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EVALUATION OF THE ROAD SAFETY BENEFITS OF THE QUEENSLAND CAMERA DETECTED OFFENCE PROGRAM (CDOP) IN 2018 & 2019

by

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Title and sub-title:
Evaluation of the road safety benefits of the Queensland Camera Detected Offence Program (CDOP) in 2018 & 2019

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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. The broad objective of this study was to measure impacts on crash frequency, severity and social costs to the community in Queensland associated with the ongoing operation of the CDOP over the years 2018 and 2019.

Evaluation results show that the Queensland CDOP was associated with sustained crash reductions across Queensland in the years 2018 and 2019 with correspondingly large economic benefits to the community accruing from its operation. Both fixed and mobile elements of the program produced significant crash reductions. Crash effects associated with red-light cameras, combined speed and red-light cameras (placed at intersections without prior red-light cameras), point-to-point speed cameras, tunnel cameras and road safety camera trailers estimated in the evaluation were robust. In contrast, the evidence of effectiveness for some fixed camera types, including fixed mid-block spot speed cameras and recently installed intersection speed and red-light cameras, remains weaker due to insufficient post-implementation history and small number of camera installations. Despite the expansion of the number of fixed cameras in use under the CDOP, the mobile camera program continues to produce around 93-94% of the measured benefits associated with CDOP reflecting the high proportion of the crash population it covers.

Overall crash reductions in Queensland associated with CDOP were 11.9% for serious casualty crashes and 11.1% for all casualty crashes in 2018 and 11.4% for serious casualty crashes and 10.9% for all casualty crashes in 2019. It was estimated that CDOP was associated with absolute casualty crash savings of 1,605 in 2018 of which 777 were fatal or serious injury savings and 1,560 casualty crashes saved in 2019 of which 748 were fatal or serious injury crashes. Conversion of the estimated crash savings into (2019 $) cost savings estimated annual savings of around $747M in 2018 associated with the program, valued using WTP estimates or $338M using HC crash costs. Corresponding economic savings in 2019 were $720M and $326M. About 89% of the total savings stem from savings in fatal and serious injury crashes which are the focus of the Queensland road safety strategy. Analysis showed crash and cost savings associated with CDOP in 2018 and 2019 were the greatest of any year of the program being over 22% higher than the previous best year of 2017. This is largely attributable to the significant increase in the hours of mobile speed camera enforcement in 2018 and 2019.

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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Contributor Statement

Stuart Newstead:	Study design, mobile camera analysis, evaluation framework design, and report editing/writing
Laurie Budd:	Fixed camera analysis and relevant report preparation
Max Cameron:	Project concept, SCRAM strategic model and review of concept and manuscript

Ethics Statement

Ethics approval was not required for this project.

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Contents

GLOSSARY OF ABBREVIATIONS AND TERMS

Term / Abbreviation	**Meaning**
CDOP	Camera Detected Offence Program.
GIS	Geographical Information System – a computer program which maps and relates information spatially.
Human Capital crash cost (HC)	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 (WTP)	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 (RLC) program and fixed speed cameras. It has been expanded over recent years to include point-to-point (PtP) cameras and combined speed and red-light cameras (RLSCs). 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 deployment hours.

The broad objective of this study was to measure impacts on crash frequency, severity and social costs to the community in Queensland associated with the ongoing operation of the CDOP over the years 2018 and 2019. An updated evaluation framework for the mobile speed camera component of the CDOP was developed which has provided more robust estimates of associated crash effects and directly links levels of operation of the mobile speed camera program by specific camera type to observed crash outcomes. 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 the end of 2019 for the analysis. 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 (QPS).

Evaluation results show that the Queensland CDOP was associated with sustained crash reductions across Queensland in the years 2018 and 2019 with correspondingly large economic benefits to the community accruing from its operation. Both fixed and mobile elements of the program produced significant crash reductions. Crash effects associated with trailer cameras, RLCs, tunnel cameras, PtP cameras, and upgrades from no camera to combined RLSCs estimated in the evaluation were robust. In contrast, the evidence of effectiveness for some of the more recently implemented fixed camera types, including fixed mid-block spot speed cameras and recently installed intersection RLSCs, remains weaker due to insufficient post-implementation history and small number of camera installations. 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. Despite the expansion of the number of fixed cameras in use under the CDOP, the mobile camera program continues to produce around 93-94% of the measured benefits associated with CDOP reflecting the high proportion of the crash population it covers.

Overall crash reductions in Queensland associated with CDOP were 11.9% for serious casualty crashes and 11.1% for all casualty crashes in 2018 and 11.4% for serious casualty crashes and 10.9% for all casualty crashes in 2019. It was estimated that CDOP was associated with absolute casualty crash savings of 1,605 in 2018 of which 777 were fatal or serious injury savings and 1,560 casualty crashes saved in 2019 of which 748 were fatal or serious injury crashes. Conversion of the estimated crash savings into (2019 $) cost savings estimated annual savings of around $747M in 2018 associated with the program, valued using WTP estimates or $338M using HC crash costs. Corresponding economic savings in 2019 were $720M and $326M. About 89% of the total savings stem from savings in fatal and serious injury crashes which are the focus of the Queensland road safety strategy. Due to recalibration of the models used to estimate the benefits of the mobile speed camera program, the total savings associated with CDOP are slightly lower than reported in previous evaluations. In assessing the effectiveness of the CDOP in 2018 and 2019, the relative savings in these years compare to previous years of the program are relevant. Analysis showed crash and cost savings associated with CDOP in 2018 and 2019 were the greatest of any year of the program being over 22% higher than the previous best year of 2017. This is largely attributable to the significant increase in the hours of mobile speed camera enforcement in 2018 and 2019.

The study also provided further evidence on the mechanisms of crash reduction effects associated with the mobile speed camera program. Hours of operation of both overt and covert car-based mobile speed cameras were statistically significantly associated with all casualty crashes, with no difference in association between high and low severity crashes. Relationships were estimated to differ between urban and rural areas with generally higher percentage crash reductions per hour of enforcement in rural areas compared to urban areas. Furthermore, covert car-based mobile operations were found to produce around double the crash savings per hour of enforcement compared to overt operations, although the difference between overt and covert effectiveness varied between urban and rural settings, being much more pronounced in urban areas. Associations between portable / LTI cameras and crash outcomes were only found in urban areas and only for serious casualty crashes where the level of effectiveness per hour enforced was similar to that of overt car-based operations.

The last finding is significant since the expansion in mobile speed camera enforcement in 2018 and 2019 largely comprised additional portable / LTI operations in metropolitan areas. Whilst this was associated with additional crash and cost savings from CDOP, evaluation evidence suggests expansion of covert car based mobile speed camera operations in favour of portable/ LTI operations may have produced greater crash savings than those measured. In addition, coverage of the fatal crash population by CDOP has fallen significantly in recent years meaning the estimated savings in fatal crashes associated with the program in 2018 and 2019 were proportionately less than for serious and minor injury crashes. This suggests a need to consider how the mobile speed camera component of the CDOP might be better focused or expanded to address the fatal crash population in Queensland.

Overall, evaluation of the Queensland CDOP shows it aligns closely with the goals and objectives of the Queensland road safety strategy. It aligns specifically on the key safe system pillars of safe speeds and safe people, and has proven to be an effective program with the actions achieved under the program producing measurable reductions in road trauma hence reducing the burden of road trauma on Queensland communities. Estimated overall serious casualty crash reductions associated with the program in 2018 and 2019 of around 11% of the total represent a significant proportion of the total strategy target reductions of 30% reduction in serious casualties by 2021 reinforcing the high value of the program in the context of the broader strategy.

1. BACKGROUND AND AIMS

1.1. BACKGROUND

The Queensland Camera Detected Offence Program (CDOP) is jointly managed by Transport and Main Roads (TMR) and the Queensland Police Service (QPS). It covers management and operation of all modes of camera-based traffic enforcement in Queensland. Currently this includes mobile speed cameras, red-light cameras (RLCs), fixed spot speed cameras (FSSCs), combined red-light / speed cameras (RLSCs), a point-to-point (PtP) speed camera system and most recently road safety camera trailers (RSCT). Covert operation of the mobile speed cameras commenced in April 2010 with cameras deployed in both urban and rural areas. Road safety trailer cameras were added to the CDOP in recent years. These are deployed to high-risk areas including highways and motorways, roadworks sites and school zones. Unlike other mobile cameras, which are sited only for short time periods and manned during operation, the road safety trailer cameras are left on site for longer periods with operation managed and monitored remotely with daily checks.

To inform the ongoing management and development of the program, evaluations of the program have been conducted previously at regular intervals. The Monash University Accident Research Centre (MUARC) developed an initial evaluation framework for the CDOP when its only component was the mobile speed camera program (Newstead and Cameron, 2003). The framework was applied to estimate the crash and economic impacts of the mobile speed camera program from its introduction in 1997 to June 2001. A further component of the initial study was to relate mobile speed camera operational measures to estimated crash outcomes to ascertain the most important operation parameters of the program that determined effectiveness.

With the progressive introduction of other camera types under CDOP, including PtP camera systems, combined RLSCs and fixed digital cameras, TMR commissioned MUARC to develop a new evaluation framework to measure the crash and economic impacts of each of these camera types in addition to the mobile speed camera program. An evaluation framework was developed and successfully applied to evaluate the CDOP to the end of 2008 including the impact of each individual camera type as well as the combined impact of the CDOP on reducing crashes across Queensland (Newstead and Cameron, 2012). The evaluation framework also incorporated the assessment of changes in measured travel speeds in Queensland using data collected from periodic state-wide travel speed surveys as an intermediate measure of CDOP effectiveness. This evaluation framework was been reapplied periodically to provide ongoing assessment of the road safety performance of the Queensland CDOP in the years 2009-2012 (Newstead and Cameron, 2014), 2013-2015 (Newstead, Budd and Cameron, 2017), and 2016 (Newstead, Budd and Cameron, 2018).

In response to a number of efficiencies note in the evaluation framework used to evaluate the CDOP up to 2017, particularly in assessing the impacts of the mobile speed camera program, TMR commissioned MUARC to develop a revised framework for the evaluation of the crash and economic impacts of CDOP. Although using similar evaluation methodology for the fixed CDOP elements as used previously, the revised evaluation made significant changes to the way in which the mobile speed camera component of CDOP was assessed. Instead of looking for relative intervention effects between enforced and unenforced mobile speed camera sites, the new framework assessed the relationship between mobile speed camera operational outputs in each police region, as measured by hours of enforcement, considering each type of mobile camera enforcement (car based overt, car based covert and portable / LTI enforcement) separately. In addition, analysis was based on the new sector-based partitioning of Queensland for enforcement scheduling, identifying those sectors which had been enforced at some stage during the program and differentiating effects in rural and urban sectors. Through this framework, it was possible to measure the relative impacts of each mobile speed camera operation type on crashes per hour enforced.

The revised evaluation framework for CDOP is described in Newstead, et al (2020) which also demonstrated the application of the framework to estimate road safety benefits of the CDOP in 2017.

1.2. AIMS

The primary aim of the project was to apply the CDOP evaluation framework developed by Newstead et al (2020) to estimate the road safety benefits of the CDOP in the 2018 and 2019 calendar years. Results of applying the evaluation framework will be used by TMR to report publicly on the crash effects and associated economic savings of the CDOP and to guide future policy development and analysis. Given trailer speed cameras were first introduced late in 2017, an associated aim of the project was to extend the evaluation framework to include methodology to evaluate the road trauma impacts of the road safety camera trailer (RSCT) component of CDOP.

As per the previous application of evaluation framework, the current application aimed to estimate 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.

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 2019 inclusive. Property damage only crashes were not reported beyond 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 516,119 crash records were contained in the data; 350,025 pertained to casualty crashes. The data included the following fields pertaining to the crash:

- Unique crash identification number
- Date of occurrence
- Severity (fatal, hospitalisation, medically treated injury, other injury, no injury)
- Police region
- Statistical Local Area
- Speed limit
- Street on
- Intersecting street
- Traffic control
- DCA code (Definition for Classifying Accidents)
- Roadway feature (intersection geometry, bridge, etc.)
- Divided/undivided carriageway
- Number of lanes
- Speed related crash indicator
- Number of traffic units involved in crash
- Sector ID, activation date, urban/rural status and urban centre name for crash
- Distance from five closest mobile speed camera sites and the unique site identifiers for the five closest mobile speed camera areas of possible influence including: sites, sectors, weighting areas and zones, all of which are further defined in the next section.
- Distance from the three closest FSSC sites and the unique site identifiers for the three closest FSSC sites
- Distance from the five closest Trailer camera sites and the unique site identifiers for the three closest Trailer camera sites
- Distance from the closest RLC site and the unique site identifier for the closest combined RLC site
- Distance from the closest combined RLSC site and the unique site identifier for the closest combined RLSC site
- Distance from the closest average speed camera site and the unique site identifier for the closest average (PtP) speed camera site
- GDA latitude and longitude for the crash
- WTP 2019 Crash cost
- HC 2019 Crash cost

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

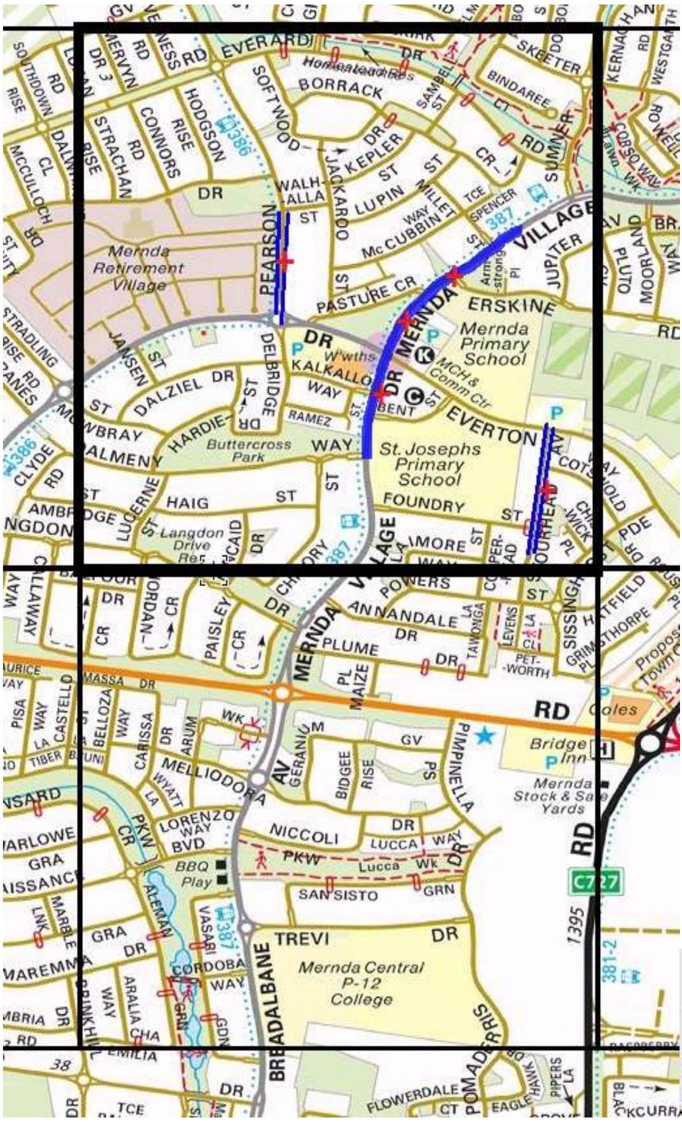
2.1.1. Mobile speed camera site selection and definition

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

During 2016, Queensland TMR changed to a new methodology for partitioning Queensland into areas for consideration of mobile speed camera enforcement. Previously areas for enforcement were based on circular zones which left gaps in areas of the road network considered. Transition to square sectors allowed all of Queensland to be considered for mobile camera enforcement. All areas of Queensland were divided up into nominally square sectors of 1km side length in urbanised (built up) areas and 5km side length in rural areas. The concepts of sectors, segments and sites are illustrated in Figure 1.

Each sector was assessed for enforcement and each sector included sites chosen for enforcement based on operational and safety criteria which included consideration of the frequency and severity of crashes.

As evident from Figure 1, the spatial disaggregation of Queensland for the purpose of speed camera operations siting allows multiple potential references for relating crash occurrence to speed camera operations. These include the specific camera site, the weighting area or the whole of the sector. Under the revised evaluation framework of Newstead et al (2020), analysis of the mobile speed camera program crash effects is based on the sector partitioning of Queensland with each sector representing an analysis unit with each being dichotomised as enforced or unenforced based on the presence of a mobile speed camera operation in that sector at some time since implementation of the mobile speed camera program in Queensland.



A sector is a rectangular (or polygon) block which may contain sites where mobile speed camera operations are carried out. To the left is a bolded block with examples of primary and secondary speed camera sites and speed camera criteria crashes (illustrative only and not from the Queensland program).

A speed camera site may be defined as a point, or a segment of road (blue line), which is called a "weighting area" in the crash data. The actual site of the scheduled operation may occur anywhere along this segment. Such a block would be defined as a treatment block in the evaluation. Under this block is another sector which has no mobile camera sites which would be used as a comparison or control site in the previous evaluation framework.

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

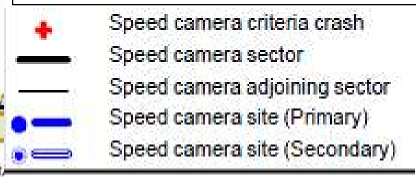


Figure 1 *The new format for the identification of mobile speed camera operations*

2.2. CAMERA DATA

2.2.1. Red-light cameras (RLCs)

The provided crash data allowed the identification of crashes within 100m of 107 RLCs. This identification process could be extended to include three additional cameras (40, 462 and 500) which were located at the same intersections as identified cameras (60, 460 and 69 respectively). Furthermore, crashes were also identified as 100m from RLSC at intersections previously fitted with RLC; this provided data on crashes within 100m of an additional 22 red light cameras. Crashes for one of the analysed cameras (115**:** Gold Coast Highway & Government Road, Labrador) were manually identified, using street names because the crash data provided placed the site at an incorrect location.

The **132** cameras at sites where crashes had been observed over the study period, were located at **118** unique intersections. Eleven intersections had two camera sites (7/55, 37/54, 40/60, 43/52, 67/68, 76/77, 110/119, 157/158, 206/209, 460/462& 69/500). Three cameras were sited in different points within the intersection of Kessels Road and Mains Road (5, 76 &77), however camera 5 was decommissioned more than four years prior to the go-live dates for cameras 76 and 77. The analysis of crashes associated with cameras 76/77 were referenced against these four years of pre-period. Four cameras were positioned at different locations at the junction of the Gateway Arterial and Old Cleveland Road in Belmont (62-65).

Twenty-four of the 132 cameras were placed at intersections (21) where red light speed cameras were later installed. Three of these intersections had two RL cameras (110/119, 157/158 and 67/68). The crashes associated with these 21 intersections were temporally partitioned so that the crash and economic effects for both the RLC (prior to upgrade) and the speed camera upgrades could be estimated.

Cameras with less than three years of crash data prior to the '*go live'* date for the intersection, were excluded from the analysis due to issues of statistical analysis power in the evaluation. Fifty-nine of the 132 red-light cameras (with associated crash data) went live prior to 1995; ten of these became RLSC sites (13, 14, 19, 83, 153, 154, 252, 304, 353 and 410); three were one camera of multi-camera intersections (62-65, 37/54 and 7/55). Although the crash effects at these RLC sites were not able to be estimated, provided that the site was identified in the crash data and the camera was 'live' in during 2018 or 2019, 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.

Crashes near 20 decommissioned or parked RL cameras (2, 5, 33, 51, 81, 103, 107, 111, 120, 127, 201, 203, 251, 301, 303, 351, 352, 354, 355 and 401) were not identified in the crash data. Information about the location of these cameras was provided in the data provided for previous CDOP analyses. For the crash years prior to 2018, spatial data from previous analysis years could be used to identify crashes prior to decommissioning within 100m of each of these cameras. Crashes occurring in 2018 and 2019 generally occurred after the, however the intersection location of those within the operational times were matched with RLC metadata from previous CDOP analyses to determine proximity to a decommissioned camera. Crashes found to be both within the operational period and 100m proximity were excluded from the fixed camera analyses. Exclusion meant that these cameras, which were not active in 2018 and 2019 were not included in the 2018-2019 evaluation of fixed cameras.

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

During the study period (1992-2019), all intersections with (included) RLCs and associated crash data had at least one camera site at the intersection upgraded to, or installed as, a digital red-light or digital RLSC. For all RLCs 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 2019.

2.2.2. Intersection fixed speed and red-light cameras (RLSCs) and mid-block fixed speed cameras

As of December 2019, there were thirty-six digital RLSCs operating in Queensland: each one is located at a different intersection with the exception of two intersections: Bridge and McDougall Streets, Toowoomba, which has two cameras (483157 & 483158); and Smith street and Kumbari Avenue, Southport which has one camera (383119) and two locations (2101 and 2028). **Twenty** RLSCs, at 20 intersections, went live in 2018 and 2019; twelve of these intersections previously housed RLCs.

Fifteen RLSC locations were analysed using a no-camera before period, as these locations were not upgraded from RLC sites (GIS: 2002, 2015-2024, 2026-2027, 2108-2109; or QPSID: 283006, 283067, 283078, 383071, 383078, 483095, 483096, 483159, 583085, 583086, 683256, 683257, 783211, 883305 and 883306). Three of these have less than one year of operating period as at the end of December 2019.

The other 21 RLSCs at the other **twenty** intersection locations were installed at sites previously enforced by RLCs, so were analysed as upgrades with the 'before' period being where the RLC was operational. The RLCs for these locations were evaluated with the before implementation period being where there was no camera operational at the sites and the post-implementation period being where the RLC was operational but before installation of the RLSC periods. As previously stated, ten of these twenty-one: 183013, 183014, 283019, 483153, 483154, 583083, 583412, 683252, 683353 and 883304 (GIS coded: 2005, 2006, 2007, 2010, 2011, 2025, 2029, 2103, 2105 and 2106); had no sufficient period prior to RLCs, so for these ten, no red-light only camera evaluations were made.

As with RLCs, the overall contribution of all RLSC 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. Although, where analysis allowed, all RLSC sites active during the crash data period were analysed.

There were nine analogue FSSC (one per site) made active prior to 2012. One of these, camera 480001 (GIS coded as 3006) located on the Warrego Highway in Redwood was not included in the crash data nor in the current QPS and TMR metadata. This camera was decommissioned in December 2013. It was reassigned to roadworks speed limit enforcement and it assumed that housing structure and signage has been removed. For these reasons, crashes associated with the operation of this camera have been excluded from this 2018-2019 analysis.

There were 49 fixed spot digital speed cameras at 19 locations that were activated prior to December 2017:

- Eight at three locations, on the PtP section of the Bruce Hwy, (The fixed spot cameras still operate when the PtP system is down)
- Six at two locations on the PtP section of the Mt Lindesay Highway, South Maclean (this system was decommissioned in 2019 due to the installation of a set of traffic lights within the system and other upgrades to the highway)
- Ten in the Airport-Link Tunnel (at four locations)
- Six in the Legacy Way Tunnel (at two locations)
- Eight in the Clem 7 tunnel (at four locations)
- Four at location number 1002 (with one in each of four lanes)
- Five at location 1012 (with one in each of five lanes)
- One at location 1011 (Nambour) and
- One at location number 1001 (Nudgee)

One of these, camera 180001 (GIS coded as 1001) located on the Gateway Motorway in Nudgee was not included in the crash data nor in the current QPS and TMR metadata. This camera was decommissioned in April 2016. It was reassigned to roadworks speed limit enforcement and it assumed that housing structure and signage has been removed. For these reasons, crashes associated with the operation of this camera have been excluded from this 2018-2019 analysis.

The active average speed PtP camera system, operating on a segment of the Bruce Highway between Landsborough and the Glass House Mountains, began operation five months after the FSSCs operating at each end of the average speed camera system on this road section went live. The PtP system was extended to Elimbah in 2017 and the extended treatment area has been evaluated for the first time in this report.

The currently decommissioned average PtP camera system on the Mount Lindesay Highway at Maclean was operational between 21 July 2017 and 6 March 2019 and was included in this analysis. The evaluation of this camera did not count crashes within its zone of influence beyond decommissioning.

2.2.3. Road Safety Camera Trailers (RSCTs)

Mobile trailer speed camera operations began December 22, 2016 with targeted operations. Trailer operations were extended to school zone and roadwork speed enforcement in 2017 (January and April respectively. Within this document, a trailer operation was defined as continuous daily enforcement with breaks in continuity of less than one week. Operations were identified with 98 different six digits site numbers. Up to six operations were carried out for each site number. Operations for 52 site numbers were carried out at uniquely identified site locations, from December 22, 2016 to December 30, 2019: Two roadwork, 17 school and 33 targeted. Additionally, over the same period, 46 site numbers were clustered into 18 locations because of overlapping camera zones of influence:

1. Gateway Motorway roadworks, Nudgee beach: 185: 903,906, 907, 910 & 911
2. Gateway Motorway roadworks, Boondall: 185: 904, 909 & 912
3. Old Cleveland road targeted, Belmont: 287909 and 287910 (exact location match)
4. Bruce Highway targeted, Parklands: 587905 & 587906 (exact location match)
5. Bruce Highway targeted, Woombye and Kiels Mountain: 587909 & 587910
6. Mt Lindesay Hwy, Jimboomba: 386903 is school zone, 387905 is targeted
7. Pacific Highway, Slacks Creek and Daisy Hill: 385919 & 385920 are road works, 387919 & 387920 are targeted.
8. Pacific Highway, Eagleby: 385906 is road works, 387906 is targeted
9. Pacific Highway targeted, Yatala: 387907 & 387918
10. Brisbane Rd, Bundamba: 486901 is school zone, 487903 is targeted
11. Ham Rd, Mansfield: 286901 is school zone, 287903 is targeted
12. Wembley Rd school zone, Logan Central: 386901 & 386902
13. Warrego Hwy targeted, Gatton: 487907 & 487913
14. Pacific Highway, Ormeau/Pimpana: 385908 is road works, 387: 901, 908, 909 & 917 are targeted
15. Pacific Mwy, Pimpama: 385916 is road works, 387916 is targeted
16. Pacific Mwy targeted, Coomera/Upper Coomera: 387910 & 387915
17. Pacific Mwy targeted, Helensvale/Oxenford: 387911 & 387913
18. Pacific Mwy, Mudgeeraba/Robina/Varsity Lakes: 385921 & 385922 are road works, 387902 is targeted.

As can be observed, operations of different types were possible at cluster locations. Clusters were necessary so that treatment and control sites could be identified along the lengths of a single road. Periods of operation were used to distinguish treatment operation types, so that analyses could be stratified by type. This required that controls for targeted and roadwork operations were shared for clusters 7, 8, 14, 15 and 18. As different lengths of 40 km/hr zoned roads were used as controls for school zone treatments, controls did not need to be shared for clusters 6,10 &11.

A summary of fixed speed camera sites available for evaluation is presented in Section 7.2 of the Appendix. The shortest post-activation observation periods are for RLSCs. The RLSC located at Moores Creek Road and High Street in Rockhampton had only 6 months of post activation, and several others had less than a year.

The pre-activation period for all fixed spot, average and RLS 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 RLC effects disaggregated by police region. Disaggregated by severity and region, low crash counts and the relatively few cameras, each with very specific halos of influence, meant that statistical power was insufficient to draw conclusions with statistical significance from this analysis. However, over all regions, for all combined fixed cameras (and also individually for some specific camera types), strongly significant injury crash reductions were estimated. Hence overall estimates of average camera effectiveness were the focus of the analysis.

2.2.4. Mobile cameras

Data on the hours and locations of mobile camera operations were provided by QPS with the locations subsequently matched to crash data to determine the spatial distribution of crashes in relation to camera locations. Data were also aggregated into tables summarising the hours of deployment per month (or quarter), deployment type (digital or analogue mobile speed, portable speed), deployment site number, camera type (vehicle mounted, tripod mounted or hand held) and covert/overt status. Vehicle mounted cameras consisted of digital, analogue or wet film deployment types and operations could be covert or overt. A small percentage of digital mobile speed camera operations were classed as other or 'N/A', these were considered 'overt' for the purposes of this analysis. Portable mobile speed cameras were either tripod mounted or hand held. Given the nature of hand-held operations, no distinction was made in the classification of operations as overt or covert. In comparison, car-based operations were dichotomised as overt or covert based on their description in the operations data.

In order to place sites into the appropriate geographical sectors for analysis, TMR provided a correspondence table between site and sector. Also included in the correspondence table was the urban or rural classification of the sector.

Notable features of mobile camera deployment included:

- Deployment hours increases in January and July 2013 and July 2014 and a significant increase in total hours enforced from 2018, carrying through in to 2019 (see Figure 2)
- A reduction in the enforcement thresholds staggered by speed zone over the period July 2013 to June 2014
- A steady increase in the use of portable speed cameras with a trial of the Poliscan system in the second half of 2014 (see Figure 2)
- Removal of the requirement for signage of mobile speed cameras in July 2015
- New Scheduler in May 2016.

Figure 2 shows the number of hours of mobile speed camera operations per quarter year by mobile camera type and overt/covert nature for the whole of Queensland broken down by urban and rural areas. Prior to April 2010, operations were only car mounted of the overt type. It shows the increase in camera hours over 2013-2014, rising from around 18,000 to 24,000 total hours of operation per quarter, as well as the introduction of both covert camera operations and the commencement and growth of use of the portable speed cameras. Operation patterns are similar between urban and rural areas. Portables cameras were relabelled LTI in 2016. Although a proportion of the LTI operations were labelled as being covert, the nature of LTI and portable camera operations suggests they are all likely to be relatively overt in nature, being hand operated at the roadside. As such, all portable and LTI operations have been combined for consideration in the analysis and assumed to be overt. Car-based operations have been considered separately based on overt and covert operation.

Figure 2 shows that the bulk of increased hours of mobile speed camera enforcement from 2013 but particularly in 2018 and 2019 have been through increased use of portable / LTI cameras in urban areas. Whilst there have been increases in car based overt operations in the most recent years, use of covert car-based operations has been relatively static in hours since the introduction of covert operations. Covert operations still comprise only a small proportion of total hours enforced.

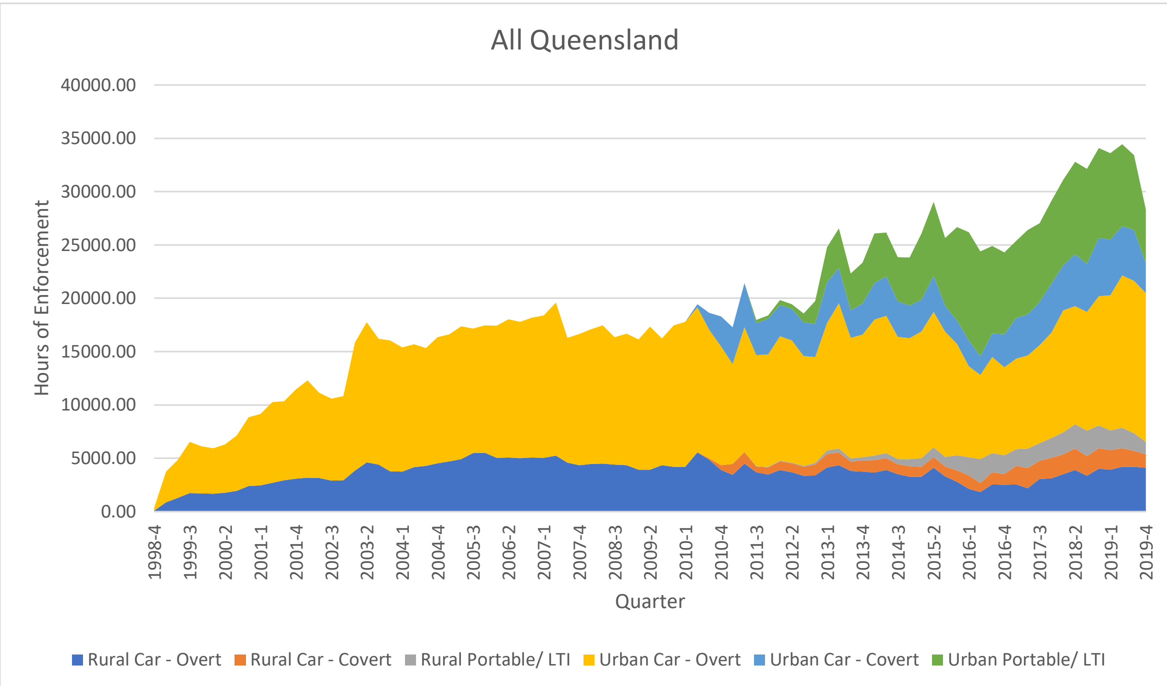


Figure 2 *Quarterly mobile speed camera hours by mobile camera type, operation nature, urban and rural areas of Queensland*

2.3. CRASH COSTS

Human Capital and Willingness to Pay crash costs for use in the economic evaluation were provided by TMR with the crash data (Table 1). The post-activation camera crash distribution by severity and police region (and speed category) was used to weight fatal, hospital, medically treated, other injury and no injury costs to produce serious injury (fatal + hospital) and minor injury (minor injury + medical treatment) unit costs (Table 2 and Table 3).

Table 1 2019 Willingness to Pay (WTP) and Human Crash (HC) Unit Costs by severity

	WTP	HC
Minor Injury	$43,265	$19,667
Medical Treatment	$132,548	$19,667
Hospitalisation	$669,368	$355,883
Fatal	$9,595,086	$3,572,206

Table 2 2019 WTP Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Serious Casualty Crashes	Minor Injury	All Casualty Crashes
Brisbane		$861,319	$113,360	$330,058
Central	Urban	$669,368	$117,242	$372,070
	Rural	$669,368	$110,227	$333,884
Northern	Urban	$803,388	$124,431	$515,043
South Eastern	Urban	$876,943	$99,526	$387,706
	Rural	$808,832	$110,432	$368,800
Southern	Urban	$803,388	$111,785	$353,900
	Rural	$669,368	$87,907	$390,266

Table 3 2019 HC Crash costs by severity and police region according to the distribution of Fixed camera crashes

		Serious Casualty Crashes	Minor Injury	Casualty Crashes
Brisbane		$425,051	$19,667	$137,115
Central	Urban	$355,883	$19,667	$174,844
	Rural	$355,883	$19,667	$154,153
Northern	Urban	$404,176	$19,667	$247,852
South Eastern	Urban	$430,681	$19,667	$172,026
	Rural	$406,138	$19,667	$162,639
Southern	Urban	$404,176	$19,667	$154,290
	Rural	$355,883	$19,667	$194,499

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

3. METHODS

The evaluation framework used in this study was that developed and escribed in Newstead et al (2020) The following sections outline the relevant specific details in applying the framework to estimate the crash and economic benefits of the CDOP in 2018 and 2019.

Analysis has considered crashes by severity: serious casualty, minor injury and all casualty crashes in aggregate. Non-injury crashes are not reported beyond 2010 in Queensland and hence cannot be considered in estimating effects of the program in 2018 and 2019. Analysis has focused on the crash and economic effects of CDOP at the state-wide level and within each of the five police regions in Queensland. State-wide savings estimates have been derived 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 (RLCs, FSSCs, RLSCs, PtP cameras and trailer cameras) is presented in Section 7.3 of the Appendix. Included in the table is the matching criteria for selecting the control sites. Choice of the matching criteria reflected the availability and quality of information available in the crash data.

For example, matching of the control sites for RLSCs, PtP and FSSC sites by number of lanes, crash history or traffic volume was not attempted due to traffic volume not being reliably available across all road segments and intersections and tight restrictions on number of lanes and crash history being too restrictive in identifying sufficient control areas to maintain adequate statistical power. An intersection identifier was provided, it was not sufficiently complete to allow broad control matching. Additional analysis using street names and GPS location was undertaken to uniquely identify control intersections for RLC/RLSC sites. Once identified, a pre-period crash history was defined and used to eliminate control intersections with a very different history[1]. Generally, there were insufficient control intersections available to do very specific crash history matching. Traffic volume data, again could not practically be identified for many RLSC and RLC intersections which precluded this factor being used to match control sites. Traffic volume data, although provided for a number of major arterial roads, were not available for all control sections of road. By matching on other road geometry characteristics, speed limits (Table 4), intersection control type (signalisation), road dividedness and 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 RLSCs were matched by SLA or the distance from the camera.

Control sites for FSSCs 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

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[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.

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.

Control sites for RSCTs used in targeted and roadworks operations were similarly chosen from the same road, but limited to 4km outside the hypothesised zone of camera influence in Brisbane, Logan, Moreton and Gold Coast locations (defined as 1km either side of the camera) and limited to 10 km in other (rural high speed) locations (defined as 4 km either side of the camera). Lengths of road segments available were found unable to produce sufficient control crashes when trailer enforcement occurred at several closely spaced locations along the same road. This meant that camera locations had to be grouped for the analysis of the trailer cameras on the Warrego Highway (Sites 487901, 487904, 487906, 487907, 487908, 487909, 487912 and 487913), some sections of the Pacific Highway (Sites 378910, 378911, 378913, 378914 and 387915), the Sunshine Motorway (Sites 587901, 587907 and 587908), some sections of the Bruce Highway (Sites 587902, 587903, 587905, 587906, 587909 and 587910). Each of these groups of treatment sites were respectively compared with a single set of control crashes.

Control sites for RSCTs used in school operations were chosen from sections of road with a 40km/hr speed limit within the same locality (SLA).

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

Red-Light Speed ID	Speed limit	Red-Light Speed ID	Speed limit
2001	60		
2002	80	2100	70
2003	60	2101	60
2004	60	2102	80
2005	60	2103	60
2006	60	2104	60
2007	80	2105	60
2010	60	2106	60
2011	60	2107	60
2012	60	2108	80
2014	60	2109	80
2015	70		
2016	70		
2017	60		
2018	70		
2019	60		
2020	70		
2021	60		
2022	60		
2023	60		
2024	70		
2025	60		
2026	60		
2027	60		
2029	70		

Tunnel ID	Speed Limit
1003-1006	80
1007-1010	80
1013-1016	80

Point-to-Point	Speed Limit
4001	110
403	unknown

Fixed Spot ID	Speed Limit
1002	100
1011	70
1012	110
3001	100
3002	60
3003	100
3004	60
3005	60
3007	100
3008	70
3009	100

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

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

Position on Bruce Hwy	Latitude	Longitude	Distance (km)
Northern end of Control segment	26°42′ S	153°00′ E	7.2
Northern End of camera Halo	26°45′ S	153°03′ E	5.0
Northern Camera	26°47′ S	153°03′ E	26.8
Southern Camera	27°01′ S	152°59′ E	26.8
Southern End of camera Halo	27°04′ S	152°59′ E	5.0
Southern end of Control segment	27°08′ S	152°59′ E	7.2
Position on Lindsay Hwy	**Latitude**	**Longitude**	**Distance (km)**
Northern end of Control segment	27°38′ S	153°02′ E	5
Northern End of camera Halo	27°41′ S	153°01′ E	5.0
Northern Camera	27°43′ S	153°01′ E	8.83
Southern Camera	27°48′ S	153°01′ E	8.83
Southern End of camera Halo	27°50′ S	153°01′ E	5.0
Southern end of Control segment	27°53′ S	152°59′ E	5.0

The *Airport-Link, Legacy Way* and *Clem 7* tunnels had no period without cameras since the cameras were installed before the roads were opened. There were also no suitable feeder roads to use as controls, so the *Southern Cross Way* and *Port of Brisbane Motorway* were chosen as control segments. The crash counts were then analysed with a volume and distance offset (an offset being a constant term included in the model) to give a comparison of relative crash rates per distance travelled across the treatment and control sections. Using volume times distance as the offset represented the total travel exposure on the road segment meaning the analysis measured change in risk associated with the cameras per unit travel. 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 6.

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

Road	Position of Volume Data	AADT 2013	AADT 2014	AADT 2015	AADT 2016	AADT 2017	AADT 2018	AADT 2019	Distance (km)
Clem 7	U12A North of Ipswich Rd O'pass	124,435	125,445	126,115	127,310	129,303	133,141	132,473	6.84
Airport-Link	400m East of Sandgate Rd	43,272	45,946	63,881	69,580	53,746	59,019	63,989	6.7
Legacy Way	Western Arterial road S of Mt Cootha Roundabout			68,526	76,545	54,021	51,036	51,019	4.6
Southern Cross Way	913 Gateway Mwy Sth of Toombul Rd O'pass	41,351	41,588	43,516	44,694	45,567	46,483	45,947	7.15
Port of Brisbane Mwy	WiM site Lytton	12,164	12,834	13,161	13,161	10,860	10,860	10,860	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 7. There were no crashes observed in the two years of observation for the *Legacy Way* tunnel.

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

Road	Serious Casualty	Minor Injury	Casualty
Treatment			
Clem 7	4	9	13
Airport-Link	5	7	12
Control			
Southern Cross Way	28	21	49
Port of Brisbane Mwy	5	6	11

3.1.2. Analysis period

The analysis periods were defined by the ‘go live’ dates for each fixed camera. For consistency, dates for the installation of signage were not used in the analysis because they were only available for the PtP cameras, four digital fixed speed cameras and the RLSCs. However, due to the RLSCs being previously RLCs, sign installation dates were not relevant for RLSCs. 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 but with signage, and then after activation). Analysis *before* periods were from the start of available data to the point of camera or signage installation, whichever was first whilst analysis after periods were from the period after installation when the camera was 'live', to the end of available data.

With RSCTs, the analysis periods were defined by camera activity at a location. A location could have just one camera (a single unique site number) or could have a cluster of cameras in operation over the 2018 to 2019 period. When a trailer camera was in operation (including intermittent dormant days of periods less than a week), plus one week after the end of the operation, the trailer camera was considered active at a location. At all other times, over 1992 to 2019 inclusive, when there were no operational cameras at a location, the location was considered not active. The regression analysis structure for RSCTs differed from fixed cameras in the analysis period variable only: instead of using an indicator of before and after, an indicator of active and not active was used. When the RSCT was considered inactive, it was considered to not be present at the site. The inactive periods summed to periods in excess of three years, although regression-to-the-mean effects are not applicable in an ON/OFF style of analysis.

3.1.3. Analysis by crash type

There was sufficient statistical power to analyse red-light (RL) and red-light speed (RLS) cameras both on crashes overall and by broad crash type (targeted – right turn against or cross traffic crashes - or rear-end). For the crash types analyses, it was necessary to exclude sites from analyses where the treatment or control sites had no before crash history of the specific crash type. Exclusions were made so that convergence was achieved during regression analysis.

3.1.4. Matching treatment and control crash history

Every attempt was made to balance both 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 the traffic volume and local events were 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 two standard error range of treatment crashes indicating statistical compatibility. From Section 7.4 of the Appendix, which presents the crash history at the trailer and fixed camera treatment and control sites, it can be seen that although this condition has not been universally met, control site crash counts are generally at least of a similar magnitude to those of the treatment sites.

3.1.5. Crash savings and community cost savings for the trailer and fixed camera program

Analysis of camera effectiveness resulted in an estimated net percentage crash saving at camera sites relative to the control site. Percentage crash savings were converted to absolute crash savings and subsequently into community cost savings using the following methods. The average annual crash counts at fixed camera treatment sites, after the camera went live, and at trailer sites when the cameras were active, were first calculated by camera type, police region (and rural/urban status) and severity for the years 2018 to 2019. 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 the average annual crash counts. Regression estimates of camera effectiveness were produced for all fixed cameras combined on average. The exceptions were for trailer cameras and for tunnel cameras. Trailer cameras were analysed in an on/off rather than before/after manner and tunnel cameras had no pre-camera periods. These properties meant that neither could not be analysed within the treatment-control, before-after quasi-experimental design.

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

3.2. EVALUATION OF THE MOBILE SPEED CAMERA PROGRAM

Application of the evaluation framework of Newstead et al (2020) required the specification of a number of details of the framework including the final definition of treatment and control areas, definition of the analysis strata, selection of the periodicity for the analysis time series data and decisions about the measure of speed camera program delivery measures that would be used as predictors in the analysis models. Each of these aspects is described in the following sections along with details about the interpretation of the analysis model outputs and the conversion of these to estimate absolute crash savings and crash cost savings both by region and for Queensland overall.

3.2.1. Treatment and control area definition and analysis strata

As illustrated in **Figure 1**, Queensland is geographically defined into segments for the identification of areas to enforce with mobile speed cameras. Within each sector chosen for enforcement, individual sites for camera placement have been identified. Through matching with the mobile speed camera operations data, sites and hence sectors in which a mobile speed camera session had taken place at some time since January 1999 were identified. The number of mobile speed camera operations by type of operation in each month in each sector were identified through linking via the sites within each sector.

Police-reported crashes in Queensland were also geographically linked to sectors. Every reported crash was linked to a sector unless locational details were missing which was the case for only a small number of crashes (less than 20 crashes). Furthermore, 3.4% of casualty crashes in the data were excluded for being within the zone of influence of a fixed camera. A total of 268,800 crashes were included in the analysis from January 1, 1999 to December 2019, the period for which mobile speed camera operations data were available.

Treatment areas were defined as those sectors in which at least one mobile speed camera operation (of any duration) had taken place during the study period. Control areas were defined as those sectors in which no mobile speed camera operations had taken place over the study period. Treatment and control sectors were then aggregated for analysis by police region (Brisbane, Central, Northern, South-Eastern and Southern) and urban and rural status according to the sector in which the crash fell (defined by TMR). Aggregation in this way allowed estimation of program effects within each region whist broadly controlling for confounding factors which differ by region and level of urbanisation. The resulting analysis stratification defined ten treatment and control pairs of crash time series data. Separate sets of treatment and control data pairs were formed for each crash severity level considered, being all casualty crashes and fatal or serious injury crashes combined. There was insufficient data to consider fatal crashes alone and non-injury crashes have not been reported in Queensland after 2010.

3.2.2. Time series periodicity

For each regression analysis by crash severity, data were aggregated into a time series structure within each police region, urban / rural split, sector and treatment and control pair having its own time series of data for analysis. To ensure a viable analysis, a periodicity for the data analysis needed to be chosen that had two properties. First, it had to display significant time to time variation in the mobile speed camera operations within each treatment time series to give analytical power in establishing a relationship between variation in crashes and variation in camera operations. Second, it needed to have sufficient number of crashes within each time period, stratum and treatment and control pair to also ensure sufficient analysis power. Following Newstead et al (2020) it was decided that quarter of a year was the most appropriate periodicity on which to form the analysis time series to ensure both criteria were met.

3.2.3. Measures of mobile speed camera operations considered

As described in Section 2.2.4, mobile speed camera operations were classified in the operations data provided into five specific types: overt car-based, covert car-based, overt portable, overt LTI and covert LTI. Also as noted in Section 2.2.4, LTI camera operations replaced portable operations, essentially presenting the same hand held mode of roadside operation. Furthermore, although a small proportion of LTI operations were designated as covert, it is unlikely that these operations are truly covert. In consultation with TMR project staff, it was decided to treat all portable and LTI camera operations in aggregate in the analysis resulting in three different types of camera operation being included in the analysis model: overt car-based, covert car-based and total portable/LTI.

Significant quarterly variation in the number of hours of deployment of each camera type was observed over the study period, as illustrated in **Error! Reference source not found.**. Furthermore, the pattern of quarterly variation differed significantly between analysis strata as did the balance between type of camera use. Time series of quarterly hours of deployment of each of the three camera types in each of the analysis strata were calculated from the operations data provided for each quarter over the study period. These were included as predictors in each analysis model as described by Equation 3 in section 3.3.2. of Newstead et al (2020)

3.2.4. Analysis output and conversion to crash and crash cost savings

Key output from the analysis model are the parameter estimates of *A, B* and *C* from Equation 3 of Newstead et al (2020). These parameters give the relationship between the number of hours of enforcement by each speed camera type in each stratum and the observed crash count in each stratum. The exponent of each of these parameters (*exp(A), exp(B) and exp(C)*) gives the proportionate change in expected crash outcome per hour change in enforcement in each stratum and quarter.

To estimate the absolute crash saving attributable to the mobile speed camera program in each stratum and quarter, the predicted crash count in each stratum at the level of enforcement observed in that stratum *s* and time period *t* was compared to that predicted if no camera enforcement of any type had occurred in that time period (i.e. O_{sgt}, V_{sgt} and $L_{sgt} = 0$). The crash saving (δ_{st}) in stratum *s* and time period *t* is then given by Equation 1.

$$\delta_{st} = \exp(\alpha + \beta_{sg} + \gamma_{st} + A.O_{sgt} + B.V_{sgt} + C.L_{sgt}) - \exp(\alpha + \beta_{sg} + \gamma_{st}) \ldots$$
(Equation 1)

Total crash savings per year, within each stratum and across Queensland as a whole were then calculated by aggregating individual savings across the appropriate time periods (e.g. quarters in the year) and strata.

Absolute crash reductions were converted into community cost savings by multiplying the estimated absolute crash savings at the crash severity level being considered by the unit cost of each crash 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 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 also described in Newstead et al (2020).

In this report average annual crash savings were calculated by crash severity, police region and camera type groupings: RLCs, RLSCs, mobile speed cameras, tunnel fixed cameras, all other fixed speed cameras (including average speed cameras) and RSCTs. The state–wide CDOP annual absolute crash reductions and average annual crash cost savings were determined through regional summation over tunnel, other fixed (combined), trailer camera and mobile camera type. The state-wide CDOP average crash reduction was weighted using the average annual *post-activation* base period crash counts. Savings were estimated separately for 2018 and 2019 calendar years.

4. RESULTS

4.1. RED-LIGHT CAMERAS (RLCs)

Table 8 presents a summary of the estimated crash effects associated with CDOP RLCs by region and crash severity grouping. The table presents the estimated relative risk, 95% statistical confidence limit on the estimate and statistical significance probability for each crash severity and region. Results of homogeneity tests indicated that there was statistical evidence that the crash effects associated with the RLC operation differed between police regions for casualty and serious injury crashes: for casualty crashes, p=0.024, for fatal and serious injury crashes p = 0.026 and for minor injury crashes p = 0.20. With statistically significant differences in estimates between police regions, average regional state crash reductions associated with the different severities were used in the estimation of savings by region.

Table 8 Estimated crash risks associated with the red-light camera sites relative to sites without red-light cameras (all urban sites)

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	0.76 (0.64,0.89) 0.001	0.84 (0.76,0.93) 0.001	0.82 (0.75,0.91) <.0001
Brisbane	0.78 (0.62,0.98) 0.03	0.91 (0.79,1.05) 0.21	0.90 (0.79,1.02) 0.10
Central	1.11 (0.77,1.61) 0.57	0.83 (0.66,1.04) 0.11	0.91 (0.72,1.15) 0.43
Northern	1.11 (0.56,2.21) 0.76	1.13 (0.71,1.81) 0.61	1.14 (0.78,1.67) 0.49
South Eastern	0.72 (0.53,0.98) 0.04	0.70 (0.57,0.85) 0.0004	0.72 (0.61,0.85) 0.0002
Southern	0.37 (0.2,0.71) 0.003	0.69 (0.44,1.06) 0.09	0.57 (0.4,0.81) 0.002

† Estimated from an all casualty crash model

Annual crashes, in the post-camera period, identified within the defined halo of influence of a RLC (<100m from camera and recorded as at a signalised intersection) were tabled by severity and police region for 2018 to 2019. The average annual count (rounded to the nearest integer) over the period is given in Table 9 as a measure of the crash population covered by this camera type. Overall crash reduction estimates by severity were applied to the annual counts to produce the absolute crash savings per year given in Table 10. These were then costed by the WTP and the HC approaches with results given in Table 11 and Table 12 respectively.

Table 9 Average annual post-activation red-light camera treatment crash counts by severity and police region

	Serious Casualty	Minor Injury	All Casualty
All*	52	112	164
Brisbane	22	69	91
Central	8	7	15
Northern	6	4	10
South Eastern	9	22	31
Southern	8	11	18

*sum of regions, rounding applies

Table 10 Average annual absolute crash savings associated with red-light cameras, by severity and police region

	Serious Casualty	Minor Injury	All Casualty†
All*	21	22	36
Brisbane	6	7	10
Central	-1	1	1
Northern	-1	0	-1
South Eastern	3	10	12
Southern	13	5	14

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

The casualty crash reductions of 18% (Table 8) associated with RLCs translated to the average annual prevention of 36 casualty crashes, 21 of which were serious, saving society about $13M per year using WTP crash cost valuations or $6M per annum using HC crash cost valuation.

Table 11 Average annual savings associated with red-light cameras, by severity and police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty†
All*	$17,413,183	$2,350,943	$12,816,640
Brisbane	$5,386,869	$748,288	$3,380,027
Central	-$547,718	$168,659	$550,679
Northern	-$496,496	-$50,135	-$611,479
South Eastern	$2,891,497	$951,627	$4,606,772
Southern	$10,179,031	$532,504	$4,890,640

*Sum of regions, rounding errors apply

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

Table 12 Average annual savings associated with red-light cameras, by severity and police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty†
All*	$8,658,400	$431,925	$5,544,870
Brisbane	$2,658,359	$129,822	$1,404,151
Central	-$291,205	$28,292	$258,776
Northern	-$249,782	-$7,924	-$294,259
South Eastern	$1,420,062	$188,049	$2,044,031
Southern	$5,120,966	$93,687	$2,132,171

*sum of regions, rounding errors apply

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

4.2. RED-LIGHT SPEED CAMERAS (RLSCs)

The intersection sites of twenty-one[2] of the evaluated 36 RLSCs previously housed RLCs. For these cameras, the period for which there was only an RLC period was evaluated with the RLCs in the previous section. The crash reduction associated with a RLSC upgrade period was evaluated and reported with the results in this section. For these twenty-one cameras, the before treatment period is defined as

[2] The intersection sites for ten of the 21 RLSCs had RLCs installed and operational prior to 1993, so there was no opportunity to evaluate the effectiveness of the RLCs as data prior to RLC installation was unavailable and furthermore, defining a pre-treatment period so far prior to the camera installation would draw questions about the representativeness of the comparison. Consequently, analysis for those ten sites (site numbers 2005-2007 & 2010-2011, 2025 2029, 2103, 2105 & 2106) focused solely on assessing the crash effects of upgrading RLC sites to RLSC.

the period where the RLC was installed and the post-period the time from which the upgraded RLSC was installed.

Red light cameras were not previously installed at fifteen RLSC sites (2002 & 2015-2024, 2026-2027 and 2108-2109). The effect of these RLSCs was assessed against a no-camera pre-period.

Defining pre-RLSC periods in these ways produced pre-periods of at least 9.5 years and operational periods of 0.5 to 8.4 years. By analysing the RLCs and RLSCs in this way, all effects could be associated with the camera of influence, be compared with a closer prior period, and be directly combined without duplication or overlap.

The relative risk analyses were carried out for all RLSCs. Results of these analyses are found in Table 13.

Large reductions in crashes of all severity were associated with upgrades from RLC to RLSC, however, none of which proved statistically significant, indicating that further follow-up of newer cameras would be required to assure solid evidence that the addition of the speed component to this set of camera enforced intersections has had road safety benefits. One third of the upgraded RLSCs were operating for 1 year or less within the study period (1992 to 2019).

Estimates of the crash effects of RLC to RLSC upgrades against the time period prior to RLC installation were generally uninformative with none of the serious casualty or all casualty crash estimates achieving statistical significance. Consequently, the evaluation was only able to provide evidence on the effectiveness of RLC to RLSC upgrades, and not a measure of the total effect of a RLSC installation from an unenforced intersection for these upgraded sites.

New RLSC installations to locations without a previous history of RLCs produced significant overall estimates of fatal and serious injury crash reduction. Reductions were also observed within each of the regions, however these were only statistically significant for Brisbane. Over all regions, minor injury crash increases were observed, which were statistically significant overall and for the Brisbane and Southern regions. Average casualty relative risk estimates are heavily influenced by minor injury crashes, which for this analysis caused non-significant estimates of casualty crash increases to be associated with RLSC at new camera installations.

Results of homogeneity tests indicated that there was no statistical evidence that the crash effects associated with the upgrade of either RLC to RLSC, or no camera to RLSC, differed between regions at any level of crash severity which indicates that the associated average crash reductions estimated across all sites could be considered to apply equally to all regions. Consequently, the overall average results were used in estimating absolute crash savings and their associated community costs.

Table 13 Estimated relative crash risks, (95% confidence interval and p-value) associated with red-light speed camera installation (Using all sites uniquely within the combined fixed camera models): All urban locations

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
Referenced to no-camera period			
Combined: 2002 & 2015-2024, 2026-2027 and 2108-2109	0.57 (0.33,0.97) 0.04	1.68 (1.2,2.35) 0.003	1.21 (0.91,1.6) 0.19
Brisbane (2002, 2016, 2027)	0.49 (0.24,1.03) 0.06	1.47 (0.98,2.21) 0.06	1.09 (0.77,1.55) 0.64
Central‡ (2020, 2023)	*	1.59 (0.14,17.93) 0.71	1.59 (0.14,17.75) 0.71
Northern (2018, 2019)	0.61 (0.16,2.29) 0.47	3.13 (0.78,12.49) 0.11	1.34 (0.53,3.42) 0.54
South Eastern (2015, 2108)	1.50 (0.4,5.7) 0.55	1.44 (0.41,4.99) 0.57	1.51 (0.61,3.73) 0.37
Southern (2017, 2021, 2022, 2024,2026, 2109)	0.53 (0.12,2.25) 0.39	2.49 (1.12,5.54) 0.02	1.46 (0.75,2.85) 0.26
Referenced to red-light camera period			
Combined: 2001,2003-2007,2010-2012 and 2014 2025, 2028,2029,2100, 2101,2102,2103,2104, 2105, 2106, 2107	0.82 (0.56,1.2) 0.30	0.90 (0.68,1.21) 0.49	0.86 (0.68,1.08) 0.18
Brisbane (2001, 2025, 2029,2104,2106)	1.13 (0.47,2.73) 0.78	0.70 (0.38,1.27) 0.24	0.76 (0.47,1.23) 0.26
Central (2005, 2007, 2103)	0.82 (0.29,2.28) 0.70	0.99 (0.42,2.31) 0.98	0.86 (0.45,1.63) 0.64
Northern (2004, 2006)	0.66 (0.29,1.48) 0.31	0.92 (0.51,1.67) 0.79	0.81 (0.5,1.3) 0.38
South Eastern (2003, 2028,2100, 2101, 2102, 2107)	1.51 (0.72,3.16) 0.27	0.99 (0.61,1.62) 0.98	1.05 (0.71,1.56) 0.81
Southern (2010,2011,2012,2014, 2105)	0.38 (0.1,1.38) 0.14	1.13 (0.38,3.38) 0.83	0.63 (0.28,1.42) 0.27

‡ operation period of 0.5 years for 2020 and 1.0 years for 2023 prevented regression for serious casualty.

*Regression estimate could not be estimated

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

Average annual crashes identified within the defined halo of influence of a RLSC (<100m from camera and recorded as at a signalised intersection) by severity and police region across the period of focus, 2018 to 2019 are given in Table 14. Average crash reductions associated with intersection upgrades of RLC or no camera, to RLSC, by severity were applied to the annual counts to produce the absolute crash savings per year given in the main results. It should be noted that the estimates for casualty crash savings in Table 15 do not result from the summation of the serious casualty and minor injury models. A separate model was fitted to all casualty crashes which is likely to be more accurate than simply summing the serious casualty and minor injury crash models given it is based on greater crash numbers. Table 15 shows the average annual crash savings estimated across 2019 to 2019 which were then costed by the WTP and the HC approaches with results given in Table 16.

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

	Serious Casualty	Minor Injury	Casualty
All*	21	34	55
Brisbane	7	18	24
Central	2	3	5
Northern	3	2	5
South Eastern	7	7	14
Southern	2	5	7

* Sum of regions, rounding error applies

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

	Serious Casualty	Minor Injury	Casualty†
All*	8	-6	0
Brisbane	3	-5	-1
Central	0	0	1
Northern	1	0	0
South Eastern	3	0	1
Southern	1	-1	0

* Sum of regions

† Estimated from an all casualty crash model

Table 16 Average annual savings associated with red-light cameras, by severity and police region

	Willingness to pay			Human Capital		
	Serious Casualty	Minor Injury	Casualty†	Serious Casualty	Minor Injury	Casualty†
All*	$6,984,593	-$686,531	$192,579	$3,469,577	-$119,643	$103,443
Brisbane	$2,627,885	-$512,409	-$407,440	$1,296,832	-$88,899	-$169,261
Central	$298,363	$7,490	$251,547	$158,631	$1,256	$118,208
Northern	$1,180,806	-$37,054	-$4,035	$594,051	-$5,856	-$1,942
South Eastern	$2,304,886	-$32,803	$356,389	$1,131,968	-$6,482	$158,130
Southern	$572,653	-$111,755	-$3,882	$288,096	-$19,662	-$1,692

*sum of regions, rounding errors apply

† Estimated from an all casualty crash model

4.2.1. Crash type analysis for red-light (RLCs) and red-light speed cameras (RLSCs)

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

Figure 2 displays the estimated relative risks with 95% confidence intervals for the RLCs and RLSCs referenced to a period of no-camera, as well as for the RLSCs, referenced to a period of RLC. From this figure, some trends are evident:

- There was no clear evidence that either RLC or RLSC upgrades were associated with a statistically significant change in *rear-end* serious or minor injury crashes, however, there was statistical evidence that RLSCs new to an intersection were associated with a doubling of minor injury *rear-end* crashes (p = 0.006).
- Both RLCs and RLSCs were likely to reduce *right-through* injury crashes. RLCs and RLSCs were significantly associated with serious crash reductions and RLC were significantly associated with minor injury crash reductions.
- The greatest reduction of *right-through* serious injury crashes reductions was observed for RLSC positioned at intersections with no previous camera: 76% (p=0.01).

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

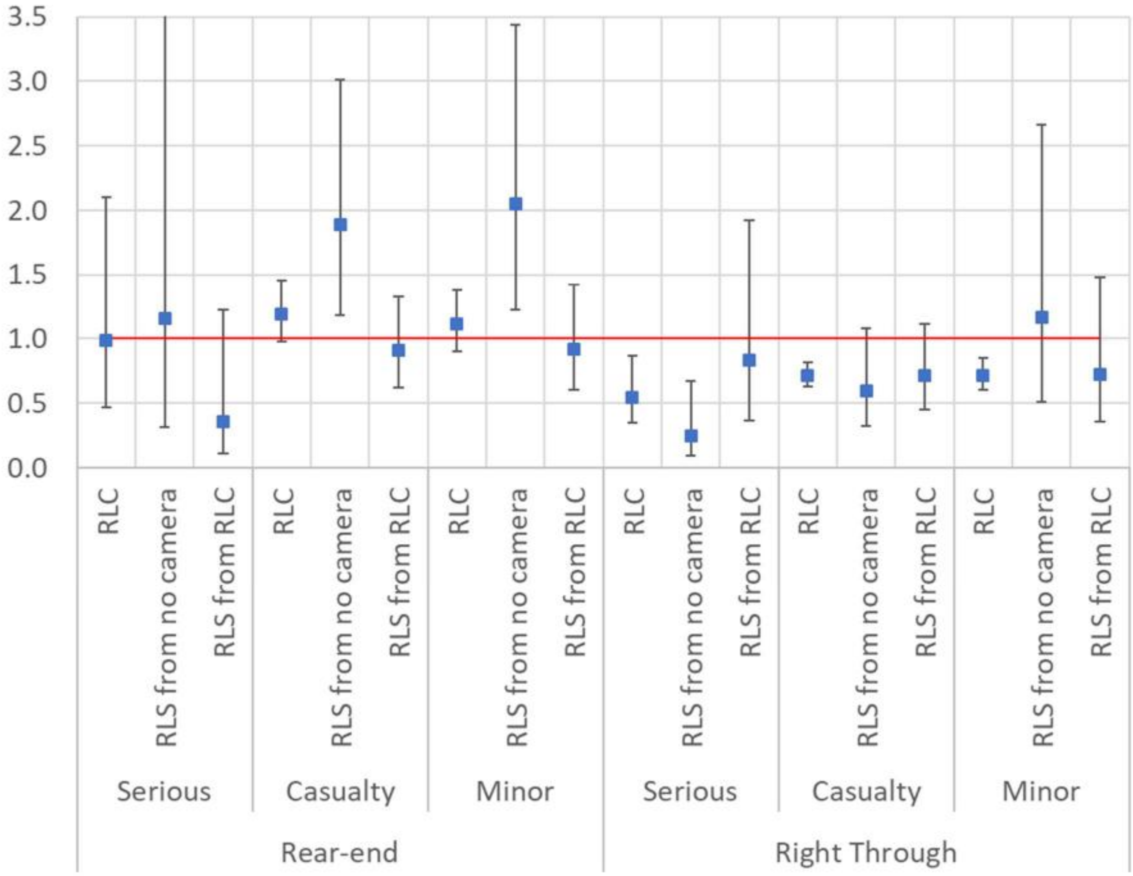

Figure 2 *State-wide relative risk estimates by crash type for each fixed intersection camera type*

A meta-analysis by Erke (2009) found a 40% increase in rear-end crashes associated with RLCs. This study provided no evidence that this was the case for CDOP RLCs, with RLC and RLSC upgrades generally having no associated effects identified on rear end crashes. However, RLSC cameras positioned at intersections with no previous camera were significantly associated with large increases in minor injury *rear-end* crashes. Large decreases in serious injury *rear-end* crashes were also associated with these cameras, although the decreases were not significant. This study evaluates 15 new RLSC with two-thirds of these having operation periods of 16 months or under. Re-evaluation after a longer operating time may reveal average increases in minor injury rear-end crashes closer in magnitude to that observed by Erke (2009).

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

- 29% (95% CI: -12% to 55%, p=0.14) for casualty crashes when upgraded from RLC;

- 41% (95% CI: -8% to 68%, p = 0.09) for casualty crashes when no previous camera at the intersection;

- 16% (95% CI: -92% to 64%, p=0.67) for fatal and serious injury crashes when upgraded from RLC;
- 76% (95% CI: 33% to 91%, p = 0.01) for casualty crashes when no previous camera at the intersection;

and with RLCs of

- 28% (95% CI: 18% to 37%, p<0.0001) for casualty crashes;
- 45% (95% CI: 13% to 66%, p=0.01) for fatal and serious injury crashes; and
- 28% (95% CI: 15% to 40%, p= 0.0001) for minor injuries.

4.3. FIXED SPOT SPEED CAMERAS (FSSCS)

The estimated effectiveness of fixed speed cameras is presented in three groups: the effects of the PtP speed camera systems (site 4001 and 403), the combined effects of the tunnel speed cameras (sites 1003 to 1010 and 1013 to 1016) and by region and overall effects of all other FSSCs at non-tunnel mid-block sites (sites 1002, 1011, 1012 and 3001 to 3005 and 3007 to 3009). Table 17 and Table 18 present a summary of the fixed speed camera effectiveness estimates. Statistically significant crash reductions were only associated with the PtP and the tunnel speed cameras. Other fixed spot speed cameras were associated with significant increases to serious casualty and all casualty crashes.

This analysis was evaluated with two fewer FSSCs than analysed previously (due to decommissioning) and the crashes in the proximity of the trailer speed cameras further depleted control crashes used in the fixed camera analyses. This left the estimates subjected to greater variation than in previous analyses. It is also possible that the chosen controls were unable to sufficiently adjust for environmental changes over time. This would happen, if changes to traffic flow, traffic volume and infrastructure over time did not have similar effects on both the treatment and control locations. An observed increase in crash risks associated with FSSCs could arise if changes to the environment in the control sections had a greater effect on reducing crash risk than FSSCs did. Further investigation to explore this possibility is warranted. However, if the effect is real and not a result of aberrant variation nor of ineffective control, it indicates that, in the periods after the FSSCs began operations, the crash risks rose more within the FSSCs zones of influence than further along the roadways leading to them. This conclusion spurs the need to discover the cause of the increased crash risk as well as the need to consider other counter-measures at these sites.

In previous analyses, statistical significance was not achieved in the estimates for the Central region PtP system. In this 2018-2019 evaluation, the additional years of observation have enabled robust and strongly significant results for minor injury and casualty crash reductions of 43% and 28% respectively. The point estimates are different from the non-significant 23% and 18% respective estimated reductions of the previous analysis. The differences are not just due to statistical variation; this evaluation was different in that it used an extended PtP zone of influence and excluded the effects of nearby trailer cameras on control crashes. The South Eastern region PtP system evaluation also excluded the effects of nearby trailer cameras on control crashes which may also contribute to the differences in point estimates from the previous analysis, although both evaluations failed to produce statistically significant relative risk estimates.

Table 17 Estimated relative crash risks associated with fixed spot speed cameras (excluding point-to-point and tunnel cameras)

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	1.31 (1.08,1.59) 0.01	1.04 (0.91,1.2) 0.55	1.12 (1.01,1.25) 0.04
Brisbane *(3002,3003)*	1.64 (1.12,2.4) 0.01	0.90 (0.7,1.15) 0.40	1.08 (0.87,1.32) 0.49
Central Urban (1011,3008)	1.30 (0.73,2.34) 0.37	1.08 (0.72,1.61) 0.71	1.12 (0.81,1.56) 0.49
Central Rural (3009)	1.02 (0.49,2.13) 0.96	0.67 (0.34,1.33) 0.25	0.78 (0.48,1.29) 0.34
South Eastern Urban (3004, 3005)	1.32 (0.89,1.96) 0.16	1.27 (0.97,1.67) 0.08	1.29 (1.03,1.61) 0.03
South Eastern Rural (1002, 1012)	1.12 (0.75,1.67) 0.59	1.12 (0.84,1.49) 0.43	1.13 (0.89,1.42) 0.31
Southern Rural (3001, 3007)	1.27 (0.69,2.33) 0.44	0.89 (0.51,1.55) 0.68	1.07 (0.72,1.59) 0.74

† 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. 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.

In this analysis, some potential for mis-identification of crashes on the Southern Cross Way and Gateway Motorway was observed through comparing the GPS co-ordinates for a crash compared to the listed road name. The source of this issue is likely to have arisen from real name changes to these roads over time as new overpasses and bypasses were built, replacing the original Gateway Arterial road sections and roundabouts. For this analysis (and the previous study), the motorway matching the GPS co-ordinate for the crash was used to identify motorway crashes instead of using street name.

Table 18 Estimated relative crash risks associated with point-to-point spot and average speed, and tunnel fixed speed cameras (*relative risk estimate, 95% C.I., statistical significance*)

	Serious Casualty	Minor Injury	All Casualty†
Tunnel			
Both	0.11	0.24	0.16
	(0.05, 0.24)	(0.12, 0.5)	(0.1, 0.28)
	<.0001	0.0001	<.0001
Clem 7	0.06	0.16	0.10
	(0.02, 0.19)	(0.06, 0.41)	(0.05, 0.21)
	<.0001	0.0001	<.0001
Airport-Link	0.22	0.43	0.31
	(0.08, 0.57)	(0.18, 1.04)	(0.16, 0.58)
	0.002	0.06	0.0003
Point-to-Point			
Both	0.94	0.69	0.79
	(0.68,1.3)	(0.53,0.91)	(0.64,0.97)
	0.70	0.01	0.02
Central	0.95	0.57	0.72
(Bruce Hwy)	(0.66,1.37)	(0.41,0.78)	(0.57,0.91)
	0.78	0.001	0.01
South Eastern	0.90	1.09	1.00
(Mt Lindsay Hwy)	(0.46,1.78)	(0.68,1.77)	(0.68,1.48)
	0.77	0.71	0.99

† Estimated from an all casualty crash model

Annual crashes identified within the defined halo of influence of a fixed speed camera (≤1000m in either direction on the same road) were tabled by severity and police region for 2018 to 2019. The average annual count over the period is given in Table 19 as a measure 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 20 shows the average annual saving across 2018 to 2019 which were then costed by the WTP and the HC approaches with results given in Table 21 and Table 22 respectively. Negative values in the table indicate an estimated crash or crash cost increase.

No evidence in heterogeneity in FSSC effectiveness by Police region was found and the 95% confidence intervals of the three overall estimates fell entirely or almost entirely within the confidence intervals for regional estimates for each severity, so the associated average crash reductions estimated across all FSSC sites could be considered to apply equally to all regions. Consequently, the overall FSSC average results were used in estimating absolute crash savings and their associated community costs.

Table 19 Average annual post-activation fixed speed camera treatment crash counts by severity and police region

	Serious Casualty	Minor Injury	Casualty
All Tunnel	1	2	3
Point-to-Point	25	39	64
Central (4001)	17	26	43
South Eastern (403)ǂ	8	13	21
All other fixed*	40	61	101
Brisbane	12	18	29
Central Urban	5	8	13
Central Rural	3	6	9
South Eastern Urban	5	7	12
South Eastern Rural	10	19	29
Southern Rural	6	5	10

*sum of regions, rounding errors apply. ǂDecomissioned in March 2019 so only 14 months of crashes counted

Table 20 Average annual absolute crash savings associated with fixed speed cameras, by severity and police region

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	8	6	15
Point-to-Point	2	18	17
Central	1	19	17
South Eastern	1	-1	0
All other fixed*	-9	-2	-11
Brisbane	-3	-1	-3
Central Urban	-1	0	-1
Central Rural	-1	0	-1
South Eastern Urban	-1	0	-1
South Eastern Rural	-2	-1	-3
Southern Rural	-1	0	-1

*sum of regions, rounding errors apply. † Estimated from an all casualty crash model
NB: Negative values indicate and estimated crash increase

Table 21 Average annual savings associated with fixed speed cameras, by severity and police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	$7,267,451	$706,010	$5,091,782
Point-to-Point	$1,306,333	$2,011,555	$5,526,036
Central	$619,369	$2,135,641	$5,539,964
South Eastern	$686,964	-$124,087	-$13,928
All other fixed*	-$7,395,722	-$269,445	-$3,953,800
Brisbane	-$2,364,908	-$80,262	-$1,048,338
Central Urban	-$799,075	-$35,576	-$509,385
Central Rural	-$479,445	-$26,758	-$329,117
South Eastern Urban	-$942,185	-$28,187	-$488,329
South Eastern Rural	-$1,931,127	-$82,657	-$1,151,192
Southern Rural	-$878,982	-$16,005	-$427,438

*sum of regions † Estimated from an all casualty crash model
NB: Negative values indicate and estimated crash cost increase (based on statistically non-significant relative risk estimates)

Table 22 Average annual savings associated with fixed speed cameras, by severity and police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty†
All Tunnel	$3,586,405	$122,487	$2,115,258
Point-to-Point	$674,244	$358,947	$2,551,649
Central	$329,300	$381,046	$2,557,791
South Eastern	$344,944	-$22,099	-$6,142
All other fixed*	-$3,746,533	-$48,538	-$1,764,198
Brisbane	-$1,167,056	-$13,925	-$435,506
Central Urban	-$424,844	-$5,968	-$239,371
Central Rural	-$254,907	-$4,774	-$151,953
South Eastern Urban	-$462,723	-$5,570	-$216,672
South Eastern Rural	-$467,329	-$3,581	-$213,025
Southern Rural	-$714,735	-$16,095	-$566,470

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

4.3.1. Homogeneity of fixed camera type and site

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

Tests of homogeneity of camera and regional crash effects were undertaken for the three injury severity groups across the four fixed camera types: (i) red-light, (ii) red-light speed from no-camera, (iii) red-light speed from RLC, and (iv) fixed speed and PtP. 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 23 with a low significance value indicating non-homogeneous crash effects across cameras. Evaluation of homogeneity for RLSCs have been carried out on the cameras with a no prior camera period, as well as for all RLC to RLSC upgrades.

There was no statistical evidence to support differential regional effects within a camera type for RLC, fixed and RLSC upgrades from RLC. In contrast, there was strong statistical evidence to show that crash effects were different for different fixed spot camera types. There is no evidence to support heterogeneity of crash effects across RLSC sites, nor across PtP sites, however there was evidence to suggest that the crash effects of RLCs are dependent upon the site of the camera within Queensland.

Table 23 Significance probabilities from tests of homogeneity by injury severity for fixed camera analyses: (X^2, *d.f.*)

		Serious Casualty	Minor injury	Casualty
Camera Type		0.0005	0.0002	0.00016
		(19.9,4)	(22.4,4)	(22.5,4)
Camera sites		<0.0001	<0.0001	<0.0001
		(188,86*)	(232, 89**)	(284,98)
Red-Light †		<0.0001	<0.0001	<0.0001
Red-Light Speed †		(121,52)	(111,52)	(136,52)
(all from no-camera)	*2002, 2015-2024, 2026-2027, 2108-2109*	0.64	0.06	0.41
		(7.8,10#)	(23.1,14)	(14.5,14)
All upgraded from RLC	*2001, 2003-2007, 2010/11,2012,2014, 2025,2029, 2100-2104, 2106,2107*	0.07	0.56	0.17
		(20.0,12‡)	(15.4,17)	(22.2,17)
Point-to-Point†		0.90	**0.03**	0.16
		(0.015,1)	(4.9,1)	(2.0,1)
Fixed Speed †		0.006	<0.0001	<0.0001
		(24.6,10)	(81.3,10)	(88.0,10)
Regions		0.23	0.29	0.46
		(5.6,4)	(5.0,4)	(3.6,4)
Red-Light †		0.03	0.20	0.02
		(11.0,4)	(6.0,4)	(11.1,4)
Red-Light Speed † (all from no-camera)		0.48#	0.72	0.91
		(2.5,3)	(2.1,4)	(0.98,4)
All upgraded from RLC		0.55	0.90	0.76
		(3.1,4)	(1.1,4)	(1.9,4)
Point-to-Point†		0.90	**0.03**	0.16
		(0.015,1)	(4.9,1)	(2.0,1)
Fixed Speed †		0.61	0.28	0.66
		(1.8,3)	(3.8,3)	(1.6,3)

† Within model of one camera type
# Excluding 2020, 2021, 2023 & 2024 to allow convergence
‡ Similarly 2106, 2103, 2102, 2101, and 2029

* Excluding the above as well as 255,116 and 84
** Excluding 508,2017,2019,2022-2025,2103-2104

4.4. ROAD SAFETY CAMERA TRAILERS

Table 24 presents a summary of the estimated crash effects associated with CDOP trailer cameras by crash severity and operation type or region grouping. The table presents the estimated relative risk, 95% statistical confidence limit on the estimate and statistical significance probability for each crash severity and region. Statistically significant crash reductions were found to be associated with the trailer camera program. An overall 40% reduction in serious casualty crashes and a 27% reduction in minor injury crashes were observed. Reductions in crash risk were estimated to be associated with all three operation types, however the estimates only reached significance for casualty crashes of targeted operations (32% reduction). Estimates were less robust when disaggregated by region and urbanisation with only camera operations in the Southern Rural district showing statistical significance across severities. Reductions of 83% of serious casualty and 75% of minor injury crashes were associated with trailer operations in the Southern Rural district.

The following operations were excluded from all analyses so that regression algorithms could converge: 187903, 286903, 286904, 287903, 287907, 296902, 386901, 386903, 386904, 386906, 386907, 387905, 486903-486905, 487914-487915, 586901-586903. Additionally, for minor & serious injury analysis the following operations were also excluded from analysis: 286902, 385906, 387916 & 487910. For just the minor crash analysis 385916, 386905, 386908, 387904 and 487903 were additionally excluded and for just the serious casualty crash analysis the following operations were also excluded from analysis: 185904, 187902, 286901, 287901, 287904, 287906, 287909, 387902, 387923, 487911, 586904 and 587904.

Annual crashes, in the trailer operational periods, identified within the defined halo of influence were tabled by severity, urbanisation and police region for 2018 to 2019. The average annual count (rounded to the nearest integer) over the period is given in Table 26 as a measure of the crash population covered by this camera type. Overall crash reduction estimates by severity were applied to the annual counts to produce the absolute crash savings per year given in Table 27. These were then costed by the WTP and the HC approaches with results given in Table 28 and Table 29 respectively.

Results of homogeneity tests indicated that there was statistical evidence that the crash effects associated with the trailer camera operation differed between police regions and urbanisation for casualty crashes (Table 25). With statistically significant differences in estimates between Police regions, average regional state crash reductions associated with the different severities were used in the estimation of savings by region for the Southern Rural region, where the casualty crash estimate was significantly different from the casualty crash regional average estimate. For all other regions, relative risk estimates were associated with large variance, lack of statistical significance or were similar in magnitude to the all-region average, so the all-region average estimates were used in the estimation of regional savings.

Table 24 Estimated crash risks associated with the road safety camera trailers

Estimate (95% CI) Significance	Serious Casualty	Minor Injury	All Casualty†
All	0.60 (0.42,0.87) 0.007	0.73 (0.55,0.98) 0.04	0.68 (0.54,0.85) 0.001
Targeted	0.61 (0.4,0.92) 0.018	0.73 (0.53,1.01) 0.06	0.68 (0.53,0.88) 0.003
Roadworks	0.61 (0.25,1.52) 0.29	0.80 (0.41,1.54) 0.50	0.73 (0.43,1.25) 0.25
School	0.41 (0.06,2.93) 0.38	0.47 (0.09,2.41) 0.36	0.49 (0.14,1.69) 0.26
Brisbane	1.03 (0.43,2.48) 0.95	1.12 (0.62,2.01) 0.71	1.08 (0.67,1.76) 0.74
Central Rural	1.78 (0.22,14.31) 0.59	0.47 (0.17,1.26) 0.13	0.65 (0.28,1.52) 0.32
South Eastern Urban	0.90 (0.3,2.72) 0.85	1.51 (0.5,4.51) 0.47	1.17 (0.54,2.56) 0.69
South Eastern Rural	0.61 (0.36,1.04) 0.07	0.68 (0.46,1.01) 0.06	0.65 (0.48,0.9) 0.01
Southern Urban	0.58 (0.1,3.52) 0.56	1.14 (0.29,4.49) 0.85	0.95 (0.32,2.79) 0.92
Southern Rural	0.17 (0.06,0.49) 0.001	0.25 (0.09,0.72) 0.01	0.21 (0.1,0.43) 0.0001

† Estimated from an all casualty crash model

Table 25 Significance probabilities from tests of homogeneity by injury severity for trailer camera analyses: (X^2, *d.f.*)

	Serious Casualty	Minor injury	Casualty
Operation Type	0.93	0.84	0.84
	(0.14,2)	(0.33,4)	(0.35,2)
Region	0.08	0.113	0.004
	(9.6,5)	(8.9,5)	(17.0,5)

Table 26 Average annual post-activation road safety camera trailer treatment crash counts by severity and police region

	Serious Casualty	Minor Injury	All Casualty
All*	29	45	73
Brisbane	6	9	14
Central Rural	4	5	9
S. Eastern Urban	2	1	3
S. Eastern Rural	14	23	37
Southern Urban	3	6	9
Southern Rural	1	2	3

*sum of regions, rounding applies

Table 27 Average annual absolute crash savings associated with road safety camera trailer, by severity and police region

	Serious Casualty	Minor Injury	All Casualty†
All*	23	20	43
Brisbane	4	3	7
Central Rural	3	2	4
S. Eastern Urban	1	0	1
S. Eastern Rural	9	8	17
Southern Urban	2	2	4
Southern Rural	5	4	10

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

The casualty crash reductions of 32% (Table 24) associated with trailer operations translated to the average annual prevention of 43 casualty crashes, 23 of which were serious, saving society about $15M per year using WTP crash cost valuations or $7M per annum using HC crash cost valuation.

Table 28 Average annual savings associated with red-light cameras, by severity and police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	Casualty†
All*	$17,799,443	$2,113,978	$15,503,325
Brisbane	$3,131,169	$349,000	$2,159,145
Central Rural	$1,769,721	$179,659	$1,326,102
S. Eastern Urban	$869,445	$36,048	$452,904
S. Eastern Rural	$7,484,562	$919,961	$6,376,105
Southern Urban	$1,327,532	$242,929	$1,405,604
Southern Rural	$3,217,014	$386,380	$3,783,466

*Sum of regions, rounding errors apply

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

Table 29 Average annual savings associated with red-light cameras, by severity and police region: Human Capital approach

	Serious Casualty	Minor Injury	Casualty†
All*	$16,663,269	$392,748	$7,020,397
Brisbane	$1,545,197	$60,549	$896,965
Central Rural	$940,908	$32,055	$612,259
S. Eastern Urban	$426,999	$7,123	$200,954
S. Eastern Rural	$3,758,214	$163,837	$2,811,832
Southern Urban	$667,868	$42,740	$612,801
Southern Rural	$1,710,391	$86,443	$1,885,587

*sum of regions, rounding errors apply

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

4.5. MOBILE SPEED CAMERAS

The evaluation design for the mobile speed camera program detailed Section 3.3.2 of Newstead et al (2020) was utilised to estimate the crash benefits of the mobile camera program in Queensland. Data were prepared as time series for analysis with interrogation of the data revealing a quarterly time period for data aggregation as being the most appropriate to support the analysis. Using quarterly time periods, crash counts in each quarter were sufficiently large enough to ensure model stability but quarter to quarter variation on operations was large enough to ensure reasonable analysis power.

Figure 3 shows an example of the resulting data series for one of the Queensland police regions, Southern Region. Colour coding indicates the comparable treatment and control pairs within urban and rural areas with the dotted line of each pair being the control area data series and the solid line the treatment series. As evident, each region has two treatment and control pairs resulting in ten treatment and control pairs (strata) for analysis across the five police regions.

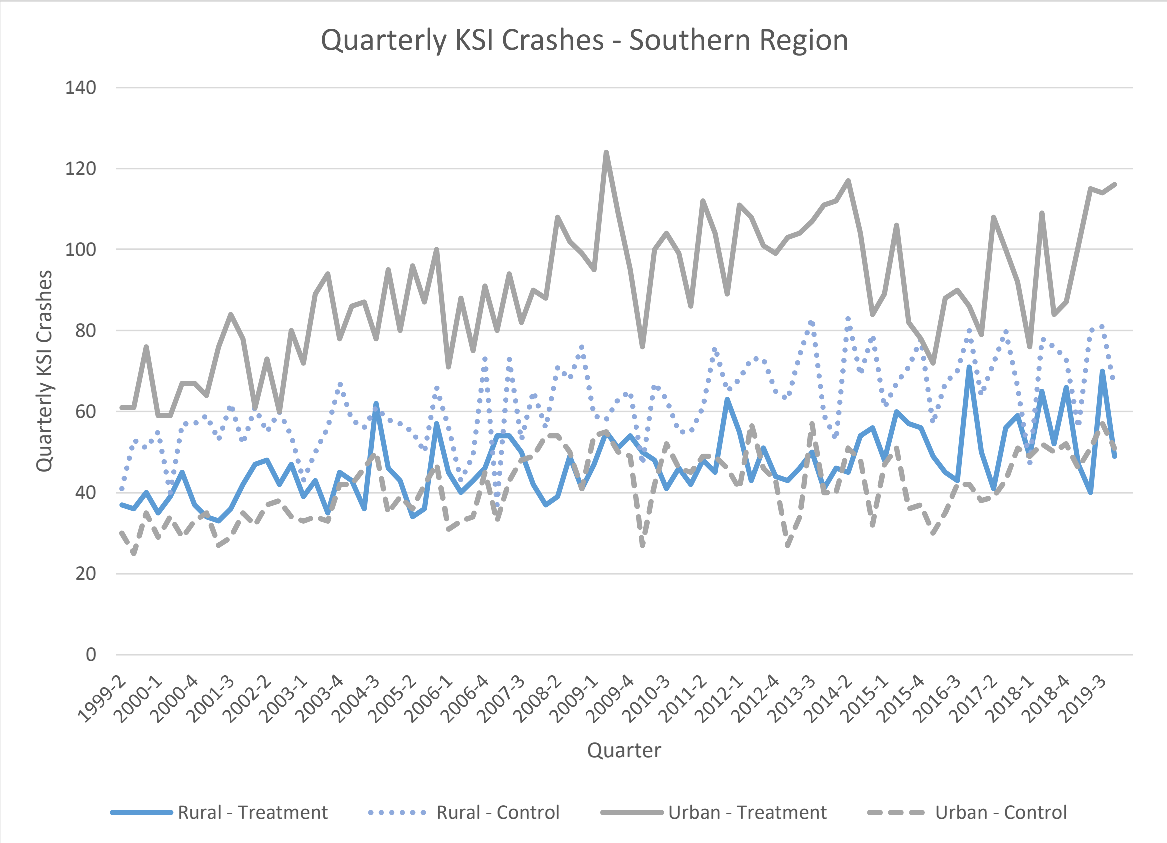

Figure 3 *Quarterly fatal and serious injury crash counts by treatment and control area in rural and urban sectors: Southern Region*

Quarterly mobile speed camera program delivery measures were prepared for inclusion in the model. Consistent with the previous evaluation of CDOP effects to 2017, three measures of speed camera program delivery were used in the model: quarterly hours of overt car-based mobile speed camera operations, quarterly hours of car-based covert mobile speed camera operations, quarterly hours of portable or LTI mobile speed camera use all of which was considered overt. Figure 2 shows the quarterly mobile speed camera delivery measures across the whole of Queensland. For use in the analysis model, data series were derived for each stratum, defined by police region and urban and rural sector classification. Mobile speed camera operations delivery for each stratum determined though matching the site data for each camera with the sector in which the site was placed, and then aggregating the data across sectors based on their stratum membership. Trends in program delivery measures for each stratum are not shown here but the general trends in each stratum are broadly similar to the overall trends seen for Queensland as a whole in Figure 2 albeit with different patterns of quarterly variation.

When assigning quarterly delivery data against the crash data within each stratum and treatment and control pair, only the treatment time series data had operations appearing against them consistent with the treatment sectors being defined as those where a mobile speed camera operation had taken place. All the quarterly control data series crash counts had zero mobile speed camera operations delivery assigned to them.

4.5.1. Analysis model results

Results of application of the analysis model to the quarterly crash data series for each stratum and treatment control pair are summarised in the following tables. Two levels of crash severity were analysed: fatal and serious injury crashes combined, and all casualty crashes. Non-injury crashes have not been reported in Queensland since 2010 so could not be modelled. In addition, a third set of models were estimated for the probability that a casualty crash was serious or fatal (i.e. the estimated by proportion of all casualty crashes that are serious or fatal). The model structure for this additional analysis was the same as described in Equation 3 but with the log transform substituted by a logit transform, and the outcome being modelled being the proportion of casualty crashes in each stratum, treatment control pair and quarter that were serious casualty or fatal crashes. The purpose of the third model set was to formally test whether there were differential associations between the mobile speed camera delivery measures and combined fatal/serious or minor crash outcomes. Where there was no difference, the all casualty crash result, which has narrower statistical confidence limits, could be used to represent the impact of the program across all crash severity levels. Where there was a detected difference, specific estimates could be used for each crash severity level.

For each crash severity considered, two separate models were estimated. The first estimated the average association between the mobile speed camera program outputs and crash outcomes across all ten strata. The second estimated average effects within urban and rural areas across all five police regions. Models were also fitted that estimated average effects across urban and rural areas within each police region and overall effects across urban and rural areas within each police region. Both these analyses lacked sufficient power for the results to achieve statistical significance so the results are not reported here.

Table 30 presents the results of applying the evaluation framework model for mobile speed cameras to all casualty crashes. Information in Table 30 includes the label of the measure of mobile speed camera operation delivery included in the model, the parameter associated with that measure in the model of Newstead et al (2020) Equation 3, and the following measures associated with the parameter estimate: the standard error, the upper and lower 95% confidence, the significance probability and the chi-squared value and degrees of freedom (a measure of improvement in model fit) from which the significance values were estimated. The larger the absolute parameter estimate in Table 30, the stronger the association between the hours of mobile camera enforcement and quarterly road trauma counts. Negative parameter estimates indicate a decrease in quarterly road trauma counts associated with an increase in quarterly mobile speed camera hours. The top section of Table 30 gives the model output estimating average association between each of the three mobile speed camera delivery measures across all ten analysis strata. The bottom section of Table 30 gives the model results estimating average effects across urban and rural strata separately. Since the average estimate for portable / LTI cameras across urban and rural areas was not statistically significant (row 3 of Table 30) separate estimates by urban and rural areas for portable / LTI cameras were not estimated.

Table 30 Crash effects evaluation model parameter estimates for the mobile speed camera program considering all casualty crashes

Whole State	Estimate	SE	LCL	UCL	Chi-Sq.	df	Sig Prob
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region	-3.145E-05	7.3535E-06	-4.586E-05	-1.704E-05	18.290	1	0.000
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region	-5.361E-05	1.4920E-05	-8.285E-05	-2.437E-05	12.910	1	0.000
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region	-4.888E-06	9.1864E-06	-2.289E-05	1.312E-05	0.283	1	0.595

Urban and Rural							
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Urban	-2.458E-05	7.7689E-06	-3.981E-05	-9.357E-06	10.013017	1	0.0015544
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Rural	-6.934E-05	2.3794E-05	-0.000116	-2.271E-05	8.4933393	1	0.0035645
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Urban	-5.859E-05	1.5672E-05	-8.93E-05	-2.787E-05	13.974513	1	0.0001853
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Rural	-0.0001139	5.5144E-05	-0.000222	-5.839E-06	4.2677671	1	0.0388419
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Urban	Not estimated						
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Rural	Not estimated						

Table 30 shows statistically significant association between quarterly hours of both covert and overt mobile speed camera hours and quarterly counts of all casualty crashes on average across all ten strata. The association with covert hours was much stronger as shown by the much larger negative parameter estimate. No statistically significant association between hours of portable / LTI camera operation and all casualty crashes was estimated in the model for Queensland as a whole. When considering average effects across urban and rural strata separately (bottom of Table 26), covert operations were once again more strongly associated with all casualty crashes compared to overt operations. There was also a significant difference in the level of association for each mobile speed camera enforcement delivery mode between urban and rural areas, with rural areas showing the stronger association with all casualty crashes.

Table 31 gives the analogous model output to Table 30 but for the models considering serious casualty crashes (fatal and serious injury crashes combined). Table 32 presents the results of the logistic regression analysis which tests whether the analogous parameters from Tables 30 and 31 are statistically different. Considering the difference measure first, Table 32 shows no statistically significant difference in the association between all casualty crashes and fatal and serious injury crashes for car-based mobile speed camera operations. For portable / LTI mobile speed camera operations, Table 32 shows the association with fatal and serious crashes is much stronger than with all casualty crashes. Table 31 shows statistically significant association between quarterly portable / LTI speed camera hours and serious casualty crash counts on average across the state (top of Table 31). Results by urban and rural areas in the bottom of Table 31 show the overall portable / LTI camera association across the state results entirely from a strong association in urban areas. The association in rural areas was not statistically significant. No statistically significant associations between the car-based mobile speed camera operations and serious casualty crashes were estimated in Table 31. However, Table 32 shows that there was no statistically significant difference between effects on all casualty crashes and serious and fatal crashes meaning the significant all casualty crash estimates can be applied equally across all crash severity levels. The lack of statistical association for the car-based operations for serious casualty crashes is most likely a result of limited statistical power for this analysis rather than a reflection of no actual association given parameter magnitudes and relative values were still consistent with the overall casualty crash effect estimates.

Table 31 Crash effects evaluation model parameter estimates for the mobile speed camera program considering all serious casualty (crashes resulting in death or seriously injury) crashes

Whole State	Estimate	SE	LCL	UCL	Chi-Sq.	df	Sig Prob
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region	-2.38E-05	1.232E-05	-4.79E-05	3.559E-07	3.728999	1	0.053475
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region	-2.64E-05	2.35E-05	-7.25E-05	1.963E-05	1.264239	1	0.26085
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region	-2.63E-05	1.452E-05	-5.48E-05	2.153E-06	3.282234	1	0.070034

Urban and Rural							
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Urban	-1.42E-05	1.333E-05	-4.03E-05	1.19E-05	1.138363	1	0.285999
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Rural	-6.51E-05	3.356E-05	-0.000131	6.861E-07	3.761734	1	0.052438
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Urban	-2.41E-05	2.525E-05	-7.36E-05	2.54E-05	0.910627	1	0.339948
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Rural	-0.000136	7.258E-05	-0.000278	6.164E-06	3.515769	1	0.060787
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Urban	-3.19E-05	1.492E-05	-6.11E-05	-2.64E-06	4.566422	1	0.032605
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Rural	0.000153	7.933E-05	-2.48E-06	0.0003085	3.719695	1	0.053774

Table 32 Crash effects evaluation model parameter estimates for the mobile speed camera program considering the odds of a serious casualty crash per casualty crash

Whole State	Estimate	SE	LCL	UCL	Chi-Sq.	df	Sig Prob
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region	1.442E-05	1.557E-05	-1.61E-05	4.494E-05	0.85818	1	0.3542484
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region	2.687E-05	3.097E-05	-3.38E-05	8.756E-05	0.75273	1	0.3856142
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region	-3.95E-05	1.896E-05	-7.67E-05	-2.35E-06	4.3417	1	0.0371898
Urban and Rural							
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Urban	1.196E-05	1.654E-05	-2.05E-05	4.438E-05	0.52231	1	0.4698562
Deployment time (quarterly hours) of Overt Car Mobile Speed Cameras in given Region - Rural	-5.98E-06	4.809E-05	-0.0001	8.827E-05	0.01548	1	0.9009728
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Urban	4.975E-05	3.262E-05	-1.42E-05	0.0001137	2.32574	1	0.1272494
Deployment time (quarterly hours) of Covert Car Mobile Speed Cameras in given Region - Rural	-9.2E-05	0.0001131	-0.000314	0.0001296	0.66229	1	0.4157531
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Urban	-4.37E-05	1.935E-05	-8.16E-05	-5.75E-06	5.09506	1	0.0239941
Deployment time (quarterly hours) of Portable / LTI Speed Cameras in Given Region - Rural	-0.000165	0.0001277	-0.000416	8.49E-05	1.67783	1	0.1952129

In summary, analysis results showed significant association between the quarterly hours of mobile speed camera operations and quarterly crash counts in areas with mobile speed camera enforcement compared to control areas without mobile speed camera enforcement. The association between covert and overt mobile speed camera operations was consistent across crash severity levels with stronger associations measured for covert versus overt operations, stronger effects in rural versus urban areas and different relative effects between covert and overt operations between urban and rural areas. Reflecting these differences, the model estimates in the bold black box in Table 30 have been used to estimate the crash effects of overt and covert car-based mobile camera operations in urban and rural areas. Statistically significant associations between portable / LTI mobile speed cameras was only identified for serious and fatal crashes in urban areas. The bold black box in Table 31 indicates the model estimate that was used for measuring the crash effects of portable / LTI cameras on serious and fatal crashes in urban areas.

In updating the evaluation of the mobile speed camera element of CDOP, the initial intent was to use the relationships between operational hours and crash outcomes established in Newstead et al (2020). Due to the significant increase in mobile speed camera hours in 2018 and 2019, it was decided to re-estimate the relationships to make sure they still held in the environment of extrapolated hours. Reassuringly, the updated estimates of association between enforcement hours and crash outcomes in this study were highly consistent with those established in the previous study of Newstead et al (2020) both in terms of the statistically significant associations as well as the relative magnitude of the parameter estimates. Estimates derived from this study are expected to be more accurate, being based on an addition 2 years of crash data related to mobile speed camera hours of operation.

Efficacy of utilising the above modelling results to estimate the casualty crash effects of the Queensland mobile speed camera program related to operation of each camera type depends on how well the models fitted predict crash outcome. Lack of model fit would suggest that other factors not represented by the mobile speed camera operations measures are impacting program effectiveness. If this was the case, basing the estimated road safety benefit of the program only on these measures would give a biased measure of effectiveness.

Figure 4 shows the observed and fitted quarterly crash counts in the treatment group across all ten strata from the all casualty crash analysis model with separate urban and rural effects for each mobile speed camera program output measure. Fits for the urban and rural effects model were chosen since parameter estimates from this model have been used to represent program crash effects related to covert and overt car-based operations. As evident from the figure, the model provides highly accurate estimation of the observed data meaning the speed camera operations measures in the data combined with the control area data are providing a highly accurate representation of the data. Concordance between the observed and modelled data, as represented by the square of the correlation between the two series, was very high at 99.8%. From this it can be concluded that the casualty crash model is highly efficacious for estimating program crash effects.

Figure 5 provides the analogous model fit data for the fatal and serious injury crash count model. Estimates from this model represent the effect of the potable / LTI cameras on serious injury and fatal crashes in urban areas so fit of this model is also critical. Figure 5 shows that the fit of this model to the observed data is also extremely good with a concordance measure of 99.1% showing this model is also efficacious for representing mobile speed camera effects on fatal and serious injury crashes.

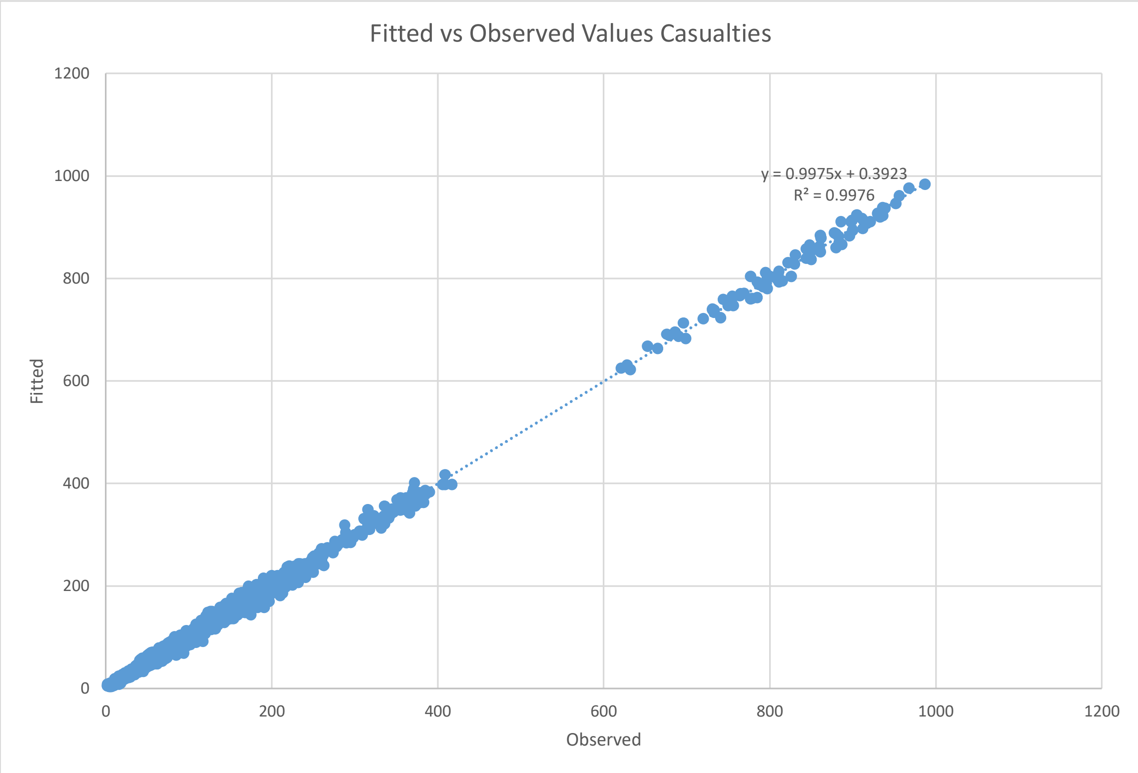

Figure 4 *Observed versus fitted quarterly treatment area casualty crash counts for model with urban and rural program effect estimates*

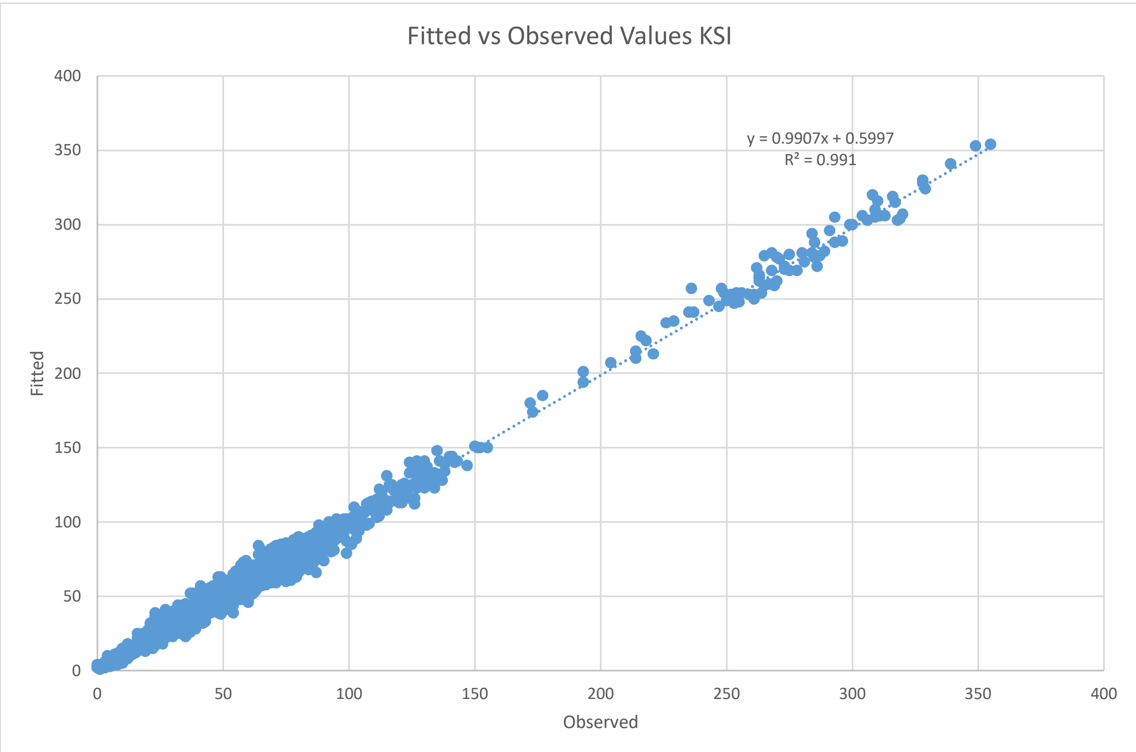

Figure 5 *Observed versus fitted quarterly treatment area fatal and serious injury crash counts for model with urban and rural program effect estimates*

Deriving a sense of the relative impact on each of the three mobile speed camera operations types on crash outcomes using the key parameter estimates from Tables 30 and 31 is difficult. To assist with interpretation, the parameters have been converted to percentage reduction in crashes associated with operation of each camera type in each area over a range of total monthly output hours across Queensland as a whole. The relationships for overt car-based, covert car-based and portable / LTI operations are shown in Figures 6, 7 and 8 respectively.

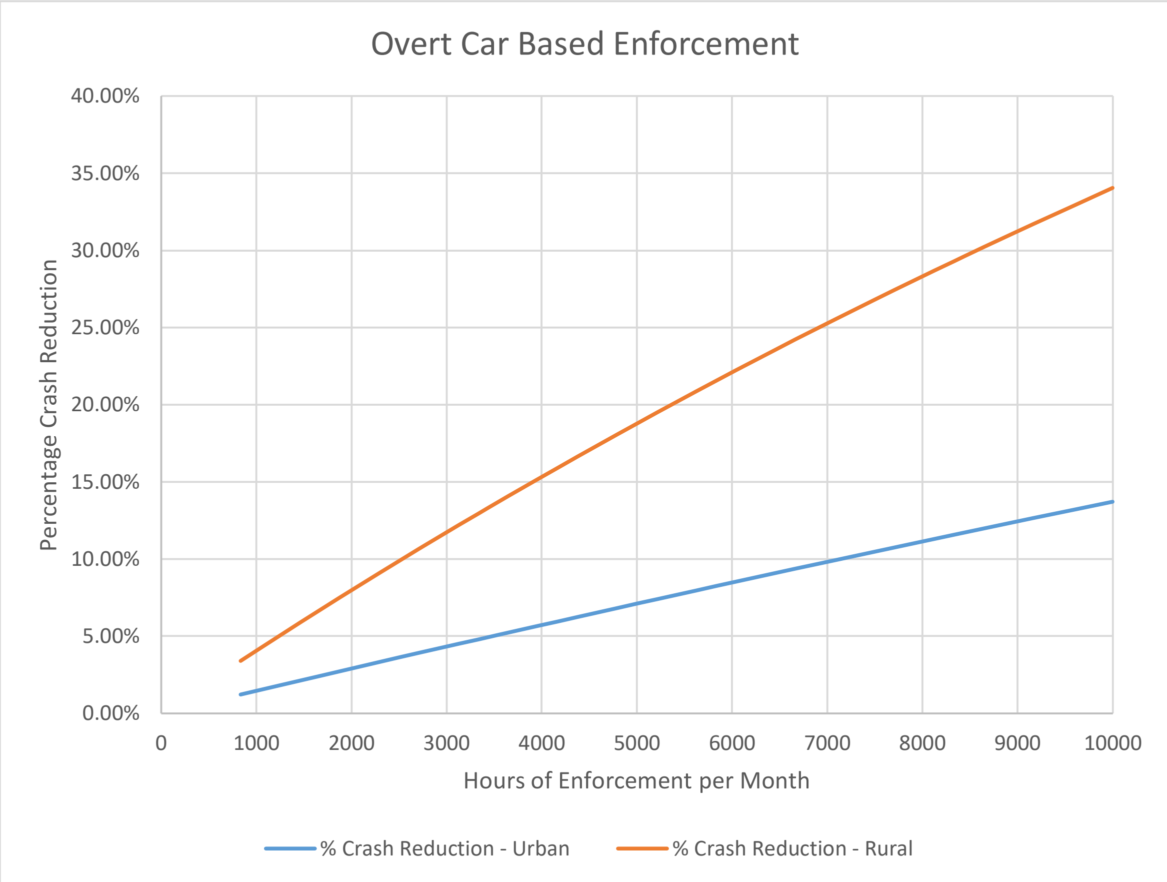

Figure 6 *Relationship between monthly hours of overt car-based mobile speed camera hours across Queensland and estimated percentage casualty crash reductions in urban and rural areas*

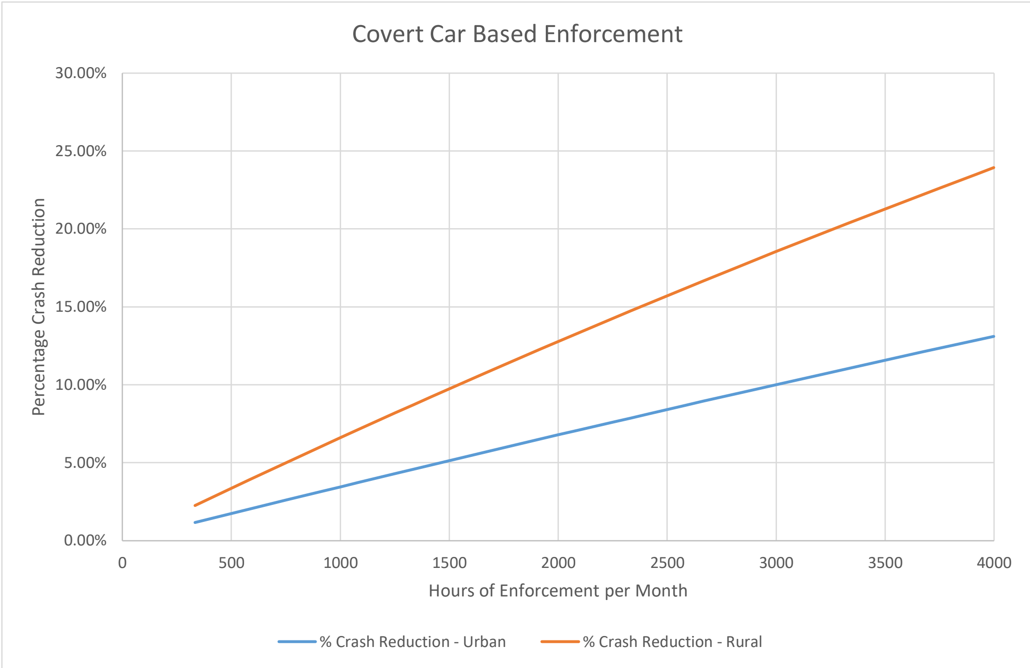

Figure 7 *Relationship between monthly hours of covert car-based mobile speed camera hours across Queensland and estimated percentage casualty crash reductions in urban and rural areas*

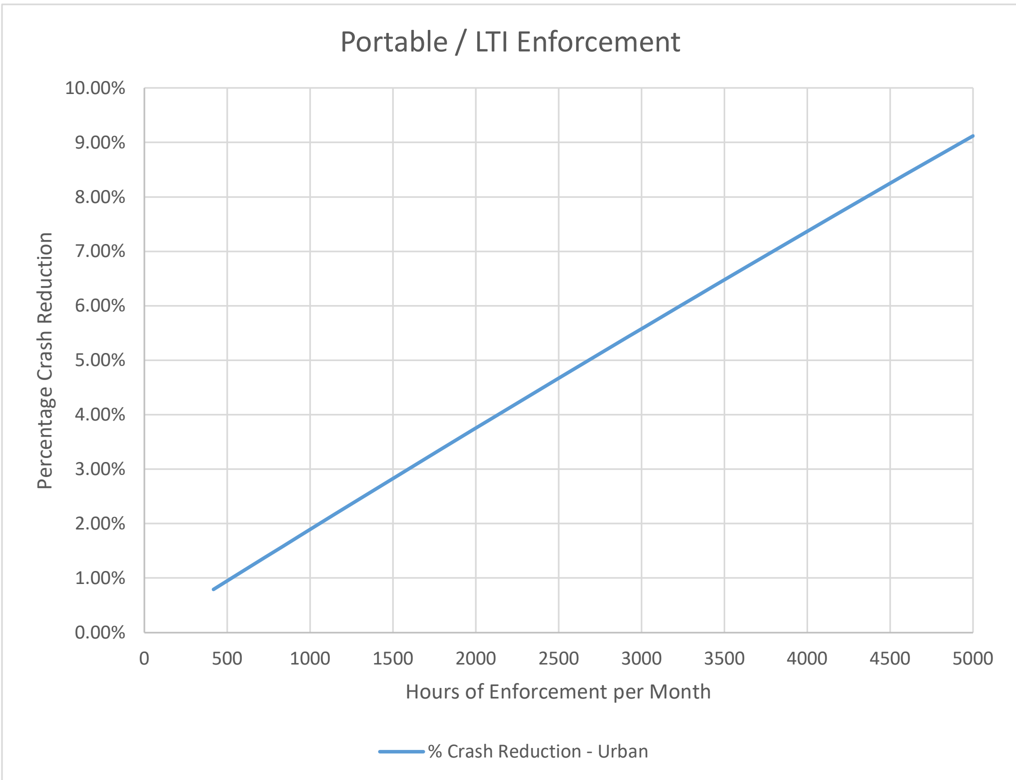

Figure 8 *Relationship between monthly hours of portable / LTI mobile speed camera hours across Queensland and estimated percentage serious casualty crash reductions in urban areas*

Comparison of the results in Figures 6-8 show some notable difference in the relative crash effects of each camera type per hour of enforcement as well as difference between urban and rural operation. Both Figures 5 and 6 show higher percentage crash reductions per hour of enforcement in rural areas compared to urban areas for car-based operations. Notably, the difference between urban and rural areas is much narrower for covert car-based enforcement. Covert enforcement also produces much greater percentage crash reductions per hour of enforcement than overt enforcement. For example, in urban areas a 10% reduction is achieved at 7,000 hours of enforcement per month for overt enforcement compared to 3000 hours for covert enforcement. In rural areas, the comparable figures are 2,500 hours for overt enforcement and 1,500 hours for covert enforcement. Portable / LTI enforcement in urban areas is slightly more efficient than car-based overt operations with a 10% reduction being achieved at around 5,400 hours of enforcement per month but with benefits only accrued for serious casualty (fatal and serious injury) crashes.

4.5.1. Crash and crash cost savings associated with the mobile speed camera program over time

Results of modelling presented above provide estimates of the relationship between levels of operation of each camera type in urban and rural areas and the corresponding percentage reduction in crashes relative to no enforcement. In order to utilise the estimates to derive the impact of the Queensland mobile speed camera program on crashes in a particular time period, the level of camera operations at the particular time point were applied to the observed crash frequency in that time period to estimate the expected crash frequency had the mobile speed camera program not been in operation. From this, it was possible to derive the absolute crash savings in the time period associated with operation of each camera type and in aggregate. Equation 5 gives the formula for estimating the crash savings, ΔC_{sgt}, in time period t for region s and treatment and control group g. In the equation, C_{sgt} is the observed crash count in the stratum and time period, Measures O_{sgt}, V_{sgt} and L_{sgt} are the hours of each speed camera operation type enforcement in the stratum in time period. Parameters A, B and C represent the association between the hours of mobile speed camera enforcement of each type respectively and crash counts in each time period estimated from the model. Crash savings in the control group will be zero since the speed camera operations hours for all camera types in the control group are zero.

$$\Delta C_{sgt} = C_{sgt}\left(\frac{1}{\exp(A.O_{sgt})\exp(B.V_{sgt})\exp(C.L_{sgt})} - 1\right) \ldots \text{(Equation 2)}$$

Crash savings across aggregate time periods or strata can be calculated by summing the individual stratum and time period savings estimated from Equation 2. Marginal effects of each camera type in each time period and stratum can be estimated by applying Equation 3 as an example.

$$\Delta C_{sgt} = C_{sgt}\ (\frac{1}{\exp\ (A.O_{sgt})} - 1)\ldots \text{(Equation 3)}$$

As demonstrated by the form of Equation 2 which related to the original form of the analysis model, total savings across all camera types are calculated by multiplying the effects of individual cameras, as distinct from simply adding the effects. These methods have been applied to estimate the annual crash savings associated with the Queensland mobile speed camera program by police region and by specific camera type and urban or rural environment.

Table 33 shows the estimated annual fatal crash savings associated with the Queensland mobile speed camera program by police region. Figure 9 gives the corresponding information in Table 33 graphically. Table 34 and corresponding Figure 10 give estimated fatal crash savings associated with the program by year, camera type and urban or rural location. Analogous information for serious injury crash savings and minor injury crash savings are given in Tables 34-37 and Figures 11-14.

Yearly trends in absolute crash savings associated with the Queensland mobile speed camera program can be seen in Figures 9 to 14. After significant growth in effectiveness of the program from 1999 to 2003, reflecting significant growth in total hours of enforcement across the state, effectiveness plateaued over the next ten years. Increasing effects on fatal crashes were observed from 2014 to 2017 corresponding to an increase in enforcement hours and in particular an increase in the number of hours of covert enforcement. Despite further increases in enforcement hours in 2018 and 2019, fatal crash savings in these years were estimated to be less than in 2017. The reason for this decrease can be seen in Figure 15 which plots the mobile speed camera program coverage of total crashes in Queensland by year and crash severity. Fatal crash coverage by the program is generally less than for serious and minor injury crashes reflecting the greater geographical spread of fatal crashes compared to serious and minor crashes which are more concentrated in urban areas. In particular, fatal crash coverage by the mobile speed camera program has fallen from nearly 60% in 2016 and 2017 to below 50% in 2018 and 2019. This suggests the geographical distribution of fatal crashes in Queensland is moving away from the current mobile speed camera enforced sectors, hence leading to smaller overall fatal savings associated with the program in 2018 and 2019 compared to 2017.

Coverage of the serious and minor injury crash population in Queensland by the mobile speed camera program has been more consistent over time at around 65% and 70% respectively. Reflecting the sustained coverage and the significant increase in enforced hours in 2018 and 2019 compared to previous years, estimated savings in crashes of these severities in 2018 and 2019 have been the largest of any years in the program, being about 25% greater than estimated in 2017. As evident from the charts, the additional crash savings in these last 2 years evaluated have been greatest in Brisbane and Central regions where crash numbers, reflecting population concentration, are highest. Enforcement in these last 2 years has also increased most significantly in urban areas, again where population density is highest.

Table 33 Estimated fatal crash savings associated with the Queensland mobile speed camera program by year and police region

Year	Brisbane	Central	Northern	South Eastern	Southern	Total
1999	1.32	1.39	0.37	0.33	0.84	4.25
2000	1.31	1.75	0.50	0.64	1.34	5.54
2001	2.34	2.81	0.54	0.79	1.93	8.41
2002	2.35	4.16	0.82	0.81	1.27	9.41
2003	4.26	6.84	0.94	1.10	1.46	14.60
2004	3.85	4.58	0.62	1.17	2.12	12.34
2005	3.56	5.91	2.13	0.99	2.09	14.68
2006	4.46	5.29	2.20	1.45	2.65	16.05
2007	3.93	6.40	1.14	1.66	2.55	15.68
2008	2.66	5.49	1.83	1.28	2.06	13.32
2009	3.14	7.26	2.17	0.81	1.52	14.90
2010	2.37	5.20	1.16	0.63	1.53	10.89
2011	4.11	4.44	0.63	1.26	2.23	12.67
2012	3.17	6.09	2.00	1.03	2.25	14.54
2013	2.86	6.04	1.41	1.02	2.03	13.36
2014	3.10	4.32	1.45	0.74	1.88	11.49
2015	4.05	4.68	1.77	0.91	1.98	13.39
2016	5.50	5.17	1.45	1.79	2.50	16.41
2017	6.90	6.93	2.10	1.73	2.62	20.28
2018	7.58	6.02	1.63	1.30	2.73	19.26
2019	5.84	3.25	2.80	0.71	2.75	15.35

Table 34 Estimated fatal crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation

Year	Covert - Rural	Overt - Rural	Portable / LTI - Rural	Covert - Urban	Overt - Urban	Portable / LTI - Urban
1999	0.00	2.15	0.00	0.00	2.10	0.00
2000	0.00	3.08	0.00	0.00	2.46	0.00
2001	0.00	4.61	0.00	0.00	3.80	0.00
2002	0.00	5.52	0.00	0.00	3.89	0.00
2003	0.00	7.65	0.00	0.00	6.95	0.00
2004	0.00	6.05	0.00	0.00	6.29	0.00
2005	0.00	8.63	0.00	0.00	6.05	0.00
2006	0.00	8.00	0.00	0.00	8.05	0.00
2007	0.00	8.91	0.00	0.00	6.77	0.00
2008	0.00	7.77	0.00	0.00	5.55	0.00
2009	0.00	9.39	0.00	0.00	5.51	0.00
2010	0.28	6.43	0.00	0.84	3.34	0.00
2011	1.67	5.03	0.00	2.40	3.52	0.05
2012	2.13	5.78	0.00	2.40	3.84	0.39
2013	2.37	5.50	0.00	1.61	2.78	1.10
2014	1.89	4.09	0.00	1.70	2.60	1.21
2015	2.04	4.52	0.00	1.38	3.21	2.24
2016	2.51	4.04	0.00	1.68	4.13	4.05
2017	4.07	4.14	0.00	4.11	4.15	3.81
2018	3.92	4.72	0.00	3.93	3.74	2.95
2019	2.22	3.73	0.00	2.83	4.32	2.25

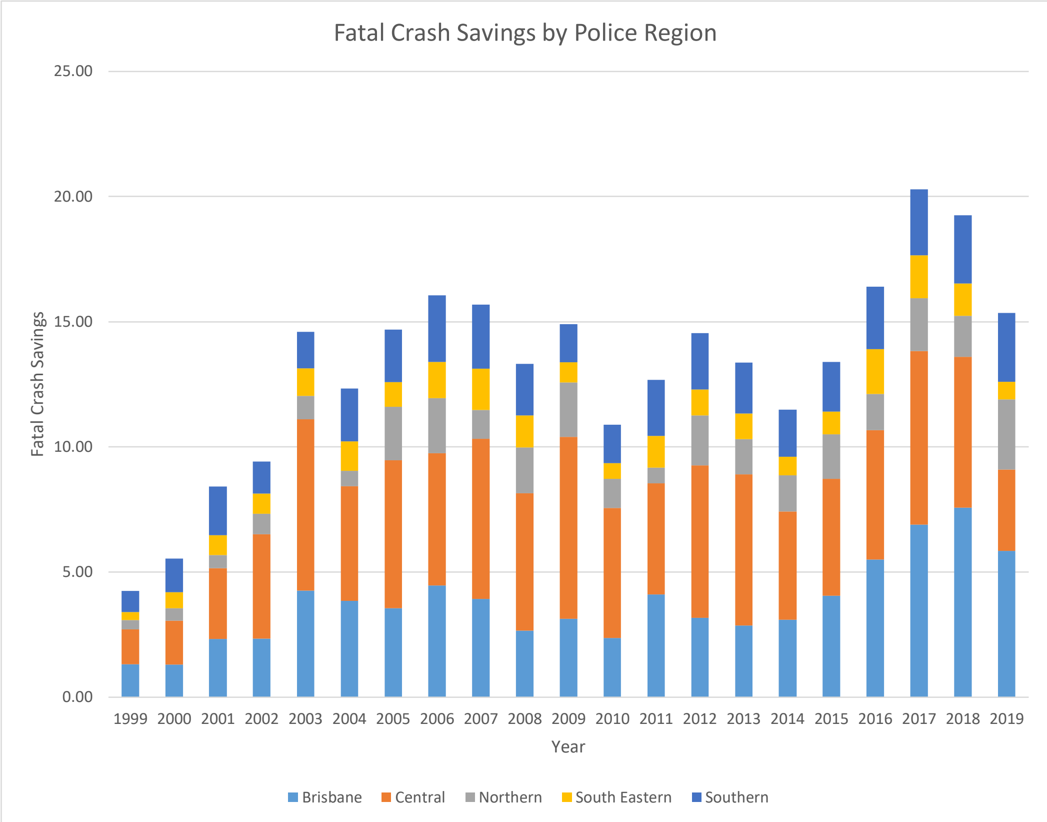

Figure 9 *Estimated fatal crash savings associated with the Queensland mobile speed camera program by year and police region*

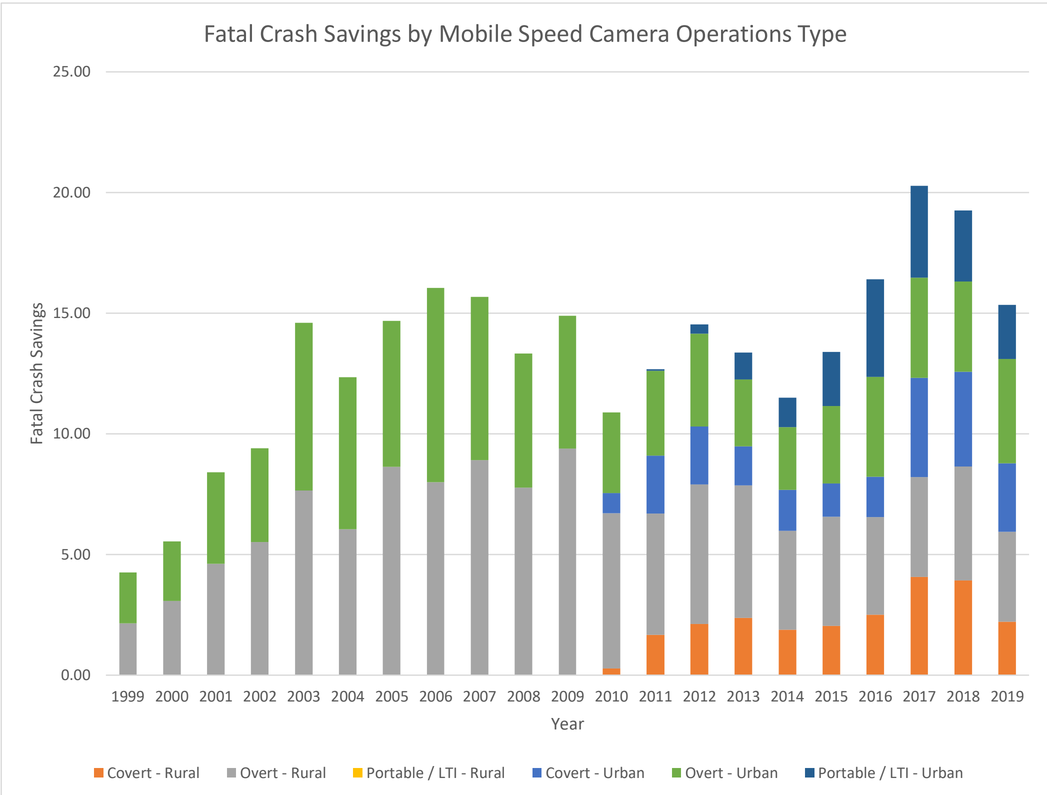

Figure 10 *Estimated fatal crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation*

Table 35 Estimated serious injury crash savings associated with the Queensland mobile speed camera program by year and police region

Year	Brisbane	Central	Northern	South Eastern	Southern	Total
1999	25.88	10.30	4.78	6.62	7.70	55.28
2000	36.91	14.05	7.29	10.17	12.10	80.52
2001	65.16	23.27	9.10	17.39	16.59	131.51
2002	75.79	27.53	11.62	17.30	15.96	148.20
2003	114.37	41.05	17.89	29.85	26.57	229.73
2004	121.00	48.12	20.35	26.59	25.75	241.81
2005	135.31	52.34	26.05	25.85	29.66	269.21
2006	135.40	50.52	27.66	25.30	28.79	267.67
2007	130.69	51.63	25.60	26.59	31.53	266.04
2008	130.85	55.90	25.53	29.14	32.01	273.43
2009	136.85	54.14	23.97	27.18	35.30	277.44
2010	178.53	56.57	29.03	31.41	36.00	331.54
2011	191.51	67.38	38.25	37.72	41.20	376.06
2012	198.75	73.45	36.33	33.79	43.80	386.12
2013	269.86	86.77	52.81	47.58	53.87	510.89
2014	254.98	86.04	50.19	53.53	55.95	500.69
2015	233.48	82.36	47.20	54.56	59.29	476.89
2016	224.32	66.56	42.15	54.27	51.02	438.32
2017	284.20	94.15	50.48	58.11	63.86	550.80
2018	388.49	111.53	61.10	63.94	79.90	704.96
2019	368.04	110.39	58.27	55.88	87.05	679.63

Table 36 Estimated fatal crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation

Year	Covert - Rural	Overt - Rural	Portable / LTI - Rural	Covert - Urban	Covert - Urban	Portable / LTI - Urban
1999	0.00	14.55	0.00	0.00	40.73	0.00
2000	0.00	21.32	0.00	0.00	59.20	0.00
2001	0.00	30.18	0.00	0.00	101.33	0.00
2002	0.00	32.21	0.00	0.00	115.99	0.00
2003	0.00	49.15	0.00	0.00	180.58	0.00
2004	0.00	55.97	0.00	0.00	185.84	0.00
2005	0.00	66.47	0.00	0.00	202.74	0.00
2006	0.00	62.81	0.00	0.00	204.86	0.00
2007	0.00	61.90	0.00	0.00	204.14	0.00
2008	0.00	61.19	0.00	0.00	212.24	0.00
2009	0.00	58.99	0.00	0.00	218.45	0.00
2010	3.99	58.98	0.00	55.17	213.40	0.00
2011	18.03	54.63	0.00	124.50	175.70	3.20
2012	20.53	56.09	0.00	108.33	180.87	20.30
2013	26.82	61.78	0.00	121.86	212.11	88.32
2014	26.41	55.21	0.00	127.71	195.67	95.69
2015	23.72	52.14	0.00	87.97	181.81	131.25
2016	25.27	36.18	0.00	66.16	155.19	155.52
2017	46.47	47.41	0.00	150.25	166.29	140.38
2018	52.55	64.80	0.00	213.51	207.74	166.36
2019	39.39	64.54	0.00	166.74	267.31	141.65

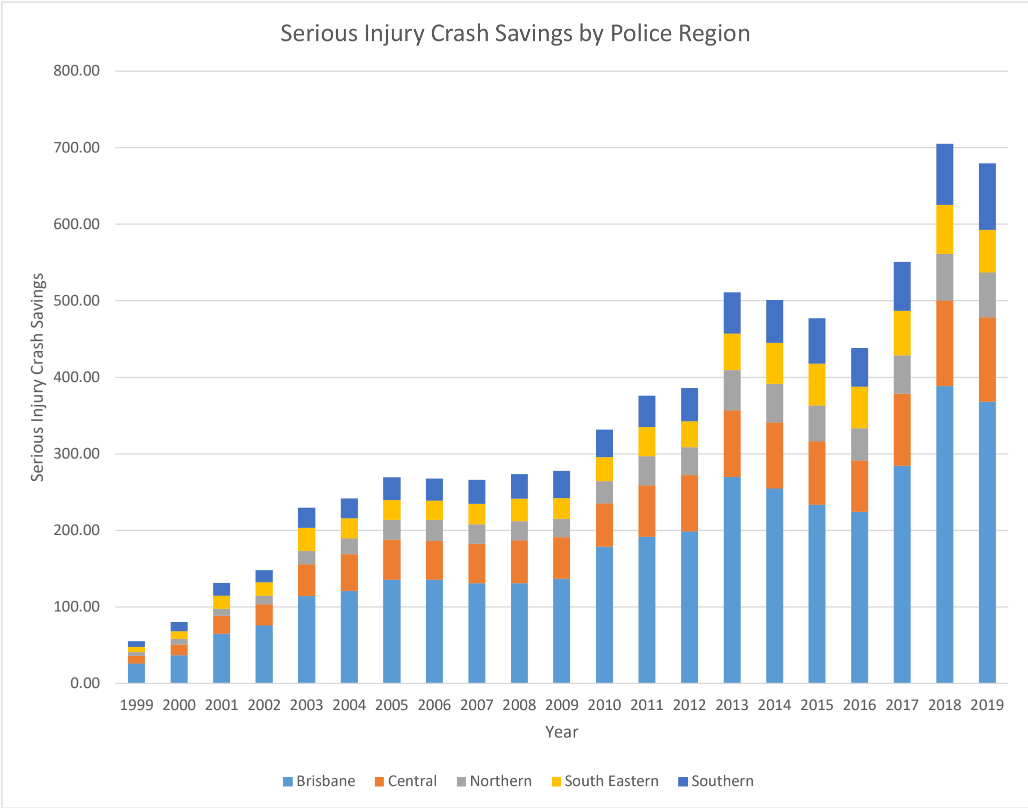

Figure 11 *Estimated serious crash savings associated with the Queensland mobile speed camera program by year and police region*

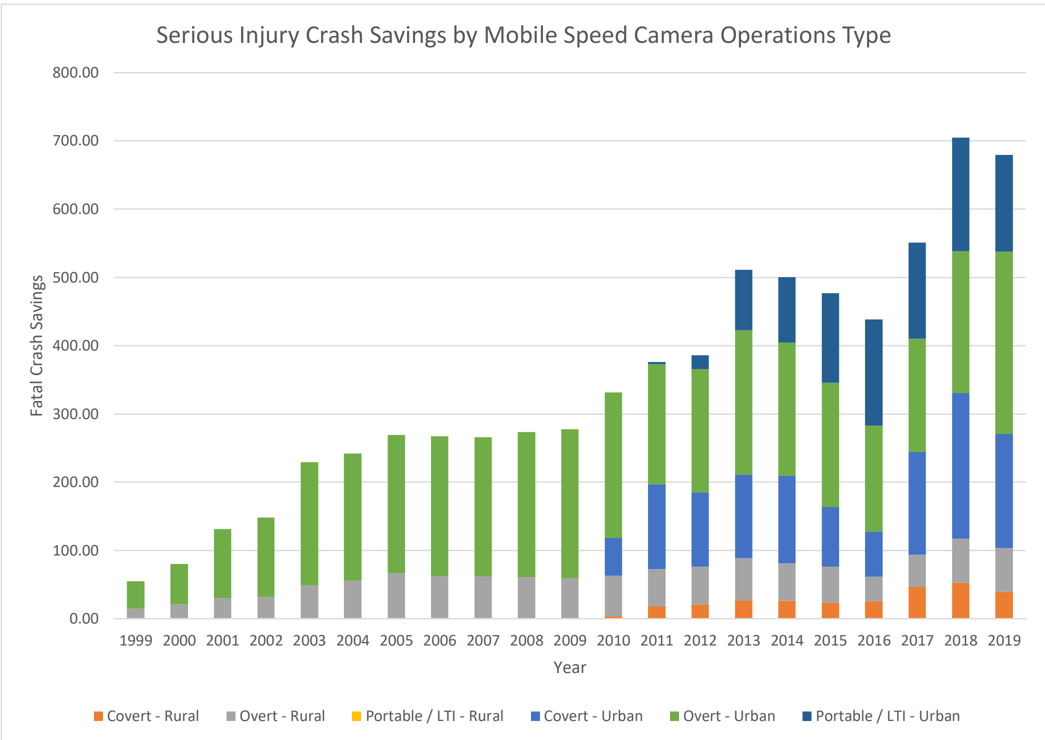

Figure 12 *Estimated serious crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation*

Table 37 Estimated minor injury crash savings associated with the Queensland mobile speed camera program by year and police region

Year	Brisbane	Central	Northern	South Eastern	Southern	Total
1999	73.29	16.20	8.73	13.20	14.35	125.77
2000	96.61	21.31	10.65	22.46	19.87	170.90
2001	201.83	35.96	16.46	40.00	32.91	327.16
2002	203.78	49.56	18.60	38.78	31.86	342.58
2003	302.00	64.50	26.18	57.56	43.48	493.72
2004	276.52	62.90	30.08	45.53	41.96	456.99
2005	269.32	73.74	34.09	45.88	47.85	470.88
2006	305.68	78.42	38.76	51.34	51.26	525.46
2007	290.30	91.94	42.96	54.01	56.90	536.11
2008	254.41	73.74	36.35	52.20	56.45	473.15
2009	240.52	71.57	33.26	48.82	49.46	443.63
2010	306.58	80.42	38.18	56.36	46.87	528.41
2011	339.18	81.02	44.97	62.64	50.96	578.77
2012	323.97	78.66	38.22	55.54	49.53	545.92
2013	311.27	84.97	46.58	58.12	53.55	554.49
2014	315.26	85.37	45.13	72.85	48.86	567.47
2015	277.23	73.54	36.27	53.49	53.65	494.18
2016	241.37	44.02	33.00	53.99	43.59	415.97
2017	393.86	70.36	33.01	62.57	57.52	617.32
2018	529.14	81.30	37.82	71.48	60.94	780.68
2019	504.58	73.89	40.99	78.53	66.68	764.67

Table 38 Estimated minor crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation

Year	Covert - Rural	Overt - Rural	Portable / LTI - Rural	Covert - Urban	Covert - Urban	Portable / LTI - Urban
1999	0.00	19.23	0.00	0.00	106.54	0.00
2000	0.00	25.95	0.00	0.00	144.95	0.00
2001	0.00	41.13	0.00	0.00	286.03	0.00
2002	0.00	48.86	0.00	0.00	293.72	0.00
2003	0.00	60.24	0.00	0.00	433.48	0.00
2004	0.00	62.45	0.00	0.00	394.54	0.00
2005	0.00	80.27	0.00	0.00	390.61	0.00
2006	0.00	81.96	0.00	0.00	443.50	0.00
2007	0.00	91.85	0.00	0.00	444.26	0.00
2008	0.00	68.04	0.00	0.00	405.11	0.00
2009	0.00	65.46	0.00	0.00	378.17	0.00
2010	4.17	70.42	0.00	92.08	361.74	0.00
2011	19.36	56.45	0.00	207.70	295.26	0.00
2012	18.15	49.61	0.00	178.80	299.36	0.00
2013	23.35	53.73	0.00	176.29	301.12	0.00
2014	22.89	47.67	0.00	197.20	299.71	0.00
2015	18.98	42.10	0.00	137.45	295.65	0.00
2016	19.80	27.85	0.00	107.25	261.07	0.00
2017	34.04	33.80	0.00	255.43	294.05	0.00
2018	36.84	44.98	0.00	354.83	344.03	0.00
2019	25.92	42.45	0.00	256.07	440.23	0.00

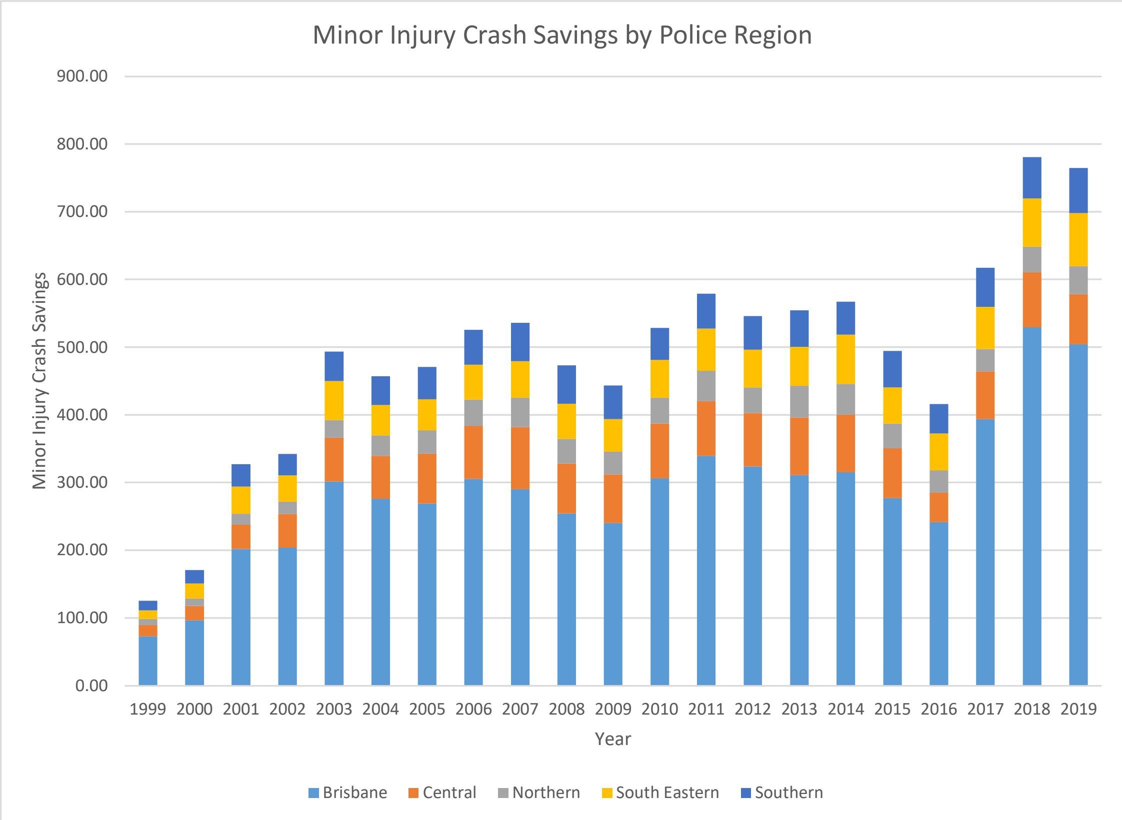

Figure 13 *Estimated minor crash savings associated with the Queensland mobile speed camera program by year and police region*

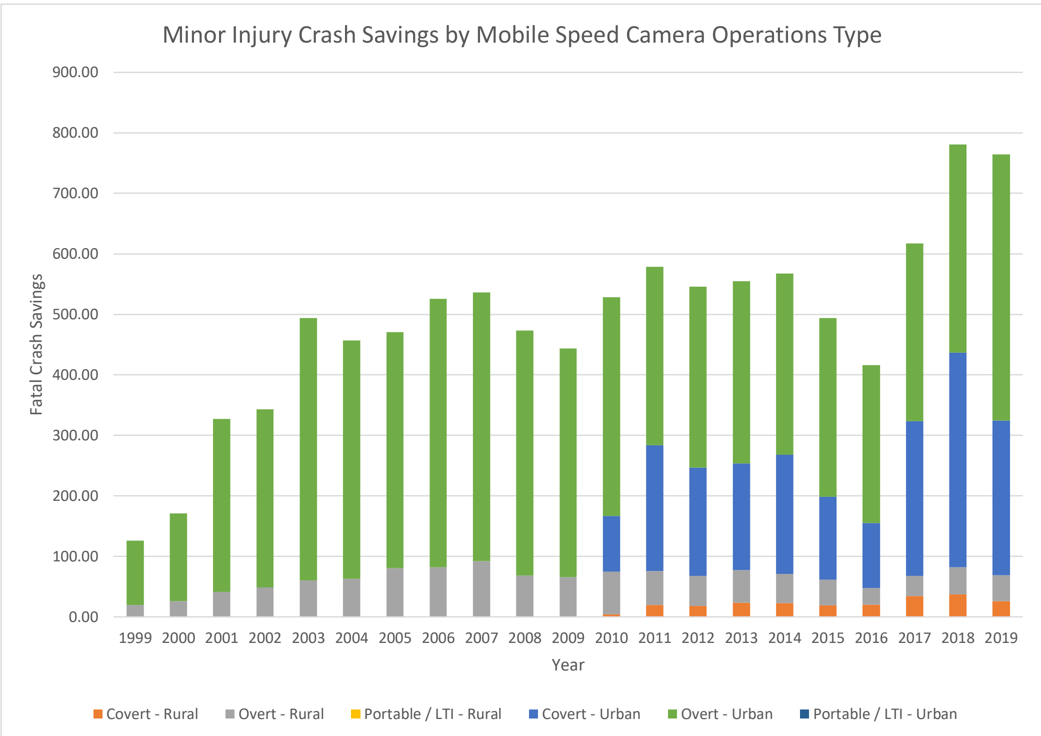

Figure 14 *Estimated minor crash savings associated with the Queensland mobile speed camera program by year camera type and level of urbanisation*

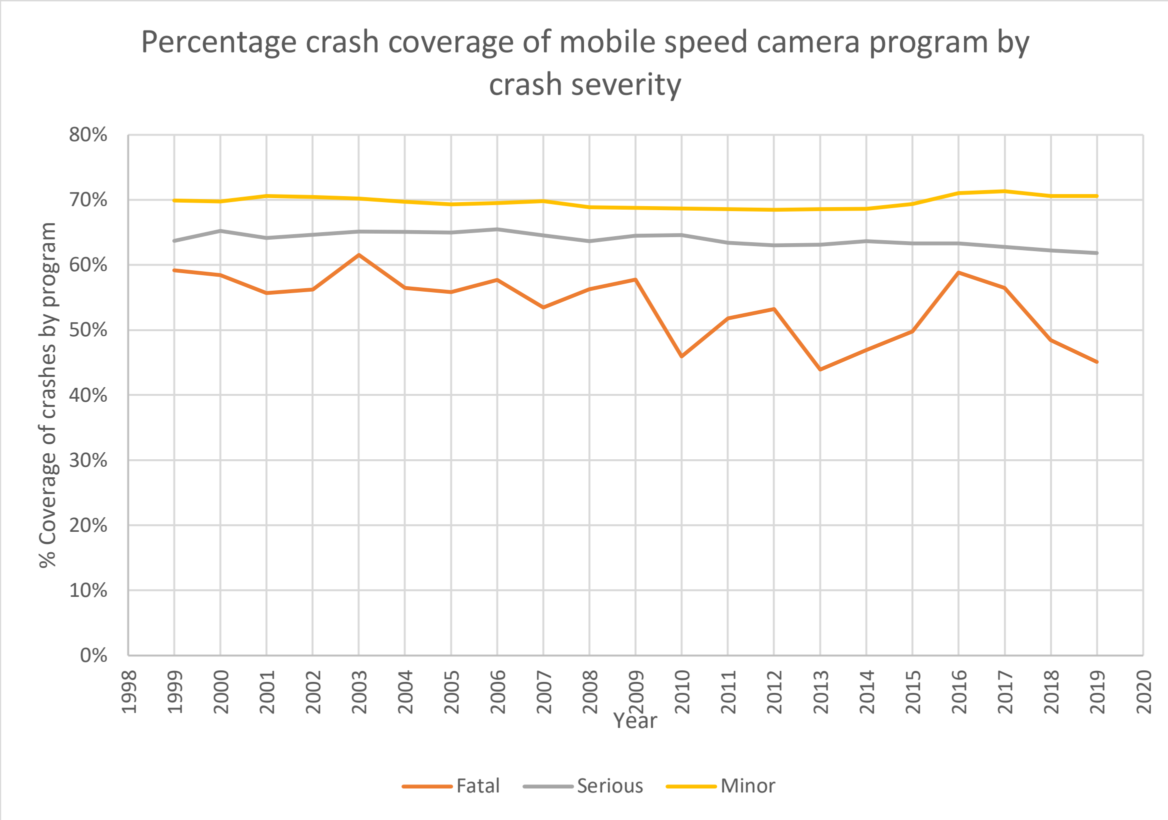

Figure 15 *Percentage of total Queensland crash population coverage by the Queensland mobile camera program by crash severity*

In order to estimate savings to the community through crash reductions associated with the Queensland mobile speed camera program, the estimated crash savings given in Tables 33-38 were converted to community cost savings using the per crash cost values given in Table 1. It was not necessary to use the average crash cost tables by severity and region derived for fixed cameras since estimated crash savings by individual severity and region were produced directly for the mobile speed camera program. Two sets of estimates were produced, the first based on the WTP valuation of crashes and the second based on crash costs derived using the HC methodology. The former is presented in Table 39 with the later presented in Table 40. Reflecting the relative costs by crash severity of the two methods, WTP estimates of savings associated with the mobile camera program are more than double those based on HC methodology.

Reflecting the growth in crash savings over the life of the program and particularly in 2018 and 2019, crash cost savings associated with the program have also increased significantly in the 2 most recent years of program evaluation. In 2018, it was estimated that the program was associated with cost savings to the community of $712M based on the WTP methodology or $323M based on HC costs. Corresponding savings for 2019 were $685M based on the WTP methodology or $310M based on HC costs. These were the greatest cost savings estimated for any years of the program being over 22% greater in magnitude than the previous greatest year. Also evident from the tables is that the vast majority of the savings, around 88% were estimated to be derived from estimated savings in fatal and serious injury crashes. Over half of the estimated savings also derived from the Brisbane region, not due to fatal crash savings being predominant in this area, but due to the high proportion of serious injury crash savings derived from this region. This result highlights the importance of not only targeting fatalities with a mobile speed camera program but particularly targeting the high proportion of serious injuries occurring in dense urban areas.

Table 39 Estimated community cost savings associated with the Queensland mobile speed camera program by year crash severity and region: Willingness to pay cost basis

Year	Brisbane	Central	Northern	South Eastern	Southern	Total
Fatal and Serious Injury Crashes						
1999	$23,427,875	$10,068,818	$4,435,792	$5,986,167	$7,355,664	$51,274,316
2000	$32,919,609	$13,608,839	$6,709,674	$9,310,858	$11,576,126	$74,125,107
2001	$58,139,027	$22,463,198	$8,303,114	$15,658,778	$15,951,626	$120,515,744
2002	$67,303,461	$27,295,197	$10,714,807	$15,598,486	$14,840,525	$135,752,476
2003	$102,178,264	$41,248,563	$16,218,635	$26,657,821	$24,142,769	$210,446,053
2004	$107,535,668	$45,391,507	$18,061,858	$23,910,213	$24,004,958	$218,904,205
2005	$119,611,359	$50,171,827	$24,271,967	$23,117,800	$27,346,876	$244,519,830
2006	$120,464,065	$48,070,209	$25,718,983	$23,040,281	$27,079,867	$244,373,405
2007	$115,950,754	$49,982,337	$23,031,668	$24,332,260	$29,353,749	$242,650,767
2008	$114,994,690	$52,876,369	$23,565,686	$26,201,322	$29,345,136	$246,983,202
2009	$120,576,036	$52,884,982	$22,514,877	$24,108,317	$31,713,763	$251,797,974
2010	$155,812,593	$53,203,670	$26,003,218	$27,596,658	$32,325,299	$294,941,439
2011	$168,491,208	$61,859,925	$33,488,080	$33,574,212	$37,407,081	$334,820,506
2012	$173,917,517	$68,509,307	$33,014,354	$29,991,125	$39,663,736	$345,096,040
2013	$234,898,897	$79,939,009	$46,700,712	$41,860,100	$48,147,728	$451,546,446
2014	$222,289,188	$77,828,778	$44,478,509	$46,743,778	$49,810,073	$441,150,327
2015	$204,589,084	$74,969,199	$42,178,788	$47,777,361	$52,773,011	$422,287,442
2016	$197,948,315	$61,782,406	$37,553,505	$48,285,539	$46,097,789	$391,667,555
2017	$250,729,939	$87,062,117	$45,288,149	$51,541,324	$57,260,482	$491,882,012
2018	$341,142,587	$101,248,040	$54,030,536	$56,192,447	$71,170,783	$623,784,392
2019	$322,029,920	$97,880,283	$52,600,747	$48,742,038	$77,346,439	$598,599,426
Minor Injury Crashes						
1999	$8,308,153	$1,836,432	$989,633	$1,496,352	$1,626,716	$14,257,286
2000	$10,951,708	$2,415,701	$1,207,284	$2,546,065	$2,252,463	$19,373,222
2001	$22,879,446	$4,076,425	$1,865,905	$4,534,399	$3,730,677	$37,086,853
2002	$23,100,498	$5,618,121	$2,108,496	$4,396,100	$3,611,649	$38,834,864
2003	$34,234,716	$7,311,719	$2,967,764	$6,525,001	$4,928,892	$55,968,093
2004	$31,346,304	$7,130,343	$3,409,868	$5,161,280	$4,756,585	$51,804,380
2005	$30,530,112	$8,359,165	$3,864,442	$5,200,956	$5,424,275	$53,378,951
2006	$34,651,881	$8,889,690	$4,393,833	$5,819,902	$5,810,833	$59,566,139
2007	$32,908,404	$10,422,317	$4,869,945	$6,122,573	$6,450,183	$60,773,423
2008	$28,839,914	$8,359,165	$4,120,636	$5,917,391	$6,399,171	$53,636,278
2009	$27,265,344	$8,113,174	$3,770,353	$5,534,235	$5,606,785	$50,289,891
2010	$34,753,905	$9,116,410	$4,328,084	$6,388,969	$5,313,183	$59,900,551
2011	$38,449,440	$9,184,426	$5,097,799	$7,100,870	$5,776,825	$65,609,360
2012	$36,725,235	$8,916,897	$4,332,619	$6,296,014	$5,614,720	$61,885,484
2013	$35,285,563	$9,632,198	$5,280,308	$6,588,482	$6,070,427	$62,856,979
2014	$35,737,869	$9,677,542	$5,115,936	$8,258,275	$5,538,769	$64,328,392
2015	$31,426,789	$8,336,493	$4,111,567	$6,063,626	$6,081,763	$56,020,238
2016	$27,361,700	$4,990,107	$3,740,880	$6,120,306	$4,941,362	$47,154,354

2017	$44,647,964	$7,976,009	$3,742,013	$7,092,934	$6,520,466	$69,979,387
2018	$59,983,303	$9,216,167	$4,287,275	$8,102,972	$6,908,158	$88,497,875
2019	$57,199,182	$8,376,169	$4,646,626	$8,902,160	$7,558,844	$86,682,981
All Casualty Crashes						
1999	$31,736,028	$11,905,250	$5,425,425	$7,482,518	$8,982,379	$65,531,601
2000	$43,871,318	$16,024,540	$7,916,958	$11,856,923	$13,828,589	$93,498,328
2001	$81,018,474	$26,539,623	$10,169,020	$20,193,178	$19,682,304	$157,602,597
2002	$90,403,959	$32,913,318	$12,823,303	$19,994,586	$18,452,174	$174,587,340
2003	$136,412,980	$48,560,282	$19,186,400	$33,182,822	$29,071,662	$266,414,146
2004	$138,881,971	$52,521,851	$21,471,726	$29,071,494	$28,761,543	$270,708,585
2005	$150,141,471	$58,530,993	$28,136,409	$28,318,756	$32,771,151	$297,898,780
2006	$155,115,946	$56,959,899	$30,112,816	$28,860,183	$32,890,700	$303,939,544
2007	$148,859,158	$60,404,654	$27,901,613	$30,454,833	$35,803,932	$303,424,190
2008	$143,834,604	$61,235,534	$27,686,321	$32,118,713	$35,744,307	$300,619,479
2009	$147,841,380	$60,998,156	$26,285,230	$29,642,551	$37,320,548	$302,087,865
2010	$190,566,498	$62,320,080	$30,331,303	$33,985,627	$37,638,482	$354,841,990
2011	$206,940,648	$71,044,351	$38,585,878	$40,675,081	$43,183,906	$400,429,865
2012	$210,642,752	$77,426,204	$37,346,973	$36,287,139	$45,278,457	$406,981,524
2013	$270,184,460	$89,571,207	$51,981,020	$48,448,582	$54,218,155	$514,403,425
2014	$258,027,058	$87,506,320	$49,594,445	$55,002,053	$55,348,842	$505,478,719
2015	$236,015,873	$83,305,693	$46,290,354	$53,840,986	$58,854,774	$478,307,681
2016	$225,310,015	$66,772,513	$41,294,385	$54,405,845	$51,039,151	$438,821,908
2017	$295,377,903	$95,038,126	$49,030,162	$58,634,259	$63,780,949	$561,861,399
2018	$401,125,890	$110,464,207	$58,317,811	$64,295,419	$78,078,940	$712,282,266
2019	$379,229,102	$106,256,452	$57,247,373	$57,644,198	$84,905,283	$685,282,407

Table 40 Estimated community cost savings associated with the Queensland mobile speed camera program by year crash severity and region: Human capital cost basis

Year	Brisbane	Central	Northern	South Eastern	Southern	Total
Fatal and Serious Injury Crashes						
1999	$11,561,394	$4,968,849	$2,189,014	$2,954,106	$3,629,938	$25,303,300
2000	$16,245,458	$6,715,810	$3,311,149	$4,594,804	$5,712,689	$36,579,909
2001	$28,690,958	$11,085,336	$4,097,494	$7,727,431	$7,871,949	$59,473,169
2002	$33,213,504	$13,469,874	$5,287,637	$7,697,678	$7,323,633	$66,992,325
2003	$50,423,828	$20,355,704	$8,003,715	$13,155,336	$11,914,186	$103,852,769
2004	$53,067,647	$22,400,200	$8,913,324	$11,799,422	$11,846,178	$108,026,772
2005	$59,026,865	$24,759,235	$11,977,944	$11,408,375	$13,495,377	$120,667,796
2006	$59,447,666	$23,722,110	$12,692,030	$11,370,121	$13,363,611	$120,595,537
2007	$57,220,397	$24,665,723	$11,365,870	$12,007,697	$14,485,746	$119,745,434
2008	$56,748,591	$26,093,895	$11,629,402	$12,930,059	$14,481,496	$121,883,442
2009	$59,502,923	$26,098,146	$11,110,839	$11,897,184	$15,650,387	$124,259,478
2010	$76,891,769	$26,255,415	$12,832,297	$13,618,642	$15,952,173	$145,550,295
2011	$83,148,523	$30,527,180	$16,525,992	$16,568,497	$18,459,975	$165,230,167
2012	$85,826,346	$33,808,575	$16,292,214	$14,800,284	$19,573,609	$170,301,028
2013	$115,919,973	$39,449,005	$23,046,278	$20,657,490	$23,760,364	$222,833,111
2014	$109,697,223	$38,407,630	$21,949,646	$23,067,531	$24,580,713	$217,702,742
2015	$100,962,420	$36,996,460	$20,814,759	$23,577,592	$26,042,889	$208,394,120
2016	$97,685,275	$30,488,925	$18,532,234	$23,828,372	$22,748,742	$193,283,549
2017	$123,732,415	$42,964,179	$22,349,194	$25,435,066	$28,257,406	$242,738,260
2018	$168,350,043	$49,964,773	$26,663,464	$27,730,343	$35,121,984	$307,830,607
2019	$158,918,156	$48,302,823	$25,957,879	$24,053,649	$38,169,601	$295,402,108
Minor Injury Crashes						
1999	$1,441,394	$318,605	$171,693	$259,604	$282,221	$2,473,519
2000	$1,900,029	$419,104	$209,454	$441,721	$390,783	$3,361,090
2001	$3,969,391	$707,225	$323,719	$786,680	$647,241	$6,434,256
2002	$4,007,741	$974,697	$365,806	$762,686	$626,591	$6,737,521
2003	$5,939,434	$1,268,522	$514,882	$1,132,033	$855,121	$9,709,991
2004	$5,438,319	$1,237,054	$591,583	$895,439	$825,227	$8,987,622
2005	$5,296,716	$1,450,245	$670,448	$902,322	$941,066	$9,260,797
2006	$6,011,809	$1,542,286	$762,293	$1,009,704	$1,008,130	$10,334,222
2007	$5,709,330	$1,808,184	$844,894	$1,062,215	$1,119,052	$10,543,675
2008	$5,003,481	$1,450,245	$714,895	$1,026,617	$1,110,202	$9,305,441
2009	$4,730,307	$1,407,567	$654,124	$960,143	$972,730	$8,724,871
2010	$6,029,509	$1,581,620	$750,886	$1,108,432	$921,792	$10,392,239
2011	$6,670,653	$1,593,420	$884,425	$1,231,941	$1,002,230	$11,382,670
2012	$6,371,518	$1,547,006	$751,673	$1,092,305	$974,107	$10,736,609
2013	$6,121,747	$1,671,105	$916,089	$1,143,046	$1,053,168	$10,905,155
2014	$6,200,218	$1,678,972	$887,572	$1,432,741	$960,930	$11,160,432
2015	$5,452,282	$1,446,311	$713,322	$1,051,988	$1,055,135	$9,719,038

2016	$4,747,024	$865,741	$649,011	$1,061,821	$857,285	$8,180,882
2017	$7,746,045	$1,383,770	$649,208	$1,230,564	$1,131,246	$12,140,832
2018	$10,406,596	$1,598,927	$743,806	$1,405,797	$1,198,507	$15,353,634
2019	$9,923,575	$1,453,195	$806,150	$1,544,450	$1,311,396	$15,038,765
All Casualty Crashes						
1999	$13,002,788	$5,287,454	$2,360,707	$3,213,710	$3,912,159	$27,776,819
2000	$18,145,487	$7,134,913	$3,520,603	$5,036,525	$6,103,472	$39,941,000
2001	$32,660,349	$11,792,562	$4,421,213	$8,514,111	$8,519,190	$65,907,425
2002	$37,221,245	$14,444,570	$5,653,444	$8,460,364	$7,950,223	$73,729,846
2003	$56,363,262	$21,624,225	$8,518,597	$14,287,368	$12,769,307	$113,562,760
2004	$58,505,966	$23,637,254	$9,504,908	$12,694,861	$12,671,405	$117,014,394
2005	$64,323,582	$26,209,479	$12,648,392	$12,310,697	$14,436,443	$129,928,593
2006	$65,459,475	$25,264,396	$13,454,323	$12,379,824	$14,371,741	$130,929,759
2007	$62,929,728	$26,473,907	$12,210,764	$13,069,912	$15,604,798	$130,289,110
2008	$61,752,072	$27,544,140	$12,344,297	$13,956,676	$15,591,698	$131,188,883
2009	$64,233,229	$27,505,713	$11,764,964	$12,857,327	$16,623,116	$132,984,350
2010	$82,921,278	$27,837,035	$13,583,183	$14,727,074	$16,873,965	$155,942,534
2011	$89,819,176	$32,120,600	$17,410,417	$17,800,438	$19,462,206	$176,612,837
2012	$92,197,864	$35,355,582	$17,043,887	$15,892,589	$20,547,716	$181,037,637
2013	$122,041,720	$41,120,110	$23,962,367	$21,800,536	$24,813,532	$233,738,266
2014	$115,897,442	$40,086,602	$22,837,218	$24,500,272	$25,541,643	$228,863,175
2015	$106,414,703	$38,442,771	$21,528,081	$24,629,580	$27,098,024	$218,113,158
2016	$102,432,299	$31,354,667	$19,181,245	$24,890,194	$23,606,027	$201,464,431
2017	$131,478,460	$44,347,949	$22,998,402	$26,665,630	$29,388,652	$254,879,093
2018	$178,756,640	$51,563,700	$27,407,270	$29,136,140	$36,320,491	$323,184,240
2019	$168,841,731	$49,756,017	$26,764,029	$25,598,099	$39,480,997	$310,440,873

4.6. STATE-WIDE ESTIMATES OF CDOP EFFECTIVENESS IN 2018-2019

A primary objective of this study was to estimate the overall effects of the CDOP in both the 2018 and 2019 calendar years. Each of the sections above has estimated the impacts of the various elements of the CDOP on crash frequency and cost, estimating total crash savings and their associated cost. Since the evaluation design has estimated discrete effects of each CDOP element, the overall impact of the program in 2018 and 2019 can be estimated by summing estimates from the individual elements to give the state-wide impact. Table 41 shows the resulting estimated crash savings across all CDOP elements by region and for the whole of Queensland. Savings are presented for serious casualty crashes (fatal and serious injury), minor injury crashes and total casualty crash savings, the sum of the previous categories.

Table 41 Overall crash savings associated with the CDOP in 2018 and 2019 by region, crash severity and in total.

	Serious Casualty	Minor Injury	Casualty†
2018			
Brisbane	414	539	953
Central	119	104	220
Northern	63	37	99
South Eastern	80	87	164
Southern	102	71	170
Total	**777**	**839**	**1605**
% Attributable to Mobile Speed Cameras	93%	93%	94%
2019			
Brisbane	392	514	907
Central	115	96	209
Northern	61	41	101
South Eastern	71	94	162
Southern	109	76	183
Total	**748**	**823**	**1560**
% Attributable to Mobile Speed Cameras	93%	93%	94%

Table 41 shows that the CDOP was associated with a total saving of 1,605 casualty crashes in 2018 and 1,560 in 2019. Of these, 777 and 748 respectively were serious casualty crashes and nearly 60% of the total savings derived from the Brisbane region. Comparing the relative contributions of each CDOP element to the overall savings given in Table 41 showed that between 93 and 94% of the overall program casualty crash savings came from the mobile speed camera program. This is slightly lower than in previous years reflecting the additional crash reductions associated with the RSCT program reducing the proportionate benefits of the mobile camera element in the CDOP as a whole

Using all reported crashes by region and severity in Queensland in 2018 and 2019, the crash savings associated with the CDOP in 2018 and 2019 in Queensland from Table 41 have been converted to percentage savings in total crashes across the state. Results are presented in Table 42 and show an overall reduction in casualty crashes across Queensland of 11.9% and 11.4% for serious casualty crashes in each year respectively and around 11% for all casualty crashes in both years.

Table 42 Percentage savings in total reported crashes associated with the CDOP in 2018 and 2019 by region, crash severity and in total.

	Serious Casualty	Minor Injury	Casualty†
2018			
Brisbane	21.9%	15.9%	18.1%
Central	8.1%	8.6%	8.2%
Northern	7.4%	6.2%	6.9%
South Eastern	6.8%	5.2%	5.7%
Southern	8.7%	6.5%	7.5%
Total	**11.9%**	**10.5%**	**11.1%**
2019			
Brisbane	20.9%	15.9%	17.7%
Central	7.6%	8.0%	7.7%
Northern	7.4%	7.2%	7.2%
South Eastern	6.5%	5.6%	5.9%
Southern	8.7%	6.9%	7.7%
Total	**11.4%**	**10.5%**	**10.9%**

Tables 43 and 44 give the community cost savings associated with the CDOP as a whole in 2018 and 2019 based on the WTP and HC cost basis respectively. These correspond to the overall crash savings presented in Table 41 and are derived by summing the estimated cost savings across the individual CDOP elements. Analogous to Table 41, the proportion of total cost savings resulting from the mobile speed camera element of CDOP are given in Tables 43 and 44. As shown, the mobile speed camera program was estimated to account for 91-95% of total community cost savings associated with the CDOP as a whole depending on severity and cost basis. As evident from the tables, total community cost savings associated with the CDOP in 2018 were around $747M using the WTP cost basis and around $339M using the HC cost basis. The corresponding savings for 2019 were around $720M using the WTP cost basis and around $326M using the HC cost basis.

Table 43 Overall crash cost savings associated with the CDOP in 2018 and 2019 by region, crash severity and in total: Willingness to Pay cost basis.

	Serious Casualty	Minor Injury	Casualty†
2018			
Brisbane	$ 357,191,052	$ 61,193,931	$ 410,301,066
Central	$ 102,109,255	$ 11,645,282	$ 117,293,997
Northern	$ 54,714,846	$ 4,200,086	$ 57,702,297
South Eastern	$ 67,556,488	$ 9,742,874	$ 74,434,139
Southern	$ 85,588,031	$ 7,942,211	$ 87,727,330
Total	**$ 667,159,673**	**$ 94,724,385**	**$ 747,458,828**
% Attributable to Mobile Speed Cameras	93%	93%	95%
2019			
Brisbane	$ 338,078,386	$ 58,409,809	$ 388,404,278
Central	$ 98,741,498	$ 10,805,284	$ 113,086,242
Northern	$ 53,285,057	$ 4,559,437	$ 56,631,859
South Eastern	$ 60,106,080	$ 10,542,062	$ 67,782,919
Southern	$ 91,763,688	$ 8,592,897	$ 94,553,673
Total	**$ 641,974,707**	**$ 92,909,492**	**$ 720,458,969**
% Attributable to Mobile Speed Cameras	93%	93%	95%

Table 44 Overall crash cost savings associated with the CDOP in 2018 and 2019 by region, crash severity and in total: Human Capital cost basis.

	Serious Casualty	Minor Injury	Casualty†
2018			
Brisbane	$ 176,269,781	$ 10,616,630	$ 182,568,246
Central	$ 50,422,656	$ 2,030,834	$ 54,719,410
Northern	$ 27,007,733	$ 730,026	$ 27,111,069
South Eastern	$ 33,882,478	$ 1,727,074	$ 33,915,248
Southern	$ 42,194,570	$ 1,385,620	$ 40,382,888
Total	**$ 337,135,969**	**$ 16,491,560**	**$ 338,755,659**
% Attributable to Mobile Speed Cameras	91%	93%	95%
2019			
Brisbane	$ 166,837,894	$ 10,133,609	$ 172,653,338
Central	$ 48,760,705	$ 1,885,102	$ 52,911,727
Northern	$ 26,302,148	$ 792,370	$ 26,467,828
South Eastern	$ 30,205,785	$ 1,865,726	$ 30,377,207
Southern	$ 45,242,187	$ 1,498,509	$ 43,543,394
Total	**$ 324,707,471**	**$ 16,176,691**	**$ 326,012,292**
% Attributable to Mobile Speed Cameras	91%	93%	95%

4.7. RESULTS IN THE CONTEXT OF THE GOSPA ROAD SAFETY FRAMEWORK

Having assessed the impact of the CDOP on crashes and crash costs in 2018-2019, the final objective of the project was to place the road safety benefits derived from CDOP into the broader context of the overall Queensland road safety strategy. The Queensland Government frames its road safety strategy around the GOSPA concept. GOSPA is an acronym representing the various level of detail in which a road safety strategy is formulated from the broad goal of the program to the specific actions implemented. Each letter in the GOSPA acronym is defined as follows:

GOALS: the overarching goal of the strategy, generally a statement of the broad intent of the strategy (e.g. a goal to reduce trauma resulting from road crashes)

OBJECTIVES: the specific measurable outcome the strategy is aiming for (e.g. a 30% reduction in deaths from road crashes) against which the objectives can be assessed

STRATEGY FOCUS AREAS: a statement of target areas on which the strategy will focus to achieve its goals and objectives (e.g. driver licensing, speed management, drug and alcohol use)

PROGRAMS: the specific programs that will be put in place under each strategy focus area to achieve the goals and objectives (e.g. a program of automated traffic enforcement)

ACTIONS: specific activities and deliverables that will be achieved under each program (e.g. installation of ten new speed and RLCs, 50% increase in the hours of mobile speed camera use)

Queensland's current road safety strategy is set out in the document "Safer Roads, Safer Queensland: Queensland's Road Safety Strategy 2015-2021" which can be found at https://www.tmr.qld.gov.au/Safety/Road-safety/Strategy-and-action-plans. Supporting the overall strategy document are a series of action plans. Most directly relevant to the evaluation of CDOP in 2018-2019 is the first action plan for the strategy covering the period 2015-2017 but also the subsequent action plan covering the years 2017-2019. A summary of key actions and deliverables planned under the broader strategy are detailed in the action plan, a number relating to the CDOP. A further initiative supporting the current Queensland road safety strategy and relevant to CDOP is the initiative entitled "The Queensland Speed Conversation" which aims to change community perceptions about speeding and speed enforcement. Entering a dialogue with the community and encouraging dialogue within the community about the issue is a stated objective of the initiative, although it does detail a range of specific actions to address speeding that are relevant to CDOP which are summarised in Table 4545 along with the more general action items listed in the strategy action plan.

The Queensland road safety strategy 2015-2021 and the strategies and actions relevant to the CDOP detailed in the 2015-2017 and 2017-2019 action plans are summarised in Table 46 using the GOSPA framework. Attempts have been made to capture the essence of the strategic elements rather than to quote extensively from the strategy and action plans.

Table 45 Elements of the Queensland road safety strategy relevant to the CDOP summarised under the GOSPA framework

GOSPA ELEMENT	**ELEMENTS OF QUEENSLAND ROAD SAFETY STRATEGY AND SUPPORTING ACTION PLANS RELEVANT TO CDOP**
Goals	• To reduce the burden of road trauma on communities. • Ultimately committed to a vision of zero deaths through adoption of a Safe Systems approach the cornerstones of which are safe roads and roadsides, safe speeds, safe vehicles and safe road users. These four factors determine the forces exerted during the crash, and therefore the seriousness of the outcome
Objectives	• Reduce fatalities from 303 (average 2008-2010) to 200 or fewer by 2020 • Reduce hospitalised casualties from 6,670 (average 2008-2010) to 4,669 or fewer by 2020.
Strategy Focus Areas	• Under the safe system framework: Safe Speeds and Safe Road Users pillars • Critical inputs to the safe system framework acknowledged as: o Enforcement strategies to encourage compliance and manage non-compliance with the road rules o Understanding crashes and risks through data analysis, research and evaluation
Programs	• Queensland Camera Detected Offence Program
Actions	Action Area 2 of the 2015-17 action plan. **Enforcement:** Enforcement to deter and detect, through highly visible or covert strategies, using technology and complemented by other efforts. Specific action items relevant to CDOP being: **16.** Better manage speeds on Queensland roads, including • enhance enforcement of speed limits at road works • installing ten new combined RLSCs • implementing four new PtP speed enforcement systems • research and evaluation (including an evaluation of the Camera Detected Offence Program) • marked and non-marked police vehicles **25.** Upgrade remaining wet film mobile speed cameras to digital technology to enhance reliability. CDOP related action items form the 'Queensland Speed Conversation' **9 Choose** enforcement sites based on crash history and impact of speed cameras. **10 Review** mobile speed camera sites to reassess current sites and include new sites with a history of speed crashes. **11 Ensure** appropriate speed enforcement on major roads and managed motorways. **12 Incorporate** a PtP camera system for all new motorway upgrades. **13 Investigate** the feasibility to allow PtP cameras to operate on road sections with multiple speed zones. **15 Develop** and implement a four-year plan for enforcement using best practice. The 2017-2019 action plan has relatively little directly related to the CDOP in Queensland, the only general item being Action 16 under the heading 'Encourage Safe Road Use': **16** Continue to deploy enforcement strategies on high-risk roads.

Outcomes of the CDOP evaluation presented in this report have been assessed against the strategic objectives summarised in Table 46 to assess the measured impact of CDOP in contributing to strategic road safety goals in Queensland. Since the evaluation is focused specifically on assessing the impact of the actions implemented under CDOP, the impact on the strategy as a whole has been considered in reverse order of the GOSPA framework.

4.7.1. Actions

Assessment of each of the specific action items described in the strategy and summarised in Table 46 follows based on the evidence derived from the evaluation presented in this report. For the actions included in the 2015-2017 action plan, assessment has been made of whether the action was achieved as well as the likely effectiveness of the action. For the actions listed in the Queensland Speed Conversation initiative, comment on the likely benefits of these actions based on evaluation evidence has been made. Since the single actions specific to CDOP in the 2017-2019 action plan was very general, this has not been considered in detail.

Table 46 Action Plan

Action	**Assessment of Action from Evaluation**
From the 2015-2017 action plan	
• enhance enforcement of speed limits at road works	Enhanced enforcement of speed limits at roadwork sites has been targeted specifically through the introduction of speed camera trailers that can be left operational at speed camera sites for extended periods of time. Introduction of the speed camera trailers occurred from late 2016. Evidence on the effectiveness of this automated enforcement type was produced by the evaluation. Although reductions by operation type were not statistically significant, overall trailer operations were found to significantly decrease serious casualty crashes by 40% and homogeneity studies found no evidence to suggest that operation types differed in their associated crash risk from this figure. Future evaluation of trailer speed cameras is recommended.
• installing ten new combined RLSCs	58% of combined RLSCs evaluated in this study were upgrades of previous RLC sites and 42% were new installations. Evaluation evidence suggested that RLC to RLSC upgrades are associated with a crash reduction of 18% estimated for serious casualty crashes and new RLSC installations were estimated to significantly reduce serious casualty crashes by 43%. This suggests additional well targeted installations of this technology at signalised intersections is warranted.
• implementing four new PtP speed enforcement systems	The Mt Lindesay Highway system was decommissioned in March 2019, so for this analysis two systems were only operational for the full calendar year in 2018. Since the previous analysis it has become possible to analyse the extensions to the Bruce Highway system. Evidence from the evaluation showed a statistically significant 21% reduction in casualty crashes associated with both systems supporting the further expansion of the enforcement type to other suitable road lengths.
• marked and non-marked police vehicles	Although this objective most likely does not apply only to car-based mobile speed camera operations, evidence on the relative merits of overt versus covert car-based mobile speed camera operations has been derived from the evaluation. Evaluation evidence has shown that the crash reductions per hour of enforcement achieved by covert camera operations are significantly larger than those achieved through overt operations in both urban and rural areas, supporting the continued and expanded use of covert mobile speed camera operations in Queensland.
• research and evaluation (including an evaluation of the CDOP)	This study meets this objective and has provided valuable evidence on both the effectiveness of the program in reducing road trauma in Queensland but also the relative effectiveness of different CDOP elements and, for the first time, an assessment of the relative impacts of different mobile speed camera types.

Table 31 continued…

From the Queensland Speed Conversation	
9 Choose enforcement sites based on crash history and impact of speed cameras and **10 Review** mobile speed camera sites to reassess current sites and include new sites with a history of speed crashes.	Changes to the sector-based selection of speed camera operation sites and the expansion of enforced sites is reflected in the last years considered in the evaluation. Analysis completed in the evaluation showed the mobile speed camera sites enforced are well targeted covering around 70% of minor injury crashes, 65% of serious injury crashes and around 50% of fatal crashes. One concern has been the falling coverage of fatal crash by the mobile camera program which fell below 50% in 2018 and 2019. There may be need to further consider how future site selection and enforcement under the CDOP mobile camera program might increase fatal crash coverage by the program.
12 Incorporate a PtP camera system for all new motorway upgrades.	Significant crash reductions associated with the PtP camera program were estimated in the evaluation supporting the future expansion of this CDOP element. Whether the additional systems are best placed on motorway upgrades or should be targeted to existing high-risk rural road lengths needs to be assessed through risk analysis of the new motorways compared to crash history on existing road lengths.
13 Investigate the feasibility to allow PtP cameras to operate on road sections with multiple speed zones.	As noted above, the technology has been proven effective in reducing crash rates, where installed. If the technology and supporting legislation can allow installation on roads with multiple speed limits this will provide the potential to expand the set of candidate sites on which this technology can be implemented based on demonstrated crash history and suitability of site.
11 Ensure appropriate speed enforcement on major roads and managed motorways and **15 Develop** and implement a four-year plan for enforcement using best practice.	Evidence on the relative effectiveness of each CDOP element derived through this evaluation provides the best-practice evidence basis on which the CDOP can be optimised through a strategic enforcement model based on analysis of crash types by location with enforcement effectiveness estimates overlaid.

4.7.2. Programs and strategic focus area

Evidence presented in this study confirms that the CDOP remains a key road safety program for the enforcement of speeding and red-light running at intersections. Expansion of the fixed elements of the CDOP continue albeit at a rate less than that documented in the early action plans, particularly for PtP systems and new RLSCs. Focus on the mobile camera program has continued to be strong which is appropriate given the vast majority of road trauma savings come from this CDOP element. Enhancements to the mobile speed camera program in recent years have included:

- revised methodology for site selection and enforcement scheduling;
- increased use of covert operations which analysis here has shown the be associated with higher crash reductions compared to overt operations;

- increased use of portable / LTI devices which are were found to be associated with serious casualty crash reductions in urban areas; and
- Increased hours of enforcement generally.

All these changes have led to the highest estimated crash reductions associated with CDOP in 2018 and 2019. Based on the results of this evaluation and the significant estimated road trauma savings associated with CDOP it is clear that it remains a key program under the safe system pillars of safe speeds and safe people.

4.7.3. Objective and goals

Reducing the burden of road trauma on Queensland communities is the stated goal of the Queensland road safety strategy with a long-term vision of zero serious road trauma facilitated through the adoption of the safe systems philosophy. Specific objectives set for the strategy were a 33% reduction in fatalities from 303 to 200 by 2020 and a reduction in serious injuries from 6,670 to 4,669, or 30%. Estimates from the evaluation show that CDOP was associated with a 11.9% and 11.4% reduction in serious casualty crashes in 2018 and 2019 respectively which represents a significant proportion of the objective of 30-33% overall reduction by 2020. As such, CDOP is clearly consistent with the objectives of the Queensland road safety strategy. It is also fully aligned with the safe system principles of safe speeds and safe people having a clear impact on the compliance of the Queensland driving population with the set parameters of system use in posted speed limits.

An additional point on strategic targets is worth noting here. To achieve a 30-33% reduction from a fixed target over a 6-year period requires the aggregate effects of programs to achieve greater reductions than the target due to likely travel exposure increases over the strategy period. Queensland population growth has averaged around 1.5% in recent years and it is expected that travel growth would increase proportionately. Over a 6-year strategy period, this would mean that the real crash reduction target of a road safety strategy would be around 40%. Even at this required reduction, the associated crash reductions estimated for the CDOP have achieved over a quarter of the required reduction as a single program. Furthermore, estimated associations between CDOP enforcement types and crash reductions show there is a great deal of further potential in the CDOP to contribute even more to achieving strategic goals. This is particularly so for the mobile speed camera program where further expansion in hours of enforcement and particularly covert use of cameras shows high potential to achieve greater benefits.

5. DISCUSSION

The aim of this project was to estimate the road safety benefits, both crash savings and cost savings to the community associated with the Queensland Camera Detected Offence Program (CDOP) in the calendar years 2018 and 2019. Estimates of effects were required overall, by CDOP element, by police region and by crash severity. Over the life of CDOP, two specific evaluation frameworks have been developed. The first was developed specifically to measure the road safety impacts of the mobile speed camera program in Queensland (Newstead and Cameron 2003). With the expansion in scope to consider fixed speed camera elements, a new evaluation framework was developed (Newstead 2012) which carried over elements of the original mobile speed camera evaluation framework adding additional constructs to accommodate the fixed elements of CDOP. Application of this framework to evaluate the CDOP proved successful for some years. However, significant changes to the operation of the mobile speed camera component of CDOP and a need to evaluate the individual impact of these changes meant the existing evaluation framework was inadequate. In response, a key objective of this study was to develop a new evaluation framework for CDOP that could estimate crash effects of specific sub-components of the mobile speed camera program in Queensland.

The following sections consider the success of the new framework in assessing the road safety benefits of CDOP, particularly in the calendar years 2018 and 2019. Strengths and limitations of applying the new framework are considered along with the significance of the results from applying the framework in terms of the effectiveness of CDOP and implications for future operation and expansion of the program. Requirements for future evaluation of the program are also considered.

5.1. CRASH AND COMMUNITY COST IMPACTS BY CAMERA TYPE

5.1.1. Intersection cameras

The RLC 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 107 operating RLCs 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 RLC sites to a mobile speed camera site, hence ensuring general speed compliance at RLC enforced intersections which could prevent rear-end crashes. Unfortunately, the absence of RLCs not in close proximity to a mobile speed camera site prevented explicit assessment of the potential synergistic effects of the mobile camera site on RLC crash effects. Estimated effects of RLCs from this updated evaluation were similar to those of the previous two evaluations ($RR_{casualty}$ = 0.84, 95% CI: 0.76 to 0.92 & $RR_{casualty}$ = 0.84, 95% CI: 0.77 to 0.93), but less than that of the 2012 evaluation. However, when only the targeted (right-through) crashes were examined the casualty relative risk associated with RLCs was not statistically different from the 2012 estimate at RR = 0.72 (0.63 to 0.82, $p<0.0001$).

Despite the large number of sites on which the RLC evaluation was based, even the extended crash data available for this evaluation were insufficient to allow estimation of yearly crash effects associated with the program. Consequently, only average crash effects over the post-implementation period were estimated and it was assumed that the average crash effects applied equally over each post-intervention year in estimating the 2018 and 2019 crash effects associated with the RLCs. This assumption is probably not unreasonable given RLCs 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 annual savings of 36 casualty crashes associated with RLCs per year of which 21 were serious casualty crashes, translating to an annual saving to society of around $6M (HC) or $13M (WTP).

Thirty-six RLSCs, all but fifteen being upgrades of previous RLC only sites, were considered in the analysis. Statistical analysis power for the RLC upgrades was low due to the large proportion of recently placed cameras with limited after installation periods, so the analysis results of these combined upgrades were inconclusive. However, there were sufficient operating periods to produce a statistically significant serious casualty crash risk reduction estimate for the fifteen new installations (Relative Risk = 0.57, p=0.04) and analysis by crash type revealed a staggering 76% (p = 0.01) reduction in serious casualty right-through crashes. However, minor (and hence casualty) crash analysis of this group of cameras yielded no evidence of crash reductions which was shown by crash type analysis to have arisen from statistically significant doubling of minor rear-end crashes (Relative Risk = 2.05, p=0.006). The analysis of similar installations across a wider number of sites in Victoria (Budd, Scully et al. 2011) has shown new installations of these cameras to reduce crashes across the whole of the intersection installed by around 25%. Based on the estimated effects (regardless of statistical significance,) of upgrades to 21 RLC and fifteen new installations of RLSCs, this evaluation found RLSCs to be associated eight serious casualty crash savings with an annual community cost saving of $7M (WTP).

5.1.2. Fixed mid-block speed cameras

Nine analogue fixed speed cameras were made active during the period of observed crash data (prior to July 2017). In addition, the PtP speed camera systems (also operating in spot speed mode) on a segment of the Bruce Highway between Landsborough and the Glass House mountains and on a segment of the Mt Lindesay Highway passing through Maclean, fixed speed digital cameras in the Clem 7, Legacy Way and Airport-Link tunnels and digital fixed speed cameras in four additional locations were made active. The Legacy Way cameras could not be evaluated because insufficient crashes have been recorded there in the available data period for robust evaluation post-camera installation. Further, two FSSC cameras: one digital and one analogue, were excluded from analysis due to decommissioning prior to 2018.

Despite the additional post camera installation crash data available for this evaluation of CDOP compared to previous evaluations, evaluation results for the non-tunnel fixed mid-block spot speed cameras remained inconclusive. Although the overall crash effect estimates for this camera type achieved statistical significance, difficulty in control selection, the relatively small number of installations and the types of roads on which they are sited contributed to less confidence in these results. An unpublished evaluation of similar camera types on a major Victorian freeway estimated statistically significant crash reductions of around 30% so it is likely that the same cameras in Queensland also produce road safety benefits. However definitive effect estimates in Queensland will need to wait for future evaluation with greater crash history at current sites and perhaps further installations.

In contrast to previous evaluations of CDOP, statistically robust estimates of casualty crash effects associated with PtP cameras were obtained in this study. Casualty crash reductions of 21% were estimated, similar to the effect estimated for the Hume Highway system in Victoria. Given the length of road covered by these systems, this corresponded to a saving of 17 casualty crashes, of which 2 were serious casualty crashes with total cost savings (willingness to pay) of around $5.5M per annum estimated.

Estimates of tunnel fixed speed camera effectiveness were obtained through cross sectional comparison of the Clem 7 and the Airport-Link routes with the Port of Brisbane Motorway and the Southern Cross Way. These control sections, although not tunnels, had suitable crash volume data available, were similarly located, had similar speed limits and freeway traffic characteristics. The comparability of these sites might be questionable given that they are not tunnels however the broad characteristics of the roads are very similar. Based on the comparisons made, the Clem 7 and Airport-Link fixed speed cameras were found to be associated with a substantial (84%) reduction in casualty crashes. This is likely to reflect high speed compliance in the tunnels related to 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. The total contribution of the tunnel cameras in terms of casualty crashes saved per year is 15 of which 8 were serious or fatal corresponding to economic savings (willingness to pay) of $5.1M. These are broadly comparable with a PtP system even though these cameras do not operate PtP but are possibly spaced closely enough to achieve similar coverage.

TMR has noted that for all fixed speed camera modes there is sometimes a significant delay between installation of the camera and its activation when enforcement commences. Presented results are based only on activation date because installation date data were only available for a selection of fixed digital speed cameras and consequently associated crash data in the installation to activation period was limited. As noted, there may be some unaccommodated crash effects in the period between installation and activation which may have contaminated the defined pre-activation data period. Consequently, crash effects for the fixed camera elements to which this delay applies may be slightly underestimated. This underestimation 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 RLSCs. The installation to activation period for the five digital speed camera sites analysed, and not in tunnels, ranged from only one to two months, which is less than 1% of the pre-activation observation time. Activation and signage were coincident for the tunnel digital cameras.

5.1.3. Mobile speed cameras

In estimating the crash effects associated with the mobile speed camera component of the CDOP, it was originally planned to use the estimated relationships between enforcement hours and crash effects estimated by Newstead et al (2020). Due to the large increases in hours of mobile speed camera operation hours in 2018 and 2019 potentially extrapolating the previous models beyond their range of calibration, it was decided to recalibrate the relationships between mobile speed camera hours of enforcement and crash risk for each mobile camera type and broad crash severity category considered. Encouragingly, the statistically significant relationships found in the previous analysis were again found in this update, with car based operation hours having an association with all casualty crash risk in rural and urban areas and portable / LTI camera operation hours being significantly associated with fatal and serious crash risk in urban areas. Furthermore, the relativity of effects between camera types and areas of operation was found to be the same with estimated effects in rural areas greater than urban areas per hour enforced, effects of covert operation being greater than overt operation per hour enforced and portable / LTI operations producing the weakest effects per hour enforced.

Although the estimated relationships between mobile speed camera operation hours and crash risk were generally consistent between this evaluation update and the previous evaluation estimating CDOP effects in 2017, the magnitude of the parameter estimates has changed slightly. Whilst the change is not outside of the bounds of statistical confidence on the estimates, the parameter estimates are slightly smaller meaning the estimated savings associated with the mobile speed camera program are slightly lower than that reported in the previous study for comparable years. Noting this, an important aspect of interpreting the impacts of the mobile speed camera program then is examining the estimated relative effects of the program from year to year. For this reason, the recalibrated models were used to estimate mobile camera crash effects for all years from 1999 where operations data was available (Figures 9-14). Comparing the relative crash effects by year, it was evident that the largest crash reductions associated with the mobile speed camera program were estimated for 2018 and 2019, reflecting the significant increase in mobile speed camera operational hours in these years compared to previous years. Overall casualty crash savings and associated economic savings in these years were over 22% higher than for 2017, quantifying the additional road safety benefits of the increased enforcement hours. The only exception to this trend was the estimated savings in fatal crashes which were slightly lower in 2019 compared to 2017 and 2018. As noted, this reflects the decreasing coverage of the fatal crash population by the mobile speed camera program over time (see Figure 15). If fatal crash savings are a particular focus of the CDOP, as opposed to serious and minor injury crashes, analysis demonstrates a need to consider how the program might be expanded in future year through inclusion of additional enforced sites, to better target the fatal crash population in Queensland which appears to becoming more diffuse in areas outside of those currently enforced.

Despite the estimated crash savings from the mobile speed camera component being slightly lower than previous years due to the recalibration, the savings associated with this program component are still substantial and comprise the bulk of benefits associate with the CDOP overall at between 91-95% depending on measure and crash severity. As such, the mobile speed camera program remains the most important element of CDOP in delivering the targeted strategic benefits aimed for in the Queensland road safety strategy. With total economic savings from this component being valued at between $680M and $720M in the most recent years, there is little doubt the program remains cost effective.

A further noteworthy result of the evaluation was that the increase in mobile speed camera enforcement in 2018 and 2019 was largely delivered through increased portable / LTI camera operations in urban areas. Analysis shows the size of the crash problem in urban areas is greatest and the portable / LTI cameras are well targeted to fatal and serious crash prevention which represents the greatest cost burden to society. However, analysis also demonstrated that covert car based cameras have greater crash reduction benefits per hour of enforcement than portable / LTI cameras. Hence, analysis suggests that expanding enforcement hours with covert car based cameras instead of portable / LTI cameras may have resulted in greater road safety benefits through increased fatality and serious injury reductions as well as better targeting minor injury crashes.

5.2. OVERALL CDOP IMPACTS

Reductions in total crashes across Queensland associated with CDOP in 2018 was 11.9% for serious casualty crashes and 11.1% and in 2019 was 11.4% for serious casualty crashes and 10.9% for all casualty crashes. As noted, this reflects largely the crash reductions associated with the mobile speed camera program which produces the bulk of measured crash effects (93-95%) for the CDOP. Translation of the percentage crash savings into absolute crash savings was achieved by applying the estimated percentage crash savings to the observed crashes at camera sites in 2018 and 2019. This method assumes the camera program is last in the order of factors reducing crashes, operating after other non-camera-based factors represented by crashes at the analysis control sites. 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 1,605 in 2018 of which 777 were fatal or serious injury crash savings and 1560 in 2019 of which 748 were fatal or serious injury crash savings. Conversion of the estimated crash savings into (2019 $) cost savings estimated annual savings of around $747M in 2018 and $720M in 2019 associated with the program valued using WTP estimates or $338M and $326M respectively using HC crash costs. About 89% of the total savings stem from savings in fatal and serious injury crashes which are appropriately the focus of the Queensland road safety strategy.

There was significant variation in estimated CDOP effects between regions of Queensland. By far the greatest effects for the program were estimated in the Brisbane area where many of the fixed speed camera elements are located, and the covert and portable mobile speed camera operations have the highest effectiveness. It is also where the crash density is highest consequently achieving the highest coverage of the crash population.

Overall, evaluation of the Queensland CDOP shows it aligns closely with the goals and objectives of the Queensland road safety strategy. It aligns specifically on the key safe system pillars of safe speeds and safe people, and has proven to be an effective program with the actions producing measurable reductions in road trauma hence reducing the burden of road trauma on Queensland communities. Estimated overall serious casualty crash reductions associated with the program in 2018 and 2019 of 11.4-11.9% of the total, represent a significant proportion of the total strategy target reductions of 30-33% reduction in serious casualties by 2021 reinforcing the high value of the program in the context of the broader strategy.

5.3. FUTURE CDOP EVALUATION

Periodic updating of the CDOP evaluation in future years will be able to estimate the ongoing road safety benefits of the program as well as quantify the impacts any future expansion or enforcement mix changes made to the program. As demonstrated in this evaluation update, regular recalibration of the evaluation models for the mobile speed camera program is also important to derive the most accurate associations between levels of mobile speed camera enforcement and associated crash risk changes. With the potential expansion of camera based enforcement in Queensland to include enforcement of mobile phone and seatbelt use, there will also be a need to carefully integrate this new elements into the CDOP framework in order to be able to estimate the road safety impacts of this new camera type separately form the existing CDOP elements.

A further area of research identified in the current evaluation is the need to better understand the lack of identified road safety benefits for the fixed mid-block speed camera component of CDOP in this evaluation. Evaluation of similar cameras in Victoria (Newstead et al, 2019) and NSW (ARRB, 2005) has identified significant crash savings associated with this camera type in areas local to the camera. The lack of similar benefit estimated for these cameras in Queensland is incongruent with these earlier studies and warrants further investigation including study of specific siting of these cameras, detailed localised crash patterns and general speed behaviour around the installations.

6. CONCLUSIONS

The study has estimated the road trauma effects associated with the Queensland CDOP in 2018 and 2019. It is based on an updated evaluation framework for the mobile speed camera component of the CDOP which has provided more robust estimates of associated crash effects and directly links levels of operation of the mobile speed camera program by specific camera type to observed crash outcomes.

Evaluation results show that the Queensland CDOP was associated with sustained crash reductions across Queensland in the years 2018 and 2019 with correspondingly large economic benefits to the community accruing from its operation. Both fixed and mobile elements of the program produced significant crash reductions. Crash effects associated with RLCs, tunnel cameras, PtP cameras and newly installed RLSCs estimated in the evaluation were robust. In contrast, the evidence of effectiveness for fixed spot speed cameras and for some of the more recently implemented fixed camera types (RLC to RLSC upgrades), remains weaker due to insufficient post-implementation history and small number of camera installations. Despite the expansion of the number of fixed cameras in use under the CDOP, the mobile camera program continues to produce around 93% of the measured benefits associated with CDOP, reflecting the high proportion of the crash population it covers.

Overall crash reductions in Queensland associated with CDOP were 11.9% for serious casualty crashes and 11.1% for all casualty crashes in 2018 and 11.4% for serious casualty crashes and 10.9% for all casualty crashes in 2019. It was estimated that CDOP was associated with absolute casualty crash savings of 1,605 in 2018 of which 777 were fatal or serious injury savings and 1,560 casualty crashes saved in 2019 of which 748 were fatal or serious injury crashes. Conversion of the estimated crash savings into (2019 $) cost savings estimated annual savings of around $747M in 2018 associated with the program, valued using WTP estimates or $338M using HC crash costs. Corresponding economic savings in 2019 were $720M and $326M. About 89% of the total savings stem from savings in fatal and serious injury crashes which are the focus of the Queensland road safety strategy. Due to recalibration of the models used to estimate the benefits of the mobile speed camera program, the total savings associated with CDOP are slightly lower than reported in previous evaluations. In assessing the effectiveness of the CDOP in 2018 and 2019, the relative savings in these years compare to previous years of the program are relevant. Analysis showed crash and cost savings associated with CDOP in 2018 and 2019 were the greatest of any year of the program being over 22% higher than the previous best year of 2017. This is largely attributable to the significant increase in the hours of mobile speed camera enforcement in 2018 and 2019.

The study also provided further evidence on the mechanisms of crash reduction effects associated with the mobile speed camera program. Hours of operation of both overt and covert car-based mobile speed cameras were statistically significantly associated with all casualty crashes, with no difference in association between high and low severity crashes. Relationships were estimated to differ between urban and rural areas with generally higher percentage crash reductions per hour of enforcement in rural areas compared to urban areas. Furthermore, covert car-based mobile operations were found to produce around double the crash savings per hour of enforcement compared to overt operations, although the difference between overt and covert effectiveness varied between urban and rural settings, being much more pronounced in urban areas. Associations between portable / LTI cameras and crash outcomes were only found in urban areas and only for serious casualty crashes where the level of effectiveness per hour enforced was similar to that of overt car-based operations.

The last finding is significant since the expansion in mobile speed camera enforcement in 2018 and 2019 largely comprised additional portable / LTI operations in metropolitan areas. Whilst this was associated with additional crash and cost savings from CDOP, evaluation evidence suggests expansion of covert car based mobile speed camera operations in favour of portable/ LTI operations may have produced greater crash savings than those measured. In addition, coverage of the fatal crash population by CDOP has fallen significantly in recent years meaning the estimated savings in fatal crashes associated with the program in 2018 and 2019 were proportionately less than for serious and minor injury crashes. This suggests a need to consider how the mobile speed camera component of the CDOP might be better focused or expanded to address the fatal crash population in Queensland.

7. APPENDIX

7.1. CAMERA TYPES

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

7.1.1. Red-light cameras (RLCs)

Red-light cameras have been operational in Queensland since 1991. Prior to December 2012, the majority of fixed RLCs 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 two 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 RLCs 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.

7.1.2. Fixed spot speed cameras (FSSCs)

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 one kilometre 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)

7.1.3. Combined red-light speed cameras (RLSCs)

Combined 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 RLCs 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 FSSCs. 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 RLSCs 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 RLSCs 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 primarily by the camera presence and also by the issuing of infringement notices.

7.1.4. Point-to-point (PtP) cameras

Point-to-point 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 PtP 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 PtP system and a second prominent sign installed in the direction of enforcement within approximately one kilometre of reaching the last camera in the PtP 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.

7.1.5. 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, tripod mounts, trailers and hand held devices; and signs advising motorists that they have passed a speed camera posted within ten meters of the camera; and covert deployments operating from a variety of unmarked vehicles. Whilst some operations using hand held devices are considered covert it is likely that they are not fully covert. Covert mobile speed cameras operate in both urban and rural 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 two 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.

7.2. FIXED SPEED CAMERA LOCATIONS AND OPERATIONAL DATA

Table 47 Fixed Speed Camera location and operational data

		Location ID	Speed Camera Go-Live Date	Before Period (years)	RLC to RLSC period	After Period (years)
Fixed Spot Speed Cameras						
Analogue	Bruce Hwy, Burpengary	3001	14/12/2007	16.0		12
	Main Street, Kangaroo Point	3002	14/12/2007	16.0		12
	Pacific Mwy, Tarragindi	3003	22/02/2008	16.1		10.8
	Gold Coast Hwy, Broadbeach	3004	31/08/2010	18.7		8.3
	Gold Coast Hwy, Southport	3005	29/09/2009	17.7		9.3
	Warrego Hwy, Muirlea	3007	24/12/2009	18.0		10
	Nicklin Way, Warana	3008	30/06/2010	18.5		8.5
	Sunshine Mwy, Mooloolaba	3009	24/02/2010	18.2		8.9
Digital	Pacific Mwy, Loganholme	1002	2/08/2011	19.6		7.3
	Nambour Connection Road (Northbound), Woombye	1011	10/01/2013	21.0		6.0
	Pacific Mwy, Gaven	1012	28/03/2013	21.2		5.8
Clem 7 tunnel		1003-1006	6/04/2010	18.3		8.7
Airport-Link tunnel		1007-1010	25/07/2012	20.6		6.4
Legacy Way Tunnel		1013-1016	25/06/2015	23.5		3.5
Point-to-Point (fixed spot and average speed cameras)						
	Bruce Hwy b/n Landsborough and the Glass House Mountains	4001	2/08/2011	19.6		7.3
	Bruce Hwy b/n Landsborough and Elimbah	4002	21/07/2017	25.6		1.4
	Mt Lindesay Hwy, Maclean	403	21/07/2017	25.6		1.4

Table 48 Fixed Speed Camera location and operational data…continued

	Location ID	RLC Go-Live Date	Speed Camera Go-Live Date	Before Period (years)	RLC to RLSC period	After Period (years)
Red-light speed cameras at new locations						
Beaudesert Rd, Calamvale (at i/s with Compton Rd)	2002		2/08/2011	19.6		8.4
Kingston Rd, Waterford West (at i/s with Muchow Rd)	2015		21/07/2017	25.6		2.4
Logan Road, Upper Mount Gravatt (at i/s with Newnham Rd)	2016		24/01/2017	25.1		2.9
Morayfield Road, Morayfield (at i/s with Devereaux Drive)	2017		24/01/2017	25.1		2.9
Riverway Drive & Douglas Arterial Road on Ramp	2018		22/12/2017	26.0		2.0
Sheridan Street & Upward Street	2019		24/09/2018	26.7		1.3
Moores Creek Road & High Street	2020		15/07/2019	27.5		0.5
Clontarf-Anzac Avenue Road & Boardman Road	2021		08/01/2019	27.0		1.0
Cunningham Highway & Fitzroy Street	2022		24/09/2018	26.7		1.3
Glenlyon Street & Tank Street	2023		08/01/2019	27.0		1.0
Warwick Rd & Cunningham Hwy Ramp	2024		24/09/2018	26.7		1.3
Old Logan Road & Alice Street	2026		24/09/2018	26.7		1.3
Redland Sub Arterial Road & Gateway Motorway	2027		24/09/2018	26.7		1.3
Brisbane Beenleigh Rd & Castile Crescent	2108		24/09/2018	26.7		1.3
Bruce Highway & Coombs Street	2109		24/09/2018	26.7		1.3

Table 49 Fixed Speed Camera location and operational data…continued

	Location ID	RLC Go-Live Date	Speed Camera Go-Live Date	Before Period (years)	RLC to RLSC period	After Period (years)
Red-light speed cameras at red light camera locations						
Waterworks Rd, Ashgrove (at i/s with Jubilee Tce)	2001	12/02/2002	2/08/2011	10.1	9.5	8.4
Markeri St, Clear Island Waters (Bermuda St) - Gold Coast	2003	11/04/2001	1/07/2013	9.3	12.2	6.5
Nathan St, Aitkenvale (at i/s with Bergin Rd) - Townsville	2004	26/06/2000	8/07/2013	8.5	13.0	6.5
Musgrave St, Berserker (at i/s with High St) - Rockhampton	2005	10/11/1992	31/07/2013	0.9	20.7	6.4
Mulgrave Rd, Mooroobool (at i/s with McCoombe St) - Cairns	2006	10/08/1992	11/07/2013	0.6	20.9	6.5
Bruce Hwy, Mount Pleasant (at i/s with Sams Rd) - Mackay	2007	01/11/1992	15/07/2013	0.8	20.7	6.5
James Street, South Toowoomba (at i/s with Neil Street)	2010	10/01/1992	25/07/2016	0	24.6	3.4
James Street, South Toowoomba (at i/s with Pechey Street)	2011	10/01/1992	25/07/2016	0	24.6	3.4
James Street, Rangeville (at i/s with MacKenzie Street)	2012	05/09/1997	25/07/2016	5.7	18.9	3.4
Bridge Street, Wilsonton (at i/s with McDougall Street)	2014(2 RLS)	01/06/2000	25/07/2016	8.4	16.2	3.4
Old Cleveland Road & Cavendish Road	2025	10/12/1992	08.01.2019	0.9	26.1	1.0
Gympie Road & Robinson Road West	2029	10/07/1991	15/02.2019	0	27.6	0.9
Southport-Nerang Road & Currumburra Road	2100	27/05/1998	13/04.2018	6.4	19.9	1.7
Smith Street & Kumbari Avenue	2101/2028	15/03/2000	08/01.2019	8.2	18.8	1.0
Bermuda Street & Christine Avenue	2102	01/09/2001	08/01.2019	9.7	17.4	1.0
Bruce Highway & Monkland Street	2103	10/11/1992	24/09.2018	.9	25.9	1.3
Lutwyche Road & Kedron Park Road	2104	29/08/2012	08/01.2019	20.7	6.4	1.0
Morayfield Road & Caboolture River Road	2105	10/11/1992	08/01.2019	.9	26.2	1.0
Lutwyche Road & Norman Avenue	2106	10/07/1991	08/01.2019	0	27.5	1.0
Bermuda Street & Rudd Street	2107	03/12/1997	13/04.2018	5.9	20.4	1.7

7.3. CONTROL AND TREATMENT CRASH SELECTION

Table 50 Treatment and control Selection Criteria

	Treatment Crash coded as:	Control Crash coded as:
Red-light cameras (RLCs)	Signalised Intersection ≤100m from camera Not a FSSC, AvSpeed nor RLSC treatment crash Not at a nearby or underground intersection	Signalised intersection >100m from camera, not an RLC, RLSC or FSSC treatment crash and Matched to camera site by: • Intersection configuration (T, Y or X) • SLA and if needed surrounding SLA • Speed limit • Divided or undivided road • Pre-period Crash History ranging 2.5% to 197.5% of treatment site Not a RLSC control. Uniquely identified control intersections labelled with more than one SLA, speed limit or dividedness were only assigned to one control group. Not decommissioned prior to 2018 without upgrade.
Red-light speed cameras (RLSCs)	Signalised Intersection ≤100m from camera Not a FSSC, AvSpeed nor RLC treatment crash Not at a nearby or underground intersection	Signalised intersection >100m from camera, not an RLC, RLSC or FSSC treatment crash and Matched to camera site by: • Intersection configuration (T, Y or X) • SLA and if needed surrounding SLA • Speed limit • Divided or undivided road • Pre-period Crash History ranging 2.5% to 197.5% of treatment site Not an RLC control. Uniquely identified control intersections labelled with more than one SLA, speed limit or dividedness were only assigned to one control group.
Fixed Spot Speed Cameras (FSSCs) (except those at PtP site and tunnel sites)	On same road and not a ramp ≤1000m from camera Not an RLC, AVSpeed or RLSC treatment crash	On same road and not a ramp >1000m from camera Not an RLC, RLSC or FSS treatment crash And Matched to camera site by: • SLA or <2km from camera • On same road • Speed limit, but widened if 70, 90 or 110 RLC and RLSC control crashes may be on the same length of road as the potential FSSC control crash pool. These could not be FSSC control crashes. . Not decommissioned prior to 2018.
Clem 7 and Airport-Link tunnels		Not a ramp, Not an RLC, RLSC or FSS treatment crash On Southern Cross Way or on Port of Brisbane Motorway
Average Speed cameras and FSSCs at the same site	On same road and not a ramp Between average speed cameras and 5km along road North and South of them. Not a FSSC, RLC or RLSC treatment crash.	On same road and not a ramp >100m from camera Not an RLC, RLSC or FSS treatment crash And Matched to camera site by: • On same road • A further 7.2km North/South of treatment section for 4001/2 and a further 5km for 403
Mobile Trailer Cameras	On same road and not a ramp ≤1000m from camera Brisbane, Logan Moreton, and Gold Coast. ≤4000m from camera other. Not an RLC, FSSC, AVSpeed or RLSC treatment crash	On same road and not a ramp for target and roadwork ops. In same SLA and 40 km/hr speed zone for School ops. P2P controls shared for Bruce Hwy 587904 1000m to 4000m from camera for Brisbane, Logan Moreton, and Gold Coast. (Use to 2 km for ops with high crash numbers.) 4000m to 10000m for other cameras. (Use to 8 km for ops with high crash numbers.) Not a fixed camera treatment or control crash.
Mobile Speed Cameras	Sector in which a mobile speed camera operation has taken place since the commencement of the program Not a RLC, FSS, AvSpeed or RLSC treatment site	Not a MSC, RLC, RLSC, AvSpeed or FSS treatment site and sector where mobile speed cameras have never been operated. And matched by police region and urban rural status of sector as defined by TMR protocol.

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

7.4.1. Red-light cameras (RLCs)

Table 51 Number of casualty crashes **(any severity)** at treatment and control intersections prior to red-light camera installation used in analysis

ID	*treatment*	*control*
20	6	22
25 &36	28	16
34&38	26	83
35&54&37	15	123
39	8	44
40 & 60	9	46
41	12	121
42	24	42
43, 44 and 52	38	352
45	9	129
46	19	57
47	39	37
48	14	54
49	6	70
50	4	22
53 (2001)	25	97
56	11	81
57	29	117
58	16	83
59	23	73
61	50	480
62,63,64 &65	111	135
67 & 68 (2104)	69	230
69 & 500	41	251
75	18	124
84	8	5
94	22	115

ID	*treatment*	*control*
110 & 119	40	173
113 (2107)	20	54
114 (2100)	19	48
115,117& 125	48	37
116	8	21
118	10	45
121	13	119
122	8	115
123 (2102)	15	83
124 (2003)	14	66
126	13	29
155 (2012)	9	10
157/158 (2014)	12	30
156 (2013)	10	80
206 & 209	20	202
207	13	30
208 (2004)	8	27
210	10	84
255	5	11
355	32	174
407	15	51
408 &411	19	44
409	3	92
451,452,453&454	37	104
460 and 462	15	39
461 & 463	28	82

7.4.2. Fixed spot (FSSCs), point-to-point (PtP) and red-light speed cameras (RLSCs)

Table 52 Number of casualty crashes **(any severity)** at treatment and control intersections prior to red-light speed camera installation

ID	*treatment*	*control*
2001 (from 53)	33	82
2002	97	175
2003 (from 124)	86	155
2004 (from 208)	20	60
2005 (from 252)	32	321
2006 (from 304)	92	349
2007 (from 353)	72	49
2010/2011 (from 153/154)	90	170
2012 (from 155)	9	23
2014 (from 157/158)	18	82
2015	51	146
2016	31	365
2017/2105	96	130
2018	20	80
2019	41	567
2020	46	151
2021	55	209
2022	17	58
2023	39	117
2024	16	53
2025 (from 19)	84	305
2026	35	76
2027	100	140
2029 (from 14)	159	425
2100 (from 114)	73	199
2101 (from 110/119)	71	598
2102 (from 123)	71	237
2103 (from 410)	47	41
2104 (from 510)	32	69
2106 (from 13)	40	113
2107 (from 113)	40	287
2108	39	89
2109	11	198

Table 53 Frequency of treatment and control crashes **(by severity)** prior to fixed spot speed camera installation

	Casualty Crash		**Serious Injury Crash**		**Minor Injury Crash**	
ID	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*
Fixed speed						
3001	46	150	13	48	234	102
3002	289	348	73	102	238	246
3003	173	163	40	55	25	108
3004	336	714	102	238	127	476
3005	328	279	90	86	68	193
3007	43	25	18	11		14
3008	175	160	48	49	88	111
3009	101	51	33	26	34	25
					76	
1002	145	286	57	101	234	185
1011	69	54	35	16	238	38
1012	121	201	45	89	25	112
Point-to-Point						
4001	608	598	272	220	336	378
403	824	252	351	106	473	146

7.4.3. Trailer cameras

Table 54 Number of casualty crashes (any severity) at treatment and control intersections not during roadworks and school trailer camera operations

Type	ID	*treatment*	*control*
Roadworks	185: 903,906,907,910 &911	105	155
Roadworks	185: 904, 909 & 912	150	81
Roadworks	185905	162	173
Roadworks	385906	170	223
Roadworks	385908	275	152
Roadworks	385916	84	77
Roadworks	385: 919&920	461	574
Roadworks	385: 921&922	164	438
School	186901	253	11
School	286901	110	11
School	286902	139	6
School	286903	40	17
School	286904	67	10
School	386: 901& 902	401	23
School	386903	42	15
School	386904	68	26
School	386905	54	29
School	386906	54	2
School	386907	248	72
School	386908	20	30
School	486901	1002	163
School	486902	111	8
School	486903	33	21
School	486904	111	98
School	486905	34	16
School	586901	149	12
School	586902	222	37
School	586903	11	12
School	586904	90	28

Table 55 Number of casualty crashes **(any severity)** at treatment and control intersections *not during* targeted trailer camera operations

Type	ID	*treatment*	*control*
Targeted	Warrego Hwy	1370	516
Targeted	187901	50	564
Targeted	187902	75	579
Targeted	187903	89	96
Targeted	187904	328	220
Targeted	187905	78	59
Targeted	287901	64	71
Targeted	287902	38	25
Targeted	287903	110	99
Targeted	287904	58	280
Targeted	287905	48	170
Targeted	287906	139	370
Targeted	287907	41	152
Targeted	287: 909 & 910	121	341
Targeted	387: 901,908,909,917	275	152
Targeted	387902	164	438
Targeted	387903	122	370
Targeted	387904	137	321
Targeted	387905	42	50
Targeted	387906	170	223
Targeted	387907 & 387918	206	176
Targeted	387916	84	77
Targeted	387: 919&920	467	574
Targeted	387923	122	285
Targeted	487902	183	336
Targeted	487903	1002	394
Targeted	487905	194	111
Targeted	487910	118	99
Targeted	487911	71	348
Targeted	487914	599	168
Targeted	487915	36	34
Targeted	587904	91	98
Targeted	Pacific Hwy, Oxenford	608	343
Targeted	Sunshine Motorway	750	253

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