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EVALUATION OF THE QUEENSLAND CAMERA DETECTED OFFENCE PROGRAM (CDOP): 2013-2015

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. 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 years 2013-2015. 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.

It was estimated that the CDOP was associated with an overall reduction in police reported casualty crashes of 30% in 2013, 27% in 2014 and 24% in 2015. Estimates for serious casualty crash reductions associated with CDOP were similar for 2013 and 2014 at 29% and 30% respectively falling to 26% in 2015. This represents an annual casualty crash saving of around 4,400 in 2013, 4,000 in 2014 and 3,400 in 2015. Corresponding serious casualty crash reductions were 2,000 in 2013 and 2014 and 1,660 in 2015. Conversion of the estimated crash savings into (2015) cost savings estimated annual savings of around $1.9B in 2013, $1.6B in 2014 and $1.4B in 2015 associated with the program valued using Willingness to Pay estimates or $850M, $717M and $618M using Human Capital crash costs. About 90% of the total savings stem from savings in fatal and serious injury crashes. 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.

Casualty crash risk reductions estimated from the speed survey data from 2013 and 2015 do not correlate particularly well with crash savings measured from the crash based evaluation. This result draws into question how well the surveys highlight speed behaviour in Queensland and highlighting the need to potentially review the speed survey methodology being used.

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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Ethics Statement

Ethics approval was not required for this project.

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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

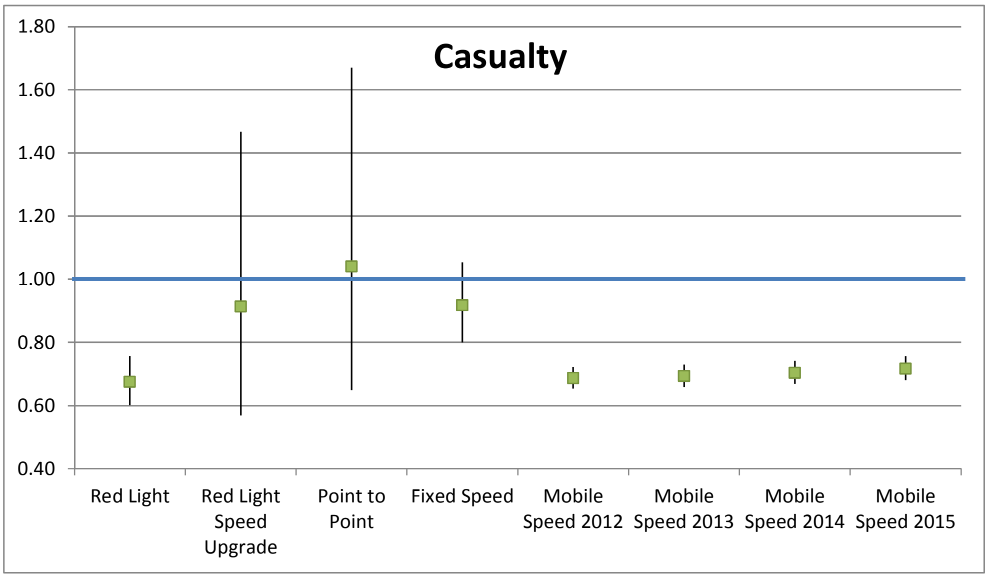
The Queensland Camera Detected Offence Program (CDOP) covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras, and has been expanded over recent years 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 years 2013-2015. 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. 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 December 2015 for the evaluation. 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 upgrades of red light cameras to red light speed camera, 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 each of the focus years of the evaluation as well as in 2012 for comparison. Separate estimates for serious casualty and all casualty crashes are shown. The relative risk estimates indicate the risk of crashing at camera sites with the CDOP program in place compared to the program not being implemented (indicated by the blue line in the figures). The lower the relative risk estimate the larger the estimated crash reduction associated with the camera type. A 95% confidence limit not overlapping the blue line indicates a statistically reliable estimate.



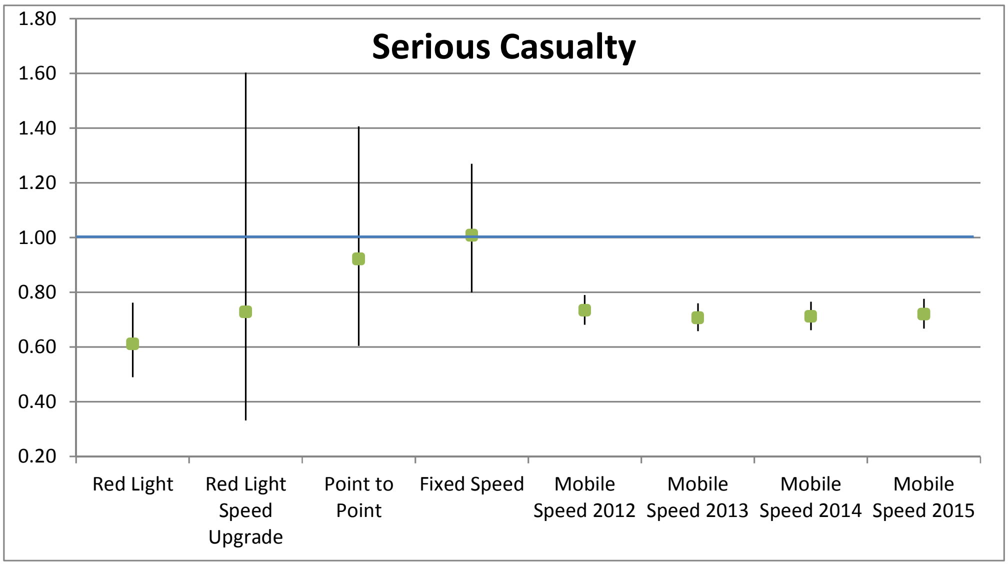


Figure E1: *State-wide relative risk estimates for each CDOP camera type*

Across all regions, estimated serious casualty crash reductions associated with CDOP were relatively consistent over the three years studied. Estimated reductions in all casualty crashes have fallen slightly over the three years with 30% reduction estimated for 2013, 27% in 2014 and 24% in 2015 although these estimates are not different within the bounds of statistical accuracy of the estimates. Estimates for serious casualty crash reductions associated with CDOP were similar for 2013 and 2014 at 29% and 30% respectively falling to 26% in 2015, again all of similar magnitude within the bounds of statistical accuracy. There was some evidence that CDOP has been trending to being more effective for higher severity crashes than minor crashes over the 3 years studied although the statistical evidence for this is weak.

Based on the percentage crash savings estimated, it was estimated that CDOP was associated with absolute casualty crash savings of 4,400 in 2013, 4,000 in 2014 and 3,400 in 2015. Corresponding serious casualty crash reductions were 2,000 in 2013 and 2014 and 1,660 in 2015. Lower absolute serious crash savings in 2015 are reflective to a small extent of the slightly smaller percentage crash savings from the program in 2015 compared to the previous 2 years. To a larger extent it is reflective of the smaller crash basis from which the absolute crash savings were estimated in 2015, a result of other factors improving road safety in Queensland during 2015 compared to previous years. These factors could include other road safety programs or economic circumstances such as a post mining boom downturn in the Queensland economy. Conversion of the estimated crash savings into 2015 dollar value cost savings estimated annual savings to the community of around $1.9B in 2013, $1.6B in 2014 and $1.4B in 2015 associated with the program valued using Willingness to Pay estimates or $850M, $717M and $618M 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 (>80km/h) areas of Northern and South Eastern regions and stronger in metropolitan (<=80km/h) 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 metropolitan highlighting the greater potential for speeding and the greater role of speeding in crash causation in metropolitan areas.

Patterns of changes in travel speed, levels of speeding and casualty crash risk reductions estimated from the speed survey data from 2013 and 2015 did not correlate particularly well with crash savings measured from the crash based evaluation. This was the case even after limiting analysis to survey sites which were represented consistently across all the speed surveys undertaken. This result draws into question how well the surveys highlight speed behaviour in Queensland and highlight the need to potentially review the speed survey methodology being used.

Based on issues identified in developing and applying the evaluation framework for the Queensland CDOP, a number of suggestions related to the future application of the CDOP evaluation framework were made by Newstead and Cameron (2012). A number of these still apply including:

1. Continued periodic application of the framework to monitor CDOP crash effects

2. Further enhancements to data systems to support the future application of the framework

3. Review the methodology of the travel speed surveys to provide more consistent and representative measures of speed behaviour in Queensland over time.

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 (originally operated only in overt mode but since April 2010 deploying up to 30% of urban operations in covert mode), 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.

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 2012-2015. 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.

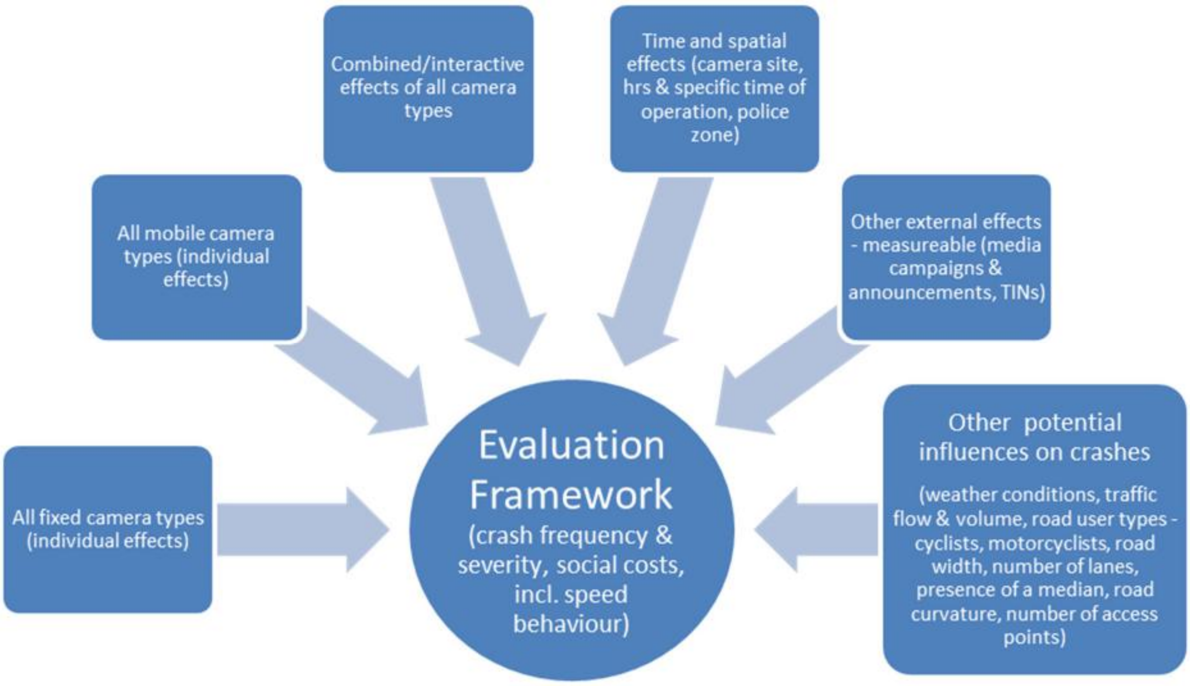


Figure 1 *Elements included in the CDOP evaluation framework design*

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. Finally, trends in speed monitoring data were used to provide a more causal link between camera operation and estimated crash outcomes.

2. DATA

2.1. CRASH DATA

The Data Analysis Unit within TMR supplied MUARC with crash data covering the period from January 1992 to December 2015 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 446,328 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
- Distance from 5 closest mobile speed camera sites and the unique site identifiers for the 5 closest mobile speed camera sites
- 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 2015 Crash cost
- Human Capital 2015 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.

2.2. SPEED SURVEY DATA

TMR has conducted regular surveys of vehicle speeds in Queensland commencing May 2009. Surveys were conducted in May and November of 2009 and 2010, but floods in Queensland interrupted some surveys in May 2011. Between 2011 and 2014, the number of data collection sites was substantially reduced, resulting in the loss of the original 60-100 km/h sites used in the previous surveys (TMR 2016). However, some other 60-100 km/h sites were surveyed during this period, resulting in reliable data being collected at the numbers of sites shown in Table 1.

Table 1 Number of sites sampled by road type and survey (from TMR 2016)

Site type	May 2009 (S1)	Nov 2009 (S2)	May 2010 (S3)	Nov 2010 (S4)	Nov 2011 (S5)	May 2014 (S6)	May 2015 (S7)
50 km/h urban	19	20	19	18	20	18	19

Site type	May 2010 (S1)	May 2011 (S2)	May 2012 (S3)	May 2013 (S4)	May 2014 (S5)	May 2015 (S6)
60 km/h urban	5	10	10	23	18	21
60 km/h rural	7	8	9	17	7	15
80 km/h urban	3	4	5	14	6	15
80 km/h rural	4	6	8	18	8	13
100 km/h urban	1	0	1	2	1	1
100 km/h rural	53	53	60	79	49	51
Total	**73**	**80**	**93**	**153**	**89**	**116**

The speeds recorded at the urban 50 km/h sites were individual speeds (to 0.1 km/h), ranging up to 143 km/h in one survey. Only 20 different sites were used in the seven surveys and 15 sites had data recorded in all seven surveys. This consistent coverage of 50 km/h sites led them to be a focus of the analysis in this report.

The speeds recorded at the other types of sites were frequencies in ranges of speed ("bins") typically 5 km/h wide except at the extremities of the speed distribution. With the exception of the rural 100 km/h surveys, very few of the site types had sites at which data was recorded at all (or most) of the six surveys. For the rural 100 km/h surveys, 16 of the 80 sites used had data recorded in all six surveys and 44 sites were used in five or more surveys. The consistent coverage of the rural 100 km/h sites also led them to be a focus of this report.

In the rural 100km/h site surveys, the first five bin widths were 0-50, 50-60, 60-70, 70-80 and 80-90 and the last bin width was 120-150. As well as for the 5 km/h bins, the analysis used the middle of these speed ranges to represent the frequency of the speeds recorded, except 45 km/h was used to represent 0-50 km/h and 130 km/h was used for 120-150 km/h. Measured speeds above 150 km/h were not recorded (TMR 2016).

2.3. CAMERA DATA

2.3.1. Red Light Cameras

Data on 138 red light camera locations at 126 intersections were provided. Seven intersections had 2 camera sites (153/483153, 157/158, 460/462, 40/60, 43/52, 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, 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 intersections were available for analysis of the crash reduction effects of red light cameras (without speed enforcement) in Queensland.

In addition to the 138 red light camera sites described, information was provided for a further ten red light camera sites (33, 51, 81, 107, 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 ten camera sites to have crashes located within 100 metres of them so they were not considered further in the analysis.

In addition to the ten decommissioned cameras, information was provided for three additional intersections, one with two cameras, 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 (sites 67, 68, 255 & 355). Their locations are described as: Lutwyche Road, Kedron at the intersection with Kedron Park Road; George Street, Rockhampton City at the intersection with Albert Street) and Bruce Highway, Mackay at the intersection with Gordon Street. No crash data was available for these sites so they were not further considered.

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 (1992-2015) all intersections with red light cameras had at least one camera site at the intersection upgraded to digital red light or red light speed camera (6 sites as listed) with the following exceptions:

1. over the period May 2009 to August 2013, red light camera sites (2 and 11) at two unique intersections with crash data were decommissioned awaiting digital upgrade;
2. over the period January 2013 to May 2015, red light camera sites (155, 203, 301, 351, and 460) at five unique intersections with crash data were decommissioned awaiting digital upgrade; and
3. site 154 continued as an analogue red light camera (conversion in 2016)

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 end of 2015. 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 59 intersections that went live prior to 1992. Although the crash effects at these sites were not able to be estimated, 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.

2.3.2. Red light speed and other 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. Only one of these sites (2002) was not previously the site of 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 the effect of a RLS *upgrade* to the sites rather than the effect of a RLS camera referenced against no camera so that all 6 sites could be analysed.

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 2015.

There were 40 fixed spot digital speed cameras at 16 locations that were activated prior to December 2012:

- 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 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 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.

A summary of the events affecting enforcement during the observation period for each of the fixed speed camera used in the analysis is given in Section 8.3 of the Appendix. Generally the events define temporary periods where cameras were off line for various reasons which were not considered significant enough to modify the overall evaluation framework.

2.3.3. 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. Other than special operations a summary of events relevant to mobile camera operations from 2013 to 2015 is given in Section 8.3 of the Appendix. Notable features include:

- Deployment hours increases in January and July 2013 and July 2014
- 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.
- Removal of the requirement for signage of mobile speed cameras in July 2015.

2.4. CRASH COSTS

Human Capital and Willingness to Pay crash costs were provided by TMR with the crash data (Table 2). 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 3 and Table 4). For mobile cameras the crash population was further disaggregated by crash year (Table 47) for the years 2013 to 2015 although showed relative consistency across the years.

Table 2 2012 Willingness to Pay (WTP) and Human Crash (HC) Unit Costs by severity

	WTP	HC
Property Damage Only	$9,678	$12,469
Minor Injury	$40,525	$18,422
Medical Treatment	$124,154	$18,422
Hospitalisation	$626,974	$333,343
Fatal	$8,987,396	$3,345,966

Table 3 2015 WTP Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Fatal and Hospitalisation	Minor Injury	Casualty Crashes
Brisbane		$759,679	$107,893	$348,025
Central	Metro	$841,344	$105,860	$384,344
	Rural	$741,500	$88,009	$142,879
Northern	Metro	$741,500	$106,234	$381,172
South Eastern	Metro	$773,648	$107,281	$329,404
	Rural	$741,500	$103,757	$287,823
Southern	Metro	$741,500	$113,700	$384,205
	Rural	$741,500	$113,700	$390,427

Table 4 2015 HC Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Fatal and Hospitalisation	Minor Injury	Casualty Crashes
Brisbane		$381,162	$18,422	$152,063
Central	Metro	$410,590	$18,422	$166,913
	Rural	$374,612	$18,422	$42,152
Northern	Metro	$374,612	$18,422	$199,784
South Eastern	Metro	$386,196	$18,422	$141,013
	Rural	$374,612	$18,422	$120,225
Southern	Metro	$374,612	$18,422	$174,972
	Rural	$374,612	$18,422	$178,789

Average fatal and hospitalisation 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 metropolitan 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 rural regions and in Northern and Southern metropolitan 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 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 no injury, all crashes in aggregate and all casualty crashes in aggregate (i.e. all crashes excluding non-injury crashes noting that non-injury crashes were not reported beyond 2010 and hence cannot be considered in estimating effects of the program in 2013-15). It should be noted that estimated savings associated with the aggregate categories of *all severity* and *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 8.4 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[1]. 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 5), 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 5 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
		1011	70	1015-1016	80
		1012	110		
2003	60	3001	100		
2004	60	3002	60		
2005	60	3003	100		
2006	60	3004	60	**Point to Point**	
2007	80	3005	60	4001	110
		3006	90		
		3007	100		
		3008	70		
		3009	100		

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

[1] 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.

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 6 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
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
Southern end of Control segment	27°01' S	152°59' E	7.2

The Airport-Link and Clem 7 tunnels had no period without cameras since the cameras were installed before the roads were opened. There was 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 7 Tunnel cameras, treatment and control road lengths and traffic volume

Road	Position of Volume Data	AADT 2013	AADT 2014	AADT 2015	Distance (km)
Clem 7	U12A North of Ipswich Rd O'pass	124,435	125,445	126,115	6.84
Airport-Link	400m East of Sandgate Rd	43,272	45946	63,881	6.7
Southern Cross Wy	913 Gateway Mwy Sth of Toombul Rd O'pass	41,351	41,588	43,516	7.15
Port of Brisbane Mwy	WiM site Lytton	12,164	12,834	13,161	7.07

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.

Table 8 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	1	6	7
Airport-Link	0	5	5
Control			
Southern Cross Way	1	7	8
Port of Brisbane Mwy	7	3	10

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, 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 insufficient statistical power to analyse red light speed cameras (RLSC) by crash type (targeted, rear-end or speed related) given the small number of cameras installed and the limited after installation crash data. Consequently, aggregate effects across all crash types were analysed.

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 8.7 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 speed category) and severity for the years 2013 to 2015. 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.

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 3 and Table 4) 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 metropolitan and rural status according to the geographical definition for selecting controls. The Brisbane region was defined as purely metropolitan due to the paucity of crashes in high speed areas precluding analysis split by speed limit range. All other regions are split into rural and metropolitan on the basis of speed limit (Metropolitan: ≤ 80 km/h or Rural: > 80km/h). A table summarising the treatment and control selection is presented in Section 8.4. 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 metropolitan (≤80 km speed zone) areas and with 4km of a mobile camera site in rural (>80km speed zones) areas. Control areas were all areas outside of the defined treatment areas. Furthermore, fixed speed camera sites were excluded from both treatment and control areas.

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.

3.2.3. Analysis

The time series data were analysed using Equation 4-14 from the CDOP evaluation framework test run of Newstead and Cameron (2012):

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

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 (Brisbane, Central, Northern, South Eastern or Southern)
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 (rural crashes greater than 4km from a speed camera site) (metropolitan crashes greater than 1km from a speed camera site)
	= 1; treatment series (rural crashes ≤ 4km from a speed camera site) (metropolitan crashes ≤ 1km from a speed camera site)
s	= 1 for crashes in the Police region of Brisbane
	= 2 for crashes in the Police region of Central in metropolitan areas (speed limit ≤ 80 km/h)

= 3 for crashes in the Police region of Central in rural areas (speed limit > 80 km/h)
= 4 for crashes in the Police region of Northern in metropolitan areas
= 5 for crashes in the Police region of Northern in rural areas
= 6 for crashes in the Police region of South Eastern in metropolitan areas
= 7 for crashes in the Police region of South Eastern in rural areas
= 8 for crashes in the Police region of Southern in metropolitan 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 month was before introduction of speed camera program

= *1* if month was in the first year (half-year or quarter) after introduction of speed of speed camera program

= *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 2015 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 47) 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, 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 summation over each 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 BOTH THIS ANALYSIS, THE PREVIOUS ANALYSIS 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.
- Suspicion of contaminating influences differentially affecting treatment and control sites was identified for two analogue speed camera sites on the Gold Coast. These sites were excluded from the analysis so that broad effects of the fixed speed camera program could be more accurately estimated. Two speed survey sites were also suspected of contamination and excluded accordingly.

Data disaggregation

- There was insufficient data to produce significant relative risk estimates at each of the severity levels from the fixed speed camera analyses.
- There was insufficient data to analyse fixed camera effectiveness varying over time.
- 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.

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 2015 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 2015 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 fixed 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 each of the years from 2013 to 2015. Results are presented for each crash severity grouping defined, by police region, two speed zone categories outside of Brisbane (≤ 80 km/hr and >80 km/hr), and by 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 9 presents the regional average estimated relative crash risk associated with the CDOP in each year from 2013 to 2015. The relative crash risk estimates are the risk of a crash occurring with the CDOP in place compared to the CDOP not being present, adjusted for the effects of confounding factors represented in the control areas. For example, a relative risk of 0.71 for serious casualty crashes across all regions in 2013 indicates an overall state-wide 29% reduction in serious casualty crash risk associated with implementation of the CDOP. Average relative risk estimates by severity of crash, region and speed limit category of the crash location, and over the entire state, were derived by combining estimates for each camera type in each year after camera implementation. Averages were calculated through weighting the estimates for each camera type by the percentage of pre-implementation crashes covered by the camera type. Combined estimates were obtained within each region over the years 2013 to 2015.

Crash savings were also calculated for each region and speed zone (urbanisation) category by weighting the fixed and mobile camera relative risk estimates for that year within region and speed category by the annual post activation period crash count associated with each in that year. Annual crash effects estimates across all regions and speed zones of both the mobile speed camera and fixed camera program by crash severity grouping are also given in Table 9.

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 10. The Brisbane region relative crash risks associated with CDOP in Table 9 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 crash history accumulating. The fixed camera Central Rural region relative crash risks associated with CDOP in Table 9 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 9 of the other two rural regions (South Eastern and Southern) are derived from five fixed speed camera sites only (two and three respectively).

Estimated serious casualty crash reductions associated with CDOP were relatively consistent over the three years studied ranging between 26% and 30% reductions. A similar magnitude of reduction was associated with all casualty crashes. Minor injury crash reductions were smaller ranging from 17 to 24%, suggesting that CDOP is associated with greater reductions in higher severity crashes than with minor injury crashes. The magnitude of crash reductions is consistent with the findings in the two previous CDOP analyses. In this analysis, results were separated by region and speed limit, resulting in larger variation in crash effects than previously encountered when considering only regional averages. Rural reduction estimates were often smaller (and non-significant) than their metropolitan counterparts. The greatest difference between metropolitan and rural reduction estimates was observed in the South Eastern region, where rural regions saw either no reduction or a non-significant increase in casualty crashes.

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 2 compares the fixed speed (excluding tunnel cameras), red light speed, red light, point-to-point and mobile camera state-side relative risk estimates and 95% confidence intervals for 2012 to 2015, for serious casualty and all severity crashes. The blue line indicates the line of no program effect (a relative risk of 1). Estimates of the mobile speed camera program are shown for 2012 as a benchmark for comparison of the mobile speed camera program crash effects over the years of interest, 2013-2015.

Crash reduction estimates associated with various camera types showed red light cameras have similar associated crash effects to mobile speed cameras, albeit with a much smaller coverage of the total crash population. 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 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 were also statistically reliable, 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 also presents the estimated absolute annual crash savings, associated with the CDOP by year, crash severity, police region, speed limit category and camera type. The estimated 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 9. 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 both 2013 and 2014, CDOP was associated with an absolute saving of over 4,000 casualty crashes in each year. In 2015, the saving was estimated to be slightly less at 3,400 casualty crashes saved. Savings in serious casualty crashes showed a similar pattern with estimated savings of around 2,000 serious casualty crashes in 2013-14 and around 1,660 in 2015. Mobile speed camera percentage crash reductions in 2015 were estimated to be consistent with effects estimated in 2013-14 (Figure 2). Noting this, the reduced total program crash savings in 2015, which are driven largely by the mobile speed camera program, are driven by the lower overall crash base in Queensland in 2015 from which the estimated absolute crash savings are estimated rather than a reduction in effectiveness of the program.

Examining regional effects, the serious casualty crash reduction estimates were greatest in the Brisbane and South Eastern metropolitan regions and over half of the 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 of South Eastern, Northern and Southern rural regions are based on non-significant relative risk estimates with wide confidence intervals produced from a small set of crashes, so are not cause for concern.

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

Table 11 presents the translation of crash savings into economic cost savings using the Human Capital and Willingness to Pay approaches respectively. Conversion of the estimated casualty crash savings into cost savings estimated annual savings of between $620M and $800M associated with the CDOP program valued using Human Capital crash costs and $1.4B to $1.9B valued using Willingness to Pay estimates over the three years of study focus. About 90% of the total casualty crash cost savings stem from savings in serious casualty crashes.

Table 9 Estimated relative risk of crashes (with CDOP vs without CDOP) and crash savings associated with the Queensland CDOP by crash severity

		Weighted average Relative Risks			Estimated Crash Savings		
2013		**Serious Casualty**	**Minor Injury**	**†All Casualty**	**Serious Casualty**	**Minor Injury**	**†All Casualty**
All**		0.71	0.76	0.70	1,969	1,867	4,404
Brisbane		0.71	0.78	0.71	656	697	1,626
Central	Metro	0.67	0.77	0.70	272	206	546
	Rural	0.66	0.77	0.70	165	67	234
Northern	Metro	0.88	0.65	0.69	56	230	370
	Rural‡	0.90	0.71	0.81	12	26	40
South-	Metro	0.55	0.82	0.67	587	225	880
Eastern	Rural‡	1.01	1.11	1.03	-1	-8	-4
Southern	Metro	0.78	0.60	0.65	143	392	589
	Rural	0.69	0.84	0.74	79	32	122
Fixed Cameras		0.84	0.89	0.87	21	29	52
Mobile Speed Cameras*		0.71	0.73	0.69	1,948	1,838	4,352
2014		**Serious Casualty**	**Minor Injury**	**†All Casualty**	**Serious Casualty**	**Minor Injury**	**†All Casualty**
All**		0.70	0.83	0.73	2,029	1,424	4,045
Brisbane		0.67	‡0.95	0.77	730	‡134	1,173
Central	Metro	0.73	0.74	0.71	197	239	487
	Rural	0.81	‡0.84	0.82	75	‡46	122
Northern	Metro	0.84	0.60	0.65	77	284	441
	Rural‡	0.90	0.90	0.89	12	6	20
South	Metro	0.52	0.80	0.65	623	275	961
Eastern	Rural‡	1.43	0.91	1.08	-28	20	-18
Southern	Metro	0.62	0.56	0.56	294	432	808
	Rural	0.80	‡1.07	‡0.88	50	‡-12	‡51
Fixed Cameras					29	28	54
Mobile Speed Cameras*		0.71	0.74	0.70	2,001	1,396	3,991
2015		**Serious Casualty**	**Minor Injury**	**†All Casualty**	**Serious Casualty**	**Minor Injury**	**†All Casualty**
All**		0.74	0.85	0.76	1,661	1,279	3,417
Brisbane		0.79	‡0.92	0.83	360	‡216	763
Central	Metro	0.70	0.66	0.66	193	303	533
	Rural	0.77	‡0.91	0.81	88	‡19	110
Northern	Metro	0.93	0.61	0.69	31	243	342
	Rural‡	0.83	1.11	0.90	18	-5	15
South	Metro	0.51	0.76	0.63	625	348	1,033
Eastern	Rural‡	0.85	1.72	1.21	20	-82	-53
Southern	Metro	0.55	0.72	0.61	327	240	663
	Rural‡	1.00	1.02	0.98	-1	-2	10
Fixed Cameras					17	27	46
Mobile Speed Cameras*		0.72	0.76	0.72	1,643	1,252	3,370

‡ based on non-significant mobile camera relative risks, see table 13 for non-significant fixed camera relative risks
* Risk is from model that estimated state-wide directly, crash savings is the sum of the regions for mobile cameras
** Risk is the weighted average of the state-wide camera based models, crash savings is the sum of the regions
† Estimated from an all casualty crash model

Table 10 Estimated relative risks and annual crash savings associated with the Queensland CDOP fixed camera types, by crash severity

	Rate Ratios (directly from regression)			Crash Savings*		
Average Effects Applied Over 2013-2015	**Serious Casualty**	**Minor Injury**	**Casual-ty†**	**Serious Casualty**	**Minor Injury**	**Casual-ty†**
All Fixed				34	34	66
All Fixed (except Clem & Airport)	0.85	0.88	0.87			
Red Light Camera	0.68	0.77	0.75	28	29	54
Red Light Speed Camera						
Upgrade from RLC to RLSC ‡	0.78	1.03	0.93	1	0.4	1
Tunnel Cameras	0.03	0.28	0.17	6	7	14
Clem 7 tunnel Cameras	0.04	0.19	0.12			
Airport Link Tunnel Camera‡		0.51	0.28			
PtP Avg/spot speed cameras‡	0.92	1.04	0.98	2	-1	1
Other fixed speed cameras‡	1.06	1.02	1.03	-2	-2	-4

‡based on non-significant relative risks
*crash savings is the sum of regions

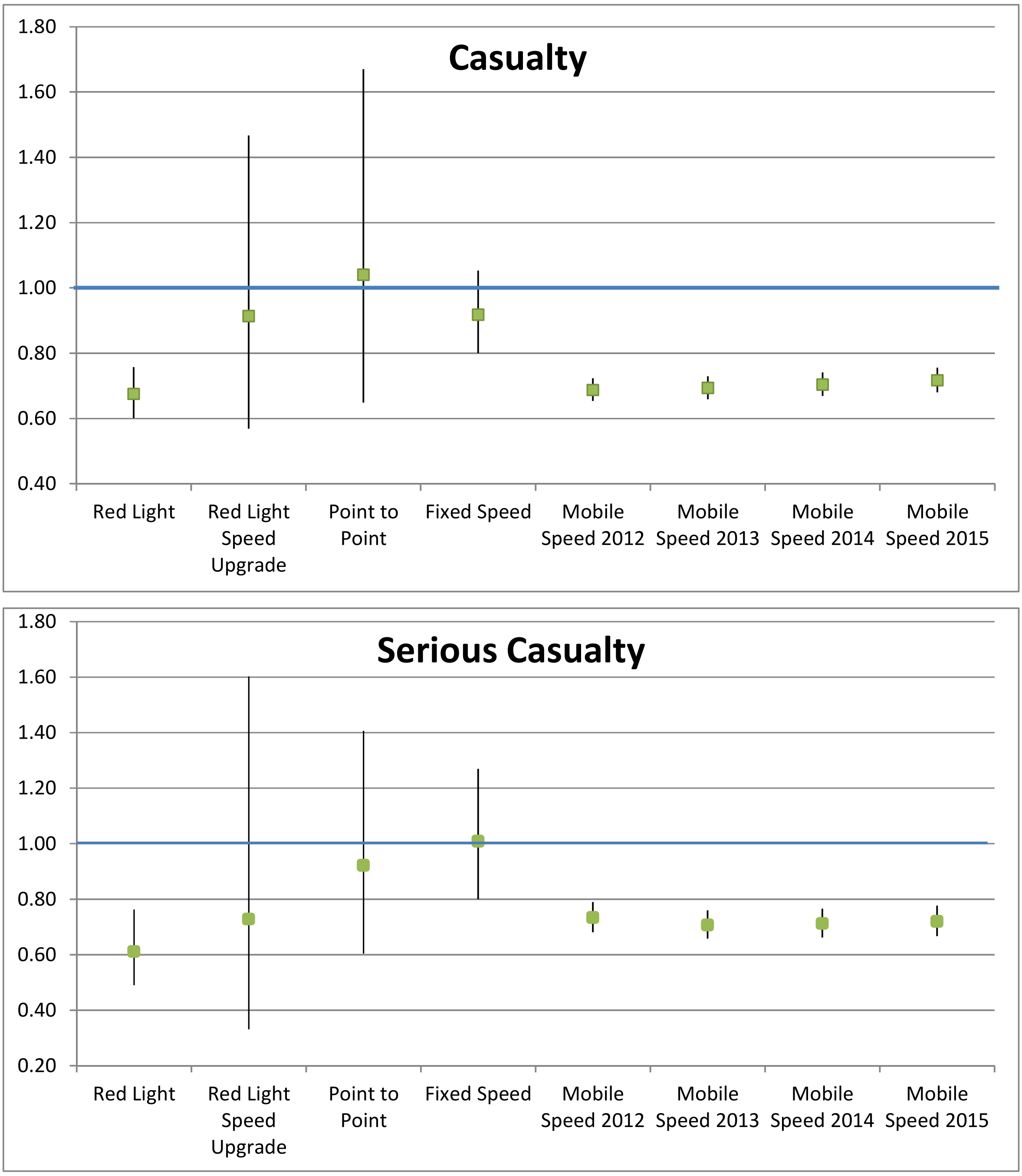


Figure 2 *State-wide relative risk estimates for each CDOP camera type*

Table 11 Estimated annual economic savings associated with the Queensland CDOP, by crash severity: Human capital approach and Willingness to Pay (2015 million AUS$)

		WTP			HC		
2013		**Serious Casualty**	**Minor Injury**	**Casualty†**	**Serious Casualty**	**Minor Injury**	**Casualty†**
All*‡		$1,734	$201	$1,928	$836	$34	$852
Brisbane		$488	$75	$591	$246	$13	$263
Central	Metro	$229	$22	$237	$112	$4	$105
	Rural	$244	$7	$212	$106	$1	$89
Northern	Metro	$40	$26	$149	$21	$4	$69
	Rural‡	$20	$3	$42	$9	$0.5	$18
South	Metro	$474	$24	$345	$234	$4	$152
Eastern	Rural‡	-$2	-$0.9	-$2	-$0.8	-$0.1	-$0.9
Southern	Metro	$109	$42	$241	$55	$7	$109
	Rural	$131	‡$3	$113	$56	$0.6	$46
Fixed Speed Cameras		$16	$3	$18	$8	$1	$8
Mobile Speed Cameras*‡		$1,718	$198	$1,910	$828	$34	$844
2014							
All*‡		$1,595	$151	$1,608	$793	$26	$717
Brisbane		$550	‡$14	$410	$276	‡$2	$180
Central	Metro	$172	$25	$217	$83	$4	$96
	Rural	$84	‡$5	$83	$38	‡$1	$36
Northern	Metro	$58	$30	$186	$29	$5	$86
	Rural‡	$17	$1	$21	$7	$0	$9
South	Metro	$455	$29	$330	$231	$5	$146
Eastern	Rural‡	-$28	$2	-$8	-$13.2	$0.4	-$3.4
Southern	Metro	$221	$46	$331	$111	$8	$152
	Rural	$67	‡-$1.3	‡$38	$30	‡-$0.2	‡$16
Fixed Speed Cameras		$22	$3	$19	$11	$0.5	$8
Mobile Speed Cameras*‡		$1,574	$148	$1,589	$782	$26	$709
2015							
All*‡		$1,423	$142	$1,422	$691	$24	$618
Brisbane		$285	‡$24	$275	$141	‡$4	$118
Central	Metro	$165	$34	$232	$80	$6	$102
	Rural	$123	‡$2	$98	$54	‡$0.4	$41
Northern	Metro	$26	$27	$169	$12.7	$4	$76
	Rural‡	$26	-$0.6	$15	$11.4	-$0.10	$6.1
South	Metro	$494	$38	$372	$245	$6	$161
Eastern	Rural‡	$18	-$9	-$22	$8.7	-$2	-$9.1
Southern	Metro	$287	$26	$275	$138	$4	$119
	Rural‡	-$0.8	-$0.2	‡$8	-$0.35	-$0.03	‡$3.3
Fixed Speed Cameras		$13	$3	$16	$6.6	$0.5	$7
Mobile Speed Cameras*‡		$1,410	$139	$1,406	$685	$23	$611

‡ based on non-significant mobile camera relative risks, see table 13 for non-significant fixed camera relative risks
*Risk is from model that estimated state-wide directly, crash savings is the sum of the regions for mobile cameras
**Risk is the weighted average of the state wide camera based models, crash savings is the sum of the regions
† Estimated from an all casualty crash model

4.1.2. Red Light Cameras

Table 12 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 minor injury crashes. As this estimate was based on three post period treatment minor injury crashes per year (and fewer pre-period crashes) and was not significant, the all-region average red light camera reduction estimate was used to estimates to northern metropolitan crash savings associated with red light cameras.

Table 12 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		0.68	0.77	0.75
		(0.55, 0.839)	(0.673, 0.877)	(0.667, 0.833)
		0.0003	0.0001	<.0001
All without sites 45, 61 &123		0.61	0.70	0.68
		(0.49, 0.76)	(0.61, 0.80)	(0.60, 0.76)
		<.0001	<.0001	<.0001
Brisbane		0.71	0.77	0.76
		(0.52, 0.97)	(0.642, 0.934)	(0.649, 0.891)
		0.031	0.007	0.0007
	Without sites 61&45	0.65	0.68	0.67
		(0.466, 0.898)	(0.56, 0.83)	(0.57, 0.80)
		0.009	<.0001	<.0001
Central		0.74	0.69	0.71
		(0.424, 1.307)	(0.478, 0.984)	(0.524, 0.954)
		0.30	0.04	0.023
Northern		0.93	1.32	1.29
		(0.293, 2.962)	(0.673, 2.571)	(0.736, 2.249)
		0.91	0.42	0.38
South Eastern		0.59	0.71	0.67
		(0.397, 0.865)	(0.55, 0.924)	(0.537, 0.825)
		0.007	0.011	0.0002
	Without site 123	0.46	0.62	0.56
		(0.299, 0.694)	(0.47, 0.81)	(0.45, 0.71)
		0.0002	0.001	<.0001
Southern		0.68	0.91	0.82
		(0.31, 1.477)	(0.52, 1.575)	(0.522, 1.285)
		0.33	0.73	0.39

† Estimated from an all casualty crash model

Individual statistically significant camera site crash reductions are presented in Table 13. Some presented very large reductions of 80% and higher, however, three sites presented statistically significant increases in crash rates: sites 45, 61 and 123. 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% units. 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 flow 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 risk.

An increase in crash rates was associated with the RL camera on Lutwyche Road, Windsor (# 45) which was made operational in 1999. Four cameras, with no associated crash data were made operational in 1999, 2012 and 2014 at intersections along Lutwyche Road in nearby suburbs (#51, # 67, #68 and #69). As they were all made operational at the same time or after #45, these 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 increase at site 123. 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. 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 CDOP to these three anomalous RL camera intersections was examined via a repeat analysis excluding them. The whole program and casualty regional (Brisbane and South Eastern Metropolitan) regression relative risks from this sensitivity analysis are presented inTable 12. Estimates did not change within the bounds of statistical confidence demonstrating that the 3 anomalous sites identified did not have a major bearing on the overall analysis.

Table 13 Statistically significant estimated CDOP red light camera effects associated with individual fixed camera sites

		All Casualty			Serious Injury			Minor Injury		
Camera	Location	Estimate	(95% CI)	Significance	Estimate	(95% CI)	Significance	Estimate	(95% CI)	Significance
decrease										
25	Newnham Road, Mount Gravatt East (at i/s with Broadwater Road)	0.17	(0.076, 0.384)	<.0001	0.17	(0.044, 0.676)	0.012	0.17	(0.062, 0.464)	0.0006
34&38	Sandgate Road, Clayfield (at i/s with Junction Road & at i/s with Bayview Terrace)	0.50	(0.264, 0.947)	0.033						
35&54	Leopard Street, Woolloongabba (at i/s with Vulture Street & at i/s with Stanley Street)							0.42	(0.206, 0.855)	0.017
36	Logan Road, Upper Mount Gravatt (at i/s with Klump Road)	0.16	(0.07, 0.348)	<.0001	0.19	(0.049, 0.718)	0.015	0.14	(0.053, 0.393)	0.0002
47	Kessels Road, Upper Mount Gravatt (at i/s with Macgregor Street)	0.51	(0.281, 0.94)	0.031				0.47	(0.239, 0.914)	0.026
48	Mains Road, MacGregor (at i/s with Leadenhall Street)				0.07	(0.009, 0.543)	0.011			
56	McCullough Street, Sunnybank (at i/s with Canna Street)	0.36	(0.129, 0.998)	0.050				0.24	(0.067, 0.895)	0.033
57	Rochedale Road, Rochedale South (at i/s with Underwood Road)	0.10	(0.035, 0.259)	<.0001				0.08	(0.022, 0.27)	<.0001
59	Strathpine Road, Bald Hills (at i/s with Bald Hills Road)	0.37	(0.162, 0.823)	0.015				0.38	(0.142, 1.011)	0.053
407	Nicklin Way, Battery Hill (at i/s with Beerburrum Street)	0.38	(0.153, 0.954)	0.039						
3005	FSC: Gold Coast Highway, Southport	0.45	(0.319, 0.647)	<.0001				0.39	(0.25, 0.617)	<.0001
461 & 463	Takalvan Street, Bundaberg (at i/s with Bourbong Street & at i/s with Johanna Street)	0.51	(0.254, 1.006)	0.052						
Site 110, 118, 119	Kumbari Avenue, Southport (at i/s with Smith Street) & Wardoo Street, Southport (at i/s with Queen Street)	0.46	(0.299, 0.714)	0.0005	0.22	(0.102, 0.459)	<.0001			
Site 460 and 462	Takalvan Street, Millbank (at i/s with Walker Street) & Walker Street, Bundaberg West (at i/s with Takalvan Street)	0.13	(0.05, 0.323)	<.0001	0.06	(0.009, 0.401)	0.004	0.16	(0.054, 0.49)	0.001
2001	RLSC: Waterworks Road, Ashgrove (at i/s with Jubilee Terrace)							0.09	(0.009, 0.894)	0.040
increase										
3004	FSC: Gold Coast Highway, Broadbeach	1.61	(1.178, 2.189)	0.003				1.78	(1.228, 2.582)	0.002
3006	FSC: Warrego Highway, Redwood	2.59	(1.054, 6.383)	0.038						
45	Lutwyche Road, Windsor (at i/s with Northey Street)	3.08	(1.272, 7.475)	0.013						
61	Moreton Bay Road, Capalaba (at i/s with Old Cleveland Road and Finucane Road)	2.50	(1.254, 4.981)	0.009				4.28	(1.864, 9.83)	0.0006
123	Bermuda Street, Burleigh Waters (at i/s with Christine Avenue)	3.17	(1.448, 6.928)	0.004				3.95	(1.28, 12.174)	0.017

For this evaluation, annual crashes 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 2015. The average annual count over the period is given in Table 14 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. Table 15 shows the average annual saving across 2013 to 2015 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 16 and Table 17 respectively.

If sites 45, 61 and 123 are excluded from the analyses the additional estimated savings has been included in Table 15, Table 16 and Table 17.

Table 14 Average annual post-activation red light camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	All Casualty
All*	59	91	151
Brisbane	30	50	80
Central	7	11	18
Northern	5	3	8
South Eastern	11	20	31
Southern	7	8	15

*sum of regions

Table 15 Average annual absolute crash savings associated with red light cameras, by severity and Police region

	Serious Casualty	Minor Injury	All Casualty
All*	28	29	54
With exclusions	38	43	77
Brisbane	12	14	25
With exclusions	16	23	38
Central	2	5	7
Northern	2	1	3
South Eastern	8	8	15
With exclusions	13	12	24
Southern	3	1	3

*sum of regions

The casualty crash reductions of 36% (Table 12) associated with red light cameras translated to the average annual prevention of 54 casualty crashes, 28 of which were serious, saving society about $19 million per year by the Willingness to Pay approach.

Table 16 Average annual savings associated with red light cameras, by severity and Police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty
All*	$21,331,393	$3,135,105	$18,932,809
With exclusions	$29,195,922	$4,599,306	$26,766,736
Brisbane	$9,299,427	$1,560,640	$8,743,280
With exclusions	$12,423,433	$2,528,333	$13,364,220
Central	$2,023,184	$533,552	$2,863,913
Northern	$1,631,129	$96,205	$999,586
South Eastern	$6,014,665	$849,647	$5,083,240
With exclusions	$10,183,020	$1,302,565	$7,888,088
Southern	$2,362,989	$95,061	$1,242,791

*sum of regions, rounding errors apply

Table 17 Average annual savings associated with red light cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty
All*	$10,673,564	$537,302	$8,329,925
With exclusions	$14,610,865	$787,862	$11,763,599
Brisbane	$4,665,907	$266,469	$3,820,222
With exclusions	$6,233,350	$431,696	$5,839,260
Central	$987,347	$92,850	$1,243,738
Northern	$824,059	$16,683	$523,914
South Eastern	$3,002,450	$145,898	$2,176,068
With exclusions	$5,083,244	$223,672	$3,376,786
Southern	$1,193,801	$15,402	$565,984

*sum of regions, rounding errors apply

4.1.3. Red Light Speed Cameras

Six of the seven RLSC sites 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 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 sites except 2002 (in Brisbane) the analysis defined a before period as the period from the red light camera operations to the red light speed camera operations; providing at least nine years of before period data. Site 2002 had no previous red light camera, so the pre-period is defined as for the other camera types.

Table 18 presents a summary of the regression result estimates, none of which achieved statistical significance. Cameras 2003 to 2007 were made operational in July 2013 so have less than two and a half years of post-period data. The overall analysis is based on only seven camera sites, with five being from regions other than Brisbane and only one camera in the South East region. Combined, these factors mean that data is too limited to produce significant estimates of risk at this point in time. Consequently, estimates presented should be viewed with some caution, particularly those from the regional analyses.

Table 18 Estimated crash risks associated with the upgrade of a red light camera to a red light speed camera from

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	0.78	1.03	0.93
	(0.366, 1.654)	(0.578, 1.822)	(0.588, 1.458)
	0.51	0.93	0.74
Brisbane	0.68	0.65	0.67
	(0.223, 2.081)	(0.259, 1.621)	(0.33, 1.351)
	0.50	0.35	0.26
Central	1.48	0.71	0.87
	(0.161, 13.611)	(0.122, 4.116)	(0.216, 3.534)
	0.73	0.70	0.85
Northern	0.59	1.02	0.83
	(0.118, 2.896)	(0.331, 3.142)	(0.335, 2.066)
	0.51	0.97	0.69
South Eastern	1.07	2.53	1.91
	(0.213, 5.321)	(0.819, 7.84)	(0.76, 4.802)
	0.94	0.11	0.17

† Estimated from an all casualty crash model

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. Thus 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 2015, and are given in Table 19. Table 14 indicates 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. Table 20 shows the average annual saving across 2013 to 2015 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 21 and Table 22 respectively.

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	9	13
Brisbane	1	3	4
Central	1	1	2
Northern	1	2	3
South Eastern	1	3	4

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

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

	Serious Casualty	Minor Injury	Casualty†
All*	0.7	0.4	0.9
Brisbane	0.5	1.6	2.0
Central	-0.3	0.5	0.3
Northern	0.6	-0.04	0.6
South Eastern	-0.1	-1.7	-1.9

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

The casualty crash reductions of 7% (Table 18) associated with red light speed camera upgrades translated to the average annual prevention of 0.9 casualty crashes, the majority of this being serious casualty crash savings, saving society about $0.4 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 20-22 do not results 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 approach

	Serious Casualty	Minor Injury	Casualty
All*	$504,363	$42,333	$395,133
With exclusion		$118,519	$1,024,984
Brisbane	$354,414	$175,693	$692,992
Central	-$221,917	$52,647	$112,389
With exclusion		$128,834	$742,240
Northern	$429,160	-$4,198	$217,859
South Eastern	-$57,293	-$181,810	-$628,107

*sum of regions, rounding errors apply

Table 22 Average annual savings associated with red light cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty
All*	$257,740	$7,213	$196,901
With exclusion		$20,471	$470,433
Brisbane	$177,824	$29,998	$302,791
Central	-$108,299	$9,162	$48,808
With exclusion		$22,420	$322,339
Northern	$216,815	-$728	$114,187
South Eastern	-$28,600	-$31,220	-$268,884

*sum of regions, rounding errors apply

4.1.4. Fixed Speed Cameras

The effectiveness of fixed speed cameras over 2013 to 2015 are 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 103 to 110) and by region and overall effects of all other fixed speed cameras (sites 1001, 1002, 1011, 1012 and 3001 to 3009). Table 23 and Table 24 present a summary of the fixed speed camera effectiveness estimates, all of which, except the Clem 7 Tunnel cameras in Table 24, were not statistically significant. There were no fixed speed cameras in the Norther region, nor in the metropolitan Southern region.

Table 23 Estimated relative crash risks associated with fixed speed cameras (excluding point-to-point and tunnel cameras)

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	1.058	1.024	1.026
	(0.857, 1.306)	(0.878, 1.194)	(0.907, 1.161)
	0.602	0.766	0.682
Brisbane	1.43	0.910	1.04
	(0.936, 2.17)	(0.679, 1.219)	(0.818, 1.321)
	0.10	0.527	0.75
Central Metro	1.298	1.098	1.150
	(0.708, 2.379)	(0.7, 1.722)	(0.803, 1.647)
	0.398	0.684	0.447
Central Rural	1.125	0.761	0.866
	(0.547, 2.313)	(0.394, 1.469)	(0.535, 1.401)
	0.749	0.416	0.558
South Eastern Metro	0.852	0.937	0.907
	(0.567, 1.282)	(0.706, 1.242)	(0.72, 1.144)
	0.444	0.650	0.411
South Eastern Rural	0.730	1.418	1.169
	(0.396, 1.346)	(0.97, 2.073)	(0.85, 1.608)
	0.313	0.071	0.336
Southern Rural	1.054	1.189	1.125
	(0.591, 1.877)	(0.731, 1.932)	(0.778, 1.625)
	0.859	0.486	0.532

† Estimated from an all casualty crash model

Table 24 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	0.03	0.28	0.17
	(0.002, 0.444)	(0.075, 1.04)	(0.053, 0.546)
	0.01	0.06	0.003
Clem 7	0.04	0.19	0.12
	(0.003, 0.662)	(0.043, 0.827)	(0.032, 0.457)
	0.02	0.03	0.002
Airport Link	*	0.51	0.28
		(0.1, 2.635)	(0.062, 1.275)
		0.43	0.10
Point-to-Point	0.92	1.04	0.98
	(0.604, 1.406)	(0.648, 1.67)	(0.717, 1.341)
	0.70	0.87	0.90

* No estimate available due to limited data.
† Estimated from an all casualty crash model

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. Serious casualty crash estimates could not be obtained for the Airport Link site as there were insufficient crash counts. 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.

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 2015. The average annual count over the period is given in Table 25 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 26 shows the average annual saving across 2013 to 2015 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 27 and Table 28 respectively.

Table 25 Average annual post-activation fixed speed camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	Casualty
All Tunnel	0.2	2.7	2.9
Point to Point	20	15	35
All other fixed*	37	66	103
Brisbane	11	17	28
Central Metro	5	9	15
Central Rural	4	4	8
South Eastern Metro	7	16	23
South Eastern Rural	5	14	20
Southern Rural	5	5	10

*sum of regions

Table 26 Average annual absolute crash savings associated with fixed speed cameras, by severity and Police region

	Serious Casualty	Minor Injury	Casualty
All Tunnel	6	7	14
Point to Point	2	-1	1
All other fixed*	-2	-2	-4
Brisbane	-3	2	-1
Central Metro	-1	-1	-2
Central Rural	-0.4	1	1
South Eastern Metro	1	1	2
South Eastern Rural	2	-4	-3
Southern Rural	-0.2	-1	-1

*sum of regions

Table 27 Average annual savings associated with fixed speed cameras, by severity and Police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty
All Tunnel	$4,614,996	$743,681	$4,865,367
Point to Point	$1,243,023	-$51,637	$98,544
All other fixed*	-$1,588,442	-$204,050	-$1,528,492
Brisbane	-$2,492,446	$178,219	-$368,290
Central Metro	-$1,032,412	-$88,283	-$734,894
Central Rural	-$329,600	$119,763	$184,277
South Eastern Metro	$937,113	$115,828	$774,228
South Eastern Rural	$1,504,900	-$433,345	-$818,541
Southern Rural	-$175,996	-$96,232	-$565,272

*sum of regions

Table 28 Average annual savings associated with fixed speed cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty
All Tunnel	$2,315,534	$126,979	$2,125,836
Point to Point	$627,985	-$10,809	$29,072
All other fixed*	-$781,746	-$32,507	-$695,031
Brisbane	-$1,250,563	$30,430	-$160,918
Central Metro	-$503,834	-$15,363	-$319,149
Central Rural	-$166,517	$25,069	$54,365
South Eastern Metro	$467,796	$19,890	$331,437
South Eastern Rural	$760,287	-$76,940	-$341,908
Southern	-$88,915	-$15,592	-$258,857

*sum of regions, rounding errors apply

The non-statistically significant casualty crash effects associated with fixed speed cameras translated to the average annual savings of 11 casualty crashes saving society about $4.3 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.

4.1.5. Homogeneity of camera type and site

As has been reported through 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: Red light, red light speed, 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 29 with a low significance value indicating non-homogeneous crash effects across cameras. Point to Point cameras are not tabled because they represent a single region and are only in one location.

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

Table 29 Significance probabilities from tests of homogeneity by injury severity: (X^2, *d.f.*)

	Serious Casualty	Minor Injury	Casualty Crash
Camera Type	<0.0001	<0.0001	<0.0001
	(27.0,3)	(28.6,3)	(52.3,3)
Camera sites	<0.0001	<0.0001	<0.0001
	(124.3,65)	(203.9,65)	(231.4, 65)
Red Light †		<0.0001	<0.0001
		(151.0,50)	(184.0,50)
Red Light Speed †	0.271	0.059	0.158
	(9.9,8)	(15.0,8)	(11.8,8)
Fixed Speed †	0.456	<0.0001	<0.0001
	(11.9, 12)	(51.0,12)	(43.0,12)
Regions			
Red Light †	0.124	0.192	0.914
	(5.75,3)	(4.74,3)	(0.52,3)
Red Light Speed †	0.782	0.313	0.198
	(1.75,4)	(4.76,4)	(6.02,4)
Fixed Speed †	0.124	0.192	0.914
	(5.75,3)	(4.74,3)	(0.52,3)

† Within model of one camera type

4.1.6. Mobile Speed Cameras

Table 30 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 sites from 2013-2015. Overall, around 76% of all police reported casualty crashes in Queensland were inside the halos of influence. This is broadly consistent with the high coverage of crashes by the mobile speed camera program observed in the previous evaluation. 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 serious casualty crashes which are over represented on high speed rural roads which predominate in the more rural areas.

For analysis, monthly aggregate crash counts were derived for each speed zone in each region as a time series of treatment and control data covering the years 1992 to 2015. The mobile speed camera program commenced operation early in 1997 which defined the before and after periods for the evaluation analysis.

Table 30 Percentage of all reported crashes in Queensland within defined mobile speed camera halos of influence (2013-2015)

		Serious Casualty	Minor Injury	Casualty
Brisbane		90	93	92
Central	Metro	57	63	61
	Rural	56	59	57
Northern	Metro	69	74	71
	Rural	56	58	56
South Eastern	Metro	78	85	82
	Rural	88	87	87
Southern	Metro	66	72	69
	Rural	50	60	54
All	Metro	75	82	79
	Rural	57	64	60

Relative risks (the risk of a crash compared to the mobile speed camera program not being in place) by crash severity and year of the mobile speed program, for all regions combined are presented in Table 31 for the 3 years of focus in this study. Each of the relative risk estimates are highly statistically significant with reductions in serious casualty crashes associated with the mobile speed camera program of between 28% and 29% estimated for each of the three years. Estimated minor injury crash reductions associated with the program were slightly smaller at between 24% and 27%.

Table 31 Estimated net relative crash risks, significance values and 95% confidence limits associated with the Queensland mobile speed camera program by year from 2013-2015: average over all police regions.

Fatal and Serious Injury Crashes

Year	Estimate	95% Confidence Interval	Sig.
2013	0.706	(0.657, 0.759)	<.0001
2014	0.711	(0.661, 0.766)	<.0001
2015	0.719	(0.667, 0.776)	<.0001

	Medical treatment and other minor injury crashes			Casualty Crashes		
Year	Estimate	95% Confidence Interval	Sig.	Estimate	95% Confidence Interval	Sig.
2013	0.731	(0.679, 0.786)	<.0001	0.693	(0.659, 0.73)	<.0001
2014	0.745	(0.691, 0.802)	<.0001	0.704	(0.668, 0.742)	<.0001
2015	0.761	(0.705, 0.821)	<.0001	0.717	(0.68, 0.756)	<.0001

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. Regression results by year, region and speed category were significant only in the 80 km/hr or lower zones (“metropolitan”). By quarter year, statistical significance was achieved only for the all-region and all-metropolitan region groupings. This is why program effects presented in Section 4.1.1 are based on the annual estimates by region (and speed category). 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 3 both overall and by speed zone and in Figure 4 by police region and speed zone.

As noted in the previous evaluations, 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. Since 2010 (53rdquarter) increased effectiveness may also be as a result of covert use of the mobile camera program commencing. Figure 3 and the corresponding estimates in Table 31 suggest that the mobile speed camera program has been effective in reducing crash risk for each severity grouping of crashes analysed, with evidence of a slightly greater reduction for serious and fatal injury crashes. This is in agreement with the previous evaluations. Figure 3 shows an estimated serious casualty crash reduction associated with the mobile speed camera program operation within the defined halos of influence in the order of 20-30% in recent years. From 2005, all region and metropolitan quarterly estimates by severity are for the most part highly statistically significant ($p<0.01$). Other by region and severity metropolitan estimates are significant in later years.

The noise in the time series plot of quarterly crash risk estimates for the South Eastern Rural region illustrated in Figure 4 reflects that this region has the least number of crashes and thus the least reliable estimates. Average annual estimates for this region produced non-significant crash gains in 2013-2015 associated with the CDOP. The confidence intervals for serious crashes estimates for 2013, 2014 and 2015 were wide, ranging from 0.2 to 3. Thus the estimated crash increases highlighted in red in the following tables for this region should not be cause for concern.

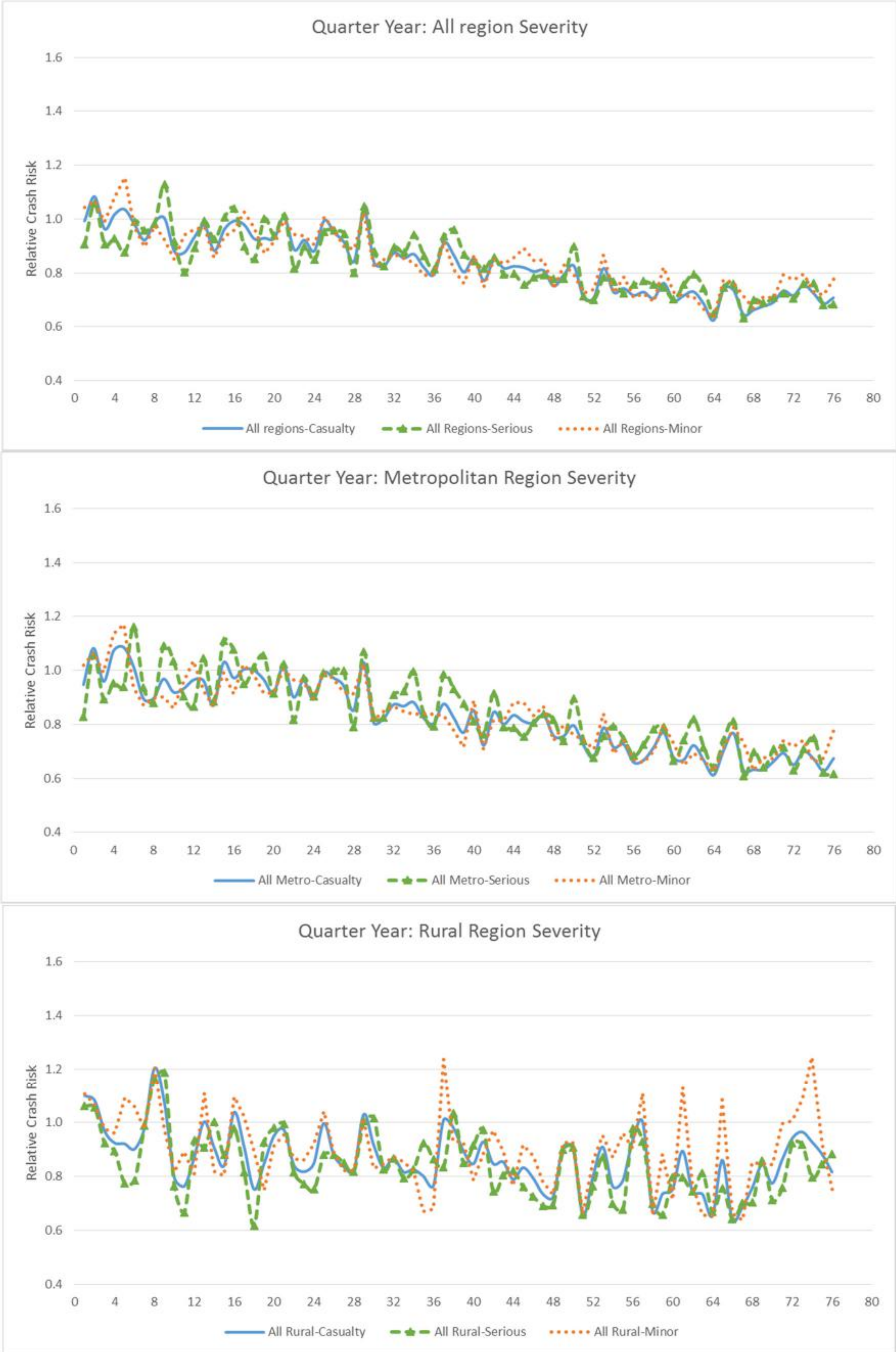


Figure 3 *Relative risks associated with the Queensland mobile speed camera program by quarter-year after program introduction (January 1997) by crash severities, across all Police regions*

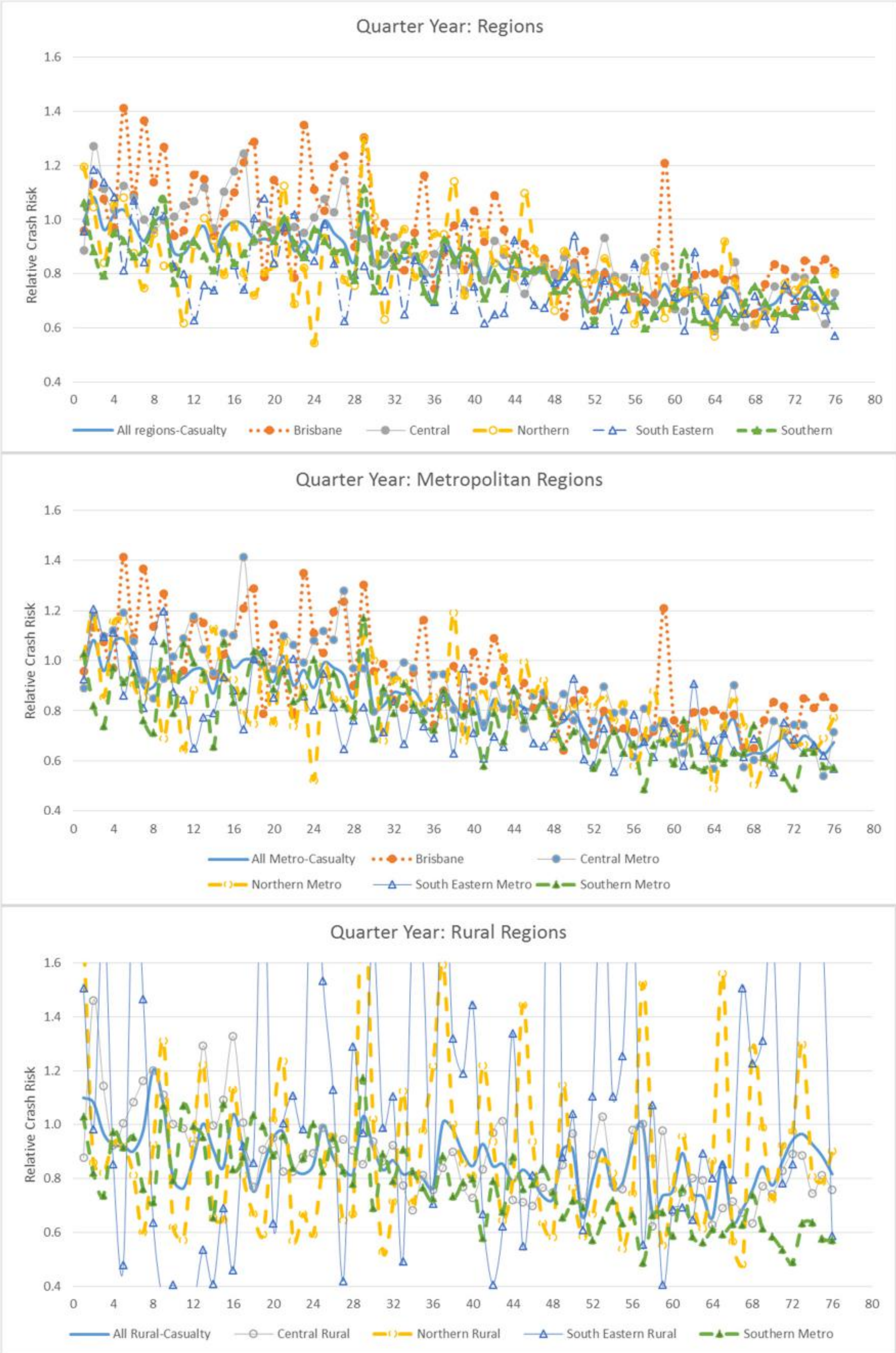


Figure 4 *Relative risks associated with the Queensland mobile speed camera program by quarter-year after program introduction (January 1997) by Police region for casualty crashes*

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 through to 2015 using data disaggregated by crash year, police region (and speed limit) and crash severity. Table 48 and Table 49 in Section 8.6 of the Appendix present the 'by year' analysis. Table 32 through to Table 36 below present annual average estimates averaged over the years 2013 to 2015 as an illustration of the crash population and crash savings associated with the mobile speed camera program.

Averaged over 2013 to 2015, the annual casualty crash savings associated with the Queensland mobile speed camera program was 3,905 which translates to a cost savings to the community of $612 million (2012) using a Human Capital approach. The bulk of the savings come from fatal and serious injury crashes.

Table 32 Average annual casualty crash counts in mobile speed camera zones of influence by crash severity and Police region: 2013-2015

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		1,431	2,319	3,750
Central	Metro	496	626	1,122
	Rural	277	195	472
Northern	Metro	395	404	798
	Rural	102	57	159
South Eastern	Metro	652	1,038	1,689
	Rural	103	141	244
Southern	Metro	454	571	1,025
	Rural	191	159	350
All Regions*	All	4,100,	5,511	9,611

*sum of regions

Table 33 Weighted average relative casualty crash risks associated with the Queensland mobile speed camera program by year and police regions: averaged over 2013 to 2015

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		0.72	0.88	0.77
Central	Metro	0.69	0.72	0.69
	Rural	0.72	0.82	0.76
Northern	Metro	0.88	0.62	0.68
	Rural	0.88	0.90	0.87
South Eastern	Metro	0.52	0.79	0.64
	Rural	1.11	1.29	1.11
Southern	Metro	0.66	0.63	0.60
	Rural	0.84	0.97	0.86
All Regions*	All	0.71	0.75	0.70

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

Table 34 Estimated annual average absolute casualty crash savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2013 to 2015

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		577	329	1161
Central	Metro	221	244	517
	Rural	109	43	154
Northern	Metro	52	252	381
	Rural	14	9	25
South Eastern	Metro	604	278	945
	Rural	-5	-20	-23
Southern	Metro	250	353	682
	Rural	43	7	62
All Regions*	All	1,864	1,495	3,905

*sum of regions

Table 35 Estimated *Willingness to Pay* average annual savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2013 to 2015, *2015 AUS$*

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		$436,953,835	$35,710,025	$416,059,983
Central	Metro	$189,154,269	$26,458,504	$226,607,877
	Rural	$149,730,061	$4,679,206	$130,856,326
Northern	Metro	$39,476,095	$27,447,589	$166,783,656
	Rural	$21,103,909	$981,310	$25,835,209
South Eastern	Metro	$468,079,415	$30,090,775	$344,927,848
	Rural	-$5,219,486	-$2,320,236	-$9,823,906
Southern	Metro	$202,218,393	$37,979,180	$280,702,352
	Rural	$65,728,599	$677,877	$52,987,099
All Regions*	All	$1,567,225,091	$161,704,230	$1,634,936,444

*sum of regions

Table 36 Estimated Human Capital average savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2013 to 2015, *2015 AUS$*

Region		Serious Casualty	Minor Injury	Casualty
Brisbane		$219,436,445	$6,063,809	$183,235,823
Central	Metro	$91,893,906	$4,502,290	$100,254,132
	Rural	$65,638,015	$799,608	$55,561,562
Northern	Metro	$19,815,143	$4,634,735	$76,302,662
	Rural	$9,091,792	$163,773	$10,842,057
South Eastern	Metro	$233,503,957	$5,129,530	$151,428,983
	Rural	-$2,447,151	-$370,434	-$4,160,103
Southern	Metro	$99,759,290	$6,504,767	$125,946,549
	Rural	$28,286,622	$121,354	$21,978,414
All Regions*	All	$764,978,020	$27,549,432	$721,390,078

*sum of regions

4.2. SPEED SURVEY DATA ANALYSIS

The available speed survey data overlaps a period of considerable changes in CDOP, including the introduction of covert use of mobile speed cameras in April 2010. Consequently it is possible to compare time based changes in speeding behaviour across Queensland to the resulting crash effects associated with the changes in CDOP. The analysis establishes and demonstrates methods for calculating summary measures of speeding behaviour and investigates those that best relate to crash outcomes. This may establish how well speed monitoring serves as a leading indicator of likely effects associated with the CDOP.

4.2.1. TMR analysis

TMR has commissioned and produced internally a series of reports on the analysis of speed survey data collected since May 2009, the most recent report (TMR 2016) comprehensively covering analysis of speeds collected at the sites in Table 1 up to May 2015 (see section 2.2).

The reports present summary results (mean and median speeds, 85th percentile speed, and proportions of vehicles exceeding the speed limit, exceeding in ranges up to 10km/h, and exceeding by more than 10km/h) on roads with speed limits of 50km/h (urban only), 60km/h, 80km/h and 100km/h (for urban and rural roads separately). Only in the case of the urban 50km/h limit sites had most of the same 20 sites been surveyed in each of the surveys. In the other six road types, sites had been lost and replaced for various reasons, making it difficult to make time series comparisons across all surveys. The reports made pair-wise comparisons between the summary speed results measured at sites used in adjacent surveys, calculating the change in each measure and testing the statistical significance of the change.

As with each of the summary measures, the May 2010 survey mean speeds were used as the reference estimates and the pairwise changes in mean speed from each of the subsequent (or previous) survey pairs were used, in a step-wise calculation, to estimate the mean speed at each other survey time (Table 37). The actual mean speed calculated from each other survey may be different because the set of sites used was substantially different from the May 2010 sites, except perhaps in the cases of the urban 50 km/h and rural 100 km/h speed limit sites.

Table 37 Summary mean speeds by survey, estimated by TMR (2016)

Speed limit	Location	May 2009 (S1)	Nov 2009 (S2)	May 2010 (S3)	Nov 2010 (S4)	Nov 2011 (S5)		May 2014 (S6)	May 2015 (S7)
50 km/h	Urban	46.33	46.51	46.38	46.07	46.07		45.36	46.20
Speed limit	**Location**			**May 2010 (S1)**	**May 2011 (S2)**	**May 2012 (S3)**	**May 2013 (S4)**	**May 2014 (S5)**	**May 2015 (S6)**
60 km/h	Urban			53.14	53.13	52.73	52.02	52.01	51.67
60 km/h	Rural			57.39	57.02	56.77	56.25	56.28	56.26
80 km/h	Urban			76.20	75.86	75.03	74.77	73.91	74.06
80 km/h	Rural			85.47	84.73	84.46	84.69	83.64	83.85
100 km/h	Urban			94.98			95.08	95.32	95.05
100 km/h	Rural			96.50	95.92	95.54	95.47	94.91	94.91
All 60-100km/h sites				93.89	93.37	92.99	92.83	92.49	92.43
All sites				89.97				88.95	88.99

The TMR method made the assumption that changes in the speed measures are not dependent on particular site characteristics, and hence that the estimated pair-wise changes are accurate measures of year-to-year changes on the road type no matter what set of sites are used. It is known that speed behaviour is highly location-dependent, so this assumption is questionable.

TMR (2016) also made a long-term comparison (2010 versus 2015) of the summary speed measures from urban 50 km/h sites and rural 100km/h sites. This was considered to be reliable indicators of change because most sites in those two road types were surveyed in May of those two years. The estimated measures, and the statistical significance of their change (shown in bold), are given in Table 38.

Table 38 Changes in speeds 2010 versus 2015

50 km/h Urban	**May 2010**	**May 2015**	**Change**
Mean	47.12	45.69	**-1.44****
Median	48.45	47.10	**-1.35****
85th Percentile	56.5	55.02	**-1.48*****
% above limit	42.04	37.75	**-4.29****
% above limit more than 10km/h	6.56	4.69	**-1.87****
% above limit up to 10km/h	30.87	29.43	**-1.44***
% 5-10 km/h above limit	11.47	10.15	**-1.33****
% 0-5 km/h above the limit	18.44	17.19	-1.25
100 km/h Rural			
Mean	96.50	95.69	-0.55
Median	96.79	96.45	-0.34
85th Percentile	107.24	106.44	-0.81
% above limit	36.72	33.83	**-2.89***
% above limit more than 10km/h	9.92	9.09	-0.83
% above limit up to 10km/h	24.04	21.78	**-2.26***
% 5-10 km/h above limit	8.96	7.51	**-1.44****
% 0-5 km/h above the limit	15.08	14.48	-0.61

The summary speed measures presented TMR (2016) are traditional ways of presenting speed survey results and indicating change over time. However, Cameron and Elvik (2010) have shown that changes in the measures of central tendency (mean and median) are inadequate to represent changes in road trauma (numbers of crashes at each level of injury severity) on urban roads. They showed that Nilsson's (1981, 2004) power functions of crash numbers at each severity level, expressed as powers of changes in mean speed, is an adequate model for rural roads and freeways, but not for urban roads. It is unclear whether 85th percentile speeds and proportions of vehicles exceeding speed limits by various degrees (except for very high speeds) are indicators of changes in road safety.

Summary methods that make use of crash risk relationships with travel speed developed by Kloeden et al (2001, 2002) to weight the TMR speed survey records are outlined below.

4.2.2. Risk-weighting of speed measurements

D'Elia et al. (2008), Gavin et al. (2010, 2011), Doecke et al. (2011) and Cameron (2013, 2015) have developed methods to summarise speed measurements that make use of the full speed distribution to indicate the potential contribution of the on-road speeds to road trauma on the roads that the survey sites represent. In each case, the observed speeds were weighted by the relative risk of (serious) casualty crash involvement for an individual driver travelling at free (unimpeded) speed on urban 60 km/h limit roads (Kloeden et al., 2002) or on rural roads with various speed limits (Kloeden et al., 2001).

Kloeden et al (2002) established a relationship between individual driver's relative risk and absolute vehicle speed, V, on urban roads with 60 km/h speed limit:

$$RR = \exp(-\,0.822957835 - 0.083680149\,V + 0.001623269\,V^2) \qquad \text{(Equation 4-1)}$$

Kloeden et al (2002) also established another relationship for the relative risk on urban roads with 60 km/h speed limit:

$$RR = \exp(0.1133374\,\Delta v + 0.0028171\,\Delta v^2) \qquad \text{(Equation 4-2)}$$

where Δv is the difference between individual speed, V, and the mean speed at the site.

The urban casualty crashes studied were those for which "at least one person was transported from the crash scene by ambulance", of whom 56% were treated in hospital emergency departments, 26% were admitted, and 2.5% had been killed or died later.

Kloeden et al (2001) found the relative risk on rural roads with 80-110 km/h speed limits to be:

$$RR = \exp(0.07039\,\Delta v + 0.0008617\,\Delta v^2), \qquad \text{(Equation 4-3)}$$

but did not develop a relationship with absolute vehicle speed because of the multiple speed limit zones covered.

The rural casualty crashes covered were those resulting in "at least one person being treated at, or admitted to hospital or fatally injured", of whom 23% died and 46% were admitted. Thus the relative risk for the rural crashes is more consistent with serious casualty crash outcome (usually defined as fatal or hospital admission) than the relative risk relationships developed for urban casualty crashes.

In each of the urban 50 km/h and rural 100 km/h speed zones, the proportion of vehicles recorded at each speed was multiplied by the applicable relative risk of a casualty crash for that speed. The number of vehicles ("exposure") multiplied by their risk is their expected crashes, so the proportion of vehicles by their relative risk estimates their relative expected crashes across the different speed ranges. The scale of the expected casualty crashes is not important, only the variation of this indicator across time. This method summarises the key changes in the whole speed distribution that reflects the importance (riskiness) of each speed in a way not captured by variations in mean speeds and proportions in ranges above the limit.

4.2.3. Crashes attributable to speeding ranges

Epidemiological methods can be used, in conjunction with Kloeden et al's (2001, 2002) risk functions, to estimate the fraction of crashes attributable to each range of speeding. The same methods indicate the proportion of crashes saved by speeds in ranges below the limit. Cameron (2013) demonstrated the application of equation (4-1) to large speed surveys at 60 km/h sites in Perth and urban Queensland to estimate casualty crashes attributable to low level (up to 10km/h above the limit) and high level (more than 20km/h above) speeding.

Cameron (2015) further demonstrated the application of equation (4-1) to Melbourne speeds and found that the fraction of casualty crashes attributable to high level speeding was substantially lower. He also found that equation (4-2), after rescaling to a risk of 1 at the speed limit, provided relative risk estimates that produced similar risk-weighted speeds and attributable fractions as equation (4-1). He concluded that rescaled versions of equations (4-2) and (4-3) could be applied to estimate casualty crash risk, relative to that at the speed limit, in other speed limit zones apart from 60km/h. This finding is relevant to the analysis here.

4.2.4. Urban 50 km/h limit sites

Nearly 33.25 million individual speeds were recorded at the 20 urban 50 km/h limit sites in the seven surveys between May 2009 and May 2015. The mean speed calculated across all the sites covered in each survey (not always all 20; see Table 1) is shown in Figure 5, together with the estimated mean speed from the TMR analysis outlined in section 1.2.1. It can be seen that the use of all 20 sites' data, analysed in these two different ways, suggests that there was a substantial increase in mean speed between May 2014 and May 2015.

Also shown in Figure 5 is the mean speed calculated across only the 15 urban 50 km/h sites that were included in all seven surveys. These sites recorded 25.8 million individual speeds (78% of the total at urban 50km/h sites). It can be seen that there was no evidence of an increase in mean speed in 2015 and that it was part of a general downward trend in mean speeds between 2009 and 2015.

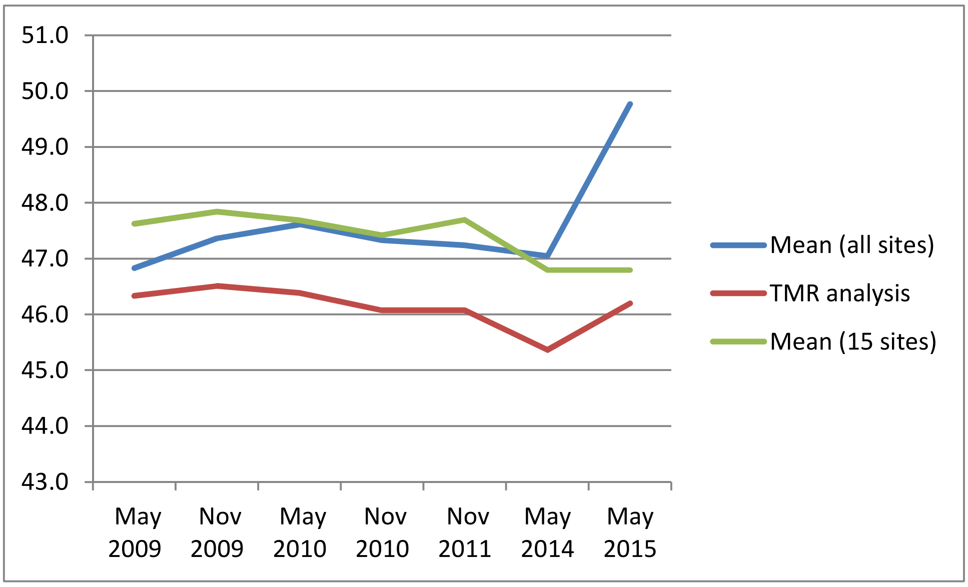


Figure 5 *Mean speeds at 50 km/h sites estimated from all sites data and from 15 sites used in all seven surveys, compared with TMR analysis estimates (**Table 37**)*

The results in Figure 5 suggested that the speeds were highly site-dependent and that the addition or exclusion of sites in a time series comparison of mean speeds may produce misleading results. For this reason, it was decided to restrict the analysis of speeds at urban 50km/h sites to data collected at the 15 sites that were used in all seven surveys.

Table 39 shows that the mean speed at the 15 sites was reasonably constant in the period up to November 2011, then decreased by about 1km/h to the level in 2014 and 2015. The percentage of surveyed vehicles that exceeded the 50km/h limit also decreased during these same two years. However, while the percentages of drivers who exceeded the limit by various higher amounts had decreased during May 2014, by May 2015 they had increased again to levels consistent with those in 2009. These substantial increases in medium- to high-level speeding in 2015 compared with 2014 are shown in Figure 6, where the logarithms of each percentage have been calculated to show the variation in each one that is not apparent if the small percentages exceeding by 20 or 30km/h had been plotted in raw form.

Table 39 Mean speed and percentage exceeding 50 km/h limit by various amounts at the 15 sites used in all seven surveys

	May 2009	Nov 2009	May 2010	Nov 2010	Nov 2011	May 2014	May 2015
Mean speed (km/h)	47.63	47.84	47.68	47.42	47.70	46.79	46.79
Exceeding limit	37.21%	38.68%	38.41%	37.70%	39.07%	35.25%	35.71%
Exceeding > 10 km/h	7.36%	8.11%	7.92%	7.94%	8.46%	6.46%	7.97%
Exceeding > 20 km/h	1.36%	1.62%	1.48%	1.57%	1.39%	1.00%	1.54%
Exceeding > 30 km/h	0.32%	0.36%	0.27%	0.35%	0.27%	0.17%	0.30%

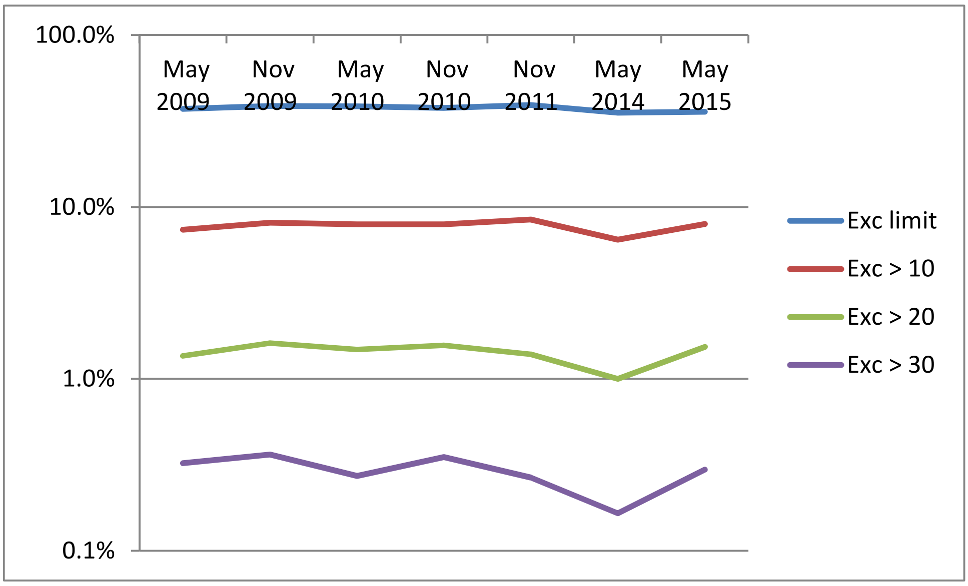


Figure 6 *Logarithm of percentage exceeding 50 km/h limit by various amounts at the 15 sites used in all seven surveys*

The implications of these variations in higher-level speeding compared with the downward shift in mean speeds were examined by risk-weighting the speed distribution recorded in each survey. The individual speeds, after rounding to 1km/h, were each weighted by equation (4-1) after rescaling the function to a risk of 1 at the 50km/h limit. It was preferable to use a rescaled version of this absolute speed risk-function than rescaling the mean-centred equation (4-2). The 60km/h speed zones in Adelaide, where Kloeden et al (1997) first developed their risk estimates, have generally now become 50km/h zones and the road environment is probably typical of 50km/h zones throughout urban Australia. The relative risk for speeds above 90km/h was capped at that for 90km/h, and the relative risk was fixed for speeds below 26km/h. These speeds represented the limits at which the risk function was considered reliable. However, this meant that the contribution of even higher speeds, although very rare, to casualty crashes may have been under-estimated.

The proportion of vehicles at each speed was then multiplied by this estimated relative risk. Figure 7 shows the expected relative casualty crash frequencies calculated by risk-weighting the speed distribution in each survey. The relative casualty crash frequency is labelled 'expected' because it is based on the assumption that the relative risk function, equation (4-1), is applicable in the context of Queensland urban 50km/h limit roads.

Figure 7 shows the contribution of each speed range to the total casualty crashes expected to have resulted from the distribution of speeds at the time of each survey. The relatively low percentage of vehicles recorded exceeding the 50 km/h limit by more than 30km/h appears to have resulted in the expected casualty crashes in May 2010 and May 2014 being relatively low compared with the other five survey periods. The relatively low percentage exceeding the limit by more than 20km/h (up to 30km/h) may also have contributed in May 2014.

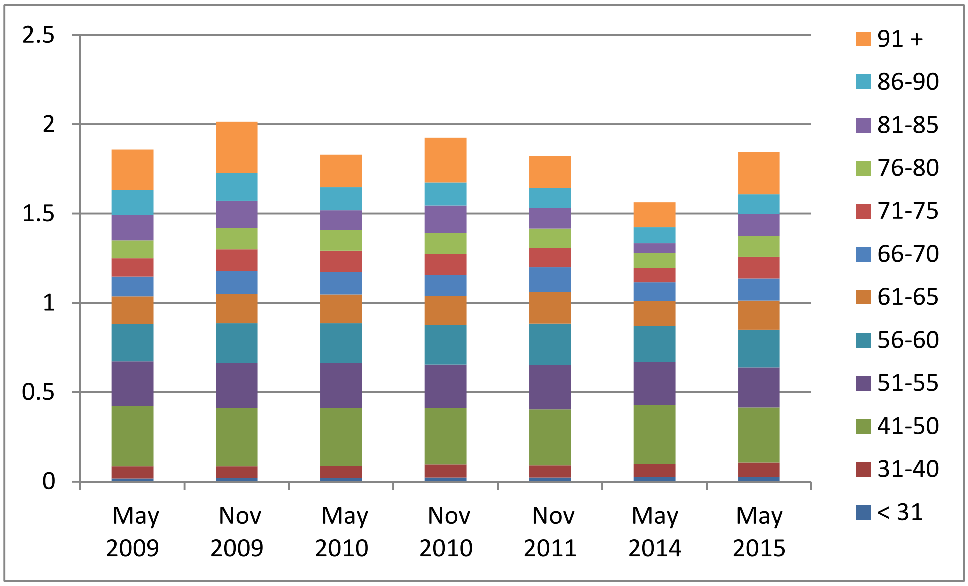


Figure 7 *Expected relative casualty crash frequencies by speed survey on 50km/h limit roads, showing contribution of each speed range*

The percentage of casualty crashes attributable to each range of speeding is shown in Figure 8. Crashes attributable to the very highest level of speeding (more than 30km/h in excess) were at their lowest in May 2010 and May 2014. Nearly 14% of crashes were estimated to have been saved by drivers travelling below the limit in 2014 and 2015, compared with travelling at the limit. However, in May 2015, more than 25% of casualty crashes were estimated as attributable to speeding more than 30km/h above the 50km/h limit.

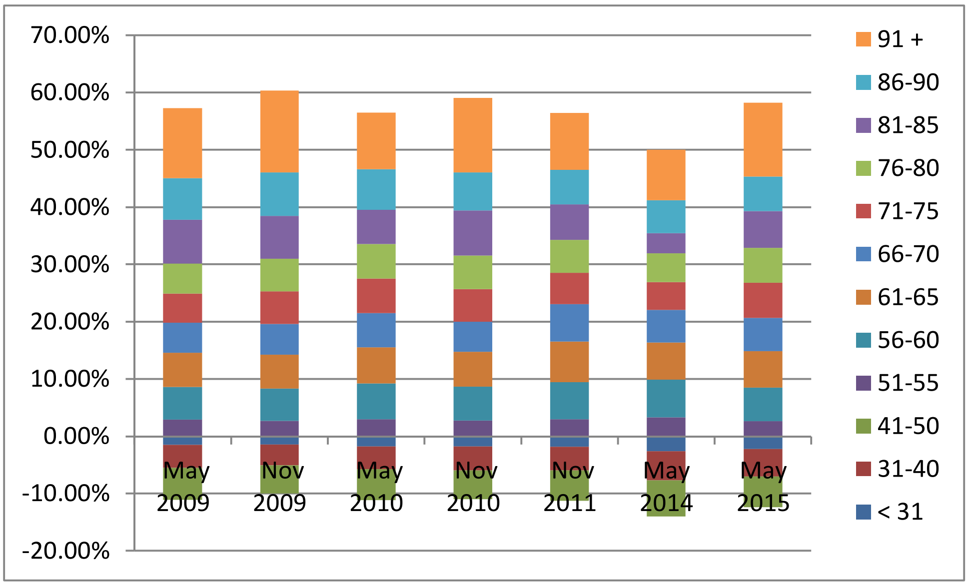


Figure 8 *Estimated fractions of casualty crashes attributable to each speed range on 50 km/h limit roads. Negative values indicate fraction of crashes saved by speeds below limit.*

Comparison of risk-weighted speeds with estimated crash reductions

Previous sections of this report have evaluated the casualty crash reduction effects of mobile speed cameras across Queensland each year from 1997 to 2015. Crash reductions were estimated within 1km of the urban mobile camera sites (those with speed limits up to 80 km/h) and within 4km of the rural sites (speed limits greater than 80km/h). The reduction in crashes in the "treated" areas was measured relative to changes in a "control" group of crashes outside those areas. Crash reductions were measured by the estimated risk associated with mobile camera operations at the sites, relative to a risk of 1.

Because of the wide-spread and dominant effect of the mobile speed camera program on crashes, it was expected that the cameras had reduced casualty crashes in Queensland through a reduction in the most risky speeds. The risk-weighted speed distributions from urban 50 km/h limit sites (expected relative casualty crashes; Figure 7) were chosen to best represent the reduction in risky speeds. The absence of consistent speed survey data from other urban speed limit sites meant that the 50 km/h sites needed to represent the changes in risky speeds on all urban roads up to 80 km/h speed limits.

The estimated relative risks associated with the urban mobile speed cameras, relative to 1992-1996, during each year from 2009 to 2015 are shown in Table 40 together with 95% confidence limits on the risk estimates. The estimates during 2009 and 2010 were each compared with the risk-weighted speed distributions from the two speed surveys in May and November of those years.

Table 40 Estimated relative risk of casualty crashes associated with mobile speed cameras in urban Queensland during each year 2009 to 2015

	2009	2010	2011	2012	2013	2014	2015
Relative risk of casualty crash (RR)	0.737	0.719	0.706	0.666	0.680	0.659	0.667
95% LCL of RR	0.695	0.678	0.665	0.628	0.641	0.621	0.628
95% UCL of RR	0.781	0.763	0.750	0.707	0.722	0.700	0.710

The risk-weighted speed distributions (or relative expected casualty crashes; Figure 7) were indexed to their value in the May 2009 survey to allow comparison with the estimated relative risks on a similar scale (Figure 9). No surveys at urban 50 km/h limit sites during 2012 and 2013 were available for comparison with the relative risk estimates during those two years.

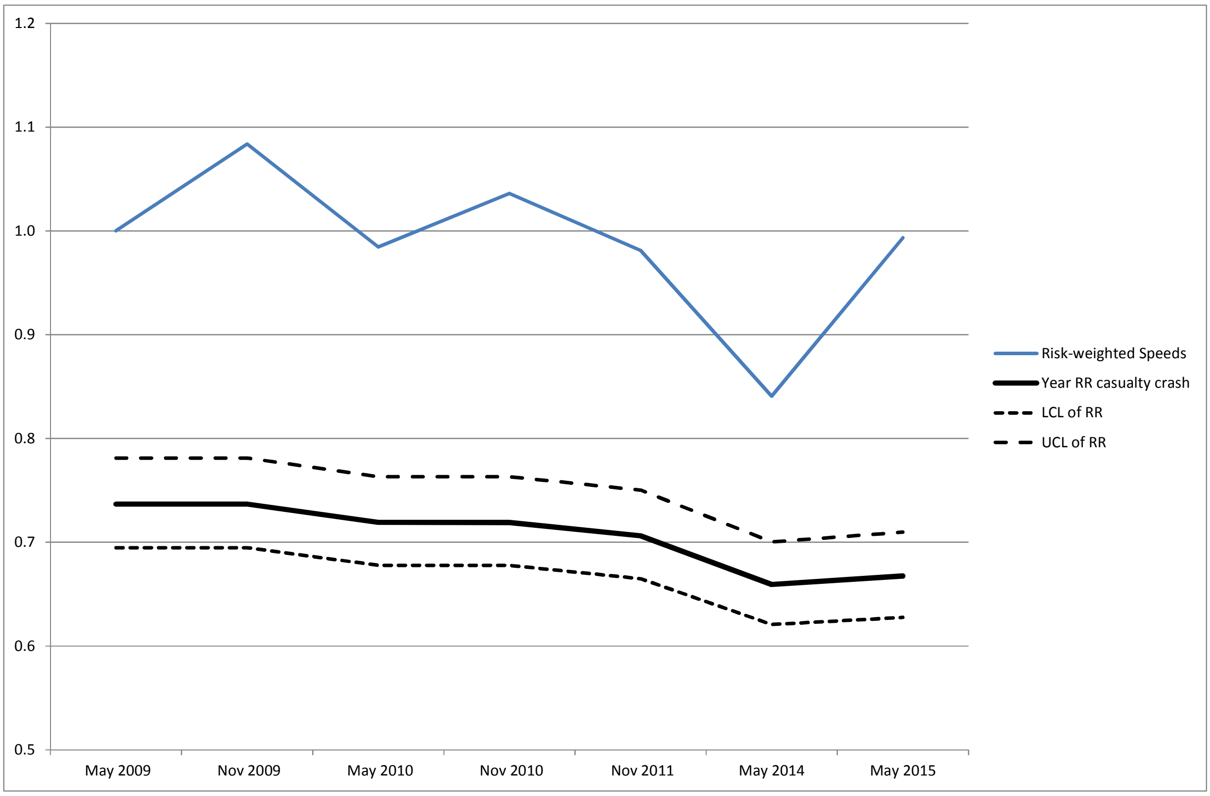


Figure 9 *Risk-weighted speed trends compared with annual relative risk estimates*

The risk-weighted speeds followed a similar downward trend to the estimated relative risks during 2009 to 2014, then increased substantially during May 2015 but not to same extent as the small increase in relative risk during 2015. However, Figure 9 compares annual relative risk estimates with speeds measured in specific months during 2009-2015.

The relative risk estimates during specific quarters in 2009-2015 (Table 41) were instead compared with the risk-weighted speeds from the surveys in the same quarters (Figure 10).

This provided a better temporal match of the relative risks and speeds, but at the expense of less-reliable estimates of risk (wider confidence limits).

Table 41 Estimated relative risk of casualty crashes associated with mobile speed cameras in urban Queensland during specific Quarters in 2009 to 2015

	Qtr 2 2009	Qtr 4 2009	Qtr 2 2010	Qtr 4 2010	Qtr 4 2011	Qtr 2 2014	Qtr 2 2015
Relative risk of casualty crash (RR)	0.796	0.677	0.715	0.660	0.678	0.663	0.672
95% LCL of RR	0.716	0.610	0.643	0.594	0.607	0.596	0.603
95% UCL of RR	0.885	0.752	0.795	0.732	0.756	0.738	0.750

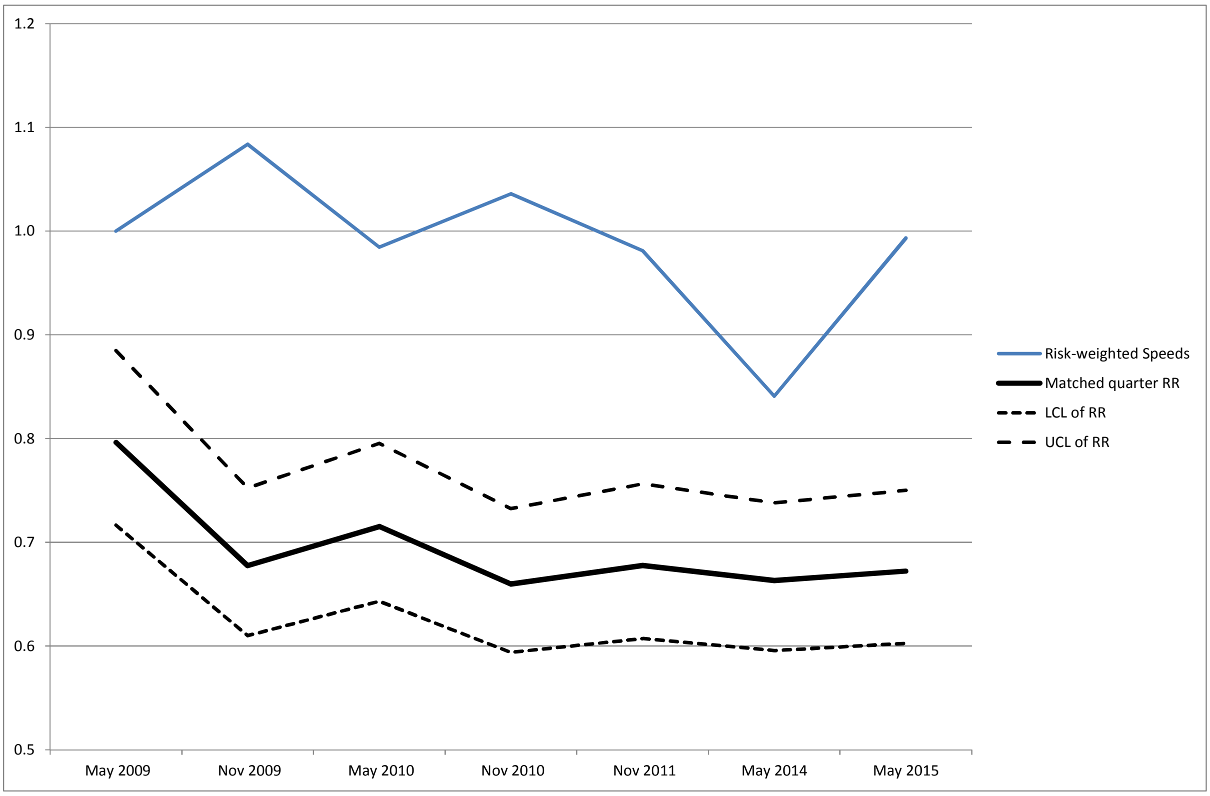


Figure 10 *Risk-weighted speed trends compared with matched quarterly relative risk estimates*

In this comparison (Figure 10), the variations in the risk-weighted speeds (or expected casualty crashes) do not match the variations in the relative risks estimated in the same quarters of 2009 to 2015. This could be because the quarterly relative risks are less reliable than those measured annually, or because the speed surveys were not representative of a full quarter.

4.2.5. Rural 100 km/h limit sites

Over 5.4 million speeds were recorded at 80 rural 100km/h limit sites in the six surveys in May from 2010 to 2015. As outlined in Section 1.1, the speeds were recorded as frequencies in speed ranges ("bins") generally 5km/h wide except at the extremities of the distribution. A mid-mark or representative speed was defined for each bin and this speed was used to calculate the mean speed across all the sites covered in each survey (not always all 80; see Table 1). In Figure 11, this was compared with the estimated mean speed from the TMR analysis outlined in Section 1.2.1. There were substantial differences in the estimated mean speeds, especially during May 2013, suggesting that the implied trends in the estimates are highly site-dependent.

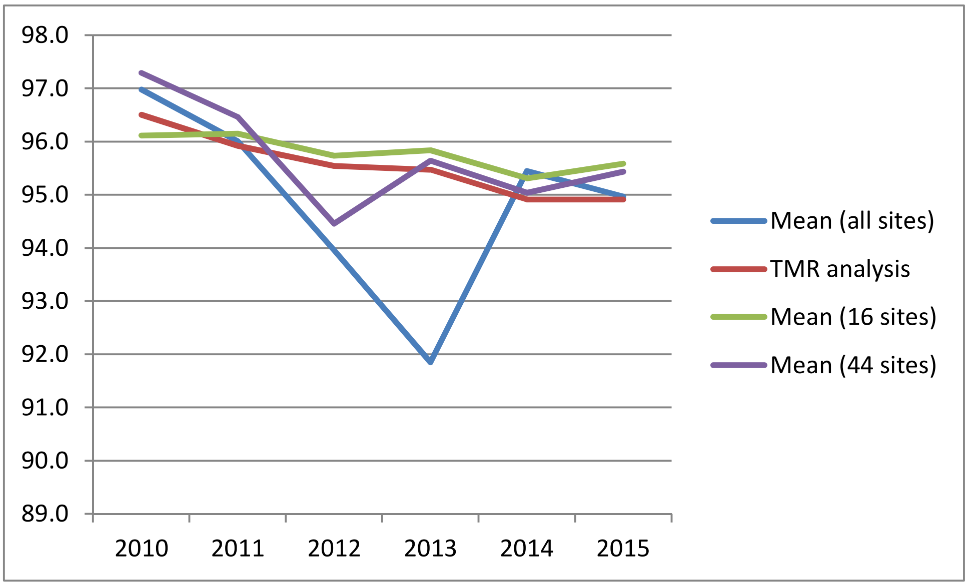


Figure 11 *Mean speeds at 100 km/h sites estimated from all sites data, 16 sites used in all 6 surveys and 44 sites in 5+ surveys, compared with TMR analysis estimates (**Table 37**)*

Also shown in Figure 11 is the mean speed from only 16 sites used in all six surveys (693,000 speeds or 13% of the total at rural 100km/h sites). There was concern that although these 16 sites have speed data recorded consistently across time, they may not be representative of rural 100km/h roads. For this reason, the mean speed was also calculated across the 44 sites used in at least five surveys (2.2 million speeds or 41% of the total). The estimates from the 44 sites are reasonably consistent with those from the 16 sites (and the TMR analysis) and do not display the major difference from trend in 2013. However, they do suggest a reduction in mean speed on rural 100km/h roads in 2012 that was not maintained in subsequent years.

Table 42 shows that the percentage of surveyed drivers who exceeded the 100km/h limit decreased consistently until 2012, rose again during 2013, then decreased again. The percentages exceeding the limit by 10 and 20km/h displayed a similar trend, but consistently decreased during 2014 and 2015 (Figure 11). These trends in higher-level speeding contrast with the stable level of mean speeds during 2013 to 2015.

Table 42 Mean speed and percentage exceeding 100 km/h limit by various amounts at the 44 sites used in at least five surveys

	May 2010	May 2011	May 2012	May 2013	May 2014	May 2015
Mean speed (km/h)	97.29	96.46	94.45	95.64	95.04	95.43
Exceeding limit	39.32%	35.77%	29.48%	31.83%	27.97%	29.43%
Exceeding > 10 km/h	6.08%	4.87%	3.84%	4.45%	3.43%	3.30%
Exceeding > 20 km/h	1.41%	1.01%	0.85%	0.99%	0.82%	0.72%

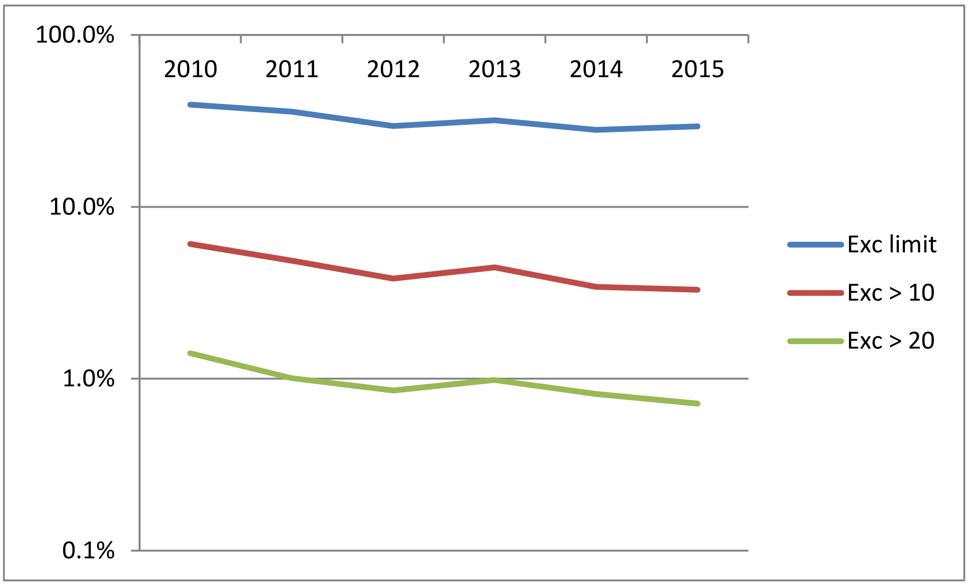


Figure 12 *Logarithm of percentage exceeding 100 km/h limit by various amounts at the 44 sites used in at least five surveys*

The implications of these variations in speeding, especially high-level speeding, compared with the recently-stable mean speeds were examined by risk-weighting the speed distribution recorded in each survey. The mean-centred risk function, equation (4-3), was calculated for each speed bin, based on the difference between its representative speed (see section 4.2.2) and the overall mean speed across all six surveys. This risk function was then rescaled to a risk of 1 at the 100km/h limit. The relative risk for speeds above 120km/h was set to that at 130km/h (i.e. 22.46, relative to 1 at the limit), the representative speed for this speed range.

The proportion of vehicles in each speed bin was then multiplied by its estimated relative risk. Figure 13 shows the expected relative casualty crash frequency, calculated in this way, for the surveys at the 44 sites with 100 km/h limits. The total expected casualty crashes show a decreasing trend over 2010 to 2015, except for 2013 when its short-term increase appears to be due to increased crashes in each speeding range above 105km/h.

Figure 14 shows the percentage of casualty crashes attributable to each range of speeding. It confirms that a relatively high proportion of expected crashes were attributable to medium- to high-level speeding in 2013. Figure 14 also shows that the relatively low level of total expected crashes during 2012 was attributable to a high contribution of crash savings from drivers travelling below the limit.

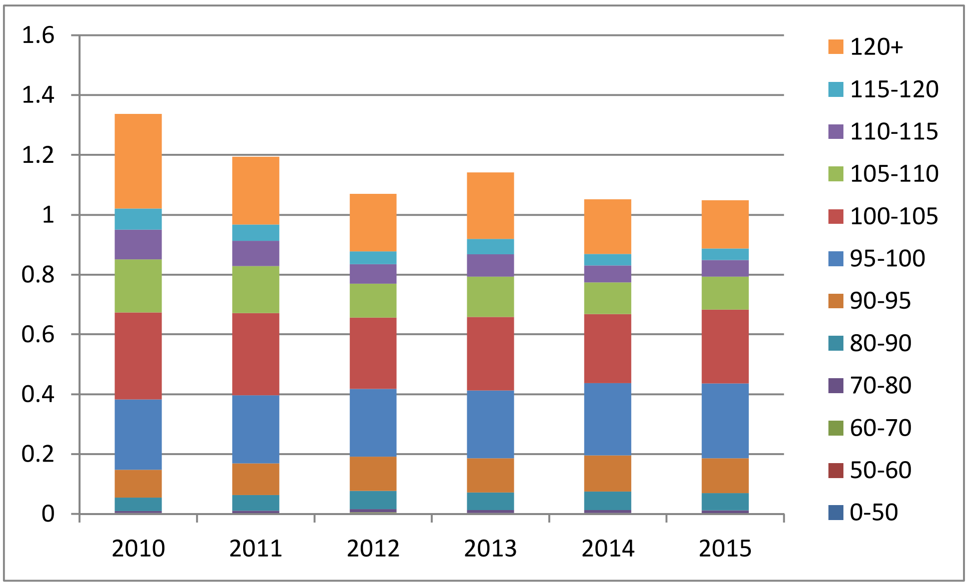


Figure 13 *Expected relative casualty crash frequencies by speed survey on 100km/h limit roads, showing contribution of each speed range*

Figure 14 *Estimated fractions of casualty crashes attributable to each speed range on 100km/h limit roads. Negative values indicate fraction of crashes saved by speeds below limit.*

Comparison of risk-weighted speeds with estimated crash reductions

Previous sections have evaluated the casualty crash reduction effects of mobile speed cameras across Queensland each year from 1997 to 2015. The estimated relative risks associated with the rural mobile speed cameras, relative to 1992-1996, during each year from 2010 to 2015 are shown in Table 43 together with 95% confidence limits on the risk estimates.

Table 43 Estimated relative risk of casualty crashes associated with mobile speed cameras in rural Queensland during each year 2010 to 2015

	2010	2011	2012	2013	2014	2015
Relative risk of casualty crash (RR)	0.841	0.768	0.746	0.726	0.853	0.894
95% LCL of RR	0.758	0.694	0.675	0.656	0.770	0.802
95% UCL of RR	0.932	0.849	0.824	0.803	0.945	0.995

The risk-weighted speed distributions (or relative expected casualty crashes; Figure 13) were compared with the estimated relative risks in the same year (Figure 15).

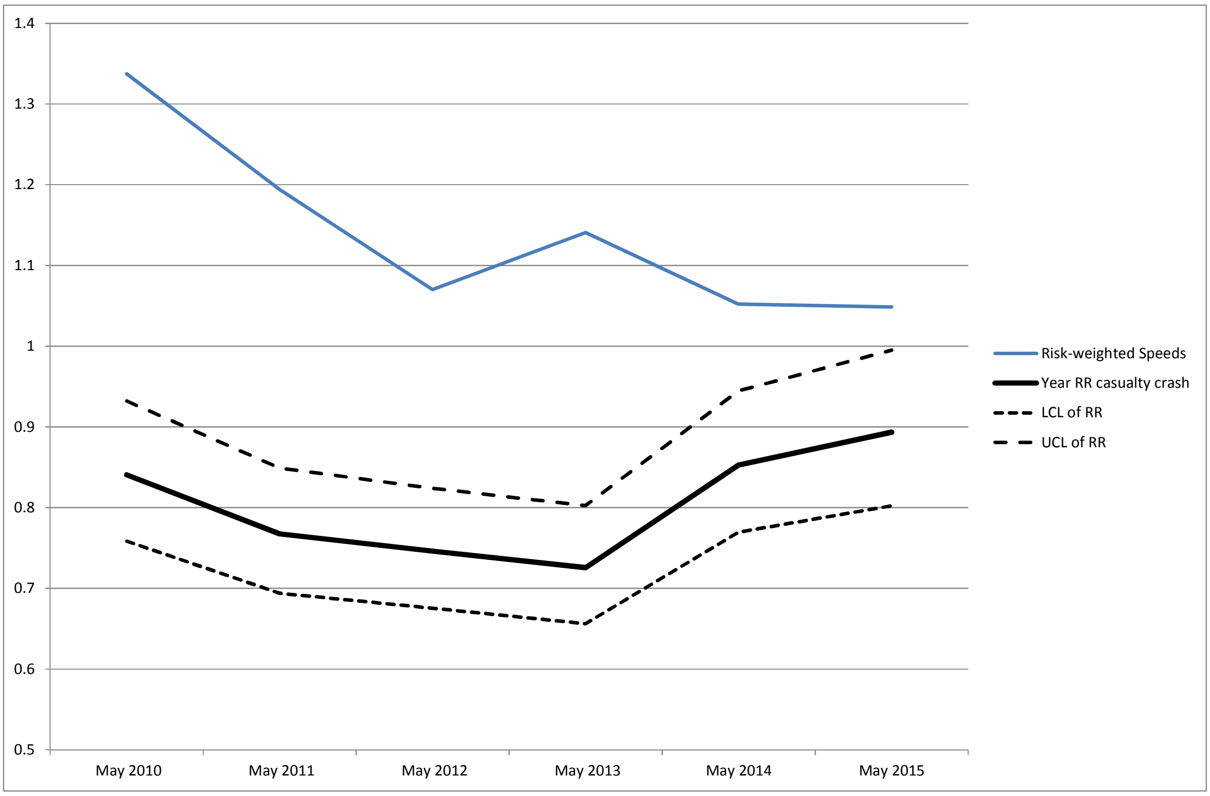


Figure 15 *Risk-weighted speed trends compared with annual relative risk estimates*

Figure 15 compares annual relative risk estimates with speeds measured in specific months during 2009-2015. The relative risk estimates during specific quarters in 2009-2015 (Table 44) were instead compared with the risk-weighted speeds from the surveys in the same quarters (Figure 16).

Table 44 *Estimated relative risk of casualty crashes associated with mobile speed cameras in rural Queensland during second Quarters in 2010 to 2015*

	Qtr 2 2010	Qtr 2 2011	Qtr 2 2012	Qtr 2 2013	Qtr 2 2014	Qtr 2 2015
Relative risk of casualty crash (RR)	0.762	0.671	0.745	0.640	0.774	0.928
95% LCL of RR	0.626	0.557	0.617	0.531	0.643	0.755
95% UCL of RR	0.928	0.808	0.899	0.771	0.933	1.140

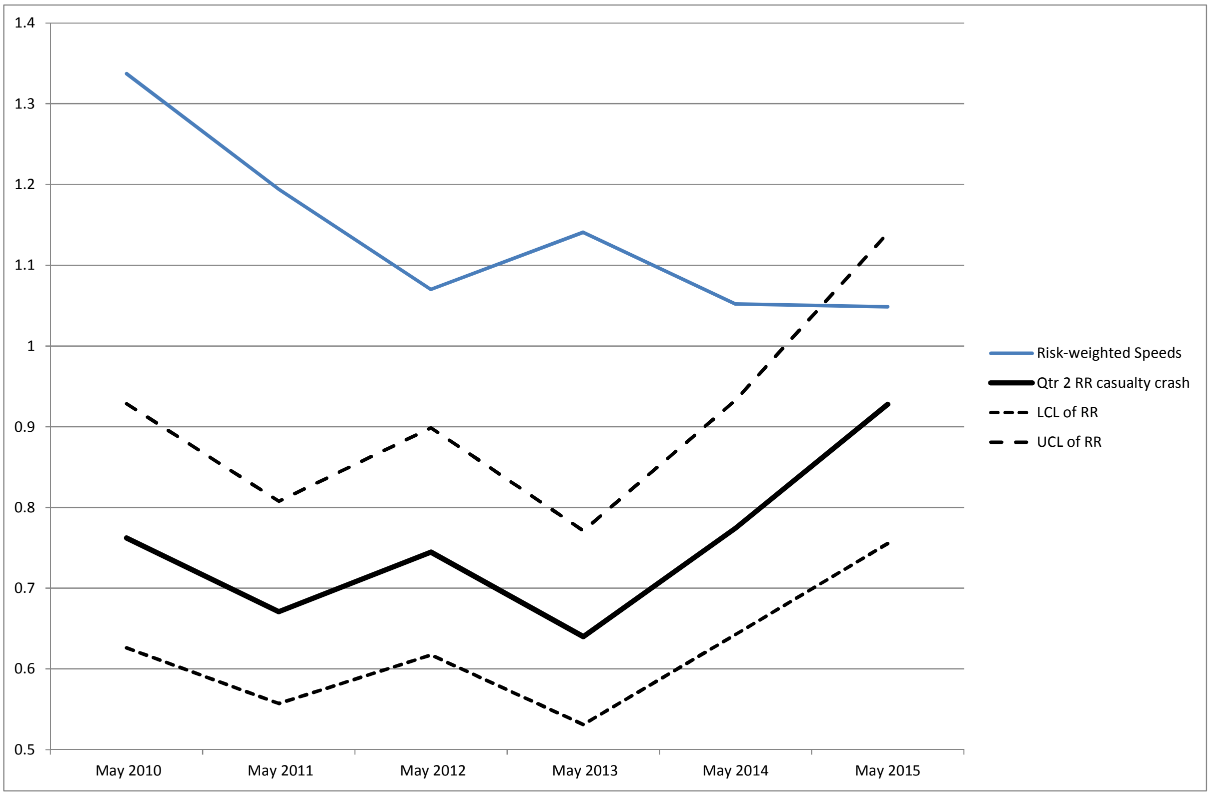


Figure 16 *Risk-weighted speed trends compared with matched quarterly relative risk estimates*

In both comparisons (Figure 15 and Figure 16), the variations in the risk-weighted speeds (or expected casualty crashes) do not match the variations in the relative risks estimated in the same years or matched quarters of 2010 to 2015. This could again be because the speed surveys in rural Queensland were not representative of a full quarter or year.

Change in casualty crashes related to changes in rural mean speeds

Cameron and Elvik (2010) have found that the use of Nilsson's (1981, 2004) power relationships, with updated exponents, provides an adequate explanation for the likely effects on road trauma due to changes in mean speed, at least on higher speed roads such as arterial roads, highways and freeways with 100km/h limits. In these road environments, they found that the change in the number of casualty crashes is related to the change in mean speed raised to a power of 3.3. From a meta-analysis of a large number of studies in which the ratio of casualty crashes was compared with the ratio of mean speeds, after period relative to before, they estimated the overall exponent of the mean speed ratio to be 3.3 with a standard deviation of 0.37.

The mean speeds at 100km/h limit sites (44 with five or more surveys during 2010-2015) were used to estimate the changes in casualty crashes relative to May 2010 (Table 45). The estimates indicate that expected casualty crashes on 100 km/h roads fell by nearly 10% in May 2012, relative to the May 2010 level (Figure 17).

Table 45 Estimated ratios of casualty crashes relative to 2010 calculated from changes in mean speeds at 100km/h limit sites (with approximate limits on estimated ratios)

	May 2010	May 2011	May 2012	May 2013	May 2014	May 2015
Mean speed (km/h)	97.29	96.46	94.45	95.64	95.04	95.43
Casualty crash ratio (relative to 2010)	1	0.972	0.907	0.945	0.926	0.938
Lower estimate of ratio	1	0.966	0.888	0.933	0.910	0.925
Upper estimate of ratio	1	0.978	0.927	0.957	0.941	0.952

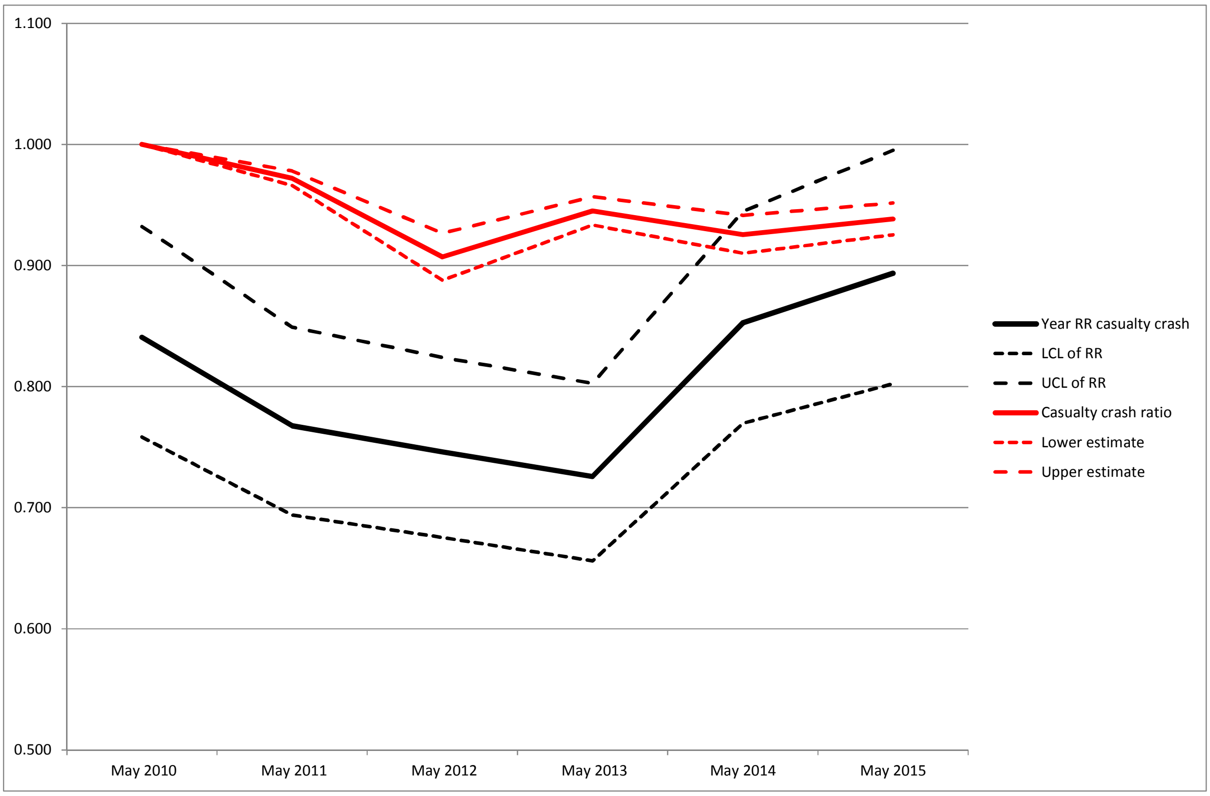


Figure 17 *Casualty crash ratio estimated from changes in mean speed (relative to 2010) compared with estimated relative risks (RR) of casualty crash in the year*

5. DISCUSSION AND CONCLUSIONS

Application of the CDOP evaluation framework involved separate evaluation of each of the CDOP elements over the history of their installation and then using the results of these specific evaluations to infer the average annual crash effects of each during 2013 to 2015 Capitalising on the mutual exclusivity of the evaluation elements in the framework noted above, the individual results were then combined to give a picture of the effects of the CDOP as a whole on crashes in Queensland.

Across all regions, estimated serious casualty crash reductions associated with CDOP were relatively consistent over the three years studied. Estimated reductions in all casualty crashes have fallen slightly over the three years with 30% reduction estimated for 2013, 27% in 2014 and 24% in 2015 although these estimates are not different within the bounds of statistical accuracy of the estimates. Estimates for serious casualty crash reductions associated with CDOP were similar for 2013 and 2014 at 29% and 30% respectively falling to 26% in 2015, again all of similar magnitude within the bounds of statistical accuracy. There was some evidence that CDOP has been trending to being more effective for higher severity crashes than minor crashes over the 3 years studied although again the statistical evidence for this is weak.

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 each of the years 2013-2015. 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 4,400 in 2013, 4,000 in 2014 and 3,400 in 2015. Corresponding serious casualty crash reductions were 2,000 in 2013 and 2014 and 1660 in 2015. Lower absolute serious crash savings in 2015 are reflective to a small extent of the slightly smaller percentage crash savings from the program in 2015 compared to the previous 2 years. To a larger extent it is reflective of the smaller crash basis from which the absolute crash savings were estimated in 2015, a results of other factors improving road safety in Queensland during 2015 compared to previous years. These factors could include other road safety programs or economic circumstances such as a post mining boom downturn in the Queensland economy. Conversion of the estimated crash savings into (2015) cost savings estimated annual savings of around $1.9B in 2013, $1.6B in 2014 and $1.4B in 2015 associated with the program valued using Willingness to Pay estimates or $850M, $717M and $618M 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 metropolitan 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 metropolitan highlighting the greater potential for speeding and the greater role of speed in crash causation in metropolitan areas.

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 120 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 slightly less that previous estimates (RR = 0.68) although still within the bounds of statistical error suggesting there is no strong evidence that their effectiveness has diminished.

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 annual 2013-2015 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 54 casualty crashes associated with red light cameras per year of which 28 were serious casualty crashes, translating to an annual saving to society of around $8-10M (HC) or $19-21M (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 and Airport-Link tunnels and digital fixed speed cameras in four additional locations were made active. The Airport-Link cameras could not be evaluated because insufficient crashes have been recorded there prior to December 2015. The fixed digital cameras had at least 21 months 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 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 metropolitan region based only on sited 3005.

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 and attracted a similar speed and freeway characteristics of traffic. However, the comparability of these sites was questionable given that they are not tunnels. The statistical reliability of the tunnel analysis is also put into question by the fact that it is based on only one serious injury and eleven minor injury treatment crashes. Based on the comparisons made, the Clem

7 and Airport-link cameras were found to be associated with a substantial (83%) 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 14. So regardless of the effectiveness of the Clem 7and Airport Link cameras, their state-wide contribution to crashes saved will always be small: e.g. less than 0.04% 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 post installation crash data were sparse for the digital cameras supplied with this information. 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 analysed digital speed camera sites, 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.

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 2013 to 2015 casualty crash reductions averaging around 30% state-wide in each year. This translated to around 3,900 casualty crashes per year, saving society $720-790 million (HC) or $1.6-1.7 billion (WTP). The analysis of time based effects in the trial run, adds the understanding that the strong localised effect in space identified is generalised over time. In practice this suggests that mobile camera site visitation frequency could be relatively low giving ability to cover more sites in the same hours of camera operation. This is certainly contrary to the current practice of high visitations made to certain sites. There was no evidence that use of mobile cameras in covert mode has changed the hypothesised area of influence of the mobile cameras or significantly changed the overall effectiveness of the program.

Analysis of 2013-2015 speed survey data showed general trends for decreased speeds albeit with variations between speed zones. There was also some concerns noted about the overall analyses of the surveys presented by TMR since the sites surveyed have changed and speed surveys are highly dependent on site based effects. Efforts to overcome this were made in the analysis presented in this report by only examining sites which have been consistent between surveys. However, this means analysis focused primarily on 50km/h and 100km/h speed limit sites which may not be representative of the broader speed behaviour across all zones in Queensland. There was some evidence of an upturn in the percentage of drivers exceeding the speed limit by more than 10km/h in 50km/h areas in 2015 after a period of relatively static behaviour. This is also reflected in the risk weighted analysis predicting expected crashes. There also seemed to be some correlation between time based patterns in speed compliance in 50km/h zones and the time based variation in the measured crash effects of CDOP although the correlation was weak. In rural 100km/h zones there was evidence of sustained reductions in speeding and risk weighted speeds over the surveys conducted. This had almost no relationship to the CDOP crash reductions estimated for the same time period which have shown rises in crash risk in these areas in recent years. Overall the speed survey analysis results raised serious questions about how representative the current speed surveys are of changes in measured crash risk on Queensland roads associated with operation of the CDOP. As such this places more emphasis on the need to undertake crash based evaluations of CDOP rather than relying on speed surveys as a leading index. It also highlights the need to potentially review the speed survey sites being used to obtain a more representative picture of time based changes in speeding in Queensland, including the need to be more consistent in the use of sites.

In summary, this evaluation of the Queensland CDOP has shown sustained crash reductions associated with the program through the years 2013 to 2015 period with correspondingly large economic benefits to the community accruing from its operation. There is some suggestion effectiveness of the program might have diminished slightly over the years of focus. Although this trend was not statistically robust, it needs to continue to be monitored in the future. Both fixed and mobile elements of the program produced significant crash reductions, although apart from red light cameras, the evidence of effectiveness for some of the more recently implemented fixed camera types including intersection speed and red light and point to point 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. A number of recommendations are made in the next section to enhance the future application of the 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.

1. *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 2013 through to 2015. 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 applications of the framework is likely to be informative.

2. *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.

3. *Comparison of general speed monitoring measures with crash outcomes*: Analysis of speed survey data was somewhat compromised by the lack of consistency in sites use for undertaking the speed surveys. There is also concern that the current sites that are consistent may not be representative of travel speeds in Queensland. It is suggested that the speed survey methodology be reviewed to identify a set of representative sites that are used consistently from now on. If possible, this should also include the use of the sites that have remained consistent across the speed surveys carried out to date to at least provide some long term consistency of measurement. The full range of recommended speed behaviour summary measures should also continue to be calculated for each speed survey time point.

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

		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		8.0
	Main Street, Kangaroo Point	3002		14/12/2007	16.0		8.0
	Pacific Mwy, Tarragindi	3003		22/02/2008	16.1		7.9
	Gold Coast Hwy, Broadbeach	3004		31/08/2010	18.7		5.3
	Gold Coast Hwy, Southport	3005		29/09/2009	17.7		6.3
	Warrego Hwy, Redwood	3006		31/08/2010	18.7		5.3
	Warrego Hwy, Muirlea	3007		24/12/2009	18.0		6.0
	Nicklin Way, Warana	3008		30/06/2010	18.5		5.5
	Sunshine Mwy, Mooloolaba	3009		24/02/2010	18.2		5.9
Digital	Gateway Mwy, Nudgee	1001		2/08/2011	19.6		4.4
	Pacific Mwy, Loganholme	1002		2/08/2011	19.6		4.4
	Nambour Connection Road (Northbound), Woombye	1011		10/01/2013	21.0		3.0
	Pacific Mwy, Gaven	1012		28/03/2013	21.2		2.8
Clem 7 tunnel		1003-1006		6/04/2010	18.3		5.7
Airport-Link tunnel		1007-1010		25/07/2012	20.6		3.4
Legacy Way Tunnel		1015-1016		25/06/2015	23.5		0.5
Point to Point (fixed spot and average speed cameras)	Bruce Hwy between Landsborough and the Glass House Mountains	4001		2/08/2011	19.6		4.4
Red Light Speed Cameras							
	Waterworks Rd, Ashgrove (at i/s with Jubilee Tce)	2001	12/02/2002	2/08/2011	10.1	9.5	4.4
	Beaudesert Rd, Calamvale (at i/s with Compton Rd)	2002		2/08/2011	19.6		4.4
	Markeri St, Clear Island Waters (Bermuda St) - Gold Coast	2003	11/04/2001	1/07/2013	9.3	12.2	2.5
	Nathan St, Aitkenvale (at i/s with Bergin Rd) - Townsville	2004	26/06/2000	8/07/2013	8.5	13.0	2.5
	Musgrave St, Berserker (at i/s with High St) - Rockhampton	2005	10/11/1992	31/07/2013	0.9	20.7	2.4
	Mulgrave Rd, Mooroobool (at i/s with McCoombe St) - Cairns	2006	10/08/1992	11/07/2013	0.6	20.9	2.5
	Bruce Hwy, Mount Pleasant (at i/s with Sams Rd) - Mackay	2007	01/11/1992	15/07/2013	0.8	20.7	2.5

8.3. SUMMARY OF EVENTS AFFECTING ENFORCEMENT

Fixed Cameras:

- Audit of all red light camera sites conducted, causing significant impact to hours in use over September 2014 to December 2014.

- 1001

  Offline from May 9, 2012 to June 27, 2012, however issues continued which were not resolved until December 11, 2012
  Disabled from April 10, 2013 to September 3, 2013
  Outage from October 2, 2013 to November 5, 2013
  Adjugating Night shots early August 2014 to October 3, 2014 (flash failure)
  Offline from March 23 to April 8, 2016 due to roadworks
  Decommissioned April 8, 2016

- 1002

  Lane 1 maintenance February 2, 2013 to March 14, 2013
  Offline due to roadworks May 26, 2013 to August 2, 2013 with lane 1 continuing off line until December 11, 2013
  Offline lane 1 from August 8, 2014
  Not enforcing lane 2 night shots August 8, 2014 to May 8, 2015 (flash failure)
  Lane 3 offline from May 4, 2015 to February 21, 2016
  Lane 4 intermittent operation for a few days from May 4 to 8, 2015

- 1003-1006 (Clem 7)

  May 5, 2011 Fines began being issued for exceeding variable speed limits other than 80 km/h
  From Jun 20, 2011 enforcement returned to just the 80 km/h speed limit
  Site CD Offline from August 2011 until roadworks completed
  Site CA removed from August 2011 to August 3, 2012
  Sites CB and CC Offline from March 12 to March 13, 2012
  Site CD Offline from March 12 to March 26, 2012
  Intermittent function for CC and CD over May 1 to May 10, 2012
  Site CC Offline from November 7 to November 14, 2012
  Site CB outage from January 23 to February 18, 2013
  Site CD outage from April 8 to May 14, 2013
  Site CB outage from August 21 to 28, 2013
  Site CD cameras removed November 11, 2013
  Site CB outage from December 18, 2013 to January 16, 2014
  Intermittent issues totalling 6 days for all sites during February 2014
  Site CB offline from March 26, 2014 to November 20, 2014
  Sites CA and CC offline October 5 to 13, 2014
  Offline November 13-16, 2014 for G20 Red Zone

- Airport Link (1007-1010)

  Outage at 1010 from November 22 to 29, 2013
  Outage at 1007 from November 22 to December 6, 2013
  Offline November 13-16, 2014 for G20 Red Zone

- Legacy Way

  began operations on June 25, 2015

- 1011
  Ceased enforcement in lane 1 from mid-December, 2013 to November 20, 2014
  Lane 2 offline from November 19, 2014
  Adjugating Night shots March 27, 2015 to April 17, 2015 (flash failure)
- 1012
  Lane 3 Outage from November 24, 2013 to June 19, 2014
  Lane 2 Outage from June 16, 2014 to April 24, 2015
  All offline from September 1 to October 24, 2014 (lane 2 still off, see above)
  Lane 5 intermittently off-line from November 2015 to March 4,2016
- 2001
  Offline from May 9 to June 27, 2012, however issues continued which were not resolved until December 11, 2012
  Not enforcing lane 2 from July 16 to 31, 2013
  Adjugating Night shots August 4, 2014 to September 6, 2014 (flash failure)
- 2002
  Outage August 16 to September 3, 2013
  Outage September 15 to 24, 2013 (lane 1 to December 5, 2014)
  Not enforced from August 24 to September 5, 2014
  Offline from May 24 to June 9, 2015
  Offline September 23 to October 1, 2015
  Offline October 6 to December 11, 2015
  Offline December 14 to December 15, 2015
- 2003
  Outage August 7 to 23, 2013
- 2004
  Outage July 12 to 25, 2013
  Offline from January 19 to 29, 2014
  Offline 6 days over February 2 to 18, 2014
  Adjugating Night shots August 4, 2014 to November 26, 2014 (flash failure)
  Adjugating Night shots September, 2015 to September 18, 2015 (flash failure)
- 2005
  Outage from November 28, 2013 to March 20, 2014
- 2007
  Outage August 11 to 20, 2013
  Offline from March 20 to 31, 2014
  Offline from March 9 to 17, 2015
- 3001
  Camera removed and replaced with digital February 4, 2015
- 3002
  Offline November 13-16, 2014 for G20 Red Zone
  Offline March 20 to 27, 2015
  Camera removed on June 9, 2015 and replaced with digital June 18, 2015

- 3003
  - Offline from October 17 to 31, 2014
  - Offline November 13-16, 2014 for G20 Red Zone
  - Camera removed January 18, 2015 and replaced with digital on January 28, 2015
- 3004
  - Offline for roadworks from Jan 6, 2011 to September 18, 2014
  - (was 3 lanes @ 70 km/hr, now 2 lanes @ 60 km/hr)
  - Digital operations began September 18, 2014
- 3005
  - Offline for 30 days over February 16 to March 18, 2014
  - Camera removed February 27, 2015 and replaced with digital on March 9, 2015
  - Offline from May 24 to June 27, 2015 (changes in speed limit and roadworks)
- 3006
  - Offline from February 22, 2011 to June 17, 2011
  - Offline May 6, 2013 to December 12, 2013
    - Then enforcement at 30 km/hr reduced roadworks speed limit of 60 km/hr Between 6 am and 6 pm until July 30, 2014
  - Offline from July 31, 2014 to December 22, 2014
    - Then enforcement returned again to 90 km/hr and digital camera became operational.
  - Offline from December 2, 2015 to February 24, 2016
- 3007
  - Offline from August ?, 2014 to September 19, 2014
  - Camera removed Jan 11, 2015 and replaced with digital on January 21, 2015
  - Offline from March 29, 2015 to December 14, 2015
- 3008
  - Offline for 8 days over February 15 to 23, 2014
  - Offline from August 29, 2014 to December 12, 2014
  - Digital operations began December 12, 2014
- 3009
  - Offline for 8 days over February 15 to 23, 2014
  - Offline from August 29, 2014 to December 12, 2014
  - Digital operations began December 12, 2014
- 4001
  - Spot speed cameras operated
    - from Aug 2, 2011 to Feb 21,2012
    - from March 23, 2013 to Aug 17, 2013
      - One spot camera continued until November 8, 2013
    - from December 11, 2015 onwards

  - Average speed cameras operated from

December 21, 2011 to February 20, 2011
May 23, 2012 to Aug 17, 2013
August 21, 2016 onwards
Average speed not enforced from August 14, 2012 to March 23, 2013

Other than special operations a summary of the events from 2013 to 2015 affecting enforcement for the mobile camera program is as follows:

Deployment hours increased:

January 2013
July 2013
July 2014

Speed Thresholds decreased by 1 km:

July 1, 2013	for 60 km/hr zone
September 20, 2013	for 40,50,70,80 & 90 zones
January 28, 2014	for 70 km/hr zones
April 4, 2014	for 60 km/hr zone
June 27, 2014	for 60 km/hr zone

Speed Thresholds decreased by 2 km:

January 28, 2014	for 40&50 km/hr zone sites

Mobile speed camera sites made public: July 4, 2013

Signage no longer required for Mobile speed camera operations: July 1, 2015
Poliscan Pilot: August 19 to December 31, 2014

Cyclones suspend mobile operations in regions affected:

28/1/2013
February 2015

8.4. CONTROL AND TREATMENT CRASH SELECTION

Table 46 Treatment and control Selection Criteria

	Treatment Crash coded as:	**Control Crash coded as:**
Red Light cameras	Signalised Intersection ≤100m from camera Not a RLSC crash	Signalised intersection >100m from camera, not a RLC, RLSC or FSC 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
Red Light speed Cameras	Signalised Intersection ≤100m from camera Not a RLC treatment crash	Signalised intersection >100m from camera, not a RLC, RLSC or FSC 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
Fixed Spot Speed Cameras (except those at PtP site and tunnel sites)	On same road and not a ramp ≤1000m from camera Not a RLC or RLSC treatment crash	On same road and not a ramp >1000m from camera Not a RLC, RLSC or FSC 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
Clem 7 and Airport-Link tunnels		Not a ramp, Not a RLC, RLSC or FSC treatment crash On Southern Cross Way or on Port of Brisbane Motorway
Average Speed cameras and FSC at the same site	On same road and not a ramp Between average speed cameras and 5 km along road North and South of them. Not a RLC or RLSC treatment crash	On same road and not a ramp >100m from camera Not a RLC, RLSC or FSC treatment crash And Matched to camera site by: • On same road • 7.2 km North/South of treatment section
Mobile Speed Cameras	≤1km from camera in ≤80 km speed zones and ≤4km from camera in >80km speed zones Not a RLC, FSC or RLSC treatment crash	Not a MSC, RLC, RLSC or FSC treatment crash And >1km from camera in ≤80 km speed zones and >4km from camera in >80km speed zones And matched to Police Region. All crashes in the Brisbane region were considered in a in ≤80 km speed zone

8.5. CRASH COSTS BY SEVERITY YEAR AND POLICE REGION

Table 47 2012 Average crash costs by severity, crash year and Police region according to the distribution of mobile camera crashes

			WTP 2015			HC		
			Serious Injury Crash	Minor Injury Crash	Casualty Crash	Serious Injury Crash	Minor Injury Crash	Casualty Crash
Brisbane	Crash Year	2013	$743,903	$107,471	$363,574	$375,478	$18,422	$162,103
		2014	$752,201	$107,672	$349,543	$378,468	$18,422	$153,536
		2015	$791,899	$112,494	$360,818	$392,773	$18,422	$155,248
Central	Metro	2013	$842,926	$105,625	$433,449	$411,160	$18,422	$193,044
		2014	$873,352	$105,687	$447,543	$422,124	$18,422	$198,198
		2015	$857,077	$112,060	$435,916	$416,259	$18,422	$191,360
Central	Rural	2013	$1,480,679	$104,501	$912,011	$640,970	$18,422	$383,719
		2014	$1,125,666	$109,576	$685,293	$513,043	$18,422	$298,675
		2015	$1,392,814	$115,194	$893,651	$609,308	$18,422	$378,450
Northern	Metro	2013	$710,162	$111,639	$403,992	$363,319	$18,422	$186,889
		2014	$753,328	$105,056	$421,617	$378,874	$18,422	$194,436
		2015	$865,843	$111,408	$494,093	$419,418	$18,422	$221,826
Northern	Rural	2013	$1,606,123	$109,552	$1,064,261	$686,173	$18,422	$444,401
		2014	$1,470,686	$112,207	$1,009,627	$637,369	$18,422	$427,302
		2015	$1,501,902	$108,375	$970,557	$648,618	$18,422	$408,327
South Eastern	Metro	2013	$808,197	$107,927	$393,482	$398,646	$18,422	$173,469
		2014	$730,509	$105,984	$343,303	$370,651	$18,422	$152,269
		2015	$789,575	$109,793	$360,796	$391,935	$18,422	$156,338
South Eastern	Rural	2013	$1,010,480	$117,782	$572,474	$471,537	$18,422	$249,214
		2014	$968,216	$105,368	$463,669	$456,307	$18,422	$200,256
		2015	$954,834	$112,141	$415,868	$451,485	$18,422	$174,508
Southern	Metro	2013	$764,312	$107,457	$408,387	$382,832	$18,422	$185,372
		2014	$750,701	$106,324	$410,203	$377,927	$18,422	$187,959
		2015	$876,539	$109,963	$415,378	$423,272	$18,422	$179,720
Southern	Rural	2013	$1,653,692	$105,810	$917,736	$703,314	$18,422	$377,675
		2014	$1,342,304	$110,999	$741,832	$591,108	$18,422	$311,825
		2015	$1,207,559	$104,989	$766,531	$542,553	$18,422	$332,901
All regions		2013	$877,538	$107,709	$447,292	$423,632	$18,422	$197,166
		2014	$840,769	$106,971	$418,744	$410,383	$18,422	$184,957
		2015	$900,262	$111,400	$437,168	$431,820	$18,422	$189,139
All Metro		2013	$769,481	$107,662	$388,466	$384,695	$18,422	$173,828
		2014	$766,030	$106,698	$375,850	$383,451	$18,422	$167,434
		2015	$820,233	$111,464	$389,582	$402,982	$18,422	$169,322
All Rural		2013	$1,469,209	$108,164	$875,030	$636,837	$18,422	$366,861
		2014	$1,217,991	$109,271	$702,510	$546,312	$18,422	$300,878
		2015	$1,279,740	$110,829	$753,151	$568,563	$18,422	$320,727

8.6. MOBILE CAMERA CRASH SAVINGS CALCULATIONS

Table 48 Annual crash counts, relative risks and crash savings in mobile speed camera zones of influence by crash severity and Police region, after introduction: 2013-2015

		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	Casual-ty Crash
Brisbane	2013	1573	2336	3909	0.708	0.775	0.710	649	677	1597

	2014	1402	2334	3736	0.659	0.953	0.765	726	115	1149
	2015	1318	2288	3606	0.787	0.921	0.830	356	195	738
	avg	1431	2319	3750	**0.716**	**0.883**	**0.767**	**577**	**329**	**1161**
Central M	2013	542	677	1219	0.666	0.770	0.692	272	202	542
	2014	509	634	1143	0.721	0.731	0.704	197	233	480
	2015	436	567	1003	0.693	0.655	0.655	193	298	528
	avg	496	626	1122	**0.692**	**0.722**	**0.685**	**221**	**244**	**517**
Central R	2013	284	200	484	0.633	0.751	0.675	165	66	233
	2014	285	218	503	0.794	0.828	0.807	74	45	121
	2015	262	168	430	0.749	0.900	0.797	88	19	109
	avg	277	195	472	**0.725**	**0.822**	**0.759**	**109**	**43**	**154**
Northern M	2013	402	421	823	0.881	0.647	0.691	54	230	367
	2014	397	416	813	0.844	0.595	0.651	74	283	437
	2015	385	374	759	0.932	0.607	0.691	28	242	340
	avg	395	404	798	**0.885**	**0.617**	**0.677**	**52**	**252**	**381**
Northern R	2013	111	63	174	0.899	0.708	0.814	12	26	40
	2014	109	56	165	0.904	0.903	0.890	12	6	20
	2015	86	53	139	0.831	1.112	0.903	18	-5	15
	avg	102	57	159	**0.882**	**0.896**	**0.866**	**14**	**9**	**25**
South Eastern M	2013	692	1005	1697	0.545	0.819	0.662	579	222	868
	2014	646	1054	1700	0.513	0.796	0.642	614	270	947
	2015	617	1054	1671	0.499	0.754	0.621	619	344	1020
	avg	652	1038	1689	**0.520**	**0.789**	**0.642**	**604**	**278**	**945**
South Eastern R	2013	109	105	214	1.024	1.065	1.014	-3	-6	-3
	2014	98	138	236	1.465	0.854	1.069	-31	24	-15
	2015	102	181	283	0.852	1.747	1.214	18	-77	-50
	avg	103	141	244	**1.107**	**1.288**	**1.109**	**-5**	**-20**	**-23**
Southern M	2013	487	576	1063	0.776	0.596	0.645	140	390	586
	2014	473	530	1003	0.624	0.552	0.556	285	431	802
	2015	402	607	1009	0.553	0.718	0.605	325	238	659
	avg	454	571	1025	**0.657**	**0.626**	**0.603**	**250**	**353**	**682**
Southern R	2013	171	155	326	0.684	0.827	0.726	79	32	123
	2014	187	178	365	0.789	1.068	0.877	50	-11	51
	2015	216	144	360	1.003	1.009	0.972	-1	-1	10
	avg	191	159	350	**0.838**	**0.972**	**0.863**	**43**	**7**	**62**
All Regions	2013	4371	5538	9909	0.706	0.731	0.693	1817	2040	4384
	2014	4106	5558	9664	0.711	0.745	0.704	1666	1907	4061
	2015	3824	5436	9260	0.719	0.761	0.717	1493	1708	3656
	avg	4100	5511	9611	**0.712**	**0.745**	**0.705**	**1659**	**1885**	**4034**
Metro-politan	2013	3696	5015	8711	0.707	0.715	0.680	1533	2001	4097
	2014	3427	4968	8395	0.673	0.701	0.659	1664	2119	4337
	2015	3158	4890	8048	0.672	0.711	0.667	1540	1985	4011
	avg	3427	4958	8385	**0.685**	**0.709**	**0.669**	**1579**	**2035**	**4149**
Rural	2013	675	523	1198	0.705	0.780	0.726	282	147	453
	2014	679	590	1269	0.824	0.920	0.853	145	51	219
	2015	666	546	1212	0.855	1.007	0.894	113	-4	144
	avg	673	553	1226	**0.794**	**0.904**	**0.825**	**180**	**65**	**272**

Table 49 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 from 2013 to 2015

		WTP			HC		
Region		**Serious Injury Crash**	**Minor Injury Crash**	**Casualty Crash**	**Fatal + Serious**	**Minor Injury**	**Casualty Crash**
Brisbane	2013	$483,085,521	$72,726,828	$580,514,448	$243,832,584	$12,466,355	$258,827,537
	2014	$546,125,800	$12,435,996	$401,533,061	$274,781,548	$2,127,723	$176,372,054
	2015	$281,650,184	$21,967,252	$266,132,442	$139,695,202	$3,597,348	$114,507,878
	avg	**$436,953,835**	**$35,710,025**	**$416,059,983**	**$219,436,445**	**$6,063,809**	**$183,235,823**
Central M	2013	$229,554,214	$21,307,072	$234,737,539	$111,971,261	$3,716,166	$104,544,399
	2014	$172,378,908	$24,671,819	$214,806,192	$83,317,178	$4,300,473	$95,128,707
	2015	$165,529,685	$33,396,621	$230,279,898	$80,393,279	$5,490,231	$101,089,291
	avg	**$189,154,269**	**$26,458,504**	**$226,607,877**	**$91,893,906**	**$4,502,290**	**$100,254,132**
Central R	2013	$243,615,243	$6,922,693	$212,242,865	$105,458,411	$1,220,367	$89,298,935
	2014	$83,245,444	$4,955,189	$82,595,512	$37,940,673	$833,066	$35,998,004
	2015	$122,329,496	$2,159,736	$97,730,600	$53,514,962	$345,389	$41,387,746
	avg	**$149,730,061**	**$4,679,206**	**$130,856,326**	**$65,638,015**	**$799,608**	**$55,561,562**
Northern M	2013	$38,659,559	$25,635,164	$148,336,047	$19,778,248	$4,230,144	$68,621,270
	2014	$55,419,346	$29,718,706	$184,052,813	$27,872,242	$5,211,295	$84,879,172
	2015	$24,349,380	$26,988,897	$167,962,107	$11,794,938	$4,462,764	$75,407,544
	avg	**$39,476,095**	**$27,447,589**	**$166,783,656**	**$19,815,143**	**$4,634,735**	**$76,302,662**
Northern R	2013	$19,935,559	$2,849,314	$42,360,835	$8,516,932	$479,133	$17,688,515
	2014	$17,018,923	$671,276	$20,583,248	$7,375,697	$110,209	$8,711,406
	2015	$26,357,244	-$576,659	$14,561,544	$11,382,747	-$98,023	$6,126,248
	avg	**$21,103,909**	**$981,310**	**$25,835,209**	**$9,091,792**	**$163,773**	**$10,842,057**
South Eastern M	2013	$467,562,670	$23,935,453	$341,647,105	$230,626,641	$4,085,511	$150,617,108
	2014	$448,286,122	$28,606,594	$325,018,700	$227,454,820	$4,972,354	$144,159,002
	2015	$488,389,454	$37,730,279	$368,117,738	$242,430,411	$6,330,725	$159,510,838
	avg	**$468,079,415**	**$30,090,775**	**$344,927,848**	**$233,503,957**	**$5,129,530**	**$151,428,983**
South Eastern R	2013	-$2,536,648	-$759,738	-$1,727,341	-$1,183,718	-$118,829	-$751,960
	2014	-$30,100,593	$2,480,373	-$7,019,664	-$14,186,009	$433,657	-$3,031,748
	2015	$16,978,783	-$8,681,343	-$20,724,714	$8,028,275	-$1,426,131	-$8,696,601
	avg	**-$5,219,486**	**-$2,320,236**	**-$9,823,906**	**-$2,447,151**	**-$370,434**	**-$4,160,103**
Southern M	2013	$107,203,771	$41,944,019	$239,197,489	$53,696,690	$7,190,700	$108,574,639
	2014	$214,241,255	$45,795,117	$329,082,380	$107,855,983	$7,934,618	$150,789,200
	2015	$285,210,152	$26,198,404	$273,827,189	$137,725,197	$4,388,985	$118,475,807
	avg	**$202,218,393**	**$37,979,180**	**$280,702,352**	**$99,759,290**	**$6,504,767**	**$125,946,549**
Southern R	2013	$130,642,798	$3,419,899	$112,871,004	$55,562,289	$595,422	$46,449,736
	2014	$67,194,268	-$1,250,813	$38,084,149	$29,590,191	-$207,592	$16,008,476
	2015	-$651,267	-$135,455	$8,006,145	-$292,613	-$23,768	$3,477,029
	avg	**$65,728,599**	**$677,877**	**$52,987,099**	**$28,286,622**	**$121,354**	**$21,978,414**
All Regions	2013	$1,594,377,324	$219,713,550	$1,960,756,715	$769,686,773	$37,578,662	$864,300,706
	2014	$1,400,385,578	$204,003,585	$1,700,454,659	$683,533,543	$35,132,528	$751,080,230
	2015	$1,344,511,048	$190,248,568	$1,598,495,584	$644,909,480	$31,460,914	$691,581,614
	avg	**$1,446,424,650**	**$204,655,235**	**$1,753,235,653**	**$699,376,599**	**$34,724,035**	**$768,987,517**
Metropolitan		**$1,567,225,091**	**$161,704,230**	**$1,634,936,444**	**$764,978,020**	**$27,549,432**	**$721,390,078**
	2013	$1,179,739,800	$215,385,789	$1,591,627,135	$589,799,270	$36,854,689	$712,211,069
	2014	$1,274,716,277	$226,134,027	$1,630,144,990	$638,083,581	$39,043,428	$726,198,150
	2015	$1,262,780,770	$221,257,107	$1,562,670,949	$620,407,550	$36,567,754	$679,175,148
	avg	**$1,239,078,949**	**$220,925,641**	**$1,594,814,358**	$616,096,801	**$37,488,624**	**$705,861,456**
Rural	2013	$414,892,574	$15,943,838	$396,204,110	$179,837,498	$2,715,488	$166,110,757
	2014	$176,659,416	$5,621,376	$153,950,350	$79,238,008	$947,709	$65,935,480
	2015	$144,688,969	-$416,098	$108,793,573	$64,282,423	-$69,164	$46,329,419
	avg	**$245,413,653**	**$7,049,706**	**$219,649,344**	$107,785,976	**$1,198,011**	**$92,791,885**

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

8.7.1. Red Light Cameras

	Casualty Crash		Serious Injury Crash		Minor Injury Crash	
ID	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*
Red Light						
2	4	9	0	2	4	7
20	4	11	1	2	3	9
25	15	13	5	5	10	8
34&38	37	31	7	10	30	21
35&54	37	27	3	9	34	18
36	21	25	8	9	13	16
39	8	23	2	2	6	21
41	12	25	2	11	10	14
42	24	21	2	7	22	14
45	8	32	1	12	7	20
46	13	58	5	14	8	44
47	31	30	3	8	28	22
48	14	15	6	2	8	13
49	6	17	1	4	5	13
50	4	14	1	5	3	9
55	7	48	2	18	5	30
56	10	30	2	6	8	24
57	28	67	3	18	25	49
58	16	13	4	1	12	12
59	23	19	7	3	16	16
61	29	149	10	27	19	122
75	17	60	4	15	13	45
84	5	9	0	6	5	3
94	22	44	8	14	14	30
113	16	18	4	6	12	12
114	16	20	2	8	14	12
116	6	8	0	2	6	6
117&125	22	56	9	18	13	38
121	13	57	5	14	8	43
122	8	25	3	9	5	16
123	9	76	5	30	4	46
126	13	10	4	1	9	9
155	1	0	1	0	0	0
156	10	19	4	4	6	15
206	1	19	1	7	0	12
207	6	10	2	1	4	9
209	16	20	3	0	13	20
210	10	31	2	7	8	24
407	15	12	4	2	11	10
408 &411	18	29	4	13	14	16
409	2	10	0	2	2	8
410	12	7	5	2	7	5
451,452,453&454	32	75	7	22	25	53
461 & 463	25	23	5	5	20	18
Site 157 and 158	7	10	3	2	4	8
Site 460 and 462	14	16	5	5	9	11
Site 43, 44 and 52	36	461	13	121	23	340
Site 110, 118, 119	47	105	20	26	27	79
Site 62,63,64&65	121	60	54	10	67	50
Site 69 & 500	35	121	14	40	21	81
Site 40 & 60	9	31	3	8	6	23

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

	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
Red Light Speed						
2001	27	13	11	6	16	7
2002	44	39	14	11	30	28
2003	49	103	19	27	30	76
2004	14	45	6	16	8	29
2005	29	264	7	83	22	181
2006	61	213	22	84	39	129
2007	41	7	13	0	28	7

8.8. CAMERA SYNERGY

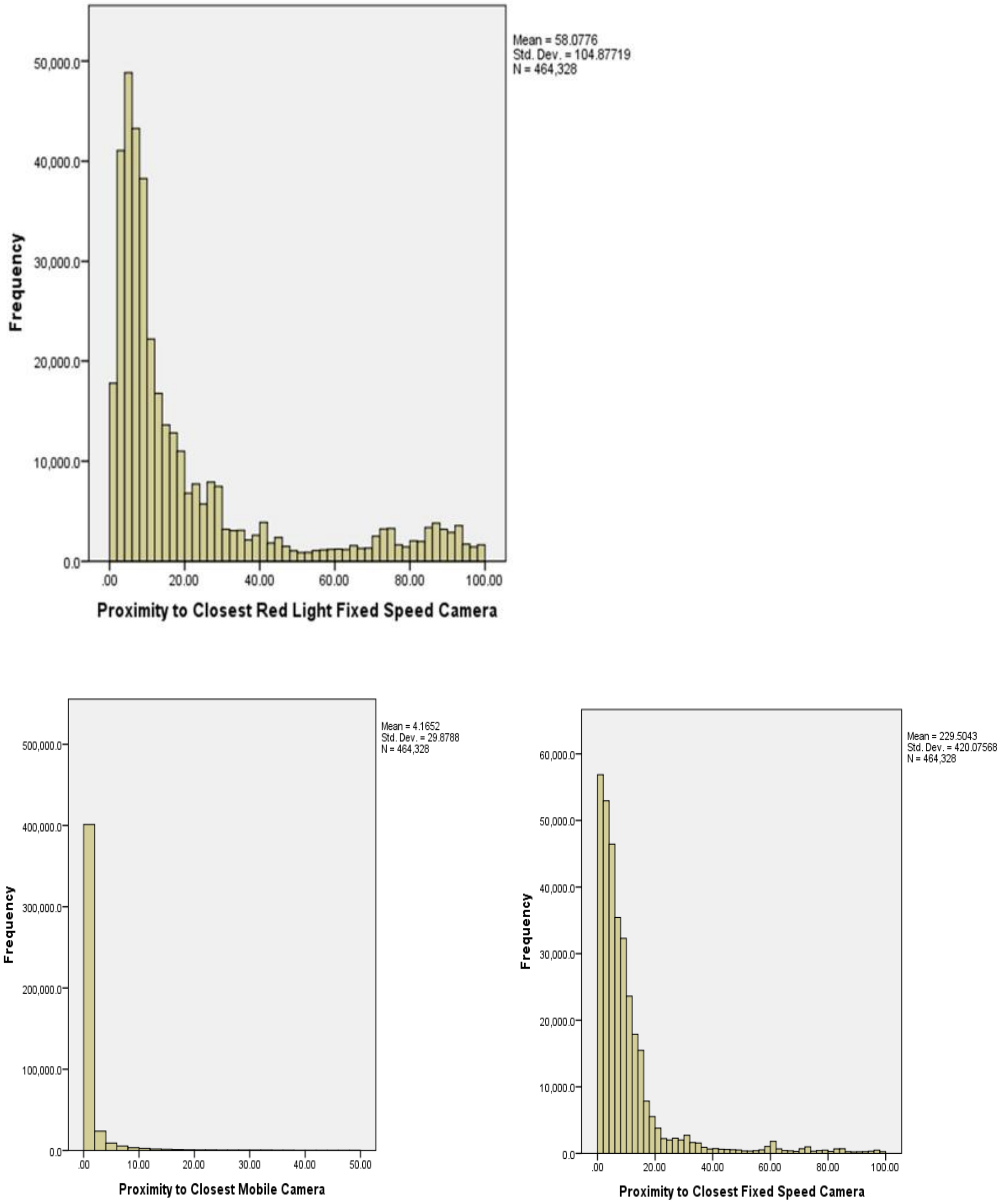

Figure 18 *The proximity of crashes to closest fixed spot speed, mobile speed cameras and Red Light speed Cameras (km)*