397	50
	2015	1348	2398	3746	1.14	0.96	1.00	-165	100	7
	2016	1406	2458	3864	0.90	0.91	0.87	163	256	587
	2017	675	1252	1927	1.43	0.97	1.10	-204	32	-178
	avg	1445	2393	3838	**0.93**	**1.01**	**0.92**	**123**	**15**	**343**
Central Urban	2013	614	741	1355	1.00	1.02	0.99	1	-14	20
	2014	586	747	1333	0.88	0.96	0.90	80	32	144
	2015	486	631	1117	1.10	0.83	0.92	-44	133	98
	2016	564	639	1203	0.97	1.03	0.97	18	-19	33
	2017	261	321	582	0.87	1.05	0.93	40	-15	41
	avg	563	690	1252	**0.98**	**0.96**	**0.95**	**14**	**33**	**74**
Central Rural	2013	704	478	1182	0.79	0.95	0.84	184	24	217
	2014	616	483	1099	1.01	1.00	1.00	-8	2	-1
	2015	599	424	1023	0.86	1.10	0.94	98	-37	66
	2016	643	397	1040	1.03	1.03	1.02	-17	-11	-18
	2017	274	175	449	1.09	1.19	1.11	-22	-27	-46
	avg	641	446	1086	**0.92**	**1.01**	**0.95**	**65**	**-5**	**66**
Northern Urban	2013	410	429	839	1.51	1.00	1.13	-138	-1	-94
	2014	431	455	886	1.26	0.82	0.93	-88	102	69
	2015	389	402	791	1.49	1.01	1.12	-127	-4	-84
	2016	348	420	768	1.12	0.91	0.93	-37	42	59
	2017	192	178	370	1.18	0.81	0.89	-30	41	46
	avg	395	427	821	**1.35**	**0.94**	**1.03**	**-98**	**35**	**-12**
Northern Rural	2013	330	222	552	1.09	1.19	1.12	-27	-36	-58
	2014	298	184	482	1.04	1.46	1.16	-11	-58	-67
	2015	282	190	472	1.11	1.44	1.22	-28	-58	-84
	2016	294	168	462	1.10	1.41	1.18	-26	-49	-70
	2017	132	76	208	1.23	1.79	1.38	-25	-33	-57
	avg	301	191	492	**1.08**	**1.37**	**1.17**	**-23**	**-50**	**-70**
South Eastern Urban	2013	741	1062	1803	0.71	0.81	0.76	301	250	556
	2014	695	1150	1845	0.68	0.88	0.79	333	154	490
	2015	673	1215	1888	0.64	0.83	0.75	378	256	635
	2016	704	1287	1991	0.64	0.79	0.73	401	332	734
	2017	376	638	1014	0.58	0.75	0.68	271	211	483
	avg	703	1179	1882	**0.67**	**0.83**	**0.76**	**353**	**248**	**604**
South Eastern Rural	2013	182	124	306	0.74	0.78	0.74	63	36	106
	2014	169	145	314	0.68	0.85	0.74	79	25	110
	2015	175	137	312	0.75	0.87	0.78	59	21	86
	2016	198	164	362	1.09	1.57	1.24	-16	-59	-70
	2017	90	89	179	0.66	2.61	1.05	46	-55	-8
	avg	181	143	324	**0.82**	**1.03**	**0.88**	**46**	**6**	**58**

Table 39 Continued.

Region		Post-period Crashes			Relative Risk			Crash Savings		
		Serious Injury Crash	Minor Injury Crash	Casual-ty Crash	Serious Injury Crash	Minor Injury Crash	Casual-ty Crash	Serious Injury Crash	Minor Injury Crash	Casual-ty Crash
Southern Urban	2013	523	635	1158	2.32	0.76	1.16	-297	203	-159
	2014	523	600	1123	1.23	0.71	0.86	-97	244	180
	2015	468	695	1163	1.16	0.83	0.92	-66	147	101
	2016	450	728	1178	1.34	0.68	0.87	-114	338	171
	2017	244	350	594	1.38	0.77	0.95	-67	104	31
	avg	**491**	**665**	**1156**	**1.53**	**0.74**	**0.95**	**-144**	**233**	**73**
Southern Rural	2013	442	352	794	0.80	1.11	0.91	108	-35	77
	2014	462	362	824	0.87	1.34	1.03	69	-91	-21
	2015	484	298	782	0.99	1.18	1.03	3	-45	-24
	2016	471	289	760	0.94	1.36	1.05	30	-77	-35
	2017	217	130	347	0.83	1.37	0.96	45	-35	13
	avg	**465**	**325**	**790**	**0.90**	**1.24**	**1.00**	**52**	**-62**	**-1**
Sum of Regions	2013	5534	6368	11902				512	529	1393
	2014	5219	6515	11734				533	15	955
	2015	4904	6390	11294				106	514	800
	2016	5078	6550	11628				402	754	1391
	2017	2461	3209	5670				55	223	324
	avg	**5184**	**6456**	**11640**				**388**	**453**	**1135**
All Regions					0.97	0.97	0.95	146	193	648
					0.96	1.01	0.96	237	-43	524
					1.01	0.98	0.97	-32	101	315
					1.00	1.00	0.98	-13	7	284
					0.98	1.05	0.99	49	-153	86
					0.98	**0.99**	**0.96**	**85**	**64**	**443**
Urban	2013	3876	5192	9068	1.15	0.91	0.98	-504	491	218
	2014	3674	5341	9015	0.97	0.89	0.89	112	631	1084
	2015	3364	5341	8705	1.08	0.87	0.93	-251	808	681
	2016	3472	5532	9004	0.98	0.87	0.89	56	834	1103
	2017	1748	2739	4487	0.98	0.88	0.89	29	375	535
	avg	3597	5352	8948	**1.05**	**0.89**	**0.92**	**-147**	**691**	**772**
Rural	2013	1658	1176	2834	0.85	1.05	0.92	286	-52	256
	2014	1545	1174	2719	0.95	1.18	1.03	79	-179	-78
	2015	1540	1049	2589	0.95	1.18	1.02	80	-159	-49
	2016	1606	1018	2624	1.02	1.24	1.08	-28	-199	-190
	2017	713	470	1183	0.99	1.43	1.11	10	-140	-116
	avg	1587	1104	2692	**0.94**	**1.16**	**1.01**	**104**	**-147**	**-15**

AVG= 2013-2016 average annual post period crashes, weighted average 2013-2016 for relative risk and average annual crash savings over 2013-2016

All region, urban and rural average annual post period crashes were produced by sum of regions.

All region, urban and rural annual relative risks were produced in regression models.

All region, urban and rural crash savings by year were produced from regression model relative risks.

Table 40 Estimated *Willingness to Pay* and *Human Capital* crash cost saving associated with the Queensland mobile speed camera program by year and police regions: after introduction for 2016 and 2017 and averaged over 2013 to 2016

		WTP			HC		
Region		**Serious Injury Crash**	**Minor Injury Crash**	**Casualty Crash**	**Serious Injury Crash**	**Minor Injury**	**Casualty Crash**
Brisbane	2016	$141,965,950	$28,867,723	$228,370,599	$69,161,085	$4,859,908	$97,840,296
	2017	-$165,230,377	$3,553,916	-$63,450,233	-$82,063,612	$613,068	-$27,381,846
	avg	**$98,484,696**	**$1,918,490**	**$132,414,777**	**$49,088,879**	**$289,583**	**$57,913,775**
Central Urban	2016	$15,929,418	-$2,120,931	$15,611,128	$7,754,715	-$361,573	$6,977,604
	2017	$35,202,818	-$1,542,265	$18,697,270	$17,127,535	-$277,094	$8,356,619
	avg	**$11,780,390**	**$3,792,032**	**$33,457,222**	**$5,745,713**	**$628,667**	**$14,799,998**
Central Rural	2016	-$22,881,024	-$1,219,274	-$16,459,531	-$10,076,358	-$204,897	-$7,033,262
	2017	-$35,450,213	-$2,883,078	-$47,166,094	-$15,195,299	-$519,812	-$19,750,563
	avg	**$88,624,051**	**-$637,770**	**$57,306,894**	**$39,065,998**	**-$101,030**	**$24,384,157**
Northern Urban	2016	-$34,078,346	$4,722,200	$28,274,954	-$16,387,228	$793,562	$12,453,293
	2017	-$31,305,512	$4,373,867	$27,441,411	-$14,581,218	$778,614	$12,101,890
	avg	**-$82,049,945**	**$3,795,102**	**-$7,037,781**	**-$40,377,622**	**$661,541**	**-$3,117,308**
Northern Rural	2016	-$36,451,228	-$5,482,756	-$65,880,404	-$16,000,662	-$920,536	-$28,135,439
	2017	-$33,609,217	-$3,591,594	-$51,425,912	-$14,838,277	-$634,055	-$22,112,663
	avg	**-$32,161,475**	**-$5,496,631**	**-$62,637,357**	**-$14,137,491**	**-$947,877**	**-$26,739,000**
South Eastern Urban	2016	$356,461,324	$36,619,532	$283,162,477	$172,740,897	$6,300,689	$120,882,286
	2017	$230,597,834	$22,072,174	$184,202,145	$113,043,044	$4,001,622	$80,483,416
	avg	**$292,140,872**	**$27,523,243**	**$229,042,311**	**$144,302,180**	**$4,706,287**	**$99,439,788**
South Eastern Rural	2016	-$12,828,064	-$6,584,046	-$34,954,983	-$6,353,891	-$1,124,731	-$16,169,129
	2017	$68,906,151	-$5,685,085	-$6,810,792	$29,889,100	-$1,040,371	-$2,845,482
	avg	**$58,965,240**	**$686,037**	**$47,813,904**	**$26,380,240**	**$106,692**	**$20,310,584**
Southern Urban	2016	-$115,100,795	$37,198,609	$77,728,713	-$54,092,362	$6,408,798	$33,057,775
	2017	-$57,164,029	$11,444,305	$12,903,010	-$27,974,039	$1,971,185	$5,677,603
	avg	**-$124,153,912**	**$25,765,150**	**$32,283,315**	**-$60,619,724**	**$4,416,879**	**$13,996,625**
Southern Rural	2016	$42,388,639	-$8,526,126	-$32,411,484	$18,549,643	-$1,458,877	-$13,791,738
	2017	$53,908,954	-$3,894,925	$10,015,132	$24,390,570	-$671,907	$4,385,473
	avg	**$81,911,979**	**-$6,785,446**	**$591,457**	**$35,304,903**	**-$1,175,630**	**$52,666**

Table 40 continued

		WTP			HC		
Region		Serious Injury Crash	Minor Injury Crash	Casualty Crash	Serious Injury Crash	Minor Injury	Casualty Crash
All Regions	2016	$335,405,874	$83,474,932	$483,441,470	$165,295,840	$14,292,343	$206,081,684
	2017	$65,856,409	$23,847,315	$84,405,936	$29,797,804	$4,221,250	$38,914,447
	avg	**$393,541,898**	**$50,560,208**	**$463,234,742**	**$184,753,077**	**$8,585,111**	**$201,041,286**
Urban	2016	$365,177,551	$105,287,134	$633,147,871	$179,177,107	$18,001,383	$271,211,253
	2017	$12,100,734	$39,901,998	$179,793,602	$5,551,711	$7,087,396	$79,237,682
	avg	**$196,202,102**	**$62,794,017**	**$420,159,845**	**$98,139,426**	**$10,702,956**	**$183,032,878**
Rural	2016	-$29,771,677	-$21,812,202	-$149,706,401	-$13,881,268	-$3,709,040	-$65,129,569
	2017	$53,755,676	-$16,054,683	-$95,387,666	$24,246,093	-$2,866,145	-$40,323,235
	avg	**$197,339,796**	**-$12,233,809**	**$43,074,898**	**$86,613,651**	**-$2,117,845**	**$18,008,408**

AVG= 2013-2016

All region, urban and rural crash savings by year were produced from sum of regions.

8.6. PRIOR CRASH HISTORY AT FIXED CAMERA EVALUATION TREATMENT AND CONTROL SITES

8.6.1. Red Light Cameras

Table 41 Mean number of crashes **(any severity)** at treatment and control intersections prior to red light camera installation

ID	*treatment*	*control*
20	5	5
25 &36	24	7
34&38	29	17
35&54	33	13
39	20	9
41	11	12
42	37	9
45	19	16
46	19	16
47	57	14
48	26	20
49	10	12
50	13	13
55	60	16
56	24	20
57	54	21
58	21	9
59	35	6
61	50	35
2, 67 & 68	72	11
75	20	16
84	7	6
94	20	14
113	26	9
114	30	9
116	19	12

ID	*treatment*	*control*
117&125	19	18
121	22	13
122	11	11
123	21	14
126	32	6
155	18	16
156	17	13
206	3	10
207	17	5
209	12	20
210	8	31
355	31	23
407	24	9
408 &411	15	9
409	3	5
451,452,453&454	12	8
461 & 463	26	11
Site 157 and 158	15	17
Site 460 and 462	27	10
Site 43, 44 and 52	56	21
Site 110, 118, 119 and 115	33	17
Site 62,63,64&65	9	8
Site 69 & 500	64	48
Site 40 & 60	18	15

8.6.1. Fixed Speed, Point to Point and Red Light Speed Cameras

Table 42 Mean number of crashes **(any severity)** at treatment and control intersections prior to red light speed camera installation

ID	*treatment*	*control*
2001	47	8
2002	154	62
2003	26	20
2004	16	16
2005	65	39
2006	133	43
2007	130	29

Table 43 Frequency of treatment and control crashes (**by severity**) prior to fixed spot speed camera installation

	Casualty Crash		Serious Injury Crash		Minor Injury Crash	
ID	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*
Fixed speed						
3001	46	162	13	51	33	111
3002	289	238	73	67	216	171
3003	173	163	40	55	133	108
3004	448	727	143	239	305	488
3005	327	292	90	86	237	206
3006	84	61	36	27	48	34
3007	43	199	18	85	25	114
3008	175	234	48	78	127	156
3009	100	131	32	62	68	69
1001	104	93	35	36	69	57
1002	143	323	57	116	86	207
1011	69	101	35	36	34	65
1012	120	309	44	122	76	187
Point to Point						
4001	585	314	265	136	320	178

8.7. CAMERA SYNERGY

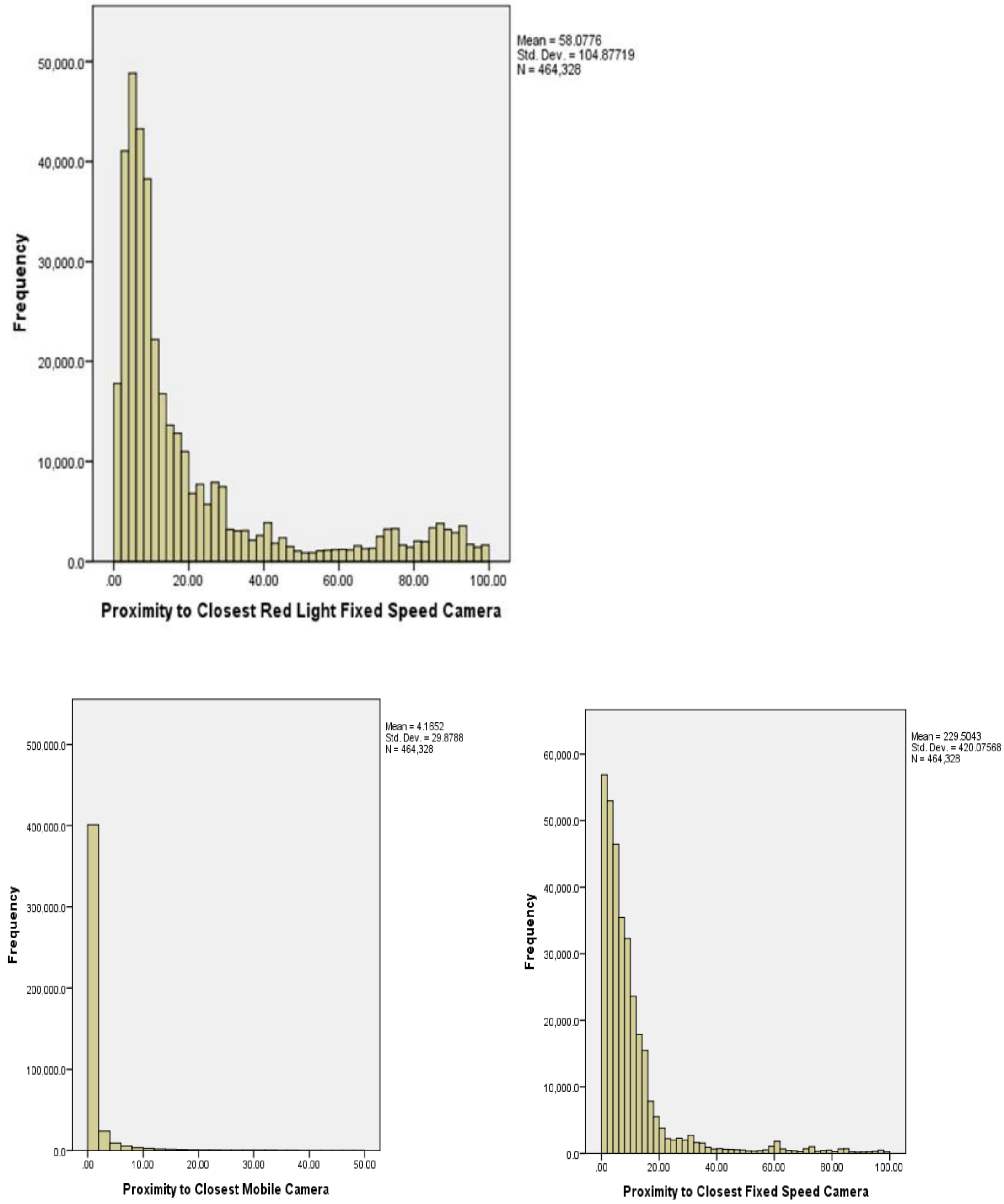

Figure 9 *The proximity of crashes to closest fixed spot speed, mobile speed cameras and Red Light speed Cameras (km)*