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EVALUATION OF THE QUEENSLAND CAMERA DETECTED OFFENCE PROGRAM (CDOP): 2009-2012

by

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Abstract:
The Queensland Camera Detected Offence Program (CDOP) covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras, and has recently been expanded to include point to point cameras and combined speed and red light cameras. Covert operation of the mobile speed cameras commenced in April 2010 and is currently confined to up to 30% of deployments in urban areas.

The broad objective of this document is to measure the 2009-2012 performance of the CDOP in terms of its effect on crash frequency, severity and social costs to the community in Queensland. The evaluation framework (Newstead and Cameron, 2012) used incorporated the impacts of different camera types, and articulated the use of available speed monitoring data as an intermediate measure of CDOP effectiveness.

It was estimated that the CDOP was associated with an overall reduction in all police reported crashes of between 23% and 26% over 2009-2012 with reductions being similar for different crash severity levels. This represents an annual saving of around 6000 crashes of all severities and 1300-1400 fatal and serious injury crashes per year, translating to annual savings to the community of around $650M (Human Capital costs) and $1.1b (Willingness to Pay values). Over 80% of the total savings stem from savings in fatal and serious injury crashes. Over 96% of the savings associated with the program derive from the mobile speed camera program, which is the CDOP technology that covers by far the largest proportion of the crash population in Queensland.

Casualty crash risk reductions estimated from the speed survey data from 2009 and 2010 for all regions across all speed zones were similar in trend to those estimated through the evaluation of CDOP based on actual crash data. Similarities observed between regional speed survey and mobile speed program crash risks were sufficient to suggest evidence of a causal path between operation of the CDOP, observed reductions in travel speed across Queensland and the measures of crash reductions associated with CDOP.

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, evaluation framework design, covert operations analysis and report editing/writing
Max Cameron:	Speed survey evaluation framework design
Laurie Budd:	Crash data analysis, speed survey data analysis and report preparation

Ethics Statement

Ethics approval was not required for this project.

Contents

GLOSSARY OF ABBREVIATIONS AND TERMS

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

EXECUTIVE SUMMARY

The Queensland Camera Detected Offence Program (CDOP) covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras, and has recently been expanded to include point to point cameras and combined speed and red light cameras. Covert operation of the mobile speed cameras commenced in April 2010 and is currently confined to up to 30% of deployments in urban areas.

The broad objective of this study was to measure the 2009-2012 performance of the CDOP in terms of its effect on crash frequency, severity and social costs to the community in Queensland. The evaluation framework (Newstead and Cameron, 2012) used incorporated the impacts of different camera types, and articulated the use of available speed monitoring data as an intermediate measure of CDOP effectiveness. Where possible, the effects of each camera type in operation before 2013 were estimated in terms of crash frequency and severity. From this, the effects of the CDOP on crash frequency and costs were able to be estimated.

Police reported data for serious and fatal injury crashes were available up to December 2012, however minor injury crash data (and hence casualty crash data) were limited to December 2011 and non-injury crash data (and hence all severity crash data) were limited to December 2010.

Statistically reliable crash reduction estimates were obtained for red light cameras and mobile cameras only. To estimate red light camera savings, the crash reduction estimates from the trial run (Newstead and Cameron, 2012) were used on 2009 to 2012 crash data disaggregated by crash severity and the 2013 redistributed Police regions.

This evaluation produced crash reduction estimates for the combined effect of all other fixed speed cameras, but they were not statistically reliable. The quasi-experimental regression analysis was limited by the short post-activation periods of the seven digital camera sites with cameras made active prior to 2013. Of the 9 analogue fixed camera sites analysed, two were excluded due to contamination and two other sites had post activation periods of only six and ten months respectively for crashes of all severities.

Time series Poisson regression analysis of mobile speed camera data produced reliable crash reduction estimates for the combined region effect in yearly time intervals. However, with each further disaggregation (by shorter intervals, or by regions), confidence intervals grew wider and evidence of significance, poorer. As a result speed survey data was compared with the mobile camera crash data using yearly intervals.

It was estimated that the CDOP was associated with an overall reduction in all police reported crashes of between 23% and 26% over 2009-2012 with reductions being similar for different crash severity levels. This represents an annual saving of around 6000 crashes of all severities and 1300-1400 fatal and serious injury crashes per year, translating to annual savings to the community of around $650M (Human Capital costs) and $1.1b (Willingness to Pay values). Over 80% of the total savings stem from savings in fatal and serious injury crashes. Over 96% of the savings associated with the program derive from the mobile speed camera program, which is the CDOP technology that covers by far the largest proportion of the crash population in Queensland.

Regionally, the greatest crash savings were from Brisbane, with almost half of all severity crash savings and almost a third of serious casualty crash savings. Over three quarters of

serious casualty crash savings were made in the most populous regions: Brisbane, Central and South Eastern.

Casualty crash risk reductions estimated from the speed survey data from 2009 and 2010 for all regions across all speed zones were similar in trend to those estimated through the evaluation of CDOP based on actual crash data. Similarities observed between regional speed survey and mobile speed program crash risks were sufficient to suggest evidence of a causal path between operation of the CDOP observed reductions in travel speed across Queensland and the measures of crash reductions associated with CDOP.

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

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

2. Enhancements to data systems to support the future application of the framework

3. Undertake regular and systematic speed / red light compliance monitoring at fixed camera sites before and after camera installation

4. Undertake future comparisons of the recommended general speed monitoring measures with crash outcomes

1. BACKGROUND AND AIMS

The Queensland Camera Detected Offence Program (CDOP) is jointly managed by the Department of Transport and Main Roads (TMR) and the Queensland Police Service (QPS) and covers management and operation of all modes of camera based traffic enforcement in Queensland. Currently this includes the mobile speed camera program, the red light camera program and fixed speed cameras and in recent years has been expanded to include point to point cameras and combined speed and red light cameras at intersections. Covert operation of the mobile speed cameras commenced in April 2010 and is currently confined to up to 30% of deployments in urban areas.

The broad objective of this project was to apply the developed evaluation framework (Newstead & Cameron, 2012) to crash data and speed survey data to estimate the effects of the CDOP during 2009-2012. Development of the evaluation framework for the assessment of the overall impact of the Queensland CDOP on road trauma outcomes in Queensland considered the likely mechanisms and scope of influence for each camera type in relation to the most appropriate evaluation designs and statistical analysis techniques identified in literature. The evaluation framework developed included a methodology to estimate the effectiveness of each CDOP element on the key outcomes, the three key outcomes being:

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

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

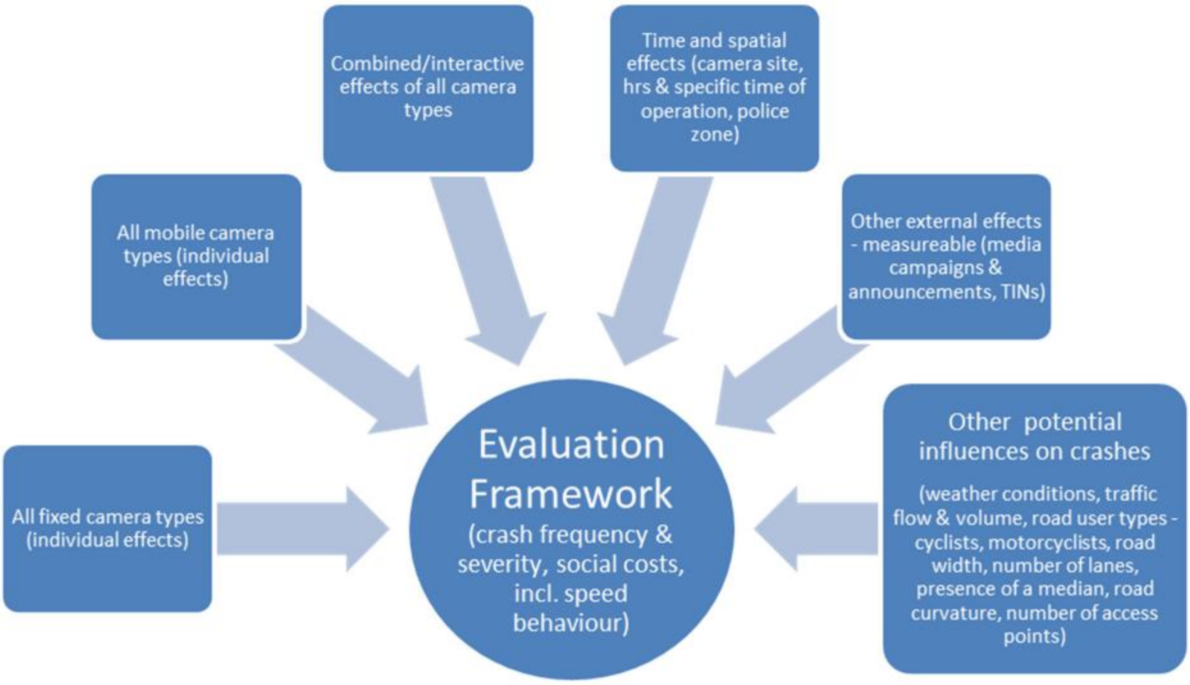


Figure 1

Elements included in the CDOP evaluation framework design

Consistent with the evaluation framework specifications, application of the framework in this study estimated crash outcomes associated with the CDOP both in aggregate and by crash severity level. Percentage crash savings were converted to absolute crash savings and subsequently into social cost savings per annum using both Willingness to Pay (WTP) and Human Capital (HC) crash costs provided by Queensland TMR. Furthermore, estimates of the effectiveness of individual program elements were brought together to arrive at aggregate effectiveness estimates both within specific police regions as well as across the whole of Queensland. This involved consideration of the crash population covered by each mode of enforcement. Finally, trends in speed monitoring data were used to provide a more causal link between camera operation and estimated crash outcomes.

2. DATA

2.1. CRASH DATA

The Data Analysis Unit within TMR supplied MUARC with crash data covering the period from January 1992 to December 2013 inclusive. Property damage only (PDO) crashes were reported to the end of 2010. Minor injury crashes were reported to the end of 2011. Serious and fatal injury crashes were reported to the end of 2012. The data covered all crashes reported to police in Queensland with each unit record in the data representing a unique crash. A total of 424,882 crash records were contained in the data. The data included the following fields pertaining to the crash:

- Unique identification number
- Date of occurrence
- Severity (fatal, hospitalisation, medically treated injury, minor injury, no injury [PDO])
- Police region
- Statistical Local Area
- Speed limit
- Street on
- Intersecting street/s
- Traffic control
- DCA code (Definition for Classifying Accidents)
- Roadway feature (intersection geometry, bridge, etc.)
- Divided/undivided carriageway
- Number of lanes
- Speed related crash indicator
- Number of traffic units involved in crash
- Distance from 5 closest mobile speed camera sites and the unique site identifiers for the 5 closest mobile speed camera sites
- Distance from the 3 closest fixed spot speed camera sites and the unique site identifiers for the 3 closest fixed spot speed camera sites
- Distance from the closest combined speed and red light camera site and the unique site identifier for the closest combined speed and red light camera site

- Distance from the closest average speed camera site and the unique site identifier for the closest average speed camera site
- GDA latitude and longitude for the crash
- Willingness to Pay 2012 Crash cost
- Human Capital 2012 Crash cost

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

2.2. SPEED SURVEY DATA

TMR conducts regular six-monthly surveys of vehicle speeds at 163 sites commencing May 2009. Two surveys were conducted each year in 2009 and 2010 (in May and November). The May 2011 survey did not proceed because of substantial floods in Queensland during the period.

Analysis used speed data only from sites (by direction) which were surveyed at each of the four survey periods over May 2009 to November 2010; all other survey data was excluded. Only in the case of the urban 50km/h speed limit sites have the same 20 sites been surveyed in each of the four surveys. In the other six road types, sites have been lost and replaced for various reasons, restricting the number of sites used to make time series comparisons across all four surveys.

Locations of Queensland Speed Surveys are listed in the appendix (Section 8.5). Counts of survey sites and sites surveyed by police region and speed limit follow in Table 1 and Table 2. During a survey period individual sites were usually surveyed once in each direction.

Table 1 Number of speed survey sites used across all surveys by speed limit and Police region

	Speed Limit				
	50	**60**	**80**	**100**	**All**
Brisbane	4	7	8	0	19
Central	6	16	19	14	55
Northern	0	4	5	6	15
Southern	6	12	9	19	46
South Eastern	4	6	11	7	28
All Regions	20	45	52	46	163

Table 2 Number of sites surveyed by survey period, speed limit and Police region

	Speed Limit									
	50	60	80	100	All	50	60	80	100	All
	Survey 1: May 2009					*Survey 3: May 2010*				
Brisbane	4	6	6	0	16	4	6	5	0	15
Central	6	15	11	13	45	6	11	13	13	43
Northern	0	2	4	5	11	0	4	2	3	9
Southern	6	11	9	17	43	6	11	9	17	43
South Eastern	4	4	4	6	18	4	3	0	3	10
All Regions	20	38	34	41	133	20	35	29	36	120
	Survey 2: Nov 2009					*Survey 4: Nov 2010*				
Brisbane	4	6	5	0	15	4	6	7	0	17
Central	6	13	10	12	41	6	12	15	13	46
Northern	0	2	3	2	7	0	3	2	4	9
Southern	6	10	9	16	41	6	11	9	17	43
South Eastern	4	3	0	5	12	4	5	7	5	21
All Regions	20	34	27	35	116	20	37	40	39	136

In addition, surveys from U060-15A, U060-15G, R060-02A and R060-02G were excluded from the 60km/h analysis because of apparently anomalous data. U060-15 and R060-02 are located in the Brisbane and South Eastern Police regions respectively. These sites were found to have a very unusual speed distribution in November 2010 compared with the earlier surveys. For U060-15 the mean speed was 50.9km/h during November 2010 compared with 58-59km/h during the earlier surveys. For R060-02, the November 2010 mean speed was 8-11km/h higher than that of the other surveys. This suggested that something unusual other than CDOP enforcement activities had influenced speeds in November 2010. Furthermore, speed bins greater than 79km/h were excluded from the 50km/h Brisbane November surveys of U050-06E because they exercised undue leverage on risk calculations (these were intended to represent risk associated with speed behaviour on average across the network rather than skewed to any single site).

The frequencies of measured vehicles within each speed range bin were provided for each site and direction. Measured speeds were provided in the form of 5 km/h speed bins with the following exceptions.

- In 50 and 60km/h speed zones the first two bin widths were 0-30 and 30-40
- In 80km/h speed zones the first three bin widths were 0-40, 40-60 and 60-70
- In 100km/h speed zones the first five bin widths were 0-50, 50-60, 60-70, 70-80 and 80-90
- In 50 and 60km/h speed zones the last three bin widths were 80-90, 90-120 and 120+
- In 80km/h speed zones the last two bin widths were 110-140 and 140+
- In 100km/h speed zones the last two bin widths were 120-150 and 150+

2.3. CAMERA DATA

Data for 136 red light camera sites were provided. All were made active prior to 2008. In October 2010, 40 analogue red light cameras were decommissioned and 10 sites were converted to digital. The last of the analogue red light cameras were decommissioned in

June 2012. It was assumed that all posts and camera housing remained in place so that effective deterrence remained plausible over the 2008 to 2012 period. The red light camera data were used to exclude crash sites from being allocated to other treatments or from being control crash sites. Red light camera crashes from 2008 to 2012 were summarised by police region and crash severity so that crash reduction estimates from the previous study (Newstead & Cameron, 2012) could be applied to the observed crash rates at red light camera sites in each of the 2013 police regions. No updated evaluation of the crash reduction effects of red light camera crashes was undertaken in this evaluation.

A summary of fixed camera sites available for evaluation is presented in Table 3.

- There were 9 analogue fixed spot speed cameras (1 per site) made active prior to 2012. Two of these were decommissioned during the observation period. However, on the assumption that the hosting structure and signage have remained in place, they were assumed to continue to remain an effective deterrent and as such the post-activation observation periods for these two cameras were considered to continue to the end of 2012.
- There were 21 fixed spot digital speed cameras (7 sites) that were activated prior to December 2012:
    - 2, one at each end, on the PtP section of the Bruce Highway (these still operate as fixed spot speed cameras when the PtP system is down)
    - 6 in the Airport-Link Tunnel (at ten locations),
    - 8 in the Clem 7 tunnel (at 4 locations),
    - 4 at location number 1002 (with 1 in each of 4 lanes) and
    - 1 at location number 1001 (Nudgee).
- As of December 2012, there were only two combined digital red light speed cameras operating in Queensland: one at each of the location numbers 2001 and 2002.
- In addition there were an average speed camera system operating on a segment of the Bruce Highway between Landsborough and the Glass House Mountains. This system began operation 5 months after the fixed spot speed cameras operated at each end of the average speed camera system on this road section went live.

From Table 3 it may be seen that the post-activation observation periods are short for fixed spot digital speed cameras, with all but the Clem 7 tunnel camera data showing:

- less than 2 years of serious injury data
- less than 1 year of minor injury data
- no property damage only data

Post activation observation data for analogue fixed spot speed cameras ranges from 1.5 to 5.0 years for casualty crash data and 0.5 to 3.0 years for property damage only data.

The pre-activation period for all cameras exceeded the suggested three year minimum period for minimisation of regression to the mean effects by providing a base level of accuracy 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 limited post-activation period of crash data has dictated that there is insufficient power to analyse digital fixed spot speed and combined speed and red light camera effects alone, or fixed cameras generally disaggregated by camera type. To maximise statistical power, analysis for all fixed cameras combined (excluding red light cameras) was undertaken in this study.

Table 3 Fixed Speed camera locations and operational data

		ID	Go Live date	Before Period (years)	After Period (years) all /pdo	casualty/minor injury	Serious Casualty
Fixed Spot Speed Cameras							
Analogue	Bruce Hwy, Burpengary	3001	14/12/2007	16.0	3.05	4.05	5.05
	Main Street, Kangaroo Point	3002	14/12/2007	16.0	3.05	4.05	5.05
	Pacific Mwy, Tarragindi	3003	22/02/2008	16.1	2.86	3.85	4.86
	Gold Coast Hwy, Broadbeach	3004	31/08/2009	17.7	1.33	2.33	3.33
	Gold Coast Hwy, Southport	3005	28/09/2009	17.7	1.26	2.26	3.26
	Warrego Hwy, Redwood	3006	31/08/2009	17.7	1.33	2.33	3.33
	Warrego Hwy, Muirlea	3007	24/12/2009	18.0	1.02	2.02	3.02
	Nicklin Way, Warana	3008	30/06/2010	18.5	0.50	1.50	2.51
	Sunshine Mwy, Mooloolaba	3009	24/02/2010	18.2	0.85	1.85	2.85
Digital	Gateway Mwy, Nudgee	1001	2/08/2011	19.6		0.41	1.42
	Pacific Mwy, Loganholme	1002	2/08/2011	19.6		0.41	1.42
	Nambour Connection Road (Northbound), Woombye	1011	10/01/2013	21.0			
	Pacific Mwy, Gaven	1012	28/03/2013	21.2			
Clem 7 tunnel		1003-1006	1/04/2010	18.2	0.75	1.75	2.75
Airport-Link tunnel		1007-1010	25/07/2012	20.6			0.44
Point to Point (fixed spot and average speed cameras) Bruce Highway between Landsborough and the Glass House Mountains		4001	2/08/2011	19.6		0.41	1.42
Red Light Speed Cameras							
	Waterworks Rd, Ashgrove (at i/s with Jubilee Tce)	2001	2/08/2011	19.6		0.41	1.42
	Beaudesert Rd, Calamvale (at i/s with Compton Rd)	2002	2/08/2011	19.6		0.41	1.42
	Markeri St, Clear Island Waters (at i/s with Bermuda St) - Gold Coast	2003	1/07/2013	21.5			
	Nathan St, Aitkenvale (at i/s with Bergin Rd) - Townsville	2004	8/07/2013	21.5			
	Musgrave St, Berserker (at i/s with High St) - Rockhampton	2005	31/07/2013	21.6			
	Mulgrave Rd, Mooroobool (at i/s with McCoombe St) - Cairns	2006	11/07/2013	21.5			
	Bruce Hwy, Mount Pleasant (at i/s with Sams Rd) - Mackay	2007	15/07/2013	21.5			

A summary of the events affecting enforcement during the observation period for each of the fixed camera used in the analysis is as follows:

- 1001
    - Offline from May 9, 2012 to June 27, 2012, however issues continued which were not resolved until December 11,2012
- 1003-1006 (Clem 7)
    - May 5, 2011 Fines began being issued for exceeding variable speed limits other than 80 km/h
    - From Jun 20, 2011 enforcement returned to just the 80 km/h speed limit
    - Site CD Offline from August 2011 until road-works completed
    - Site CA removed from August 2011 to August 3, 2012
    - Sites CB and CC Offline from March 12 to March 13, 2012
    - Site CD Offline from March 12 to March 26, 2012
    - Intermittent function for CC and CD over May 1 to May 10, 2012
    - Site CC Offline from November 7 to November 14, 2012
- 2001
    - Offline from May 9 to June 27, 2012, however issues continued which were not resolved until December 11, 2012
- 3004
    - Offline since Jan 6, 2011 (due to light rail road works)
- 3006
    - Offline from February 22 to June 17, 2011 (road works)
- 4001
    - Spot speed cameras operated from Aug 2, 2011 to Feb 21,2012
    - Average speed component commenced December 21, 2011
    - Average speed cameras offline from February 21 to May 22, 2012
    - Average speed not enforced from August 14, 2012 to March 23, 2013 (tested for one day September 1, 2012)

Average speed limits were only enforced for 4 months of the post activation observation period for the point to point speed cameras: only 1 of these months was available for minor injuries data and none for property damage only data. The first 5 months of post observation period at the point to point road segment involved spot speed cameras alone.

2.4. CRASH COSTS

Human Capital and Willingness to Pay crash costs for 2012 were provided by TMR with the crash data (Table 4). The post-activation camera crash distribution by severity and police region was used to weight fatal, hospital, medically treated, minor injury and no injury (PDO) costs to produce a serious injury (fatal + hospital), minor injury (minor injury + medical treatment), all crash and casualty crash (fatal + hospital + minor injury + medical treatment) unit costs (Table 5 and Table 6). For mobile cameras the crash population was further disaggregated by crash year (Table 41) for the years 2008 to 2012.

Table 4 2012 Willingness to Pay (WTP) and Human Crash (HC) Unit Costs by severity

	WTP	HC
Property Damage Only	$11,920	$11,647
Minor Injury	$37,944	$17,208
Medical Treatment	$106,907	$17,208
Hospitalisation	$365,761	$311,379
Fatal	$8,147,446	$3,125,491

Table 5 2012 WTP Crash costs by severity and police region according to the distribution of Fixed camera crashes

	Fatal and Hospitalisation	Minor Injury	PDO	All Crashes	Casualty Crashes
Brisbane	$365,761	$88,930	$11,920	$176,263	$223,808
Central	$1,392,193	$78,063	$11,920	$565,469	$810,055
South Eastern	$365,761	$72,426	$11,920	$120,061	$154,841
Southern	$1,070,679	$85,019	$11,920	$219,351	$424,301

Table 6 2012 HC Crash costs by severity and police region according to the distribution of Fixed camera crashes

	Fatal and Hospitalisation	Minor Injury	PDO	All Crashes	Casualty Crashes
Brisbane	$311,379	$17,208	$11,647	$127,126	$160,535
Central	$682,570	$17,208	$11,647	$272,547	$387,826
South Eastern	$311,379	$17,208	$11,647	$78,392	$99,858
Southern	$566,300	$17,208	$11,647	$109,517	$206,216

Average fatal and hospitalisation crash costs in Table 5 and 6 vary a relatively large amount between police regions. This is due to the different mix of fatal and hospitalisation crashes in each region with Central and Southern regions having a higher rate of fatal crashes per hospitalisation crash.

3. EVALUATION FRAMEWORK AND ANALYSIS METHODS

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

This evaluation did not undertake analysis of the localised time based effects of mobile speed cameras since no time based effects were detected in the test run. Nor does this evaluation re-estimate the crash effects of Red Light cameras (RLC) since the test run since the test run produced robust estimates of the average crash effects of RLCs and, even with the additional crash data available for this evaluation, there was not sufficient data to obtain crash effects by time. Estimates of crash effects associated with RLC placement were taken straight from the test run and applied to the observed crash data over the period 2009-2012 to estimate absolute crash savings and crash cost savings.

Newstead & Cameron (2012) proposed testing the use of negative binomial error distributions in the statistical analysis of CDOP crash count data. Ultimately (for both this and the trial analysis), Poisson distributions were found to adequately represent the variability in the data reflecting the short after-activation fixed camera crash periods and low crash counts when mobile camera crash data were disaggregated by police region, treatment group and crash severity. In the fixed camera analyses, where possible, modelling with both negative binomial and Poisson distributions was compared in this analysis to validate the distribution chosen.

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

Regression analysis models were applied to crashes by severity: serious casualty, minor injury, no injury (PDO), all crashes in aggregate and all casualty crashes in aggregate (i.e. all crashes excluding non-injury crashes). It should be noted that estimated savings associated with the aggregate categories of *all severity* and *casualty* crashes were determined from the respective regression model crash reduction estimates and not from the summation of savings associated with fatal, serious, minor injury and no-injury crashes. This provides more robust statistical assessment of camera effects on the aggregate crash groupings. In contrast, state-wide savings estimates presented in the results sections were calculated by summation of regional savings estimates.

3.1. EVALUATION OF FIXED CDOP ELEMENTS

3.1.1. Treatment and Control selection

A table summarising the treatment and control selection for fixed CDOP elements (fixed spot speed cameras (FSS), speed and red light intersection cameras (RLS), point-to-point cameras (PtP) is presented in Section 8.2 of the Appendix.

Both in this analysis and in the trial analysis the proposed matching of the control sites for RLS, PtP and fixed spot speed camera sites by number of lanes, crash history or traffic volume was not attempted. Crash history and traffic volume data, again could not practically be identified for many RLS cameras 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 sites. Similarly, intersection identifier was provided where available but was not sufficiently complete to allow broad control matching. By matching on other road geometry characteristics, speed limits (Table 7), intersection control type (signalisation), road dividedness and generally by the locality (SLA and similar surrounding SLAs), it was deemed that a sufficiently similar and sizeable set of control crash sites were identified that were likely to broadly represent traffic volume and crash history. To extend the numbers of control sites to enhance statistical power, control crashes for red light speed cameras were matched by SLA and not the distance from the camera.

Control sites for fixed spot cameras were chosen from the same road, limited to 2km outside the hypothesised zone if 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 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 cameras in 70, 90 and 110km/h speed zones 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:

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

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

Table 7 Speed limits (km/h) associated with Fixed Speed Cameras

Red Light Speed ID	Speed limit	**Fixed Spot ID**	Speed Limit	**Tunnel ID**	Speed Limit
2001	60	1001	90	1003-1006	80
2002	80	1002	100	1007-1010	80
2003	60	3001	100		
2004	60	3002	60		
2005	60	3003	100		
2006	60	3004	70	**Point to Point**	
2007	80	3005	60	4001	110
		3006	90		
		3007	100		
		3008	70		
		3009	100		

Direction of travel was not available as a variable in the data (since vehicles in a crash can have multiple directions of travel) so control crashes for the point to point average speed 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 8 Segment Distances and GDA of Point to Point camera and control segments

Position	**Latitude**	**Longitude**	**Distance (km)**
Northern end of Control segment	26°42' S	153°00' E	
Northern End of camera Halo	26°45' S	153°03' E	7.2
Northern Camera	26°47' S	153°03' E	5
Southern Camera	26°55' S	152°60' E	14.8
Southern End of camera Halo	26°58' S	152°59' E	5
Southern end of Control segment	27°01' S	152°59' E	7.2

The Airport-Link and Clem 7 tunnels had no period without cameras since the cameras were installed before the roads were opened, and no suitable feeder roads to use as controls, so the Southern Cross Way and Port of Brisbane Motorway were chosen as control segments. The crash counts were then analysed with a volume and distance offset (an offset being a constant term included in the model) to give a comparison of relative crash rates per distance travelled across the treatment and control sections. The Inner City Bypass was not chosen as no suitable traffic volume data were available. Crash counts, volume data, volume location and distances measured using Google Maps are tabled below.

Table 9 Tunnel cameras, treatment and control road lengths and traffic volume

Road	**Position of Volume Data**	**AADT**	**Distance (km)**
Clem 7		122,730	2.8
Airport-Link	Airport end of link	34,158	5.1
Southern Cross Wy		56,530	7.2
Port of Brisbane Mwy		19,458	7.1

Table 10 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**	**Property damage only**
Clem 7	1	1	0
Airport-Link	0	n/a	n/a
Southern Cross Way	5	3	2
Port of Brisbane Mwy	6	10	5

3.1.2. Analysis period

The analysis periods were defined by the 'go live' dates for each camera. For consistency, dates for the installation of signage were not used in the analysis because they were only available for the PtP cameras, 2 digital fixed speed cameras and the 2 RLS cameras which were analysed. In addition, the crash data were too few to attempt a two point after period effect (i.e. measuring the crash effects after camera placement but before activation and then after activation).

3.1.3. Analysis by Crash Type

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

3.1.4. Crash History

Every attempt was made to balance control site proximity to the camera site and the size of the control crash group. However, in order to preserve the integrity of the crash location, so that traffic volume and local events are controlled, the control crash population did not always meet the preferred size. Newstead & Cameron (2012) suggested that the pre-activation control crash history should be in the range of treatment crashes ± 2√(treatment crashes). From Table 11 one can see that although this condition has not been universally met, control site crash counts are generally of a similar magnitude to those of the treatment sites.

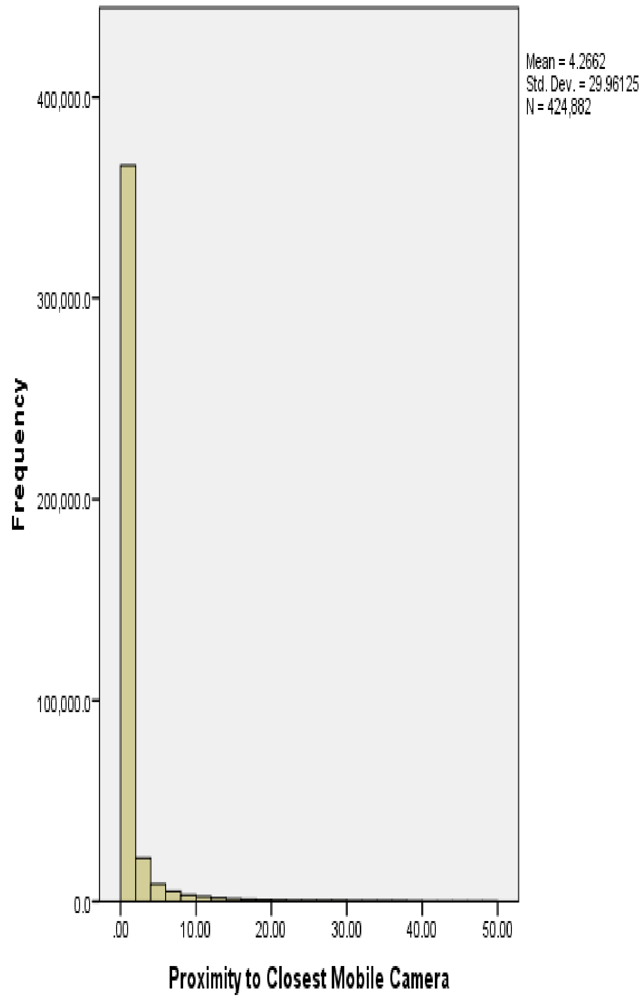
3.1.5. Crash savings for Fixed Camera program

The average annual crash counts at fixed camera treatment sites, after the camera went live, were first calculated by camera type, police region and severity. Because all RLC were live by sometime in 2007, annual crashes over 2008-2012 within 100 metres of a red light camera were used as the base 'after RLC activation' period. Absolute annual crash savings for each crash severity, police region and fixed speed camera type were determined from the application of crash reduction percentages (for each crash severity) determined from regression analysis to these average annual crash counts. For RLC, percentage reductions for all severity, serious casualty, minor injury and property damage only crashes were obtained from the regression analysis in the trial run (Newstead & Cameron, 2012). The RLC casualty crash reduction was approximated by the weighted average of the minor and serious casualty crash reductions; using the after period fixed camera crash distribution.

Average annual absolute crash reductions were converted into community cost savings according to the process illustrated in the CDOP framework (Newstead & Cameron, 2012) by multiplying the estimated absolute crash savings at the crash severity level being considered by the per unit cost of each crash (Table 5 and Table 6) to derive the community cost savings related to the crash reductions.

Table 11 Before Period Crash history within camera site hypothesised halos of influence

	all crash		Casualty Crash		Serious Injury Crash		Minor Injury Crash		No injury Crash	
ID	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*	*treatment*	*control*
Fixed Speed Cameras										
3001	293	95	162	46	51	13	111	33	131	49
3002	429	462	269	290	77	74	192	216	160	172
3003	271	315	163	173	55	40	108	133	108	142
3004	1099	563	708	361	237	115	471	246	391	202
3005	466	475	319	327	94	90	225	237	147	148
3006	112	166	61	80	26	35	35	45	51	86
3007	399	87	199	43	85	18	114	25	200	44
3008	585	335	297	175	100	48	197	127	288	160
3009	239	178	131	101	62	33	69	68	108	77
1001			93	104	36	35	57	69		
1002			322	144	116	57	206	87		
Point to Point cameras										
4001			315	585	136	265	179	320		
Red Light Speed Cameras										
2001			41	47	13	16	28	31		
2002			28	44	11	14	17	30		



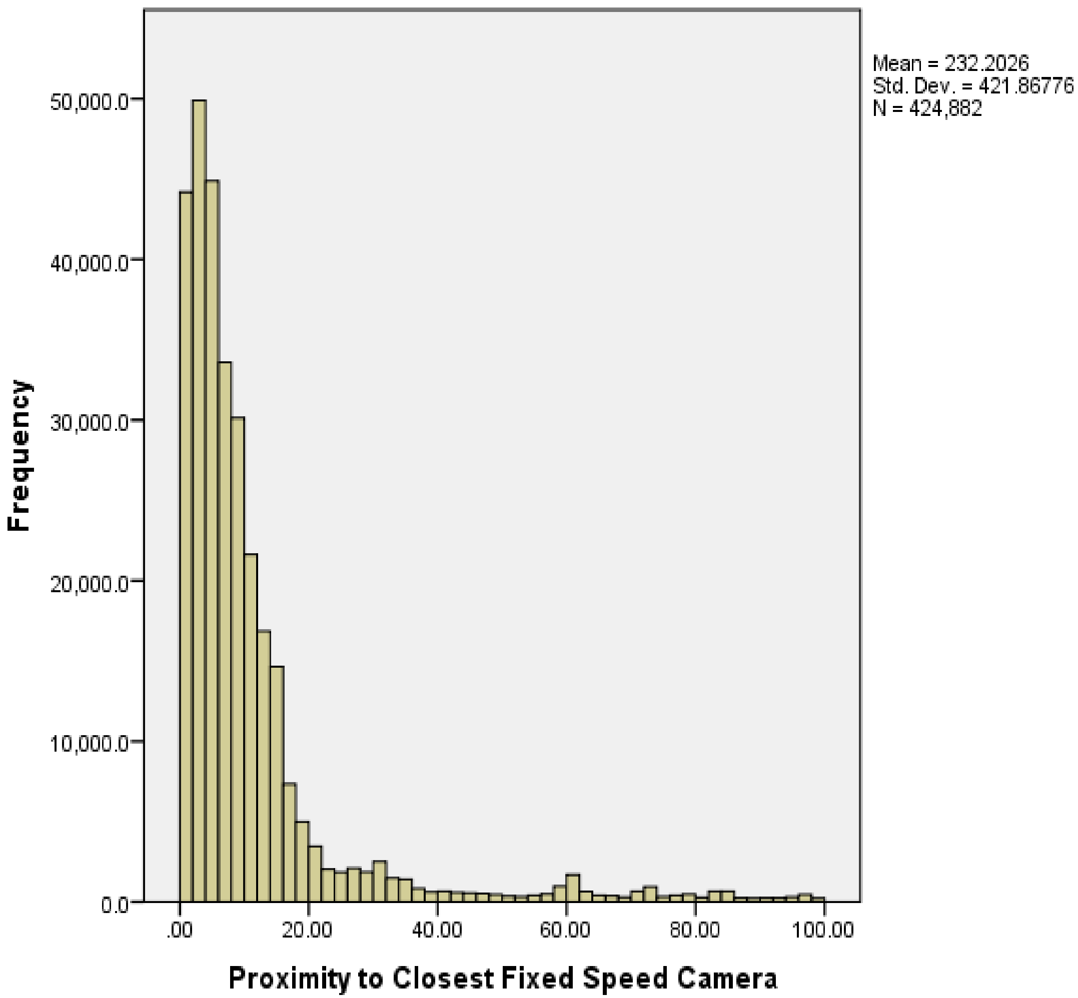


Figure 2 *The proximity of crashes to closest fixed spot speed and mobile speed cameras (km)*

3.2. EVALUATION OF THE MOBILE SPEED CAMERA PROGRAM

3.2.1. Police Regions and Control Selection

This study uses the Queensland Police Regions established on 1 July, 2013[1] (Brisbane, Central, Northern, South-Eastern and Southern) disaggregated by metropolitan and rural status according to the geographical definition for selecting controls. The Brisbane region was defined as purely metropolitan due to the paucity of crashes in high speed areas precluding analysis split by speed limit range. All other regions are split into rural and metropolitan on the basis of speed limit (≤ 80 km/h or > 80km/h respectively). A table summarising the treatment and control selection is presented in Section 8.2.

3.2.2. Time Series

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

3.2.3. Spatial Analysis

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

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

where

y	is the crash count per period and analysis stratum
i	is an indicator for treatment or control area
t	is a linear time period indicator variable
p	is the speed camera program post implementation time period indicator
s	is an indicator for analysis stratum
r	is the police region (Brisbane, Central, Northern, South Eastern or Southern)

β, δ, ϕ are parameters of the model

The factors in the model take the following values.

t = 1 in the time period of data
= 2 in the second time period of data etc.

i = 0; control series (rural crashes greater than 4km from a speed camera site)
(metropolitan crashes greater than 1km from a speed camera site)
= 1; treatment series (rural crashes ≤ 4km from a speed camera site)
(metropolitan crashes ≤ 1km from a speed camera site)

S = 1 for crashes in the Police region of Brisbane
= 2 for crashes in the Police region of Central in metropolitan areas
(speed limit ≤ 80 km/h)
= 3 for crashes in the Police region of Central in rural areas (speed limit > 80 km/h)
= 4 for crashes in the Police region of Northern in metropolitan areas
= 5 for crashes in the Police region of Northern in rural areas
= 6 for crashes in the Police region of South Eastern in metropolitan areas
= 7 for crashes in the Police region of South Eastern in rural areas

[1] Prior to this, there were 8 Police Regions.

= 8 for crashes in the Police region of Southern in metropolitan areas

= 9 for crashes in the Police region of Southern in rural areas

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

For annual, half-yearly or quarterly program estimates

p = *0* if month was before introduction of speed camera program

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

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

etc.

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

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

The key differences in the application of the analysis model in this evaluation update are in the use of the five police regions and the use of quarterly time periods instead of the previously defined eight police regions and yearly time periods.

3.2.4. Absolute crash savings for the Mobile Camera program

The average yearly crash counts at mobile camera treatment sites, for years 2008 to 2012 were first calculated by crash year, police region and severity. Percentage reduction estimates from the regression analysis were then applied to the after-period average annual mobile camera treatment area crashes to produce absolute crash savings for each crash year.

Absolute crash reductions were converted into community cost savings according to the process illustrated in the CDOP framework (Newstead & Cameron, 2012) by multiplying the estimated absolute crash savings at the crash severity level being considered by the unit cost of each crash (Table 37 and Table 38) to derive the cost savings related to the crash reductions. Savings were calculated by Police region, crash severity and crash year.

3.2.5. Measurement of Halo of Influence Change for Mobile Speed Cameras due to Covert Operations

Introduction of covert mobile speed camera operations in Queensland during 2010 had the potential to change the influence of the mobile speed camera program on crashes in both time and space. It would be expected that moving to covert mobile speed camera operations would broaden the crash effects in time and space. Test run of the evaluation framework by Newstead and Cameron (2012) showed there was no evidence of time based effects of the mobile camera program during the time of exclusively overt operation. Hence there is no scope for a further broadening of time based effects. This leaves the only possible change of influence associated with covert mobile speed camera operation as a broadening of the geographical effects of the program beyond the hypothesised spatial halos of influence used in the CDOP evaluation framework to date.

A change in spatial halo of influence of the mobile speed camera program would manifest in a change in the control crash series defined in the analysis design. It was not possible to measure changes in the control crash series in response to covert camera operations by comparing the control series to the current hypothesised treatment areas in a crossover type design. This is because the change to covert operations most likely also affects crashes in treatment areas. Since together the treatment and control areas for mobile cameras cover almost all crashes in Queensland, there was no possibility to define any other comparison area against which to test for changes in mobile speed camera control crashes in response to covert operations. To test for a change in the control series crash count in response to covert mobile speed camera operations, it was decided to use an intervention time series modelling approach to test for intervention effects in the control series at the time of commencement of covert operations.

Consistent with analysis methods used in the rest of the evaluation, a time series formulation of a Poisson regression model was fitted to the control area crash data using a cubic spline formulation with seasonal effects and an intervention term indicating the commencement of covert mobile camera operations in each region.

$$Ln(y_{it}) = \alpha_i + \beta_i t + \gamma_i t^2 + \delta_i t^3 + \mu_{is} + \tau_{ic}$$

The terms in the model are as follows:

- i is the analysis stratum indicator (police region by metro / rural)
- t is the quarterly time interval from Q1 1992 to Q4 2012
- α is the intercept parameter for each analysis stratum i
- β, γ, δ are the cubic spline coefficients within each analysis stratum i
- μ are the seasonal parameters for each stratum (1=Q1, 2=Q2 etc.)
- τ are the intervention effects associated with covert camera operations introduction (=0 before covert operations, =1 after covert operations)

The modelling framework allows each analysis stratum to have its own trend and seasonality and measures the effects of covert camera operations separately in each. The τ_i parameters represent the covert operations intervention effect and can be assessed for statistically significant difference from 0 (i.e. whether the covert operations were associated with a statistically significant change in the control data series for each stratum).

3.3. COMBINED ESTIMATE OF STATE-WIDE CDOP CRASH EFFECTS

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

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

3.4. RESOLVED DATA RELATED ISSUES STEMMING FROM THE TEST RUN

- Traffic volume data were made available for a limited set of sites, so could be used as an offset in the treatment and control sections used in the cross sectional analysis of the Clem 7 and Airport-Link tunnel camera crash effects.
- During the selection of controls for fixed speed cameras, street names appeared fairly consistent and were no longer creating the issue for control selection that was experienced in the trial run. No attempt was made to identify intersections by street names for red light (speed) camera control crash selection.
- The newly available GIS information made selection of controls and treatments on the PtP road segment possible.
- The additional years of crash data available meant that speed survey analysis of 2009 and 2010 could be compared with the effectiveness of the 2009 and 2010 CDOP.
- Dates of installation or signage were provided for fixed digital speed cameras however the fixed speed cameras considered in the analysis were mostly analogue. Digital fixed speed camera data were too limited to analyse by two starting dates. A future analysis may compare the treatment effects by installation and activation dates.
- With 'ramp' crashes excluded and up to five years of post-activation observation, site 3002, south of Story Bridge, had similar treatment and control crash counts in both the before and after crash periods for treatments and did not appear problematic, nor contaminated differentially to the control, so there seemed no need to exclude it from this evaluation. It was excluded from the previous trial run due to Clem 7 road work contamination.

3.5. ISSUES FACED IN BOTH THIS ANALYSIS AND THE TRIAL RUN

<u>*Control Selection*</u>

- The lack of unique intersection identifiers in crash data for all intersections meant that control intersection sites could not be matched by prior crash history, making for a less accurate set of intersection controls, and a larger potential for regression to the mean effects. As noted previously, this was not anticipated to provide a significant bias in the analysis results.
- Traffic volume data were only available at a limited set of sites, meaning that it was still unavailable for use in broader control matching.
- Control road segments for the cross sectional analysis of the Clem 7 and Airport-Link were not tunnels, so measured effects might be biased.
- Suspicion of contaminating influences differentially affecting treatment and control sites was identified for two analogue speed camera sites on the Gold Coast. These sites were excluded from the analysis so that broad effects of the fixed speed

camera program could be more accurately estimated. Two speed survey sites were also suspected of contamination and excluded accordingly.

Data disaggregation

- There was insufficient data to produce significant relative risk estimates at each of the severity levels from the fixed speed camera analyses. There were insufficient digital camera numbers and insufficient digital camera post-activation time.
- There was insufficient data to analyse fixed camera effectiveness varying over time.
- There was insufficient fatality data to estimate camera effects associated with fatal crashes alone
- Recoding of Police regions into a reduced number of regions has meant that partitioning of the mobile camera crash data by police region, year, speed limit and crash severity, enabled significant average crash effect estimates across all regions by year to be obtained. Analysis by region or by time intervals shorter than 1 year still lacked statistical power. This meant the analytical power of comparisons between estimated crash reductions and mobile camera hours enforced and random scheduler compliance was also limited.
- Although there were some significant differences in mobile speed camera crash effects measured between police regions, using regional based estimates by crash severity resulted in greater volatility in the crash and cost savings estimates reflected in the wider confidence limits on the regional estimated effects. If the primary objective of the evaluation framework were to only measure effectiveness of the CDOP mobile speed camera program on crashes in Queensland as a whole, using the average estimates of crash effects across all regions in calculating the crash savings and economic benefits would yield more accurate results. However, since the stated objective of the evaluation framework was to estimate CDOP crash effects on a region by region basis so a higher degree of statistical uncertainty in the estimates is expected.

Other

- Traffic migration issues in the evaluation were considered unlikely with the potential effects not readily assessed.
- It is also possible that the mobile speed camera program has produced generalised effects over space that cannot be readily detected by the evaluation framework employed.

4. RESULTS

4.1. CRASH ANALYSIS

Results of the crash analyses are presented as relative risks, absolute annual crash savings and crash cost savings using the Willingness to Pay and the Human capital approaches (expressed in 2012 dollars).

Regression analysis models were applied to crashes by the defined crash severity groupings: serious casualty (fatal + hospitalisation), minor injury (medical treated + other injury), no injury (PDO), all severity and all casualty crashes (all severities excluding PDO). Estimated savings associated with the aggregate categories of *all severity* and *casualty* crashes were determined from the respective regression model crash reduction estimates and not from the summation of savings associated individually with fatal, serious, minor injury and no-injury (PDO) crashes.

In contrast, although state-wide effects were modelled, the presented crash reduction estimates for these models were not used to estimate state-wide savings. For consistency, state-wide savings estimates presented in the results sections were calculated by summation of regional savings estimates.

4.1.1. State-wide Estimates of CDOP Effectiveness

This section presents the crash and economic effects estimated to be associated with the CDOP in each of the years from 2009 to 2012. Results are presented for each crash severity grouping defined, by police region and by broad camera type. The base camera-specific crash effect analysis, from which the overall crash and economic effects for each broad camera type are derived, is described in the sections immediately following this section (Sections 4.1.2 to 4.1.4). Results for 2009 and 2010 cover all crash severity levels since complete data were available for these years. Results for 2011 cover only casualty crashes since PDO crashes after 2010 are not being cleansed. 2012 results only cover serious casualty crashes reflecting the time lag in cleansing minor injury data.

Table 12 presents the regional average estimated relative crash risk associated with the CDOP in each year from 2009 to 2012. The relative crash risk estimates are the risk of a crash occurring with the CDOP in place compared to the CDOP not being present, adjusted for the effects of confounding factors represented in the control areas. Average estimates by region and for the whole state were derived by weighting the annual post-activation period treatment crash counts for each camera type within each region. Annual estimates of mobile speed camera program associated crash effects were available by crash severity grouping and are given in the table. For the fixed CDOP camera types, yearly crash effect estimates were not available due to the limited quantities of crash data associated with these sites. Instead, the average crash effects associated with each fixed camera types in their entire post implementation period were used to derive subsequent crash and crash cost savings. These average relative risk estimates are reported at the bottom of Table 12. The Brisbane region relative crash risks associated with CDOP include the effects of the Clem 7 fixed spot speed cameras however no contribution for the Airport-Link cameras could be calculated due to the lack of sufficient crash history accumulating.

Table 13 presents the estimated absolute annual crash savings, associated with the CDOP by year, crash severity, police region and camera type. Table 14 and Table 15 present the translation of crash savings into economic cost savings using the Human Capital and Willingness to Pay approaches respectively.

Estimated serious casualty crash reductions associated with CDOP were relatively consistent over the four years studied ranging between 23% and 26% reductions. A similar magnitude of reduction was associated with all casualty crashes and crashes of all severities, suggesting CDOP is associated with crash reductions which are uniform by crash severity. This finding is consistent with those of the test run of the evaluation framework which estimated 2008 crash effects. Some variation in crash effects by police region was estimated with overall effects varying up to 14% between police regions.

Estimated overall crash effects for CDOP as a whole were closely aligned to the estimates for the mobile camera program which has by far the highest coverage of reported crashes in Queensland of all the CDOP elements. Figure 3 compares the fixed speed, red light and mobile camera state-side relative risk estimates and 95% confidence intervals for 2008 to 2012, for serious casualty and all severity crashes. The blue line indicates the line of no program effect (a relative risk of 1) and the red dashed line indicates the CDOP average over the years studied. Crash reduction estimates associated with camera types, showed red light cameras to have similar associated crash effects to mobile speed cameras, albeit with a much smaller coverage of the total crash population, hence the smaller influence of red light cameras on the overall CDOP effect. Estimated crash effects associated with fixed cameras other than the red light cameras should be treated with extreme caution since they were not statistically significant being based on a small number of cameras with very short after installation time periods. This is despite the estimates presented being for the average effect of all other fixed cameras combined. The results for other fixed cameras will be discussed later in this report including the rationale for estimating their average effectiveness across all camera types.

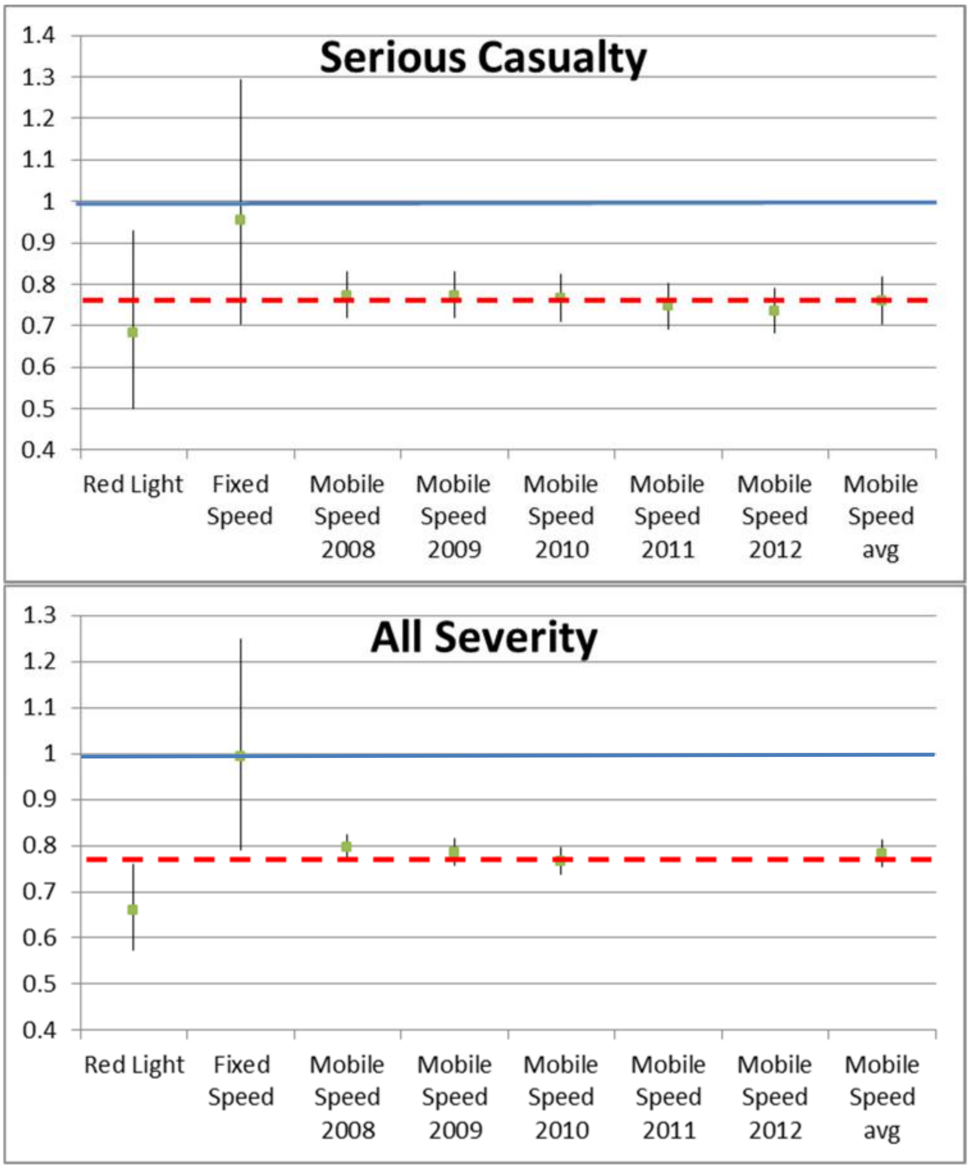
The estimated reductions in crash risk presented in Table 12 in combination with the observed actual crash numbers in each hypothesised halo of influence for each camera type have been used to derive absolute crash savings in Table 13. This methodology produced the most conservative estimates of crash savings and subsequent crash cost savings as it assumes factors other than the CDOP act proportionately first. During both 2009 and 2010, CDOP was associated with an absolute saving of around 6000 crashes of all severities and between 1300 and 1400 serious casualty crashes in each year. A similar magnitude in reduction of serious casualty crashes was also estimated for 2011 and 2012 suggesting program effects are being maintained at a relatively steady level over the 4 years considered. Over half of the crash savings come from the Brisbane and South Eastern regions reflecting both the high proportion of the Queensland crash population in these regions and the high coverage of these crashes by the mobile speed camera program. It is also evident that the vast majority of the estimated crash savings come from operation of the mobile camera program, again reflecting its high coverage of the crash population. This is again consistent with the findings of the 2008 evaluation reported in Newstead and Cameron (2012).

Conversion of the estimated crash savings into cost savings estimated annual savings of around $650M associated with the program valued using Human Capital crash costs and around $1.1B valued using Willingness to Pay estimates. Over 80% of the total crash cost savings stem from savings in serious casualty crashes.

Table 12 Estimated relative risk of crashes (with CDOP vs without CDOP) associated with the Queensland CDOP, by crash severity

2009	**Serious Casualty**	**Minor Injury**	**PDO**	**All Severities†**	**Casualty†**
All**	0.77	0.78	0.83	0.78	0.76
Brisbane	0.74	0.80	0.64	0.69	0.75
Central	0.78	0.81	0.93	0.84	0.79
Northern	0.88	0.81	0.80	0.81	0.82
South Eastern	0.65	0.85	0.84	0.78	0.75
Southern	0.78	0.68	0.80	0.74	0.71
Mobile Speed Cameras*	0.77	0.78	0.83	0.79	0.76
2010					
All**	0.77	0.78	0.78	0.76	0.76
Brisbane	0.76	0.78	0.66	0.70	0.75
Central	0.77	0.83	0.83	0.81	0.80
Northern	0.85	0.71	0.67	0.71	0.75
South Eastern	0.71	0.78	0.94	0.80	0.75
Southern	0.75	0.77	0.78	0.76	0.74
Mobile Speed Cameras*	0.77	0.78	0.78	0.77	0.76
2011					
All**	0.75	0.76			0.74
Brisbane	0.77	0.88			0.81
Central	0.77	0.78			0.76
Northern	0.88	0.74			0.78
South Eastern	0.69	0.81			0.75
Southern	0.67	0.70			0.66
Mobile Speed Cameras*	0.75	0.77			0.74
2012					
All**	0.74				
Brisbane	0.78				
Central	0.74				
Northern	0.84				
South Eastern	0.65				
Southern	0.70				
Mobile Speed Cameras*	0.74				
Average Effects Applied Over 2009-2012	**Serious Casualty**	**Minor Injury**	**PDO**	**All Severities†**	**Casualty†**
Red Light Camera*	0.68	0.61	0.70	0.66	0.64
Clem 7 tunnel Cameras	0.14	0.08		0.04	0.09
Other fixed speed cameras*‡	0.96	1.05	1.10	0.99	1.05

‡ based on non-significant relative risks
*From model that estimated state-wide directly
**Weighted average from state wide camera based models
† Estimated from an all crash/all casualty crash mode, except for casualty RLC



NB: Dashed line is the average relative risk across all camera types and years of study

Figure 3 *State-wide relative risk estimates for red light, fixed speed and mobile speed cameras (2008-2010)*

Table 13 Estimated annual crash savings associated with the Queensland CDOP, by crash severity

2009	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	1,438	1,746	2,107	5,950	3,507
Brisbane	561	692	1,217	2,904	1,455
Central	222	245	118	635	490
Northern	71	163	221	501	263
South Eastern	395	236	207	895	667
Southern	190	411	343	1,015	632
Red Light Camera*	35	80	47	161	115
Clem 7 tunnel Cameras	0	0	0	0	0
Other fixed speed cameras*‡	0	-1	-2	0	-2
Mobile Speed Cameras*	1,403	1,667	2,062	5,789	3,394
2010					
All*	1,319	1,832	2,360	6,085	3,447
Brisbane	509	771	1,140	2,842	1,461
Central	214	203	324	769	440
Northern	91	253	444	809	379
South Eastern	302	354	73	773	671
Southern	202	251	379	893	496
Red Light Camera*	35	73	55	165	108
Clem 7 tunnel Cameras	0	12	16	26	10
Other fixed speed cameras*‡	1	-2	-4	1	-4
Mobile Speed Cameras*	1,283	1,749	2,292	5,894	3,333
2011					
All*	1,369	1,391			3,094
Brisbane	438	345			964
Central	232	247			510
Northern	67	196			297
South Eastern	323	274			620
Southern	309	329			702
Red Light Camera*	37	60			96
Clem 7 tunnel Cameras	6	0			10
Other fixed speed cameras*‡	2	-2			-6
Mobile Speed Cameras*	1,324	1,333			2,994
2012					
All*	1,436				
Brisbane	400				
Central	286				
Northern	92				
South Eastern	379				
Southern	279				
Red Light Camera*	30				
Clem 7 tunnel Cameras	0				
Other fixed speed cameras*‡	2				
Mobile Speed Cameras*	1,404				

‡based on non-significant relative risks
*sum of regions, rounding errors apply
† Estimated from an all crash/ all casualty crash model

Table 14 Estimated annual savings associated with the Queensland CDOP, by crash severity: Human capital approach (2012 million AUS$)

2009	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	$603	$30	$25	$653	$618
Brisbane	$206	$12	$14	$294	$212
Central	$119	$4	$1	$86	$119
Northern	$34	$3	$3	$64	$55
South Eastern	$160	$4	$2	$94	$105
Southern	$84	$7	$4	$115	$127
Red Light Camera*	$13	$1	$1	$19	$19
Clem 7 tunnel Cameras	$0.00	$0.00	$0.00	$0.00	$0.00
Other fixed speed cameras*‡	$0.16	-$0.02	-$0.03	$0.04	-$0.29
Mobile Speed Cameras*	$591	$29	$24	$635	$599
2010					
All*	$534	$32	$27	$637	$579
Brisbane	$184	$13	$13	$283	$210
Central	$108	$3	$4	$92	$95
Northern	$37	$4	$5	$90	$73
South Eastern	$115	$6	$1	$78	$102
Southern	$90	$4	$4	$95	$98
Red Light Camera*	$13	$1	$1	$18	$17
Clem 7 tunnel Cameras	$0.00	$0.21	$0.18	$2.88	$1.55
Other fixed speed cameras*‡	$0.50	-$0.04	-$0.04	$0.09	-$0.67
Mobile Speed Cameras*	$521	$30	$27	$616	$561
2011					
All*	$562	$24			$554
Brisbane	$161	$6			$139
Central	$106	$4			$113
Northern	$25	$3			$53
South Eastern	$137	$5			$106
Southern	$135	$6			$144
Red Light Camera*	$14	$1			$16
Clem 7 tunnel Cameras	$2.01	$0.00			$1.55
Other fixed speed cameras*‡	$0.71	-$0.04			-$1.03
Mobile Speed Cameras*	$546	$23			$538
2012					
All*	$602				
Brisbane	$142				
Central	$136				
Northern	$43				
South Eastern	$160				
Southern	$121				
Red Light Camera*	$11				
Clem 7 tunnel Cameras	$0.00				
Other fixed speed cameras*‡	$1.11				
Mobile Speed Cameras*	$590				

‡based on non-significant relative risks
*sum of regions, rounding errors apply
† Estimated from an all crash/ all casualty crash model

Table 15 Estimated annual savings associated with the Queensland CDOP, by crash severity: Willingness to Pay approach (2012 million AUS$)

2009	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	$956	$150	$25	$1,142	$1,113
Brisbane	$293	$60	$15	$488	$358
Central	$220	$21	$1	$167	$234
Northern	$58	$14	$3	$118	$104
South Eastern	$247	$20	$2	$165	$187
Southern	$139	$35	$4	$203	$230
Red Light Camera*	$17.44	$6.80	$0.56	$30.52	$31.78
Clem 7 tunnel Cameras	$0.00	$0.00	$0.00	$0.00	$0.00
Other fixed speed cameras*‡	$0.21	-$0.11	-$0.03	$0.06	-$0.45
Mobile Speed Cameras*	$938	$143	$25	$1,112	$1,081
2010					
All*	$824	$156	$28	$1,088	$1,012
Brisbane	$258	$66	$14	$464	$351
Central	$193	$17	$4	$173	$184
Northern	$57	$22	$5	$152	$125
South Eastern	$167	$31	$1	$131	$174
Southern	$149	$20	$5	$167	$178
Red Light Camera*	$18.36	$6.18	$0.66	$29.53	$28.21
Clem 7 tunnel Cameras	$0.00	$1.06	$0.19	$4.34	$2.36
Other fixed speed cameras*‡	$0.76	-$0.19	-$0.04	$0.15	-$1.16
Mobile Speed Cameras*	$805	$149	$27	$1,054	$983
2011					
All*	$877	$120			$973
Brisbane	$227	$30			$235
Central	$177	$21			$204
Northern	$34	$17			$84
South Eastern	$218	$24			$193
Southern	$220	$28			$257
Red Light Camera*	$19.49	$5.09			$26.11
Clem 7 tunnel Cameras	$2.56	$0.00			$2.36
Other fixed speed cameras*‡	$1.16	-$0.18			-$1.82
Mobile Speed Cameras*	$854	$115			$946
2012					
All*	$953				
Brisbane	$194				
Central	$235				
Northern	$73				
South Eastern	$255				
Southern	$197				
Red Light Camera*	$16.48				
Clem 7 tunnel Cameras	$0.00				
Other fixed speed cameras*‡	$1.93				
Mobile Speed Cameras*	$935				

‡based on non-significant relative risks
*sum of regions, rounding errors apply
† Estimated from an all crash/ all casualty crash model

4.1.2. Red Light Cameras

Estimates of crash effects associated with Red Light Cameras were derived in the evaluation framework test run (Newstead and Cameron, 2012). Table 16 presents a summary of the regression result estimates, all of which show strong evidence of significance. Results of the homogeneity tests conducted during the trial run indicated that there was no statistical evidence that the crash effects associated with the red light camera operation differed between police regions at any level of crash severity, thus whole state crash reductions associated with the different severities were applied equally to all police regions.

Table 16 Estimated crash risks associated with the red light camera sites relative to sites without red light cameras

	Serious Casualty	Minor Injury	PDO	All Severities	All Casualty*
Estimate (95% CI)	0.682 (0.501-0.930)	0.613 (0.498-0.754)	0.702 (0.574-0.858)	0.66 (0.573-0.76)	0.64
Significance	0.015	<0.001	0.001	<0.001	

** A weighted average of serious casualty and minor injury relative risks.*

For this evaluation, annual crashes identified within the defined halo of influence of a red light camera (<100m from camera and recorded as at a signalised intersection) were tabled by severity and police region for 2009 to 2012. The average annual count over 2009 and 2010 is given in Table 17 as an indication of the crash population covered by this camera type. Crash reductions by severity were applied to the annual counts to produce the absolute crash savings per year given in the main results. Table 18 shows the average annual saving across 2009 and 2010 which were then costed by the Willingness to Pay and the Human Capital approaches with results given in Table 19 and Table 20 respectively.

Table 17 Average annual post-activation red light camera treatment crash counts by severity and Police region

	Serious Casualty	Minor Injury	PDO	All Severities	Casualty
All*	82	123	118	323	205
Brisbane	42	61	44	146	102
Central	8	13	21	41	20
Northern	7	7	11	25	15
South Eastern	19	29	23	71	48
Southern	7	13	20	39	20

*sum of regions, rounding errors apply

Table 18 Average annual absolute crash savings associated with red light cameras, by severity and Police region

	Serious Casualty	Minor Injury	PDO	All Severities	Casualty
All*	39	77	50	166	115
Brisbane	20	38	19	75	57
Central	4	8	9	21	11
Northern	3	5	5	13	8
South Eastern	9	18	10	37	27
Southern	3	8	8	20	11

*sum of regions, rounding errors apply

The casualty crash reductions of 36% (Table 16) associated with red light cameras translated to the average annual prevention of 115 casualty crashes saving society over $31 million per year by the Willingness to Pay approach. In addition to these crash savings, Newstead and Cameron (2012) demonstrated a large statistically significant reduction in all severity crashes targeted by red light cameras (42%, 95% CI 31-51%) without a significant change in rear end crashes.

Table 19 Average annual savings associated with red light cameras, by severity and Police region: Willingness to Pay approach

	Serious Casualty	Minor Injury	PDO	All Severities	Casualty
All*	$20,118,000	$6,533, 000	$597, 000	$31,400, 000	$31,176, 000
Brisbane	$8,245,000	$3,370, 000	$221, 000	$12,621, 000	$13,169, 000
Central	$4,401, 000	$649, 000	$105, 000	$8,447, 000	$7,397, 000
Northern	$1,274, 000	$391, 000	$54, 000	$1,779, 000	$1,866, 000
South Eastern	$4,155, 000	$1,509, 000	$118, 000	$5,729, 000	$5,807, 000
Southern	$2,044, 000	$614, 000	$100, 000	$2,824, 000	$2,938, 000

*sum of regions, rounding errors apply

Table 20 Average annual savings associated with red light cameras, by severity and Police region: Human Capital approach

	Serious Casualty	Minor Injury	PDO	All Severities	Casualty
All*	$14,220, 000	$1,331, 000	$583, 000	$19,066, 000	$18,848, 000
Brisbane	$6,488, 000	$660, 000	$216, 000	$8,369, 000	$8,648, 000
Central	$2,232, 000	$139, 000	$102, 000	$4,176, 000	$3,615, 000
Northern	$1,084, 000	$79, 000	$53, 000	$1,315, 000	$1,362, 000
South Eastern	$3,070, 000	$318, 000	$115, 000	$3,530, 000	$3,530, 000
Southern	$1,346, 000	$136, 000	$97, 000	$1,676, 000	$1,693, 000

*sum of regions, rounding errors apply

4.1.3. Other Fixed CDOP Elements

Fixed CDOP elements other than red light cameras were limited in their number available for analysis and had very limited after installation crash history available for analysis. In order to maximise the limited statistical power for the non-RLC fixed CDOP elements, average effects across all these camera types were estimated for inclusion in the state-wide effectiveness estimates rather than attempting to estimate effects of each fixed CDOP element individually. Estimated relative crash risks adjusted for the crash effects at control sites associated with the other fixed CDOP elements are presented in Table 21 excluding the Clem 7 and Airport-Link tunnel cameras due to the lack of available pre installation crash data. Table 22 presents estimated crash effects associated with the Clem 7 and Airport-Link tunnel cameras based on the alternative cross sectional analysis design. "n/a" has been used to indicate where crash data did not extend into the observed post-activation period, and '*' indicates that an estimate could not be made due to insufficient statistical power. Note that no other fixed CDOP elements were located in the Northern Police region.

Evidence to support relative risks at greater or less than unity was found only for the Clem 7 tunnel analysis. However, these estimates should be treated with caution because the control road, although adjusted for traffic volume and distance, was not a tunnel and because the analysis was based on only 2 crashes in the Clem 7 tunnel.

Table 21 Estimated relative crash risks associated with fixed CDOP cameras other than RLCs and tunnel cameras

	Serious Casualty	Minor Injury	PDO*	All Severities*†	Casualty†
Estimate	0.914	0.918	1.022	0.911	0.941
(95% CI)	(0.705-1.185)	(0.719-1.171)	(0.734-1.422)	(0.749-1.109)	(0.776-1.140)
Significance	0.50	0.49	0.90	0.35	0.53

* Based on analogue fixed speed cameras 3001-3009 only, † Estimated from an all crash/ all casualty crash model.

Table 22 Estimated relative crash risks at Clem 7 and Airport-Link camera sites relative to Port of Brisbane Motorway and Southern Cross Way determined from Cross-sectional Treatment-Control analysis

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
Clem 7					
Estimate	0.141	0.077		0.037	0.089
(95% CI)	(0.018-1.094)	(0.004-1.329)	*	(0.026-0.525)	(0.010-0.778)
Significance	0.061	0.078		0.0148	0.029
Airport-Link	*	n/a	n/a	n/a	n/a

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

The relative risk estimates associated with fixed camera types other than RLCs presented in Table 21 were estimated using data for more than one camera type and generally more than one camera of each type. 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 crash effects were undertaken across fixed camera types (other than red light cameras), the fixed spot speed camera sites assessed and the red light speed camera sites assessed. These results indicate if camera effectiveness varies by fixed camera type or across specific sites using the same camera type. The significance values for the tests of homogeneity of camera types: fixed speed analogue, fixed speed digital, point to point and red light speed camera, are presented in Table 23. There was no statistical evidence to show that relative risks were not the same for different fixed camera types or between the two camera sites which made up the red light speed camera analyses. However, amongst the combined fixed spot speed camera sites, strong evidence of heterogeneity of treatment effectiveness was found (Table 23) ($p < 0.01$).

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

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty Crash†
Camera Type	0.407	0.438			0.099
	(2.9,3)	(2.7,3)			(6.2,3)
Fixed Spot Speed sites	0.008	<0.0001	0.421	0.0005	<0.0001
	(23.7,10)	(36.0,10)	(8.0,8)	(27.5,8)	(44.8, 10)
Red Light Speed sites	0.262	1			1
	(1.2,1)	(0,1)			(0,1)

† Estimated from an all crash/ all casualty crash model

The analysis of fixed spot speed cameras by camera site (which excluded, tunnel, point to point and red light speed camera data), and the relative risk estimates for two fixed speed camera sites, 3004 and 3005, were statistically significant, whilst the estimates for the remaining fixed speed cameras were not statistically significant reflecting limited data quantities at these sites. The estimates for cameras 3004 and 3005 are presented in Table 24.

Table 24 Estimated relative crash risks at fixed spot speed camera sites 3004 and 3005

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty Crash†
3004					
Estimate	0.362	0.327	0.388	0.330	2.849
(95% CI)	(0.223, 0.589)	(0.209, 0.512)	(0.194, 0.777)	(0.193, 0.563)	(1.049, 7.738)
Significance	<.0001	<.0001	0.0075	<.0001	0.04
3005					
Estimate	2.378	2.449	1.768	2.739	0.517
(95% CI)	(1.195, 4.733)	(1.383, 4.336)	(0.848, 3.684)	(1.291, 5.808)	(0.22, 1.212)
Significance	0.0136	0.0021	0.1284	0.0086	0.1291

† Estimated from an all crash/ all casualty crash model

These cameras are both positioned on the Gold Coast Highway. Camera 3004 (Broadbeach) has been offline since January 6, 2011. It was turned off as a part of the extensive road works carried out with the construction of the Gold Coast Light Rail system. The significant crash reduction observed at site 3004 therefore is confounded by the effects of road works. From Table 25, it may be seen that annual crash rates have reduced at camera 3005 (Labrador), however, Table 24 shows that relative to the control, they have increased significantly. Because the almost 18 years of pre-activation crash history for the control site is similar to that of the treatment site (Table 11), it can be deduced that the observed treatment effect is due to greater crash reductions in the control segment than in the treated segment of the road during the 1-3 year post activation period. Control site contamination is suspected at this site; road works or infrastructure improvements applied in the control section, post-activation, may offer an explanation.

Table 25 Average annual, pre- and post-activation, fixed speed camera treatment crashes by severity, Police region and camera type

		Serious Casualty		Minor Injury		PDO		All Severities		Casualty	
		before	*after*	*before*	*after*	*before*	*after*	*before*	*after*	*before*	*after*
Brisbane											
RLSC	*2001*	0.82	2.8	1.6	0	2.4	n/a	4.7	n/a	2.4	2.8
	2002	0.72	1.4	1.5	0	1.8	n/a	4.0	n/a	2.2	1.4
FSC	*1001*	1.8	3.5	3.5	0	3.7	n/a	9.0	n/a	5.3	3.5
	3002	4.6	4.6	13.5	9.4	10.8	6.6	29.0	20.6	18.2	14.0
	3003	2.5	2.3	8.2	6.0	8.8	2.1	19.5	10.4	10.7	8.3
Clem 7		n/a	0.4	n/a	0.6	n/a	0	n/a		n/a	1.0
Airport		n/a	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
Central											
FSC	*3008*	2.6	5.2	6.9	4.7	8.7	9.9	18.1	19.8	9.5	9.9
	3009	1.8	2.1	3.8	2.7	4.2	7.1	9.8	11.9	5.6	4.8
P2P		13.5	14.1	16.3	9.7	26.6	n/a	56.4	n/a	29.9	23.8
Northern											
South Eastern											
FSC	*1002*	2.9	0	4.4	4.8	6.3	n/a	13.7	n/a	7.4	4.8
	3004	6.5	6.0	13.9	16.3	11.4	8.3	31.9	30.6	20.4	22.3
	3005	5.1	4.0	13.4	4.4	8.3	3.2	26.8	11.6	18.4	8.4
Southern											
FSC	*3001*	0.8	0.6	2.1	0.5	3.1	2.3	6.0	3.4	2.9	1.1
	3006	2.0	2.4	2.5	3.0	4.9	5.3	9.4	10.7	4.5	5.4
	3007	1.0	0.7	1.4	3.5	2.5	3.0	4.8	7.2	2.4	4.2

Despite the lack of statistical significance, absolute annual crash savings (Table 29) were estimated from the application of the relative risk estimates to the regional totals of the average annual post activation period treatment crashes (Table 25). Relative risks were assumed homogenous within crash severity types across cameras and camera types. The events occurring at camera sites 3004 and 3005 which confounded the effectiveness estimates were not considered as evidence of heterogeneity of the other camera site effectiveness across camera sites and types. Inclusion of these camera sites makes the analysis susceptible to some bias given concerns about a-typical influences of other factors at the treatment or control sites. Exclusion of these sites in the combined fixed speed camera analysis did not change statistical significance but changed the point estimates of crash effect slightly but not outside the bounds of statistical reliability (Table 26). Exclusion also led to non-significant tests of homogeneity (Table 27) and non-significant remaining fixed speed camera site and camera type (Table 28) estimates. These risk estimates excluding sites 3004 and 3005 were used for the remaining calculations to avoid potential bias in the analysis.

Table 26 Estimated relative crash risks associated with fixed CDOP cameras other than RLCs and tunnel cameras and excluding sites 3004 and 3005

	Serious Casualty	Minor Injury	PDO*	All Severities*†	Casualty†
Estimate (95% CI)	0.955 (0.705-1.294)	1.047 (0.776-1.413)	1.102 (0.758-1.602)	0.994 (0.791-1.248)	1.054 (0.835-1.330)
Significance	0.77	0.76	0.61	0.96	0.66

* Based on analogue fixed speed cameras 3001, 3002, 3003, 3006, 3007, 3008 and 3009 only.
† Estimated from an all crash/ all casualty crash model

Table 27 Significance probabilities from tests of homogeneity by injury severity for models excluding sites 3004 and 3005: significance (X^2, *d.f.*)

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty Crash†
Camera Type	0.432	0.575			0.139
	(2.747,3)	(1.987,3)			(5.492,3)
Fixed spot Speed sites	0.070	0.154	0.570	0.576	0.238
	(14.478,8)	(11.937,8)	(4.795,6)	(4.748,6)	(10.401, 8)

† Estimated from an all crash/ all casualty crash model

Table 28 Estimated relative crash risks associated with fixed speed camera types – excluding sites 3004 and 3005

	Serious Casualty	Minor Injury	Casualty Crash†
FSC Analogue			
Estimate (95% CI)	0.915 (0.64,1.31)	0.991 (0.72,1.34)	1.01 (0.79,1.29)
Significance	0.96	0.91	0.96
FSC Digital			
Estimate (95% CI)	1.86 (0.68, 5.46)	2.51 (0.50, 12.69)	2.73 (0.75, 9.99)
Significance	0.26	0.27	0.13
PtP			
Estimate (95% CI)	0.97 (0.44, 2.14)	1.79 (0.44, 7.24)	1.44 (0.53, 3.91)
Significance	0.95	0.42	0.47
RLS			
Estimate (95% CI)	0.40 (0.07, 2.21)	1.40	0
Significance	0.29	1.00	1.00

*all severity and non-injury estimates were based solely on analogue fixed cameras.
† Estimated from an all casualty crash model

Although lacking statistical significance, Table 28 suggests that some relative risk estimates associated with digital fixed speed camera types appear unusually high. There were five digital cameras analysed: two Brisbane region RLSC sites, a Brisbane and a South Eastern region FSC and a Central Region PtP. All of these five sites had their respective cameras made operational in August 2011; so not only is the post-activation observation period short, consisting of only a few months for minor injury crashes, the relative risks associated with the different digital camera types (FSC, PtP and RLS) have each been calculated on data from only 1-2 camera sites. Section 2.3 points out also that the average speed Point to Point cameras began operations even later and have only 4 months of post-activation observation period when infringements were issued. On this basis it is considered that there is insufficient post-activation data to draw conclusions about the crash effects associated with these three camera types.

Even though analogue fixed spot camera data are based on longer periods and more sites, no statistically significant estimates of associated crash risk were found. It is anticipated that accumulation of longer time frames of post implementation crash history will eventually provide sufficient evidence to validate the small crash decrease estimates observed. Indeed it can generally be concluded that the limited number of camera installations and very short post implementation crash history for all fixed CDOP elements other than RLCs considered in this report has led to generally inconclusive estimates of their associated crash effects from this evaluation. Future evaluation incorporating additional years of crash data will potentially overcome this problem.

Estimated WTP and HC crash costs were applied to the average annual absolute crash savings over 2009-2012 presented in Table 29 to derive estimates of crash cost savings from fixed CDOP elements other than RLCs. These results are presented in Table 30 and Table 31. These estimates should be seen as only illustrative given the lack of statistical significance in the underlying crash reduction estimates. The same technique was used to derive the estimates by year presented in Section 4.1.1 but based on the observed crashes at each camera site in each year.

Table 29 Average annual absolute crash savings associated with (non-significant) fixed speed camera site crash reductions, by severity and Police region

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	2	-3	-4	1	-7
Brisbane	0.7	-0.7	-0.8	0.2	-1.5
Central	1.0	-0.8	-1.6	0.4	-2.0
Northern	0.0	0.0	0.0	0.0	0.0
South Eastern	0.5	-1.2	-1.1	0.3	-2.6
Southern	0.2	-0.3	-1.0	0.1	-0.5
Clem 7	0.36	0.57	0.0	2.67	1.14

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

Table 30 Average annual savings associated with (non-significant) fixed speed camera site crash reductions, by severity and Police Region: Willingness to Pay Approach

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	$1,841, 000	-$242, 000	-$52, 000	$246, 000	-$2,325,000
Brisbane	$287, 000	-$61, 000	-$10, 000	$41, 000	-$349, 000
Central	$1,230, 000	-$62, 000	-$19, 000	$140, 000	-$1,268,000
Northern	$0	$0	$0	$0	$0
South Eastern	$221, 000	-$94, 000	-$13, 000	$46, 000	-$564, 000
Southern	$103, 000	-$25, 000	-$12, 000	$19, 000	-$144, 000
Clem 7	$930, 000	$606, 000	$682, 000	$11,574, 000	$2,693, 000

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

Table 31 Average annual savings associated with non-significant fixed speed camera site crash reductions, by severity and Police Region: Human Capital approach

	Serious Casualty	Minor Injury	PDO	All Severities†	Casualty†
All*	$1,081, 000	-$50, 000	-$51, 000	$136, 000	-$1,274,000
Brisbane	$226, 000	-$12, 000	-$9, 000	$27, 000	-$229, 000
Central	$624, 000	-$13, 000	-$18, 000	$69, 000	-$620, 000
Northern	$0	$0	$0	$0	$0
South Eastern	$163, 000	-$20, 000	-$12, 000	$29, 000	-$343, 000
Southern	$68, 000	-$5, 000	-$11, 000	$11, 000	-$83, 000
Clem 7	$732, 000	$119, 000	$667, 000	$7,675, 000	$1,768, 000

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

4.1.4. Mobile Speed Cameras

Table 32 shows the proportion of total crash numbers in Queensland as a whole and by police region that fell into the hypothesised halos of influence of the mobile speed camera sites from 2008-2012. Overall, around 76% of all police reported crashes in Queensland were inside the halos of influence. This is broadly consistent with the high coverage of crashes by the mobile speed camera program observed in the previous evaluation. There was some variation in crash coverage of the mobile camera treatment areas by crash severity and police region. Police regions with higher proportions of rural roads had smaller coverage of crash numbers due to the diffuse nature of crash distributions on rural roads. The differential coverage by region also translates to lower coverage of serious casualty crashes since serious casualty crashes are over represented on high speed rural roads which predominate in the more rural areas.

For analysis, aggregate crash counts were derived for each speed zone in each region as a time series of treatment and control data covering the years 1992 to 2012. The mobile speed camera program commenced operation early in 1997 which defined the before and after periods for the evaluation analysis.

Table 32 Percentage of all reported crashes in Queensland within defined mobile speed camera halos of influence (2008-2012)

	Serious Casualty	Minor Injury	PDO	All Severities	Casualty
Brisbane	91%	93%	92%	92%	92%
Central	58%	64%	67%	63%	61%
Northern	65%	72%	72%	69%	68%
South Eastern	78%	83%	84%	81%	80%
Southern	60%	68%	70%	66%	63%
All	72%	79%	77%	76%	75%

Relative risk ratios by crash severity and year of the mobile speed program, for all regions combined are presented in Table 33. In these tables, relative risks generally, onwards from the fifth year of the program, are highly statistically significant. When program effects were estimated by half year, or by quarter year, and additionally disaggregated by police region, there is reduced analytical power and hence many of the results are not statistically significant. This is why the program effects presented in Section 4.1.1 are based on the annual estimates. When analysed by quarter and half year, trends seen in the annual estimates continue to be seen as demonstrated by the half-year estimates presented in Figure 4 and in Figure 5.

Table 33 Estimated net relative crash risks, significance values and 95% confidence limits associated with the Queensland mobile speed camera program by year after introduction: average over all police regions.

	Fatal and Serious Injury Crashes			
Year	Significance.	Estimate	95% Confidence Interval	
1997	0.232	0.947	0.866	1.036
1998	0.416	0.964	0.882	1.054
1999	0.049	0.916	0.839	1.000
2000	0.665	0.981	0.900	1.070
2001	0.053	0.921	0.848	1.001
2002	0.007	0.895	0.825	0.970
2003	0.057	0.924	0.852	1.002
2004	0.015	0.908	0.840	0.981
2005	0.001	0.876	0.812	0.946
2006	0.012	0.905	0.837	0.979
2007	<0.0001	0.812	0.753	0.877
2008	<0.0001	0.773	0.718	0.831
2009	<0.0001	0.773	0.718	0.832
2010	<0.0001	0.766	0.711	0.826
2011	<0.0001	0.747	0.693	0.804
2012	<0.0001	0.735	0.683	0.791

	Medical treatment and other minor injury crashes				Casualty Crashes			
Year	Significance.	Estimate	95% Confidence Interval		Significance.	Estimate	95% Confidence Interval	
1997	0.189	1.051	0.976	1.132	0.642	1.014	0.957	1.073
1998	0.895	0.995	0.924	1.071	0.604	0.985	0.931	1.043
1999	0.015	0.915	0.851	0.983	0.002	0.917	0.867	0.969
2000	0.070	0.935	0.870	1.005	0.082	0.952	0.901	1.006
2001	0.063	0.938	0.876	1.003	0.012	0.935	0.887	0.985
2002	0.152	0.952	0.889	1.018	0.004	0.927	0.880	0.977
2003	0.275	0.962	0.898	1.031	0.026	0.942	0.894	0.993
2004	0.004	0.904	0.845	0.968	<0.0001	0.897	0.853	0.944
2005	<0.0001	0.830	0.777	0.888	<0.0001	0.841	0.800	0.885
2006	<0.0001	0.840	0.786	0.897	<0.0001	0.861	0.819	0.906
2007	<0.0001	0.834	0.783	0.890	<0.0001	0.822	0.782	0.863
2008	<0.0001	0.848	0.794	0.906		0.803	0.765	0.843
2009	<0.0001	0.781	0.731	0.836		0.765	0.728	0.803
2010	<0.0001	0.778	0.727	0.834		0.759	0.722	0.799
2011	<0.0001	0.765	0.713	0.822		0.739	0.702	0.778
	Property Damage Only crashes					**All Severity Crashes**		
1997	0.188	0.956	0.895	1.022	0.519	0.986	0.944	1.029
1998	0.001	0.897	0.840	0.957	0.008	0.944	0.904	0.985
1999	0.000	0.884	0.829	0.942	<0.0001	0.901	0.864	0.939
2000	0.008	0.915	0.857	0.976	0.001	0.933	0.894	0.973
2001	0.001	0.899	0.842	0.960	<0.0001	0.913	0.877	0.951
2002	0.005	0.912	0.856	0.972	<0.0001	0.915	0.879	0.952
2003	0.000	0.882	0.828	0.940	<0.0001	0.913	0.877	0.950
2004	0.002	0.908	0.854	0.966	<0.0001	0.898	0.863	0.934
2005	0.046	0.938	0.882	0.999	<0.0001	0.873	0.840	0.908
2006	<0.0001	0.856	0.803	0.911	<0.0001	0.852	0.819	0.886
2007	<0.0001	0.850	0.798	0.905		0.822	0.791	0.855
2008	<0.0001	0.800	0.753	0.850		0.795	0.765	0.825
2009	<0.0001	0.831	0.782	0.883		0.785	0.756	0.816
2010	<0.0001	0.780	0.735	0.828		0.766	0.737	0.796

As noted in the previous evaluations, the crash reductions associated with the camera program have grown over time as a result of steady increases in the number of sites that are actively enforced each year along with increases over time in the number of hours of mobile speed camera enforcement undertaken each year. Since 2010 increased effectiveness may also be as a result of covert use of the mobile camera program commencing. Figure 4 and the corresponding estimates in Table 33 suggest that the mobile speed camera program has been approximately equally effective in reducing crash risk for the three severity groupings of crashes analysed, with slight evidence of a slightly greater reduction for serious and fatal injury crashes. This is in agreement with the previous evaluation. Figure 4 shows an estimated crash reduction associated with the mobile speed camera program operation within the defined halos of influence in the order of 20-30%. These estimates are for the most part highly statistically significant ($p < 0.01$). Figure 4 plots the half-yearly (half year since January 1997) relative risk estimates associated with the mobile speed camera program by crash severity grouping averaged across all regions. In line with the previous evaluations it shows steadily increasing crash risk reductions in the hypothesised halos of speed camera influence with increasing time after implementation.

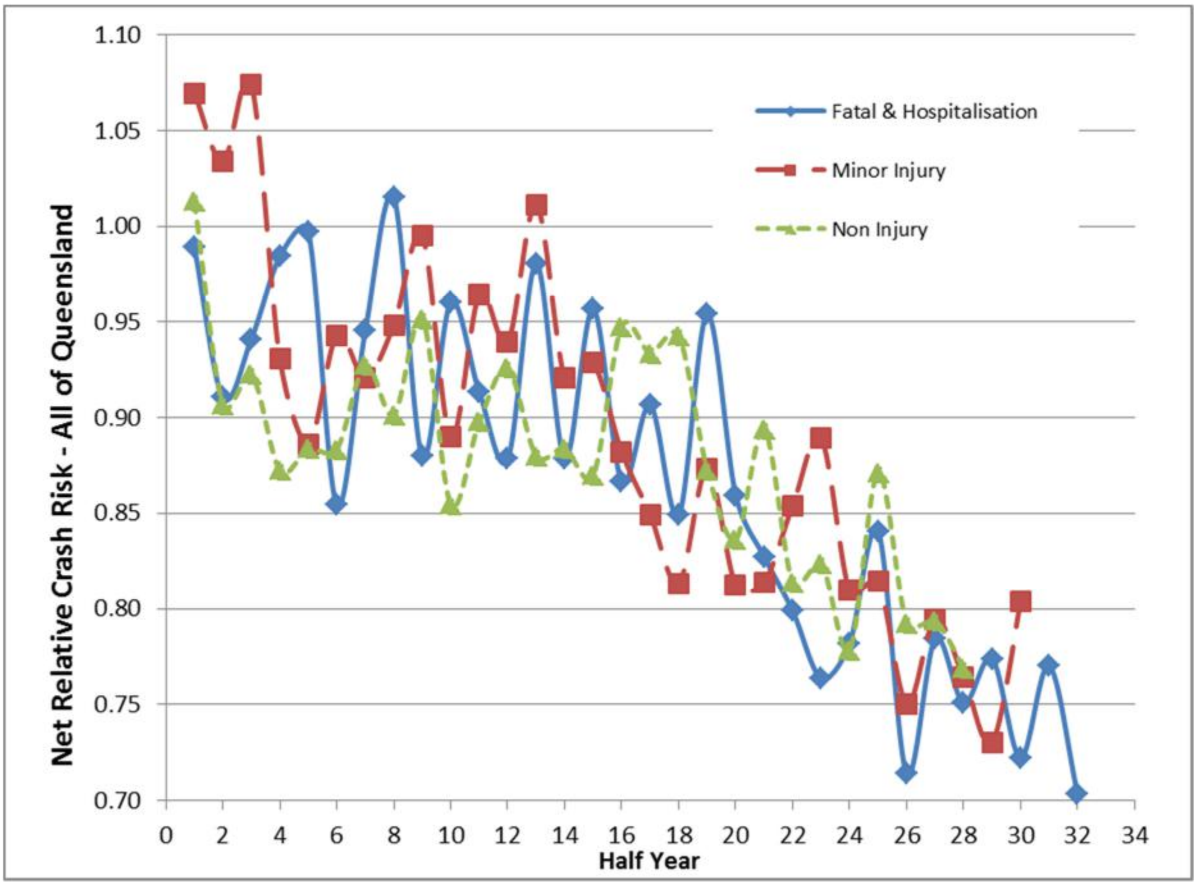


Figure 4 *Relative risks associated with the Queensland mobile speed camera program by half-year after introduction by crash severities, across all Police regions*

Figure 5 shows half-yearly estimates of relative crash risk for all crashes of all severity levels associated with operation of the mobile speed camera program by police region. It shows differential trends by police region however for the most part differences in these trends were not statistically significant.

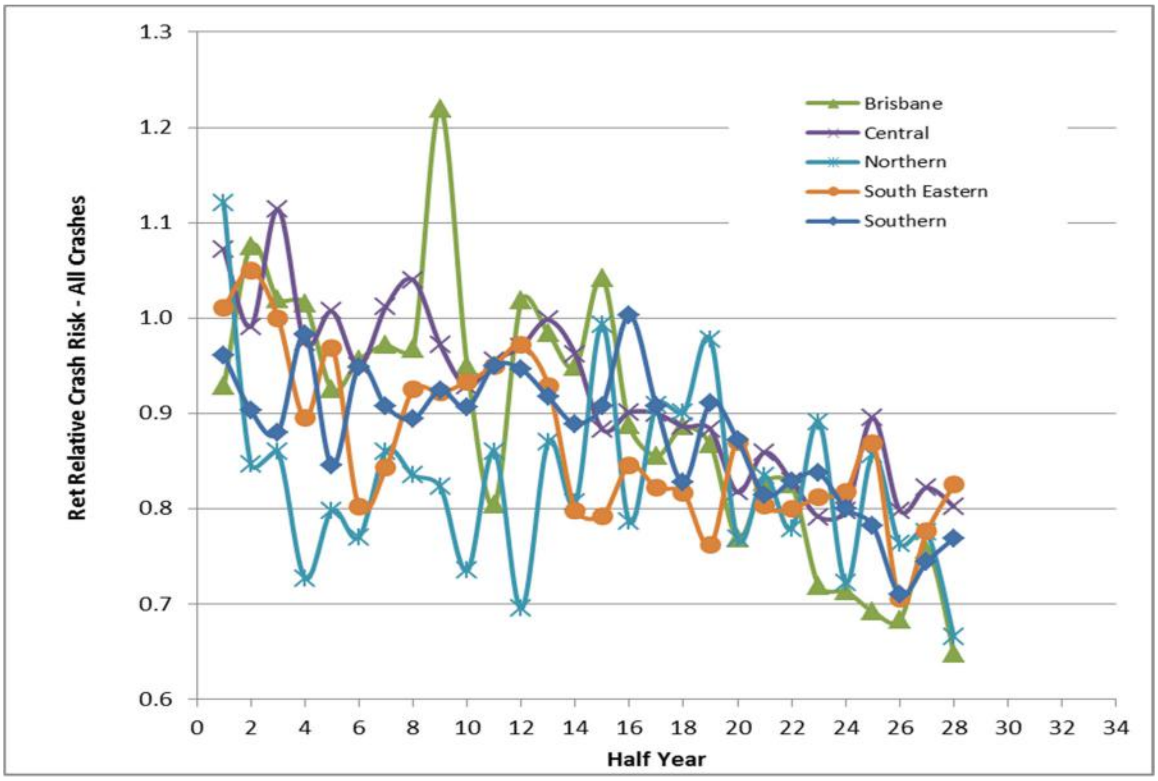


Figure 5 *Relative risks associated with the Queensland mobile speed camera program by half-year after introduction by Police region for all crash severities*

Using the same process as demonstrated for the fixed spot speed and red light cameras, absolute crash savings and crash cost savings were estimated for the mobile speed camera program. Calculations were made for the years 2008 through to 2012 using data disaggregated by crash year, police region and crash severity. Table 42 through to Table in Section 8.4 of the appendix present the 'by year' analysis. Table 34 through to Table 38 below present annual average estimates averaged over the years 2008 to 2012 (or to 2010 for other than serious casualty crashes) as an illustration of the crash population and crash savings associated with the mobile speed camera program.

Table 34 Average annual crash counts in mobile speed camera zones of influence by crash severity and Police region: 2008-2012

Region	Serious Casualty	Minor Injury	PDO	All	Casualty
Brisbane	1,465	2,657	2,097	6,345	4,137
Central	738	1,000	1,519	3,307	1,730
Northern	499	648	875	2,074	1,153
South Eastern	709	1,212	1,069	3,034	1,930
Southern	625	863	1,326	2,858	1,485
All Regions*	4,036	6,380	6,886	17,618	10,434

*sum of regions

Averaged over 2008 to 2012, the annual crash savings associated with the Queensland mobile speed camera program was 5,682 which translates to a cost savings to the community of $612 million (2012) using a Human Capital approach. The bulk of the savings come from fatal and serious injury crashes.

Table 35 Weighted average relative crash risks associated with the Queensland mobile speed camera program by year and police regions: averaged over 2008 to 2012

Region	Serious Casualty	Minor Injury	PDO	All†	Casualty†
Brisbane	0.7871	0.8261	0.6220	0.7002	0.7861
Central	0.7500	0.8232	0.8597	0.8166	0.7827
Northern	0.8904	0.7630	0.7350	0.7744	0.8019
South Eastern	0.6721	0.8325	0.9025	0.7990	0.7581
Southern	0.7240	0.7663	0.8190	0.7739	0.7309
All Regions*	0.7592	0.7957	0.8038	0.7821	0.7680

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

Table 36 Estimated annual average absolute crash savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2008 to 2012

Region	Serious Casualty	Minor Injury	PDO	All†	Casualty†
Brisbane	405	566	1,286	2,719	1,139
Central	247	216	254	745	481
Northern	63	203	322	612	288
South Eastern	347	247	118	764	617
Southern	241	276	297	841	556
All Regions*	1,303	1,509	2,277	5,682	3,081

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

Table 37 Estimated *Willingness to Pay* average annual savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2008 to 2012, *2012 AUS million dollars*

Region	Serious Casualty	Minor Injury	PDO	All†	Casualty†
Brisbane	$208	$48	$15	$451	$276
Central	$213	$18	$3	$174	$201
Northern	$48	$17	$4	$135	$101
South Eastern	$227	$21	$1	$145	$181
Southern	$175	$23	$4	$164	$200
All Regions*	$868	$129	$27	$1,069	$959

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

Table 38 Estimated Human Capital average savings associated with the Queensland mobile speed camera program by year and Police regions: averaged over 2008 to 2012, *2012 AUS million dollars*

Region	Serious Casualty	Minor Injury	PDO	All†	Casualty†
Brisbane	$148	$10	$15	$270	$163
Central	$121	$4	$3	$92	$106
Northern	$28	$4	$4	$75	$57
South Eastern	$144	$4	$1	$83	$101
Southern	$107	$5	$3	$92	$110
All Regions*	$547	$26	$27	$612	$537

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

4.1.5. Assessment of Covert Mobile Speed Camera Program Halo of Influence Effects

Using the methods described in Section 3.2.5, the effect of the move to covert operation of the mobile speed cameras on crash trends in the control series has been analysed to assess whether the move to covert operations has increased the geographical area of crash effects associated with the camera. Table 39 summarises the covert camera intervention parameters for each analysis stratum estimated from the intervention time series model. The model was fitted to the time series of quarterly serious casualty crash data. This provided the longest after covert operations data on which to assess the intervention effect. It also focused on the crash severity level accounting for the majority of economic benefits associated with the mobile speed camera program. Table 39 presents the relative crash risks in each stratum after introduction of covert operations compared to before, the statistical significance and 95% confidence limits of these estimates. The model fitted values and the actual data are plotted in the Appendix (Section 8.6).

Table 39 Estimated change in control area series casualty crash trends associated with the introduction of covert mobile speed camera operations

Police Region and Urban / Rural Area	Statistical Sig.	Relative Crash Risk After Covert Operations	Confidence Interval for Relative Risk	
			Lower	Upper
BRISBANE	.430	1.126	.838	1.513
CENTRAL METRO	.972	.997	.841	1.182
CENTRAL RURAL	.536	1.067	.868	1.312
NORTHERN METRO	.843	.977	.777	1.229
NORTHERN RURAL	.143	.805	.603	1.076
SOUTH EASTERN METRO	.351	.894	.707	1.131
SOUTH EASTERN RURAL	.461	1.367	.596	3.133
SOUTHERN METRO	.786	.973	.797	1.187
SOUTHERN RURAL	.781	.970	.785	1.200

Results presented in Table 39 show no statistically significant change in the mobile speed camera control series trends associated with the introduction of covert mobile speed camera operations. Many of the estimated relative risks are very close to 1 suggesting any real change, if present, might be small. The exceptions to this are Northern rural and South Eastern Metro areas where a larger drop in post covert operation crash levels was observed although this result is not statistically significant. This result however suggests this analysis should be repeated in future applications of the CDOP evaluation framework to continue to monitor the effects of covert mobile camera operations on the validity of the analysis design.

The lack of detectable intervention effects associated with covert camera operations in the control series for mobile speed camera analysis suggest the analysis framework used to measure overall crash effects of the mobile camera program has not been compromised by covert operations introduction. It suggests that any change in mobile camera effects associated with covert operations are confined to the previously hypothesised areas of influence and will be reflected in the mobile camera crash effects previously presented.

4.2. SPEED SURVEY DATA ANALYSIS

TMR has arranged for regular six-monthly surveys of vehicle speeds at around 135 sites, commencing in May 2009. Two surveys were conducted each year in 2009 and 2010 (May and November), but the May 2011 survey did not proceed because of substantial floods in Queensland during that period.

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

The existing reports on the 2009 and 2010 surveys present summary results (mean and median speeds, 85th percentile speed, and proportions of vehicles exceeding the speed limit and exceeding by 10 km/h) on roads with speed limits of 50 km/h (urban only), 60 km/h, 80 km/h and 100 km/h (for urban and rural roads separately). Only in the case of the urban 50 km/h limit sites had the same 20 sites been surveyed in each of the four surveys. In the other six road types, sites had been lost and replaced for various reasons, making it difficult to make time series comparisons across all four surveys. The existing reports made pair-wise comparisons between the summary speed results measured in adjacent surveys and developed adjustment procedures to indicate the longer term trends. The trends over the first four surveys during 2009 and 2010 are shown in Kloeden (2011).

The summary speed measures presented by Kloeden (2011) are traditional ways of presenting speed survey results and indicating change over time. However, Cameron and Elvik (2010) have shown that changes in the measures of central tendency (mean and median) are inadequate to represent changes in road trauma (numbers of crashes at each level of injury severity) on urban roads. They showed that Nilsson's (1981, 2004) power functions of crash numbers at each severity level, expressed as powers of changes in mean speed, is an adequate model for rural roads and freeways, but not for urban roads. It is unclear whether 85th percentile speeds and proportions of vehicles exceeding speed limits by various degrees (except for very high speeds) are indicators of changes in road safety.

4.2.1. Risk-weighting of speed measurements

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

Kloeden et al (2002) found the relative risk on urban roads with 60 km/h speed limit to be:

$$RR = \exp(0.1133374\ \Delta v + 0.0028171\ \Delta v^2) \qquad \text{(Equation 1)}$$

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

Kloeden et al (2002) also established another relationship between individual driver's relative risk and absolute vehicle speed on urban 60 km/h roads:

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

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

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

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

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

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

4.2.2. 50 km/h limit sites

Equation 1 was used to weight the speed observations at each 50 km/h limit site, relative to the mean speed in each direction. However, while Equation 2 had also been developed for speeds on urban roads, it was considered appropriate to use it for weighting of speeds only at 60 km/h limit sites because it is related to absolute speed on those roads.

The frequencies of measured speeds were provided for each urban site and direction in 5 km/h wide categories (bins) between 40 and 80 km/h, and wider bins at each extremity. The mid-mark speed for each bin was used to represent its contents for calculating the relative risk associated with the bin speeds, except for bins 0-30 (20 km/h), 90-120 (100 km/h) and 120+ (120 km/h). Surprisingly, there were some speeds recorded in these two high speed bins at urban 50 km/h limit sites during the surveys.

For each site and direction, the mean speed for each six-monthly survey was calculated. The difference between the bin mid-mark speed and the mean speed was used to calculate the expected relative risk of a casualty crash, using Equation 1. The relative risk for bins above 90 km/h was capped to that for the 80-90 km/h bin, and the relative risk for the 0-30 km/h bin was set at the same risk as the 30-40 km/h bin.

The bin frequency was then multiplied by this estimated relative risk. These risk-weighted speed frequencies were then added across all urban 50 km/h site/directions to provide an indicator of the expected relative casualty crash frequency associated with the bin speed on these roads. Two very extreme speed measurements exceeding 80 km/h at one site observed in November 2009 (where the mean speed was 28km/h) were ignored because of the distorting effect of the very high risk-weights calculated for these speeds.

Figure 6 shows the expected relative casualty crash frequencies calculated by risk-weighting the speed measurements in each bin in each six-monthly survey. The magnitude of the expected total casualty crashes is a function of the total number of speed observations, which was 95-96,000 for the May surveys and just above 98,000 for each November survey (this may be a result of seasonal variation in traffic). The relative casualty crash frequency is labelled 'expected' because it is based on the assumption that the relative risk curve detailed in Equation 1 is applicable in the Queensland context.

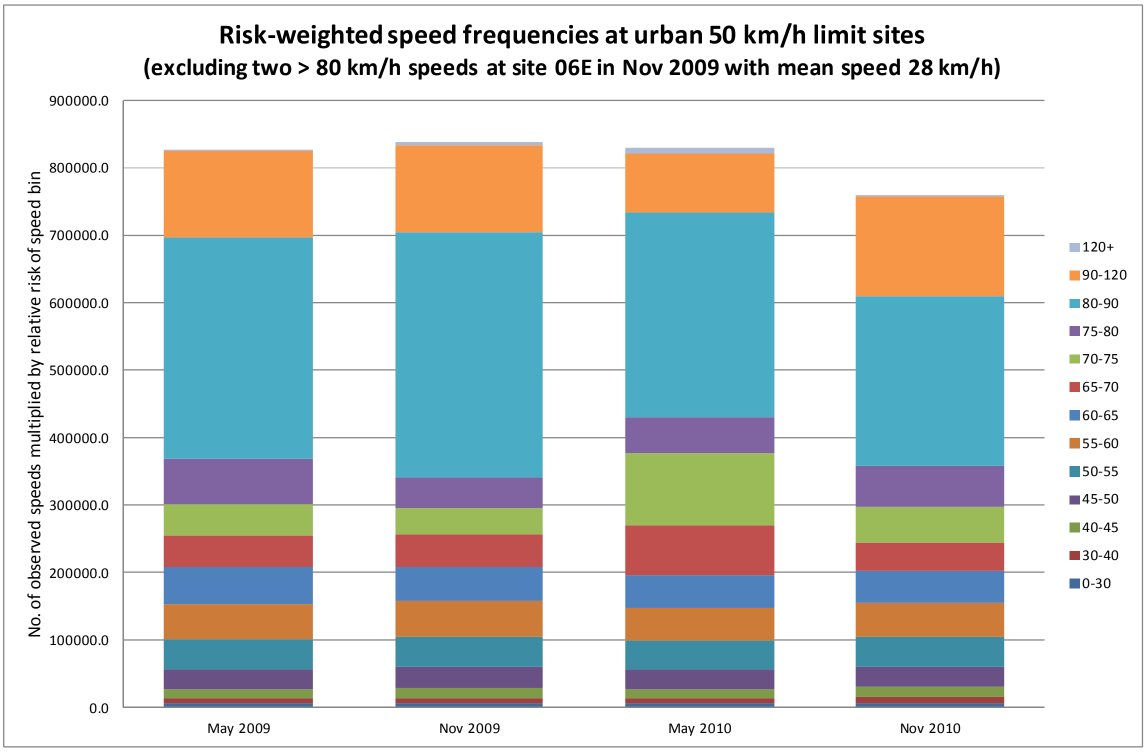


Figure 6: *Expected relative casualty crash frequencies by speed survey with contribution from each speed category (50km/h limit roads)*

It can be seen that there were substantial decreases in the relative crash frequencies associated with 90-120 and 80-90 km/h speeds in May 2010, but increases in frequency associated with 70-75 and 65-70km/h speeds, resulting in little change in the total relative crash frequency across all speeds. In November 2010, the relative crash frequencies associated with the lower level (illegal) speeds appeared to return to 2009 levels, but the frequency associated with the 90-120km/h bins increased and exceeded the 2009 levels.

4.2.3. 60 km/h limit sites

The frequencies of measured speeds at the 60km/h speed limit sites were initially analysed in the same way as at the 50km/h limit sites, using Equation 1 to estimate the crash risk associated with each observed speed relative to the mean speed for the same site/direction. Secondly, the observed speeds were weighted by the relative risk associated with each absolute speed calculated from Equation 2 that was derived for 60 km/h limit roads.

Only those sites that were surveyed in each of the four six-monthly surveys were considered. Two sites covered in all four surveys was found to have a very unusual speed distribution in November 2010 compared with the earlier surveys, so these sites' results were not included in the analysis. This left 26 sites with all four survey results for analysis.

Relative risk of individual speeds relative to mean speed

Figure 7 shows the expected relative casualty crash frequencies calculated by risk-weighting the speed measurements by Equation 1. That is the risk relevant to the difference between the measured speed and the mean speed at the site/direction at the time of the survey (as described in section 4.2.2).

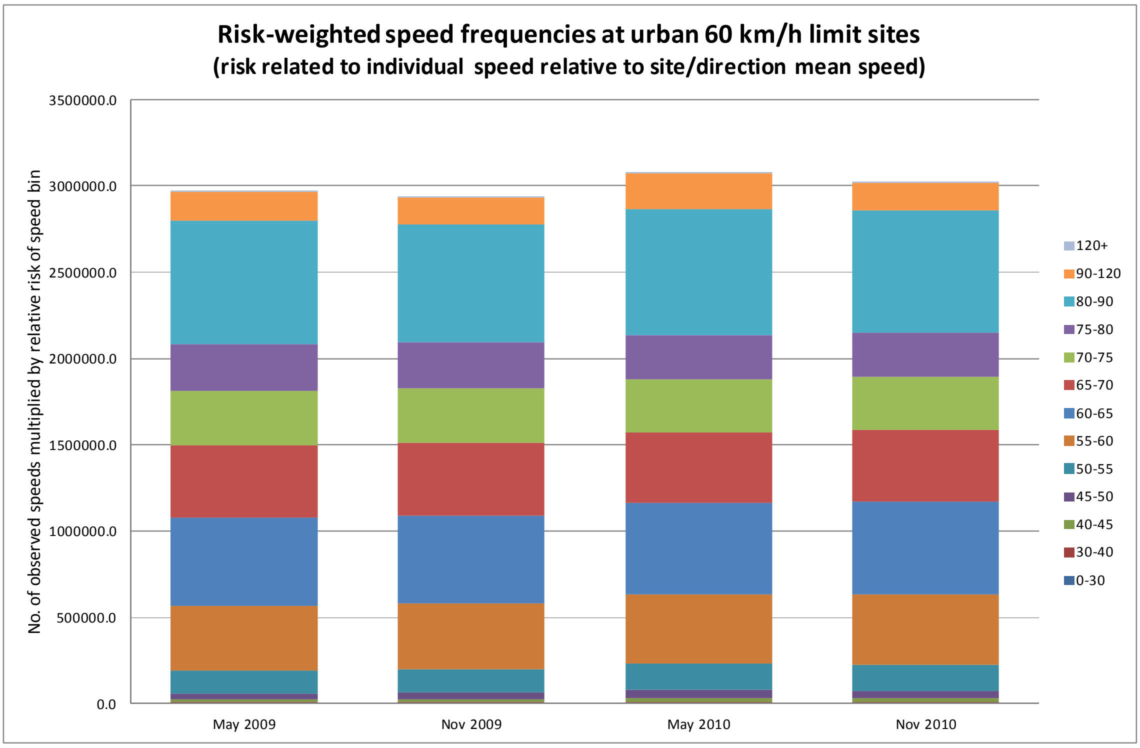


Figure 7: *Expected relative casualty crash frequencies by speed survey with contribution from each speed category (60 km/h limit roads)*

There was relatively little change in the expected relative crash frequency pattern at the 60 km/h limit sites over the period of the four surveys, apart from a small increase in the total relative crash frequency in May 2010, apparently contributed principally by an increase in vehicles speeding in the high-risk 90-120 km/h range relative to the mean speeds at the sites at which they were observed (see Figure 7).

Relative risk of absolute speeds

Equation 2 developed for 60km/h limit roads provided an alternative way of risk-weighting the speed measurements in this road environment. The relative risk was calculated for the individual speeds, represented by the mid-mark of their bin, using Equation 2 directly rather than first calculating the difference between the absolute speed and the site/direction mean speed and applying Equation 1 (Figure 8).

It can be seen that there were decreases in the relative crash frequencies associated with the speed categories above 65km/h in May 2010, resulting in the total relative crash frequency being substantially less than the previous surveys. However, by November 2010 the relative crash frequencies from these speeding categories had increased again, especially the crash frequencies associated with speeds above 90km/h on 60km/h limit roads.

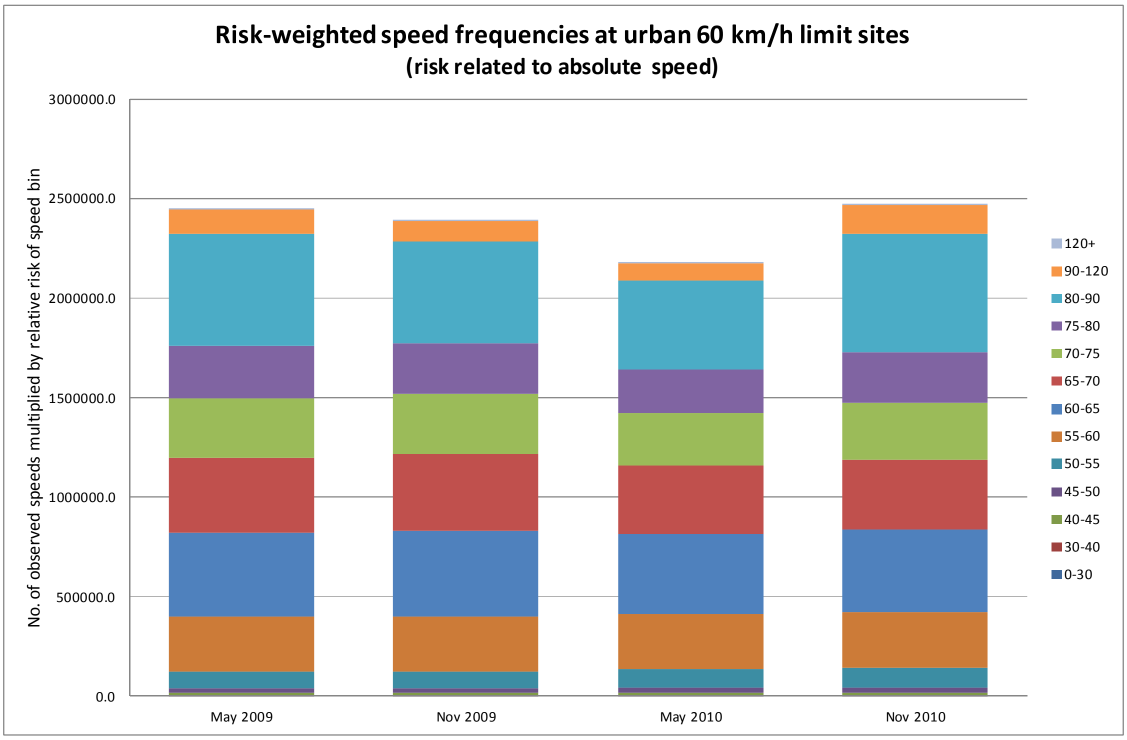


Figure 8: *Relative casualty crash frequencies for each speed category (60 km/h limit roads)*

The trends in the total relative crash frequency in Figures 7 and 8 are substantially different, especially in May 2010. The relative risk-weighting associated with absolute speeds may capture the additional effect of other changes in the speed distributions (e.g., changes in mean or median speed) as well as the speeding pattern. Kloeden (2011) had found a substantial decrease in mean speed at 60 km/h limit sites between November 2009 and May 2010, but this remained at a lower level in November 2010, in contrast with the increase in relative crash frequency in that survey compared with May 2010 (Figure 8).

Alternative models of crash frequencies for urban road speeds

With a focus on illegal speeds, Taylor et al (2000) developed a relationship connecting casualty crash frequency on urban roads with the proportion of drivers exceeding the speed limit, P, and the mean speed by which drivers exceed the limit, V_{ex}. Taking other relevant factors into account, casualty crashes were related to:

$$CC1 = P^{0.141} \exp(0.175\ V_{ex}).$$

Extending the focus on the proportion speeding, Taylor et al (2000) also examined a range of alternative relationships with P(n), the proportion of drivers exceeding the speed limit by “n” miles/h, where n ranged from 0 to 25. The model explaining most of the explainable (i.e. non-random or non-chance) variation in casualty crashes was that including P(15), the proportion exceeding the limit by 15 miles/h (approximately 25 km/h), a level of speeding normally considered to be excessive. The model including relevant traffic and road factors found that urban casualty crashes were related to:

$$CC2 = P(15\text{mph})^{0.325}.$$

The available data from the four surveys allowed these alternative indicators of relative casualty crash frequency to be calculated for the 60 km/h sites in each survey, the exception being that it was necessary to substitute CC2 by:

$$CC3 = P(20km/h)^{0.325}.$$

Comparison of crash frequency indicators from speeds on 60 km/h limit roads

The previous sections have presented a range of different measures based on the analysis of speed data that each purport to be a representation of relative crash risk in urban areas. It has shown that each can be calculated from crash risk curve relationships with absolute or relative speed using the speed survey data collected in Queensland during 2009-2010. Figure 9 compares the risk-weighted frequencies (RWF) based on absolute speeds [RWF(abs), in millions] and speeds relative to mean speed [RWF(rel), in millions] with the overall mean speed (km/h, divided by 20), CC1 and CC3 (divided by 10)

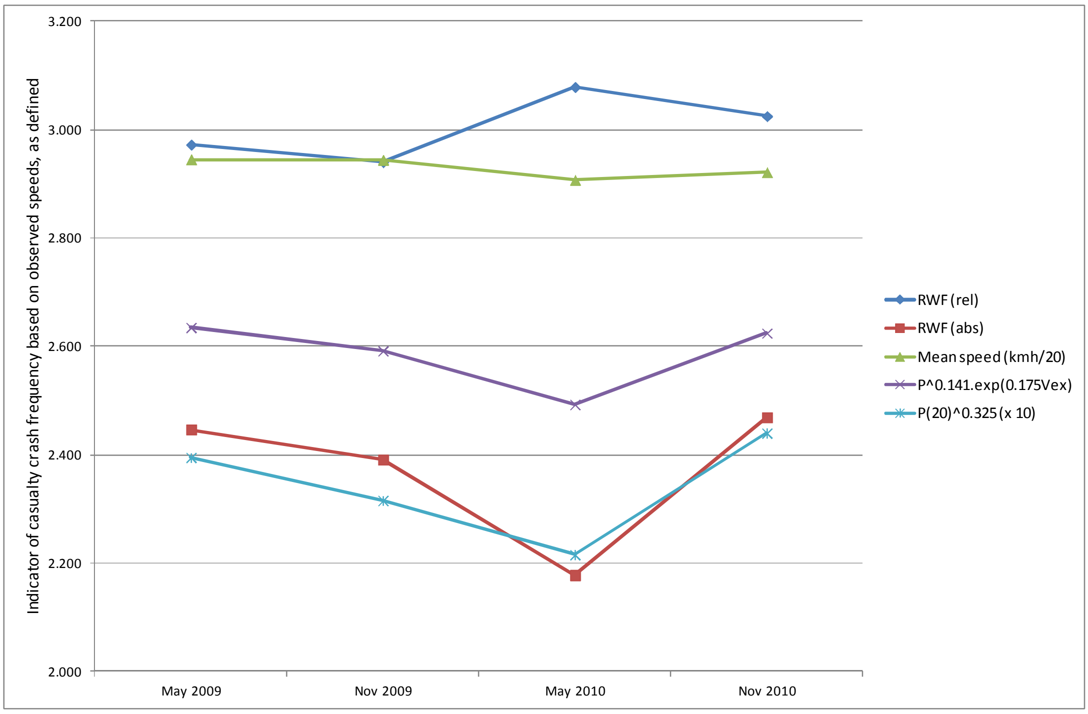


Figure 9: *Comparison of trends in casualty crash frequency indicators based on speed measurements on 60 km/h limit roads (all Queensland)*

As noted previously, RWF(abs) appears sensitive to the substantial decrease in speeding in each category above 65 km/h during May 2010. The decrease in the contribution of this level of speeding to casualty crashes is mirrored almost to the same degree by the trends in CC1 [i.e. $P^{0.141}\exp(0.175V_{ex})$] and CC3 [i.e. $P(20)^{0.325}$]. However, RWF(rel) demonstrates a different trend in the expected contribution of changes in the speed distributions to casualty crashes, perhaps because of its greater focus on the risk associated with individual speeds when they are much higher than the mean speed.

By comparison, the absence of trend in the mean speed at these 60 km/h limit sites indicates that it is insensitive to the substantial changes in the speed distribution illustrated in Figures 7 and 8 and indicated by the trends in the other summary measures.

Selection of the most appropriate summary measure of crash risk derived from speed surveys in urban areas is difficult at this stage. Clearly, the most appropriate summary measure would be that which best relates to crash outcomes associated with the CDOP. This comparison with the crash-based estimates of the effects of CDOP will be presented later at the State-wide level and in each Police Region, where applicable.

Crash frequency indicators on 60 km/h limit roads in Police Regions

Trends in the crash frequency indicators in each Police Region are shown in Figures 10 to 13. There were no usable 60 km/h limit sites in the South Eastern Region.

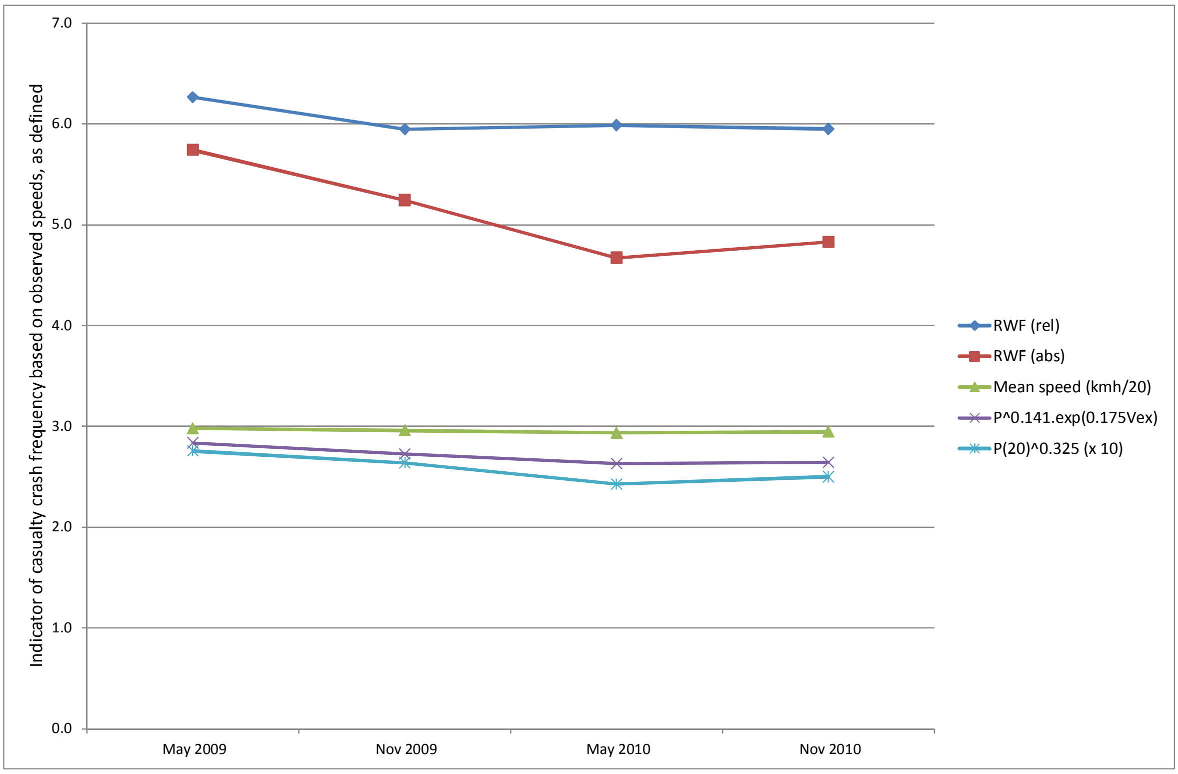


Figure 10: *Comparison of trends in casualty crash frequency indicators on 60 km/h limit roads in BRISBANE Police Region (5 sites)*

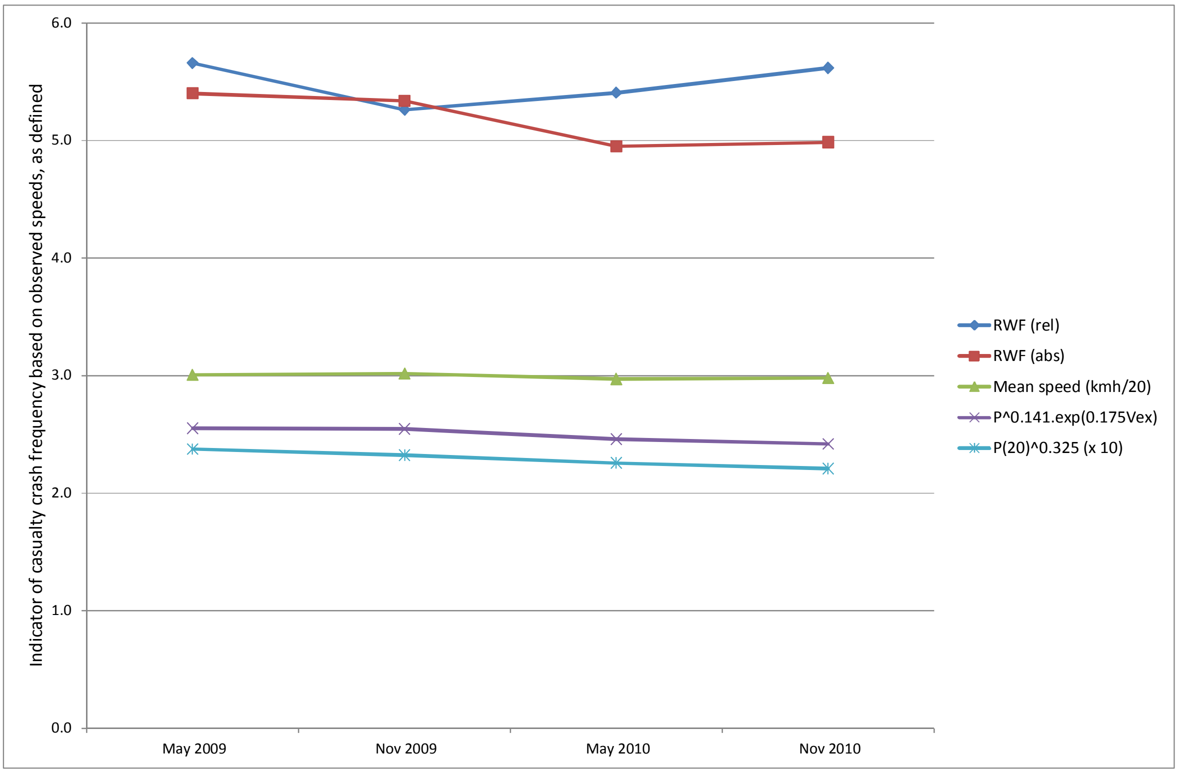


Figure 11: *Comparison of trends in casualty crash frequency indicators on 60 km/h limit roads in CENTRAL Police Region (9 sites)*

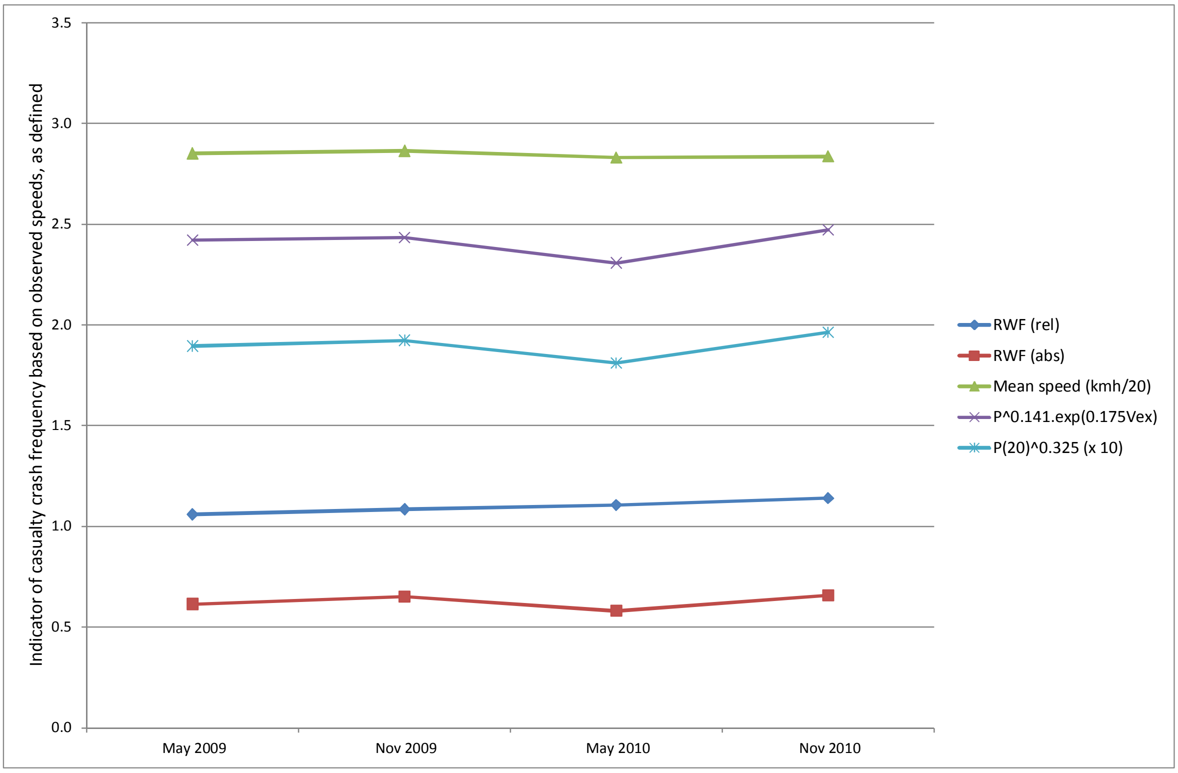


Figure 12: *Comparison of trends in casualty crash frequency indicators on 60 km/h limit roads in SOUTHERN Police Region (10 sites)*

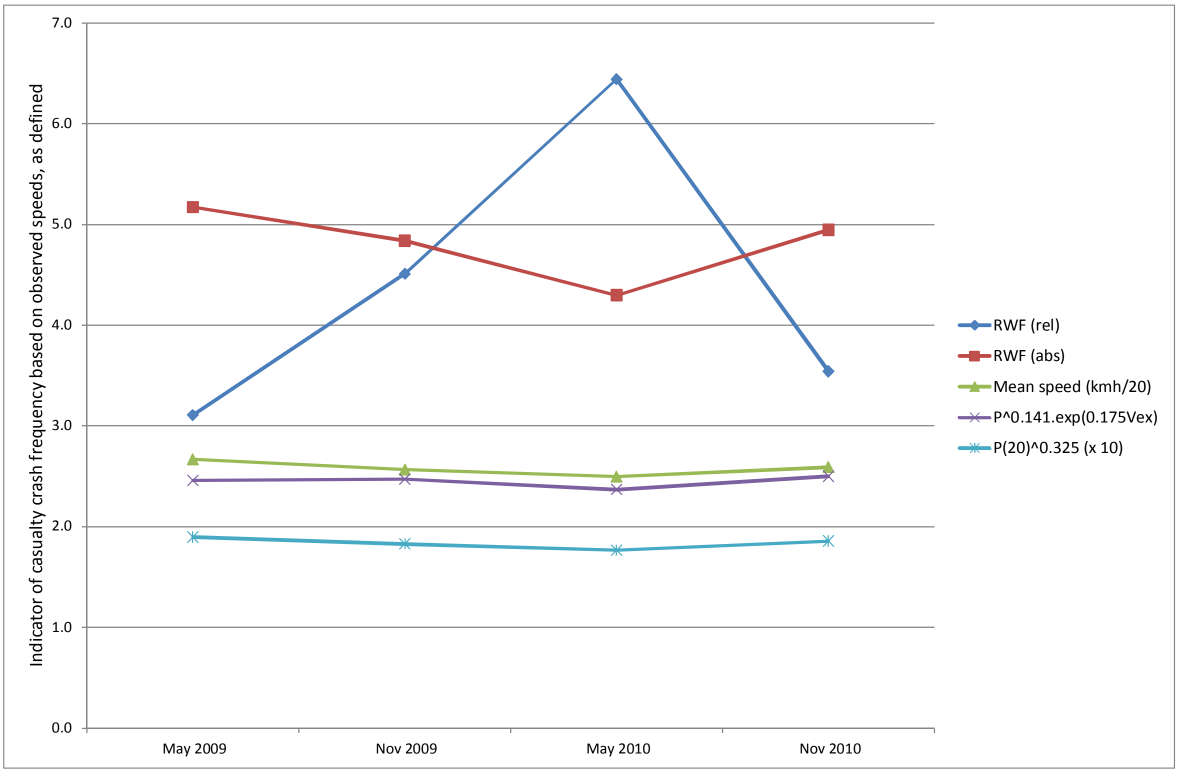


***Figure 13:** Comparison of trends in casualty crash frequency indicators on 60 km/h limit roads in NORTHERN Police Region (2 sites)*

Comparison of crash frequency indicators with estimated crash reductions

Previous sections have evaluated the casualty crash reduction effects of mobile speed cameras across Queensland each year from 1997 to 2011. Crash reductions were estimated within 1 km of the urban mobile camera zone centroids and within 4 km of the rural zone centroids. The reduction in crashes in the "treated" areas was measured relative to changes in a "control" group of crashes outside those areas. Any effect of the mobile speed cameras outside the treated areas would tend to weaken the apparent effect on crashes but add to the effect on vehicle speeds across the full road system.

The estimated relative risks associated with mobile speed cameras, relative to 1992-1996, during each half year are shown in Table 40 together with 95% confidence limits on the risk estimates. The half year estimates during 2009 and 2010 correspond with the crash frequency indicators from the speed surveys in May and November of those years.

Table 40 Estimated relative risk of casualty crashes associated with mobile speed cameras in Queensland during each half year in 2009 to 2011

	1st half (H1) 2009	2nd half (H2) 2009	1st half (H1) 2010	2nd half (H2) 2010	1st half (H1) 2011	2nd half (H2) 2011
Relative risk of casualty crash (RR)	0.813	0.721	0.776	0.744	0.734	0.744
95% LCL of RR	0.761	0.676	0.725	0.696	0.686	0.695
95% UCL of RR	0.869	0.769	0.832	0.795	0.786	0.796

The relative risk estimates and the crash frequency indicators from the 60 km/h limit surveys (Figure 9) are all on different scales making comparisons difficult. For this reason, each estimate and indicator was indexed to its value during the first half (H1) of 2009 or May 2009, respectively (Figure 14).

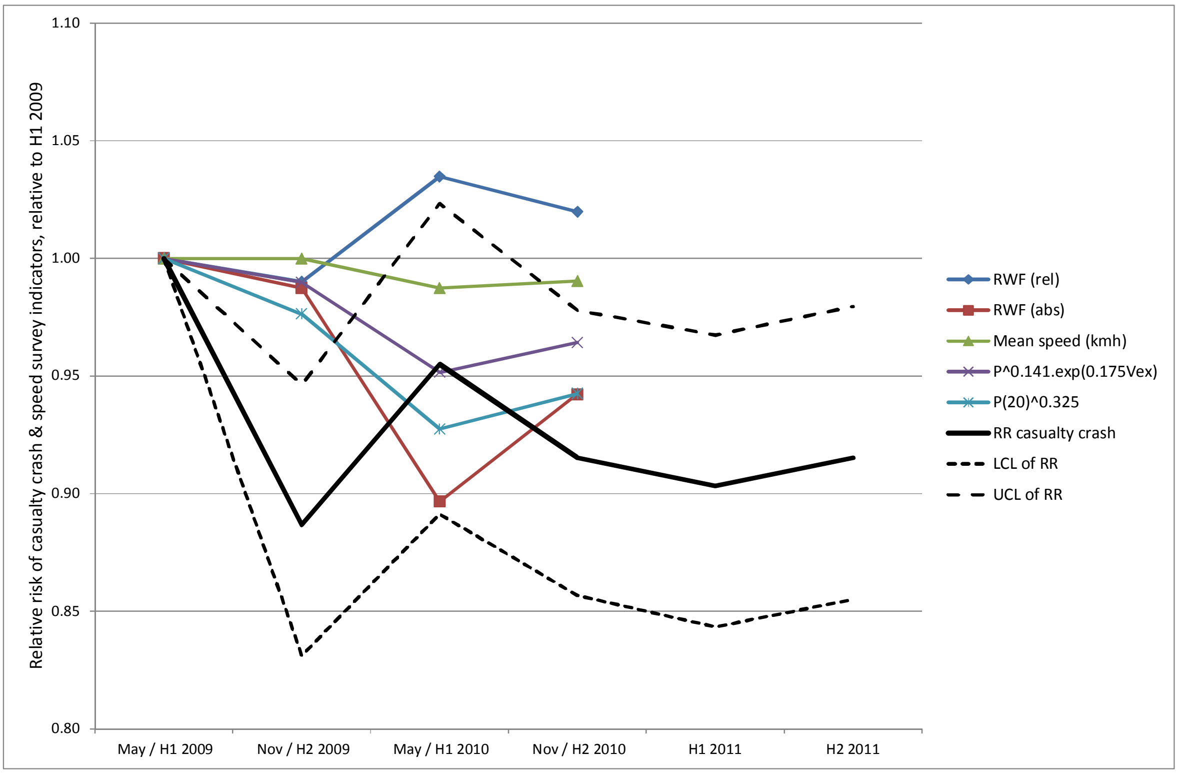


Figure 14: *Crash frequency indicators and estimated relative risk, indexed to H1 2009*

The crash frequency indicators did not reflect the substantial decrease in relative risk during 2009. However, apart from RWF(rel) and mean speed, all other indicators were within the 95% confidence limits for the trend in relative risk during H1 and H2 of 2010.

Figures 15 to 18 show a similar comparison of the estimates and indicators in each Police Region where there were usable speed survey sites with 60 km/h limits.

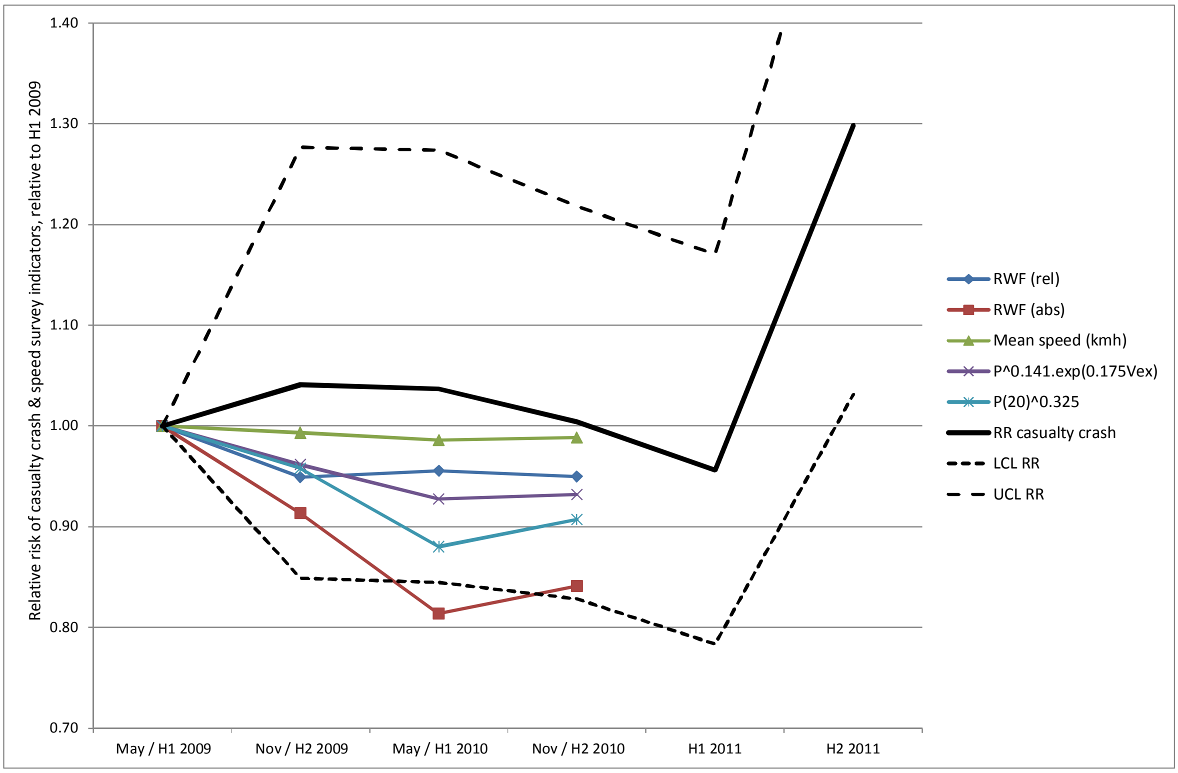


Figure 15: *Crash frequency indicators and estimated relative risk in Brisbane Region*

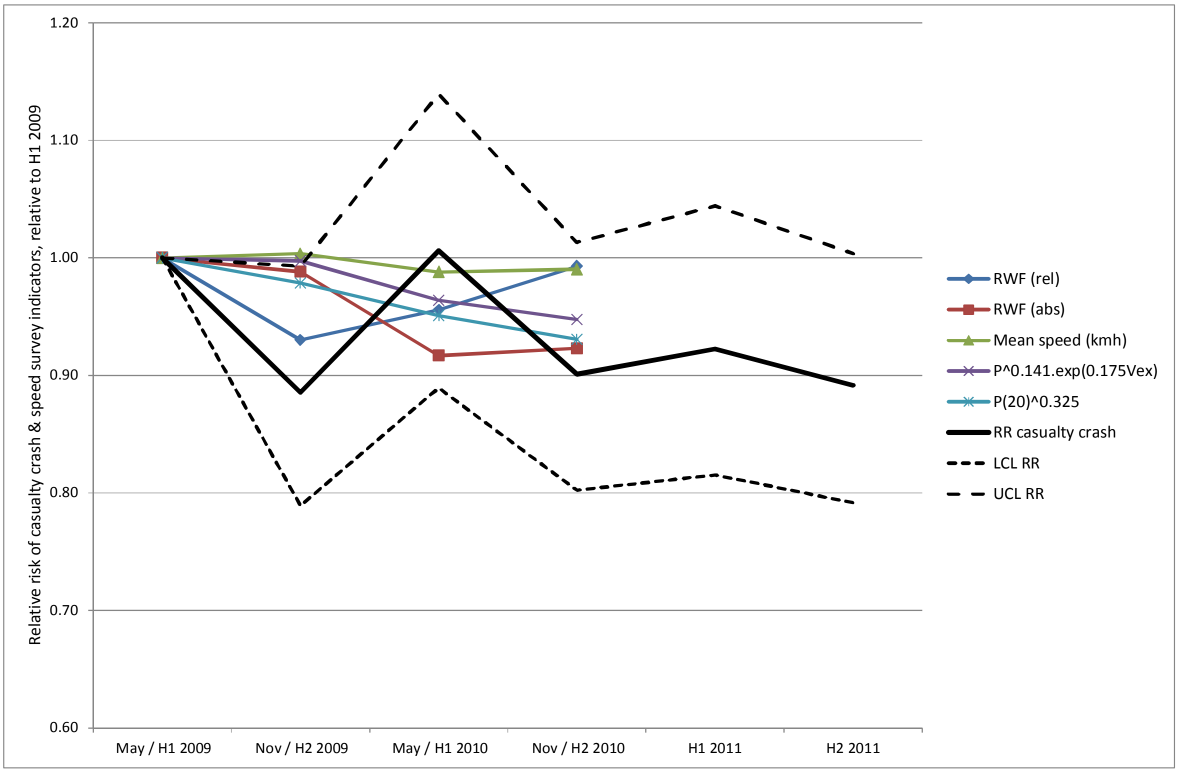


Figure 16: *Crash frequency indicators and estimated relative risk in Central Region*

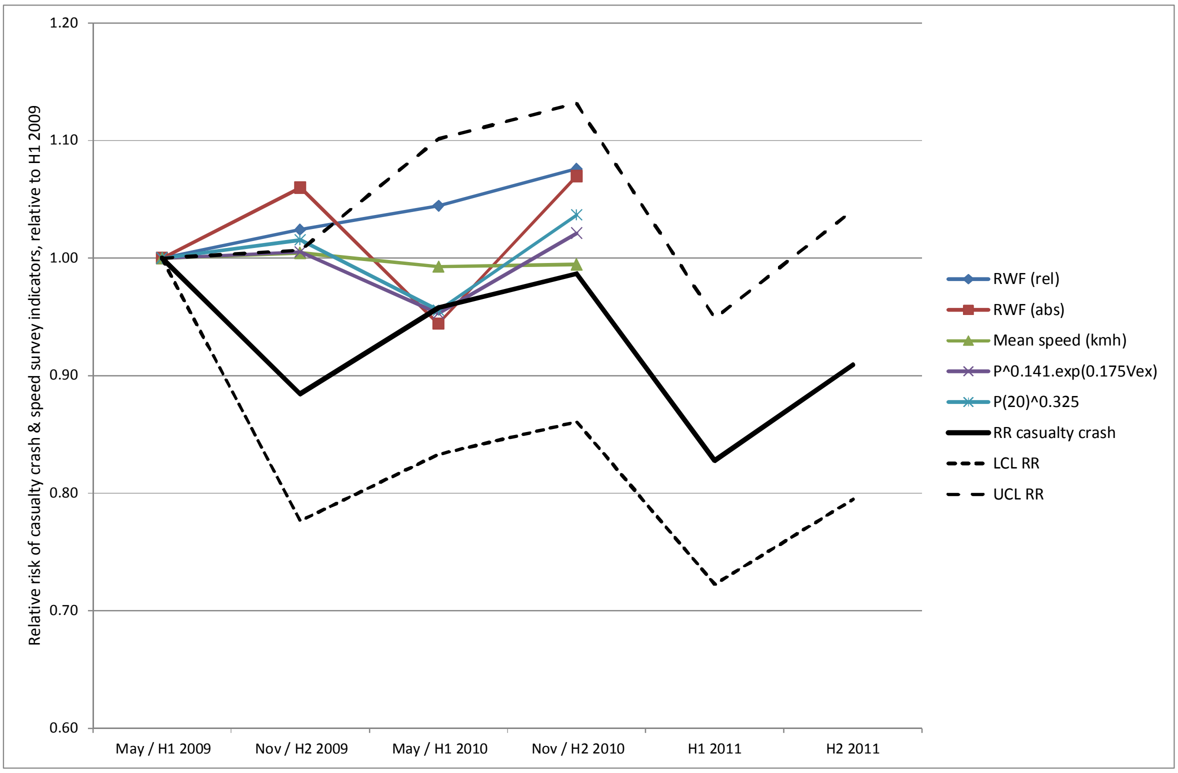


Figure 17: *Crash frequency indicators and estimated relative risk in Southern Region*

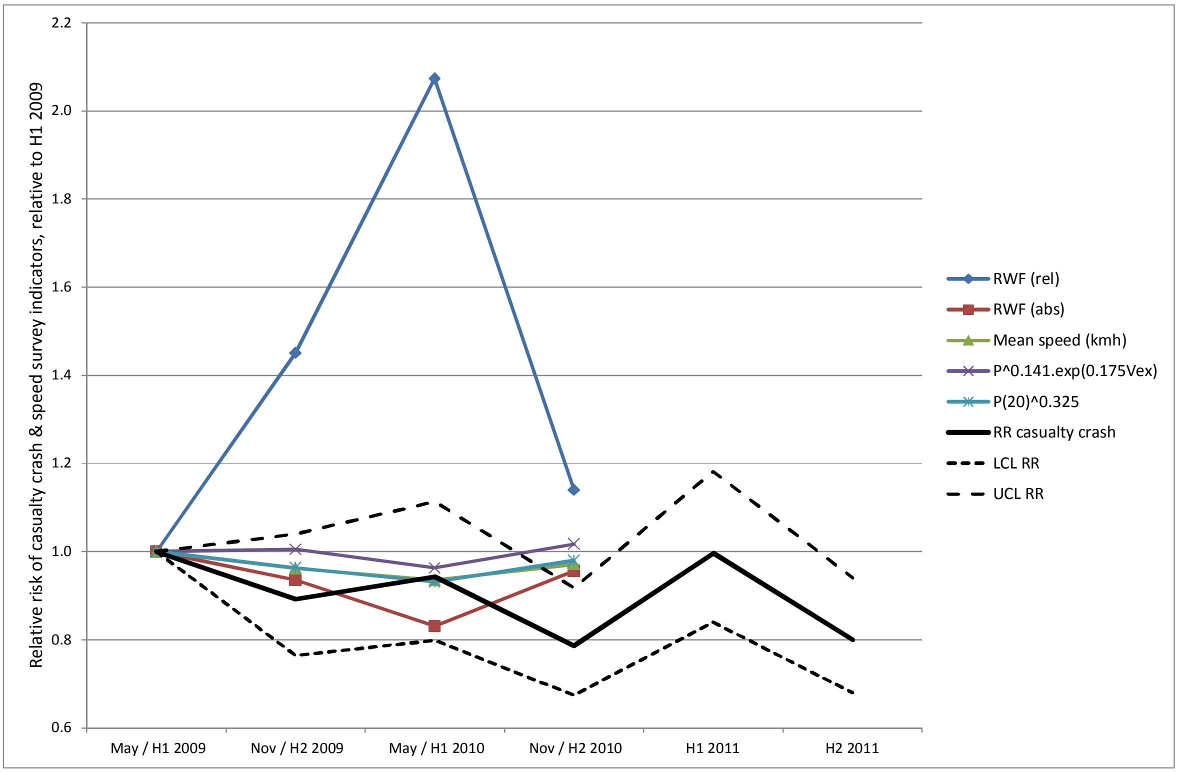


Figure 18: *Crash frequency indicators and estimated relative risk in Northern Region*

The relative risk estimates in each Police Region have wider confidence limits than those estimated for all casualty crashes in Queensland (Table 40) because there were fewer crashes in each region. The crash frequency indicators generally fell within the confidence limits, except for H2 of 2010 in the Northern Region, however in most cases the regional indicators were poor at representing the general downward trend in relative risk.

4.2.4. 80 and 100 km/h speed limit sites

Relative risk of individual speeds relative to mean speed

Equation 3 could be applied to the speed measurements at the speed survey sites with 80 and 100km/h speed limits. Kloeden et al (2001) developed this relationship in these road environments, so it could be applied with confidence. However, the expected casualty crash frequencies can be calculated based only on the relative difference between the individual speeds, represented by the mid-mark of their bin, and the site/direction mean speed. In addition, the analysis of speeds observed at 60 km/h sites has suggested that the risk-weighted frequencies based on relative speeds, RWF(rel), are less sensitive to changes in the relative risk of casualty crashes associated with the mobile speed cameras than the risk weighting of absolute speeds, RWF(abs).

For these reasons, the risk weighting of speeds observed at 80 km/h and 100 km/h sites was not carried out. An alternative method for estimating the expected changes in casualty crashes from changes in the level of speeds on these higher speed limit roads is described in the following section.

Change in casualty crashes related to changes in mean speed

Cameron and Elvik (2010) have found that the use of Nilsson's (1981, 2004) power relationships, with updated exponents, provides an adequate explanation for the likely effects on road trauma due to changes in mean speed, at least on higher speed roads such as arterial roads, highways and freeways with 80 km/h and 100 km/h limits. In these road environments, they found that the change in the number of casualty crashes is related to the change in mean speed raised to a power of 3.3. From a meta-analysis of a large number of studies in which the ratio of casualty crashes was compared with the ratio of mean speeds, after period relative to before, they estimated the overall exponent of the mean speed ratio to be 3.3 with a standard deviation of 0.37.

The mean speeds at 80 km/h limit sites with four surveys during 2009-2010 (21 sites) were used to estimate the change in casualty crashes relative to May 2009 for each of the three subsequent surveys (Table 41). The estimates indicate that expected casualty crashes on 80 km/h roads fell by 4.2% in November 2009 relative to May 2009, and fell by 6.9% in May 2010, before rising again in November 2010 (but to less than the May 2009 level).

Table 41 Estimated ratios of casualty crashes relative to May 2009 calculated from changes in mean speeds at 80 km/h limit sites (with 95% confidence limits on estimated ratios)

	May 2009	Nov 2009	May 2010	Nov 2010
Mean speed (km/h)	76.05	75.06	74.41	74.67
Casualty crash ratio (relative to May 2009)	1.000	0.958	0.931	0.941
95% LCL of ratio	1.000	0.967	0.946	0.954
95% UCL of ratio	1.000	0.949	0.916	0.929

The mean speeds at 100 km/h limit sites (29 with four surveys during 2009-2010) were also used to estimate the changes in casualty crashes relative to May 2009 (Table 42). The estimates indicate that expected casualty crashes on 100 km/h roads fell by 2% in May 2010, and by 2.9% in November 2010, each relative to the May 2009 level.

Table 42 Estimated ratios of casualty crashes relative to May 2009 calculated from changes in mean speeds at 100 km/h limit sites (with 95% confidence limits on estimated ratios)

	May 2009	Nov 2009	May 2010	Nov 2010
Mean speed (km/h)	94.80	94.85	94.23	93.97
Casualty crash ratio (relative to May 2009)	1.000	1.002	0.980	0.971
95% LCL of ratio	1.000	1.001	0.985	0.977
95% UCL of ratio	1.000	1.002	0.976	0.965

Change in casualty crashes in each Police Region

Mean speeds on 80 km/h limit roads in Queensland varied across Police Regions, but in general they all decreased in May 2010 relative to that in May 2009 (Figure 19). There were no sites in the South Eastern region with four speed surveys during 2009-2010.

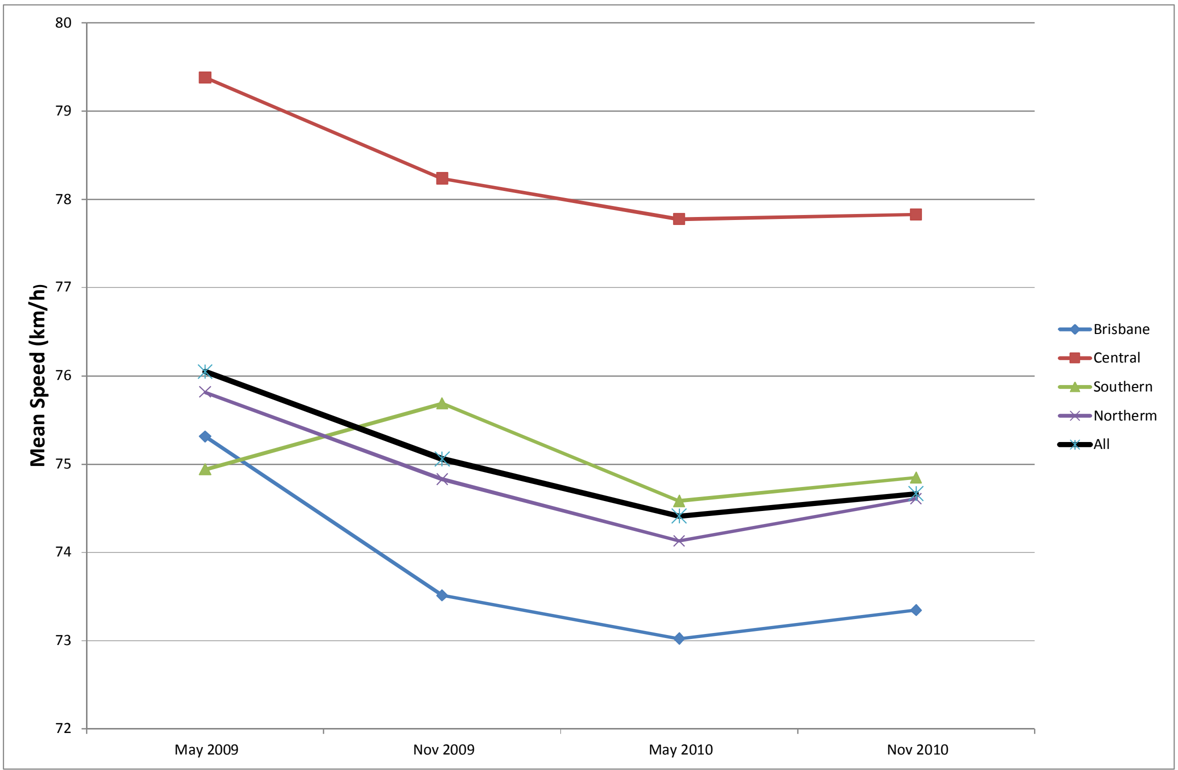


Figure 19: *Mean speeds at 80 km/h limit sites in each Police Region plus overall average*

The expected casualty crash ratios on 80 km/h roads followed similar trends in each Police Region as for 80 km/h roads overall (Figure 20), with reductions in expected crashes during May 2010 (except in the Southern region) compared with May 2009. The reduction in casualty crashes in Brisbane was estimated to be nearly 10% during May 2010.

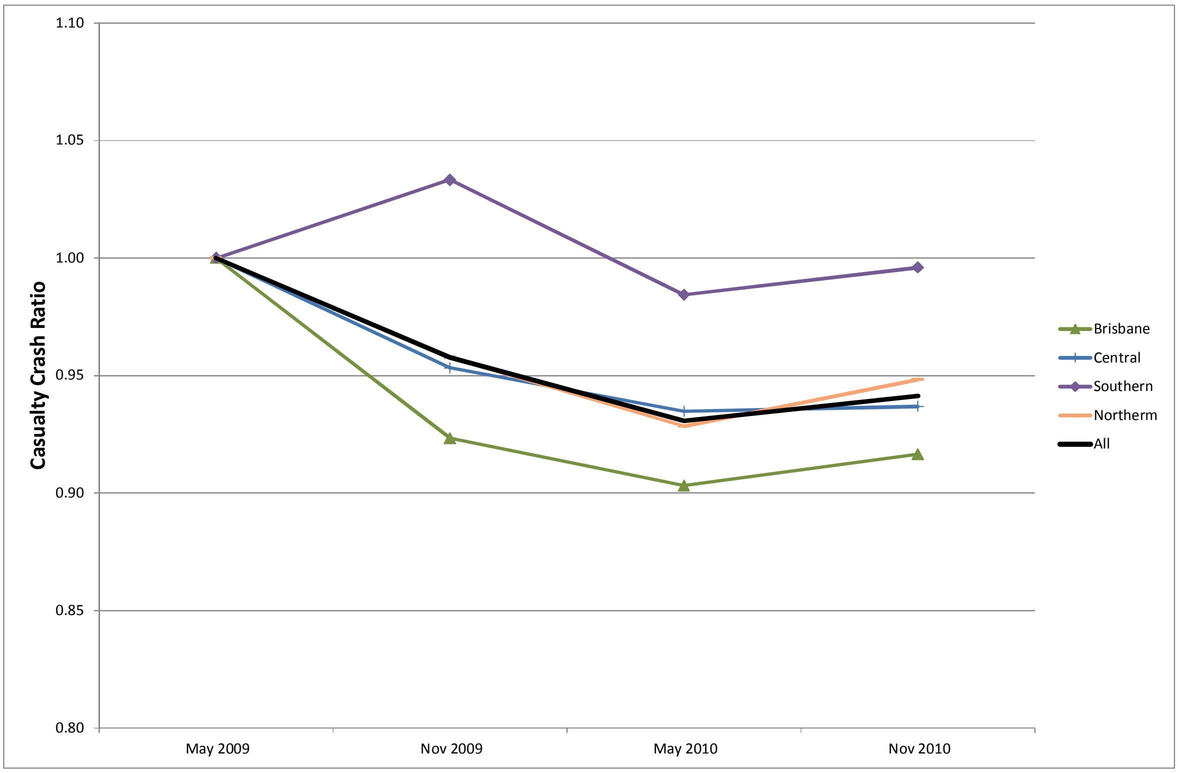


Figure 20: *Casualty crash ratio relative to May 2009 at 80 km/h speed limit sites in each Police Region plus overall Queensland*

Mean speeds on 100 km/h limit roads in Queensland also varied across Police Regions, with increasing trends in the Southern and Northern regions but a decreasing trend in the South Eastern region and a substantial decrease in the Central region during May 2010 (Figure 21). There were no sites surveyed on 100 km/h roads in the Brisbane region.

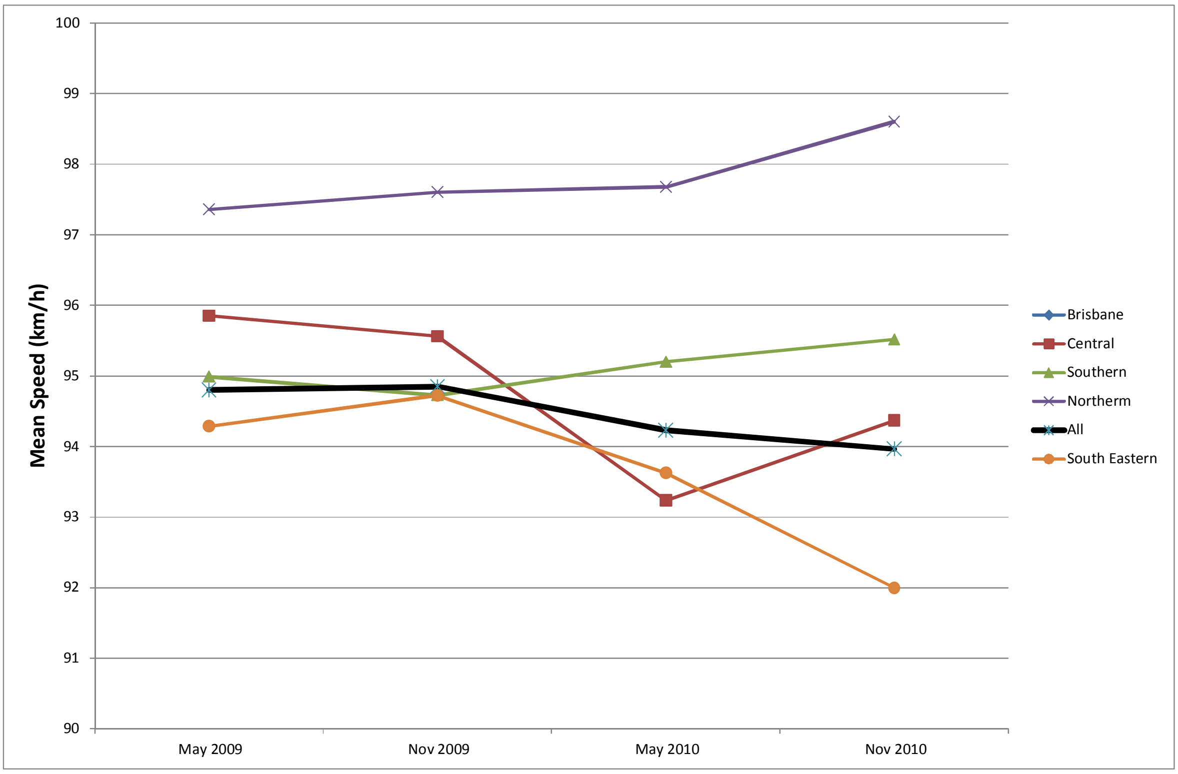


Figure 21: *Mean speeds at 100 km/h limit sites in each Police Region plus overall average*

As expected from the disparate trends in mean speeds on 100 km/h roads across Police Regions, the expected casualty crash ratios indicate increases in crashes in some regions during 2010 but substantial decreases (8-9%) in the Central and South Eastern regions during some periods in 2010 (Figure 22).

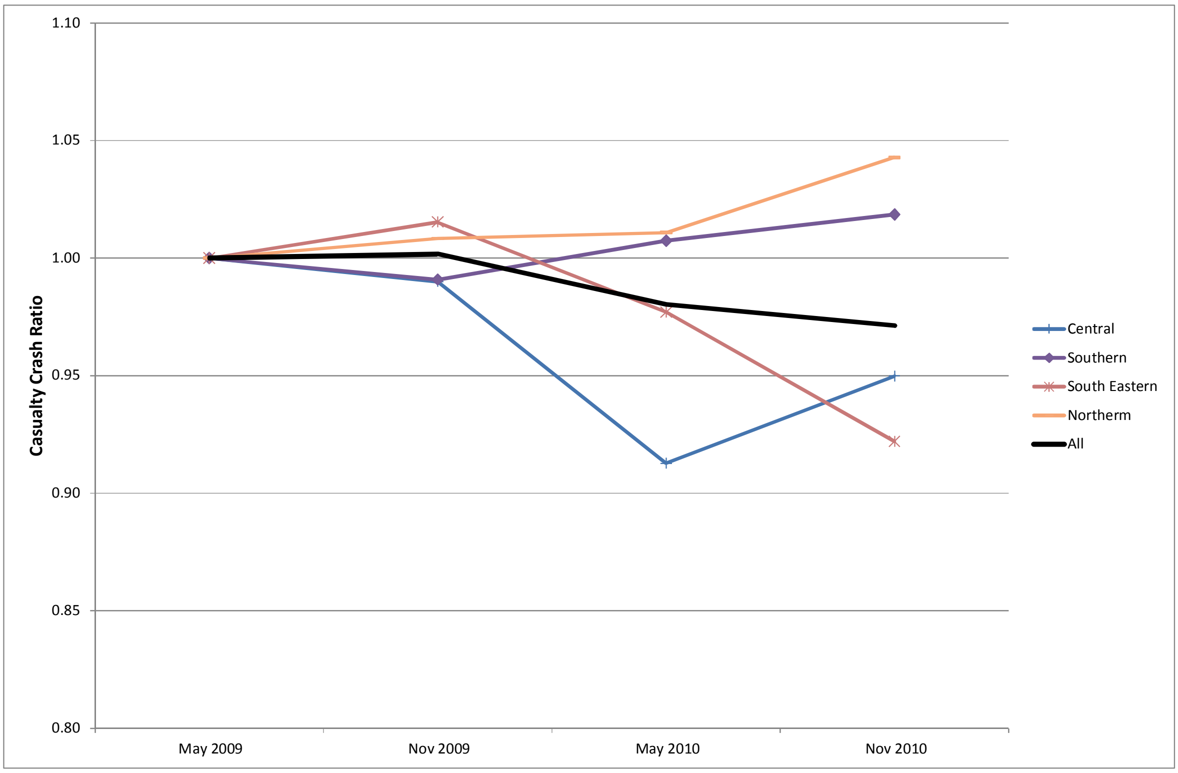


Figure 22: *Casualty crash ratio relative to May 2009 at 100 km/h speed limit sites in each Police Region plus overall Queensland*

Comparison of estimated casualty crash ratios with estimated crash reductions

The casualty crash ratios in each Police Region and Queensland overall were compared with the estimated relative risks of casualty crashes associated with mobile speed cameras during each half year, relative the ratios and risk estimates during May 2009 and H1 2009, respectively. The relative risk estimates for each Police Region were not included in this analysis because of their wide confidence limits, however the risk estimates for all casualty crashes in Queensland (Table 40) were considered sufficiently reliable for this purpose.

Apart from 80 km/h limit sites in the Southern Region, the trend in the casualty crash ratios were consistent with the downward trend in the estimated relative risk since H1 2009 (Figure 23).

However, the casualty crash ratios estimated from the mean speeds at 100 km/h limit sites were all outside the 95% confidence limits for the relative risk during H2 of 2009 (Figure 24). During the 2010 half years, only the casualty crash ratios for sites in the Central and South Eastern Regions (at 100 km/h sites in Queensland overall) were consistent with the downward relative risk trend and within the 95% confidence limits.

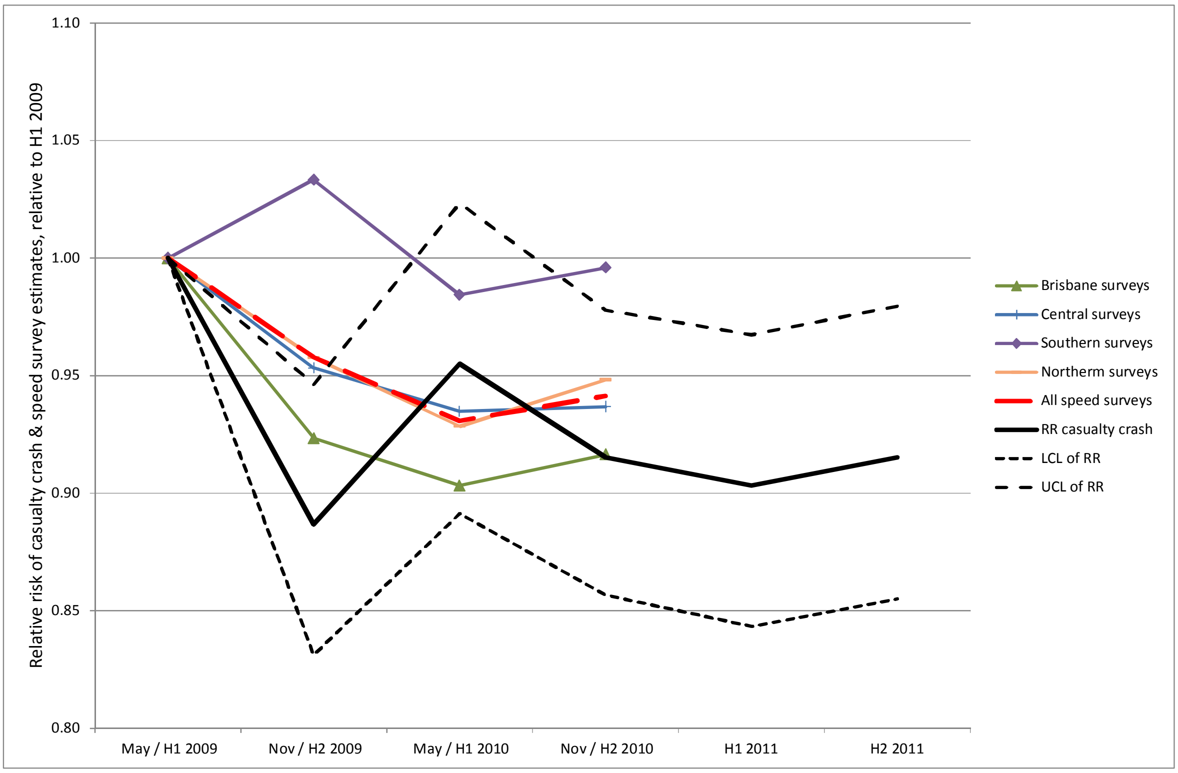


Figure 23: *Speed survey estimates of casualty crash ratios at 80 km/h speed limit sites compared with Queensland relative risk estimates, all indexed to H1 2009*

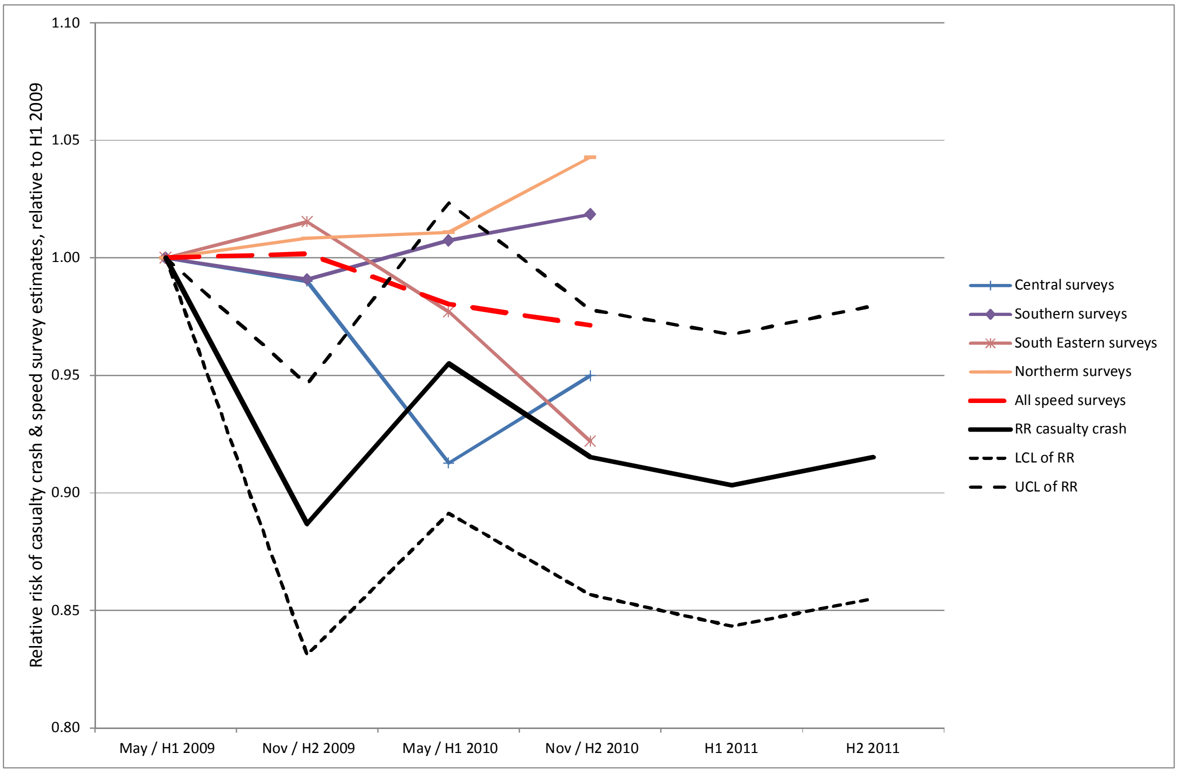


Figure 24: *Speed survey estimates of casualty crash ratios at 100 km/h speed limit sites compared with Queensland relative risk estimates, all indexed to H1 2009*

5. DISCUSSION AND CONCLUSIONS

Application of the CDOP evaluation framework involved separate evaluation of each of the CDOP elements over the history of their installation and then using the results of these specific evaluations to infer the average annual crash effects of each during 2009 to 2012. Capitalising on the mutual exclusivity of the evaluation elements in the framework noted above, the individual results were then combined to give a picture of the effects of the CDOP as a whole on crashes in Queensland. Across all regions, estimated serious casualty crash reductions associated with CDOP were relatively consistent over the four years studied ranging between 23% and 26% reductions. A similar magnitude of reduction was associated with all casualty crashes and crashes of all severities, suggesting CDOP is associated with crash reductions which are uniform by crash severity. During both 2009 and 2010, this translated to an absolute saving of around 6000 crashes of all severities and between 1300 and 1400 serious casualty crashes in each year. A similar magnitude in reduction of serious casualty crashes was also estimated for 2011 and 2012 suggesting program effects are being maintained at a relatively steady level over the 4 years considered. Conversion of the estimated crash savings into cost savings estimated annual savings of around $650M associated with the program valued using Human Capital crash costs and around $1.1B valued using Willingness to Pay estimates. Over 80% of the total crash cost savings stem from savings in serious casualty crashes.

The red light camera element of the CDOP has been in operation in Queensland for over 20 years meaning there was a large number of sites and extensive crash data on which to base the analysis. Consequently, the evaluation results for the 621 unique red light cameras sites are likely to be highly robust. The test run of the evaluation framework by Newstead and Cameron (2012) showed particularly strong associated effects for targeted intersection crashes: RR 0.58 (0.48-0.69, $p<0.00005$) and, in contrast to previous studies, the test run evaluation showed no increase in rear end crashes. This might be as a result of the close proximity of each of the red light camera sites to a mobile speed camera site, hence ensuring general speed compliance at red light camera enforced intersections which could prevent rear end crashes. Unfortunately the absence of red light cameras not in close proximity to a mobile speed camera site prevented explicit assessment of the overlay effects of the mobile camera site on red light camera crash effects.

Despite the large number of sites on which the red light camera evaluation was based, even the extended crash data available for this evaluation were insufficient to allow estimation of yearly crash effects associated with the program. Consequently, only average crash effects over the post implementation period were estimated and it was assumed that the average crash effects applied equally over each post intervention year in estimating annual 2009-2012 crash effects associated with the red light cameras. This assumption is probably not unreasonable given red light cameras are a static and generally highly visible technology which should achieve stable crash effects after an initial short familiarisation period. Reflecting the robust evaluation estimates and the likely stable crash effects, this CDOP evaluation did not re-estimate red light camera effectiveness. The estimated crash effects from the test run in combination with the observed crashes at red light cameras over 2009-2012 translated to a savings of 110 casualty crashes associated with red light cameras per year, saving society $17-19 (HC) or $28-31 (WTP) million per year.

Two red light speed cameras and 9 analogue fixed speed cameras were made active during the period of observed crash data (prior to December 2012). In addition, average and fixed point speed cameras on a segment of the Bruce Highway between Landsborough and the

Glass House mountains, fixed speed digital cameras in the Clem 7 and Airport-Link tunnels and digital fixed speed cameras in two additional locations were made active. Of the analogue cameras, 2 were excluded from analysis due to suspected site contamination. The Airport-Link cameras could not be evaluated because no crashes have been recorded there prior to December 2012. The remaining fixed digital cameras had less than 5 months of post activation casualty crash data. The limited number of sites and the short after installation period of crash data available meant that the associated crash estimates obtained from the combined analysis of fixed speed cameras were not statistically reliable. With more observation time, a further full evaluation of the effectiveness of fixed spot speed cameras is likely to be more reliable given the similarity of evaluating these CDOP elements to the successful red light camera evaluation.

A cross sectional comparison of the Clem 7 and the Airport-Link routes with the Port of Brisbane Motorway and the Southern Cross Way was undertaken. These control sections, although not tunnels, had suitable crash volume data available, were similarly located and attracted a similar speed and freeway characteristics of traffic. However, the comparability of these sites was questionable given that they are not tunnels. The statistical reliability of the tunnel analysis is also put into question by the fact that it is based on only two treatment crashes. Based on the comparisons made, the Clem 7 cameras were found to be associated with a substantial (91%) reduction in casualty crashes in the tunnel. However the total contribution of the Clem 7 tunnel cameras in terms of casualty crashes saved per year is only one. Thus regardless of the effectiveness of the Clem 7 cameras, their state-wide contribution to crashes saved will always be small: e.g. less than 0.04% of all casualty crash savings.

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

Over 96% of casualty crash savings associated with CDOP was derived from the mobile speed camera program which is the CDOP technology that covers by far the largest proportion of the crash population in Queensland. The mobile cameras were found to produce strong crash effects localised in space with 2009 to 2012 casualty crash reductions averaging around 23% over all regions. This translated to 3,300 casualty crashes per year, saving society $550-600 million (HC) or $950-980 million (WTP). The analysis of time based effects in the trial run, adds the understanding that the strong localised effect in space identified is generalised over time. In practice this suggests that mobile camera site visitation frequency could be relatively low giving ability to cover more sites in the same hours of camera operation. This is certainly contrary to the current practice of high visitations made to certain sites. There was no evidence that use of mobile cameras in covert mode has changed the hypothesised area of influence of the mobile cameras.

Application of the mobile speed camera evaluation framework to the crash data identified that there was only sufficient data to give reliable annual and half-yearly all region estimates of crash effects by crash severity; further disaggregation by region led to mostly non-significant crash reduction estimates regardless of the time interval used. Although this meets the objective of providing annual estimates of CDOP crash effects by police region, it limits the accuracy to some degree of comparing crash effects with variation in travel speeds at the half yearly level as presented in Section 4.2.

Analysis of 2009-2010 speed survey data showed trends for decreased speeds. Figure 8 and Figure 9 demonstrated trends for decreased speeding in 60 km/h surveyed speed zones, and decreased average speeds were observed in 80 km/h and 100km/h (in all but Southern and Northern regions). Overall, casualty crash risk reductions estimated from the speed survey data for all regions across all speed zones were similar in trend to those estimated through the evaluation of CDOP based on actual crash data. Similarities observed between regional speed survey and mobile speed camera program crash risks were sufficient to suggest evidence of a causal path between operation of the CDOP and measures crash reductions observed reductions in travel speed across Queensland.

In summary, this evaluation of the Queensland CDOP has shown through the 2009 to 2012 period, large associated crash reductions and associated reductions in speeding behaviour. A number of recommendations are made in the next section to enhance the future application of the framework.

6. RECOMMENDATIONS

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

1. *Continued periodic application of the framework to monitor CDOP crash effects:* This report has detailed the application of the CDOP evaluation framework to estimate crash effects of the CDOP program in 2009 through to 2012. Property damage only and minor injury crashes were only evaluated to 2010 and 2011 respectively. Fixed digital speed camera analyses in particular would benefit from further evaluation with additional crash history. Future applications of the framework are recommended, most likely on an annual basis, to derive estimated crash effects of the CDOP in the years after 2012. Due to noted delays in crash data availability, updates may have to consider hospital and fatal crashes initially, followed by minor and non-injury crashes later as the data becomes available.

    a. As part of the recommended updates there will need to be full re-runs of evaluations of fixed spot speed cameras, intersection speed and red light cameras and point to point cameras with more data from a longer post-activation period. Many fixed digital cameras had not been activated by 2012 and those that were had insufficient post-activation time to be analysed reliably.

2. *Data Enhancements*: If possible, intersection locations across Queensland should each be allocated a unique identifying number which is appended to the crash data. This will allow individual intersections to be reliably identified without the need to use road names which can be variable.

3. *Speed / red light compliance monitoring at fixed camera sites*: Institution of regular speed / red light infringement monitoring data are recommended for new fixed camera sites both before and after installation and at a suitable set of control sites to monitor speed and red light compliance related to the fixed camera technologies.

4. *Comparison of general speed monitoring measures with crash outcomes*: The full range of recommended speed behaviour summary measures should continue to be calculated for each speed survey time point. In addition, better estimates of all speed zone regional averages are possible if speed survey sites included all speed zones within a region.

7. REFERENCES

Cameron, M.H. and Elvik, R. (2010) *Nilsson's Power Model connecting speed and road trauma: Apllicability by road type and alternative models for urban roads*. Accident Analysis and Prevention, 42: 1908-1915.

Cameron, M. H. (2013) 'Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding'. *Journal of the Australasian College of Road Safety*, Vol. 24, No. 3.

Doecke, S. D., Kloeden, C. N., McLean, A. J. (2011) *Casualty crash reductions from reducing various levels of speeding,* Report No. CASR076. Centre for Automotive Safety Research, Adelaide.

Kloeden, C.N. (2012), *Vehicle speeds on Queensland roads – November 2011.* Centre for Automotive Safety Reasearch, The Univeristy of Adelaide.

Kloeden, C.N., McClean, A.J. and Glonek,G. (2002), *Re-analysis of travelling speed and the rate of crash involvement in Adelaide, South Australia.* Report CR207, Australian Transport Safety Bureau, Canberra, Australia.

Kloeden, C.N., Ponte, and McLean, A.J. (2001), *Travelling speed and the rate of crash involvement on rural roacs*. Report CR 204, Australian Transport Safety Bureau, canberra, Australia.

Newstead, S.V. & Cameron, M.H. (2012) *Development of an Evaluation Framework for the Queensland Camera Detected Offence Program (CDOP)*, Monash University Accident Research Centre

Nilsson, G., (2004) *Traffic safety dimensions and the Power Model to describe the effect of speed on safety.* Bulletin 221, Lunde Institue of Technology, Department of Technology and Society, Traffic Engineering, Lund, Sweeden. http://www.dissertations.se/dissertation/a9952d343f/.

Nilsson, G., (1981) *The effects of speed limits on traffic accidents in Sweeden.* In: Proceedings, International symposium on the effects of speed limits on traffic crashes and fuel consumption, Dublin. OECD, Paris.

Taylor, M.C., Lynam, D.A., and Baruya (2000), *The effects of drivers' speed on the frequency of road accidents.* TRL Report 421, Transport Research Laboratory, Crowthorne, U.K.

8. APPENDICES

8.1. CAMERA TYPES

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

8.1.1. RED LIGHT CAMERAS

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

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

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

8.1.2. FIXED SPOT-SPEED CAMERAS

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

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

1. ‘FIXED SPEED CAMERA AHEAD FOR ROAD SAFETY’ (placed furthest from the camera site)

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

8.1.3. COMBINED RED LIGHT SPEED CAMERAS

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

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

8.1.4. POINT TO POINT CAMERAS

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

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

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

8.1.5. MOBILE SPEED CAMERAS

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

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

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

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

8.2. CONTROL AND TREATMENT CRASH SELECTION

Table 403 Treatment and Control Selection Criteria

<table>
<tr><th></th><th>Treatment Crash coded as:</th><th>Control Crash coded as:</th></tr>
<tr><td>Red Light cameras</td><td>Signalised Intersection, ≤100m from camera</td><td>Not identified in this evaluation</td></tr>
<tr><td>Red Light speed Cameras</td><td>Signalised Intersection
≤100m from camera
Not a RLC treatment crash</td><td>Signalised intersection >100m from camera, not a RLC, RLSC or FSC treatment crash and
Matched to camera site by:
• Intersection configuration (T, Y or X)
• SLA and if needed surrounding SLA
• Speed limit
• Divided or undivided road</td></tr>
<tr><td>Fixed Spot Speed Cameras (except those at PtP site and tunnel sites)</td><td rowspan="2">On same road and not a ramp
≤100m from camera
Not a RLC or RLSC treatment crash</td><td>On same road and not a ramp
>100m from camera
Not a RLC, RLSC or FSC treatment crash
And
Matched to camera site by:
• SLA or <2 km from camera
• On same road
• Speed limit, but widened if 70, 90 or 110</td></tr>
<tr><td>Clem 7 and Airport-Linktunnels</td><td>Not a ramp,
Not a RLC, RLSC or FSC treatment crash
On Southern Cross Way or on Port of Brisbane Motorway</td></tr>
<tr><td>Average Speed cameras and FSC at the same site</td><td>On same road and not a ramp
Between average speed cameras and 5 km along road North and South of them.
Not a RLC or RLSC treatment crash</td><td>On same road and not a ramp
>100m from camera
Not a RLC, RLSC or FSC treatment crash
And
Matched to camera site by:
• On same road
• 7.2 km North/South of treatment section</td></tr>
<tr><td>Mobile Speed Cameras</td><td>≤1km from camera in ≤80 km speed zones and
≤4km from camera in >80km speed zones
Not a RLC, FSC or RLSC treatment crash</td><td>Not a MSC, RLC, RLSC or FSC treatment crash
And
>1km from camera in ≤80 km speed zones and
>4km from camera in >80km speed zones
And matched to Police Region. All crashes in the Brisbane region were considered in a in ≤80 km speed zone</td></tr>
</table>

8.3. CRASH COSTS BY SEVERITY YEAR AND POLICE REGION

Table 414 2012 Average crash costs by severity, crash year and Police region according to the distribution of mobile camera crashes

		WTP 2012					HC 2012				
	Crash Year	Serious Casualty Crash	Minor Injury Crash	PDO	all crash	Casualty Crash	Serious Casualty Crash	Minor Injury Crash	PDO	all crash	Casualty Crash
Brisbane	2008	$535,599	$83,533	$11,920	$165,766	$237,828	$372,798	$17,208	$11,647	$98,086	$138,574
	2009	$524,362	$86,553	$11,920	$168,205	$246,742	$368,734	$17,208	$11,647	$100,950	$145,828
	2010	$509,014	$85,802	$11,920	$163,242	$240,613	$363,184	$17,208	$11,647	$99,068	$143,766
	2011	$525,620	$86,908			$244,226	$369,189	$17,208			$143,425
	2012	$487,350					$355,350				
Central	2008	$870,519	$82,503	$11,920	$225,835	$393,341	$493,916	$17,208	$11,647	$120,226	$205,248
	2009	$988,704	$84,939	$11,920	$258,486	$472,703	$536,656	$17,208	$11,647	$133,881	$240,079
	2010	$895,818	$84,468	$11,920	$221,625	$414,752	$503,065	$17,208	$11,647	$117,503	$214,990
	2011	$755,900	$85,184			$396,106	$452,466	$17,208			$218,980
	2012	$811,007					$472,395				
Northern	2008	$851,249	$81,229	$11,920	$250,182	$410,233	$486,947	$17,208	$11,647	$135,030	$217,912
	2009	$836,427	$86,876	$11,920	$237,815	$399,820	$481,587	$17,208	$11,647	$127,793	$211,090
	2010	$633,011	$86,448	$11,920	$189,150	$333,524	$408,025	$17,208	$11,647	$112,072	$193,879
	2011	$515,729	$87,870			$284,921	$365,612	$17,208			$177,666
	2012	$808,088					$471,339				
South Eastern	2008	$709,368	$85,741	$11,920	$216,002	$319,184	$435,638	$17,208	$11,647	$119,374	$173,840
	2009	$628,434	$87,031	$11,920	$186,055	$282,729	$406,370	$17,208	$11,647	$105,675	$157,876
	2010	$555,558	$86,935	$11,920	$170,434	$261,510	$380,016	$17,208	$11,647	$101,016	$152,364
	2011	$679,719	$87,378			$312,753	$424,917	$17,208			$172,334
	2012	$677,028					$423,943				
Southern	2008	$752,972	$79,991	$11,920	$192,555	$333,631	$451,407	$17,208	$11,647	$106,653	$180,853
	2009	$734,125	$84,179	$11,920	$201,365	$365,461	$444,591	$17,208	$11,647	$113,739	$202,170
	2010	$739,495	$81,727	$11,920	$188,647	$359,610	$446,534	$17,208	$11,647	$106,664	$198,583
	2011	$713,043	$85,473			$367,763	$436,967	$17,208			$206,022
	2012	$706,743					$434,689				
All regions	2008	$700,636	$83,012	$11,920	$200,084	$312,311	$432,481	$17,208	$11,647	$111,704	$171,382
	2009	$698,248	$86,103	$11,920	$201,933	$325,558	$431,617	$17,208	$11,647	$113,226	$179,314
	2010	$633,220	$85,340	$11,920	$182,543	$299,464	$408,101	$17,208	$11,647	$105,597	$169,978
	2011	$625,352	$86,649			$304,189	$405,256	$17,208			$173,910
	2012	$656,152					$416,394				

8.4. MOBILE CAMERA CRASH SAVINGS CALCULATIONS

Table 425 Annual crash counts in mobile speed camera zones of influence by crash severity and Police region, after introduction: 2008-2012

Region	Crash Year	Serious Casualty	Minor Injury	PDO	All	Casualty
Brisbane	2008	1512	2918	2075	6505	4430
	2009	1521	2636	2089	6246	4157
	2010	1521	2637	2126	6284	4158
	2011	1363	2438			3801
	2012	1408				
	average	*1465*	*2657*	*2097*	*6345*	*4137*
Central	2008	738	1135	1461	3345	1873
	2009	761	1012	1539	3319	1773
	2010	685	1001	1556	3256	1686
	2011	737	852			1589
	2012	768				
	average	*738*	*1000*	*1519*	*3307*	*1730*
Northern	2008	561	752	882	2195	1313
	2009	496	692	852	2040	1188
	2010	495	600	892	1987	1095
	2011	467	547			1014
	2012	475				
	average	*499*	*648*	*875*	*2074*	*1153*
South Eastern	2008	770	1287	1040	3097	2057
	2009	711	1256	1092	3059	1967
	2010	697	1174	1075	2946	1871
	2011	694	1130			1824
	2012	675				
	average	*709*	*1212*	*1069*	*3034*	*1930*
Southern	2008	623	1030	1291	2944	1653
	2009	676	886	1353	2915	1562
	2010	583	797	1335	2715	1380
	2011	605	740			1345
	2012	639				
	average	*625*	*863*	*1326*	*2858*	*1485*
All Regions	2008	4204	7122	6749	18086	11326
	2009	4165	6482	6925	17579	10647
	2010	3981	6209	6984	17188	10190
	2011	3866	5707			9573
	2012	3965				
	average	*4036*	*6380*	*6886*	*17618*	*10434*

Table 436 Estimated relative crash risks associated with the Queensland mobile speed camera program by year and police regions: after introduction from 2008 to 2012 (significance where able to be estimated)

Region	Crash Year	Serious Casualty		Minor Injury		PDO		All	Casualty	
Brisbane	2008	0.889	.351	0.836	.074	0.572		0.716	0.839	.025
	2009	0.736	.010	0.802	.032	0.635		0.688	0.748	
	2010	0.756	.019	0.784	.017	0.658		0.696	0.748	
	2011	0.768	.035	0.886	.271				0.808	.009
	2012	0.785	.052							
	average	*0.787*		*0.826*		*0.622*		*0.700*	*0.786*	
Central	2008	0.714		0.856	0.008	0.814		0.794	0.785	
	2009	0.776		0.813	0.001	0.933	0.187	0.844	0.788	
	2010	0.765		0.834	0.003	0.830		0.812	0.796	
	2011	0.764		0.779					0.760	
	2012	0.732								
	average	*0.750*		*0.823*		*0.860*		*0.817*	*0.783*	
Northern	2008	0.989	0.9	0.775	0.001	0.739		0.798	0.847	0.005
	2009	0.879	0.139	0.814	0.014	0.798	0.003	0.807	0.823	0.001
	2010	0.849	0.058	0.709		0.671		0.715	0.748	
	2011	0.877	0.138	0.741	0.001				0.777	
	2012	0.842	0.049							
	average	0.890		0.763		0.735		0.774	0.802	
South Eastern	2008	0.675		0.881	0.153	0.917	0.369	0.815	0.780	
	2009	0.649		0.852	0.071	0.846	0.07	0.781	0.755	
	2010	0.703	0.001	0.779	0.005	0.946	0.563	0.801	0.744	
	2011	0.688		0.811	0.021				0.751	
	2012	0.645								
	average	*0.672*		*0.833*		*0.903*		*0.800*	*0.758*	
Southern	2008	0.722		0.887	0.077	0.875	0.027	0.818	0.797	
	2009	0.785	0.001	0.685		0.801		0.745	0.715	
	2010	0.745		0.766		0.783		0.757	0.739	
	2011	0.665		0.696					0.660	
	2012	0.698								
	average	0.724		0.766		0.819		0.774	0.731	
All Regions	2008	0.773	<0.001	0.848	<0.001	0.800	<0.001	0.795	0.803	
	2009	0.773	<0.001	0.781	<0.001	0.831	<0.001	0.785	0.765	
	2010	0.766	<0.001	0.778	<0.001	0.780	<0.001	0.766	0.759	
	2011	0.747	<0.001	0.765	<0.001				0.739	
	2012	0.735	<0.001							
	average	*0.759*		*0.796*		*0.804*		*0.782*	*0.768*	

Table 447 Lower and upper 95% confidence interval estimate of relative crash risks associated with the Queensland mobile speed camera program by year and police regions: after introduction from 2008 to 2012

Region	Crash Year	Serious Casualty		Minor Injury		PDO		All		Casualty	
		UCL	LCL	UCL	LCL	UCL	LCL	UCL	LCL	UCL	LCL
Brisbane	2008	.694	1.138	.687	1.018	.469	.697	.635	.808	.719	.978
	2009	.583	.928	.656	.981	.517	.781	.609	.776	.643	.870
	2010	.598	.955	.642	.957	.535	.809	.616	.786	.643	.870
	2011	.601	.981	.714	1.099					.688	.948
	2012	.616	1.002								
	average	.618	1.001	.675	1.014	.507	.762	.620	.790	.673	.917
Central	2008	.628	.812	.763	.961	.736	.901	.743	.847	.721	.855
	2009	.681	.883	.722	.915	.841	1.034	.790	.902	.722	.860
	2010	.669	.876	.739	.941	.752	.917	.759	.867	.728	.871
	2011	.670	.871	.687	.884					.694	.832
	2012	.644	.831								
	average	.658	.855	.728	.925	.776	.951	.764	.872	.716	.855
Northern	2008	.836	1.171	.663	.905	.641	.852	.730	.872	.756	.950
	2009	.741	1.043	.691	.959	.688	.926	.736	.885	.732	.926
	2010	.717	1.006	.599	.838	.585	.770	.654	.783	.664	.843
	2011	.737	1.043	.622	.883					.687	.878
	2012	.709	.999								
	average	.748	1.052	.644	.896	.638	.849	.707	.847	.710	.899
South Eastern	2008	.557	.819	.741	1.048	.759	1.108	.733	.906	.686	.886
	2009	.533	.789	.716	1.014	.707	1.014	.703	.867	.663	.859
	2010	.575	.861	.655	.926	.784	1.141	.720	.891	.652	.848
	2011	.562	.841	.679	.969					.658	.858
	2012	.528	.788								
	average	.551	.820	.698	.989	.750	1.088	.719	.888	.665	.863
Southern	2008	.623	.836	.777	1.013	.777	.985	.758	.882	.723	.879
	2009	.679	.908	.600	.783	.715	.897	.691	.802	.648	.788
	2010	.640	.867	.665	.883	.700	.877	.702	.817	.667	.820
	2011	.575	.770	.603	.803					.596	.731
	2012	.604	.806								
	average	.624	.837	.661	.871	.731	.920	.717	.834	.659	.805
All Regions	2008	.718	.831	.794	.906	.753	.850	.765	.825	.765	.843
	2009	.718	.832	.731	.836	.782	.883	.756	.816	.728	.803
	2010	.711	.826	.727	.834	.735	.828	.737	.796	.722	.799
	2011	.693	.804	.713	.822					.702	.778
	2012	.683	.791								
	average	.705	.817	.741	.849	.757	.854	.753	.812	.729	.806

Table 458 Estimated absolute crash saving associated with the Queensland mobile speed camera program by year and police regions: after introduction from 2008 to 2012

Region	Crash Year	Serious Casualty	Minor Injury	PDO	All	Casualty
Brisbane	2008	189	572	1553	2580	850
	2009	546	651	1201	2832	1400
	2010	491	727	1105	2745	1401
	2011	412	314			903
	2012	386				
	average	405	566	1286	2719	1139
Central	2008	296	191	334	868	513
	2009	220	233	111	613	477
	2010	210	199	319	754	432
	2011	228	242			502
	2012	281				
	average	247	216	254	745	481
Northern	2008	6	218	312	556	237
	2009	68	158	216	488	255
	2010	88	246	437	792	369
	2011	65	191			291
	2012	89				
	average	63	203	322	612	288
South Eastern	2008	371	174	94	703	580
	2009	385	218	199	858	638
	2010	294	333	61	732	644
	2011	315	263			605
	2012	372				
	average	347	247	118	764	617
Southern	2008	240	131	184	655	421
	2009	185	407	336	998	623
	2010	200	243	370	872	487
	2011	305	323			693
	2012	276				
	average	241	276	297	841	556
All Regions	2008	1236	1276	1689	4675	2777
	2009	1221	1813	1407	4812	3276
	2010	1215	1767	1966	5254	3230
	2011	1312	1749			3378
	2012	1428				
	average	1282	1651	1687	4914	3165

Table 469 Estimated *Willingness to Pay* crash cost saving associated with the Queensland mobile speed camera program by year and police regions: after introduction from 2008 to 2012

Region	Crash Year	Serious casualty	Minor Injury	PDO	All	Casualty
Brisbane	2008	$101,114,412	$47,817,029	$18,507,259	$427,709,734	$202,176,173
	2009	$286,079,409	$56,327,207	$14,313,104	$476,439,071	$345,559,499
	2010	$249,877,192	$62,337,109	$13,171,636	$448,055,903	$337,056,832
	2011	$216,418,367	$27,262,524			$220,586,578
	2012	$187,936,994				
	average	*$208,285,275*	*$48,435,967*	*$15,330,666*	*$450,734,903*	*$276,344,770*
Central	2008	$257,337,105	$15,752,645	$3,979,376	$195,989,989	$201,778,794
	2009	$217,188,773	$19,771,574	$1,317,371	$158,571,759	$225,479,543
	2010	$188,502,315	$16,829,446	$3,798,890	$167,072,738	$179,210,450
	2011	$172,087,883	$20,589,927			$198,762,055
	2012	$228,039,202				
	average	*$212,631,056*	*$18,235,898*	*$3,031,879*	*$173,878,162*	*$201,307,710*
Northern	2008	$5,311,486	$17,734,188	$3,713,136	$139,007,581	$97,297,761
	2009	$57,109,248	$13,737,055	$2,570,777	$116,025,269	$102,153,751
	2010	$55,729,554	$21,288,881	$5,213,321	$149,811,054	$123,038,369
	2011	$33,778,795	$16,799,948			$82,917,619
	2012	$72,027,353				
	average	*$44,791,287*	*$17,390,018*	*$3,832,411*	*$134,947,968*	*$101,351,875*
South Eastern	2008	$262,991,570	$14,905,246	$1,122,066	$151,849,585	$185,184,206
	2009	$241,652,689	$18,988,224	$2,369,459	$159,593,442	$180,465,084
	2010	$163,592,527	$28,954,517	$731,455	$124,741,314	$168,356,287
	2011	$213,921,945	$23,010,167			$189,141,217
	2012	$251,523,923				
	average	*$226,736,531*	*$21,464,539*	*$1,407,660*	*$145,394,781*	*$180,786,699*
Southern	2008	$180,623,507	$10,496,271	$2,198,389	$126,127,589	$140,467,957
	2009	$135,920,633	$34,297,019	$4,006,772	$200,912,112	$227,541,912
	2010	$147,566,564	$19,898,140	$4,410,172	$164,410,426	$175,269,972
	2011	$217,317,220	$27,626,301			$254,814,849
	2012	$195,395,064				
	average	*$175,364,597*	*$23,079,433*	*$3,538,444*	*$163,816,709*	*$199,523,673*
All Regions						
	2008	$865,956,619	$105,900,913	$20,132,251	$935,328,726	$867,219,529
	2009	$852,810,238	$156,096,846	$16,768,205	$971,793,259	$1,066,372,568
	2010	$769,238,661	$150,778,042	$23,429,972	$959,106,366	$967,343,562
	2011	$820,440,032	$151,525,277			$1,027,685,796
	2012	$937,119,543				
	average	*$849,113,019*	*$141,075,269*	*$20,110,143*	*$955,409,450*	*$982,155,364*

Table 50 Estimated Human Capital crash cost saving associated with the Queensland mobile speed camera program by year and police regions: after introduction from 2008 to 2012

Region	Crash Year	Serious Casualty	Minor Injury	PDO	All	Casualty
Brisbane	2008	$70,379,587	$9,850,386	$18,083,393	$253,081,766	$117,801,280
	2009	$201,172,638	$11,198,675	$13,985,296	$285,940,654	$204,229,566
	2010	$178,288,668	$12,501,963	$12,869,970	$271,914,728	$201,391,154
	2011	$152,009,757	$5,398,029			$129,542,452
	2012	$137,033,631				
	average	*$147,776,856*	*$9,737,263*	*$14,979,553*	*$270,312,383*	*$163,241,113*
Central	2008	$146,008,209	$3,285,602	$3,888,238	$104,337,590	$105,289,849
	2009	$117,887,209	$4,005,548	$1,287,199	$82,131,387	$114,517,747
	2010	$105,857,347	$3,428,519	$3,711,885	$88,579,900	$92,895,321
	2011	$103,008,248	$4,159,344			$109,881,644
	2012	$132,828,044				
	average	*$121,117,811*	*$3,719,753*	*$2,962,441*	*$91,682,959*	*$105,646,140*
Northern	2008	$3,038,375	$3,756,895	$3,628,096	$75,026,194	$51,683,645
	2009	$32,881,625	$2,720,978	$2,511,899	$62,347,974	$53,933,444
	2010	$35,922,083	$4,237,682	$5,093,922	$88,763,124	$71,522,623
	2011	$23,946,571	$3,290,026			$51,704,366
	2012	$42,011,871				
	average	*$27,560,105*	*$3,501,395*	*$3,744,639*	*$75,379,097*	*$57,211,019*
South Eastern	2008	$161,508,937	$2,991,438	$1,096,368	$83,919,907	$100,858,248
	2009	$156,262,148	$3,754,414	$2,315,192	$90,645,510	$100,772,039
	2010	$111,901,432	$5,731,302	$714,702	$73,934,036	$98,089,724
	2011	$133,730,166	$4,531,581			$104,220,990
	2012	$157,499,932				
	average	*$144,180,523*	*$4,252,184*	*$1,375,421*	*$82,833,151*	*$100,985,250*
Southern	2008	$108,283,922	$2,257,992	$2,148,040	$69,860,212	$76,144,314
	2009	$82,314,541	$7,011,067	$3,915,006	$113,483,032	$125,874,366
	2010	$89,105,931	$4,189,631	$4,309,167	$92,960,377	$96,786,806
	2011	$133,176,514	$5,561,942			$142,748,093
	2012	$120,179,696				
	average	*$106,612,121*	*$4,755,158*	*$3,457,404*	*$92,101,207*	*$110,388,395*
All Regions						
	2008	$534,527,970	$21,952,638	$19,671,168	$522,182,647	$475,890,185
	2009	$527,158,831	$31,196,442	$16,384,169	$544,892,652	$587,346,717
	2010	$495,763,007	$30,402,921	$22,893,363	$554,823,673	$549,070,890
	2011	$531,681,328	$30,091,941			$587,545,357
	2012	$594,695,951				
	average	*$536,765,418*	*$28,410,986*	*$19,649,566*	*$540,632,991*	*$549,963,287*

8.5. SPEED SURVEY LOCATIONS

Table 51 Queensland Speed Survey Locations 2009 to 2012

ID	Limit	(July 2013)	Location
U050-01	50	Southern	Clearview Street, Toowoomba, 200m west of Holberton
U050-02	50	Southern	Champagne Street, Toowoomba, at property no.31
U050-03	50	Southern	Campbell Street, Toowoomba, west of Lindsay Street
U050-04	50	Southern	Hill Street, Toowoomba, at property no.45
U050-05	50	Brisbane	Wincott Street, Salisbury, outside property no.17
U050-06	50	Brisbane	Royal Parade, Alderley, outside property no.198
U050-07	50	Brisbane	Crump Street, Holland Park, outside property no.30
U050-08	50	Brisbane	Beverley Street, Morningside, outside property no.88
U050-09	50	Southern	Bluebell Street, Caboolture, outside property no.38
U050-10	50	Southern	Avoca Esplanade, Sandstone Point, outside property no.12
U050-11	50	Central	Currumundi Road , Currumundi, outside no.54
U050-12	50	Central	Parkway Drive, Mooloolaba, outside property no.52
U050-13	50	South Eastern	Oberon Way, Oxenford, outside property no.9
U050-14	50	South Eastern	Fawn Street, Coomera, outside property no.7
U050-15	50	South Eastern	Vaughan Drive Ormeau, outside property no.38
U050-16	50	South Eastern	Sambit Street, Tanah Merah, outside property no.14
U050-17	50	Central	Crofton Street, Bundaberg, outside property no.61
U050-18	50	Central	Coomber Street, Bundaberg, outside property no.28
U050-19	50	Central	Targo Street, Bundaberg, outside property no.177
U050-20	50	Central	Pitt Street, Bundaberg, at EP3053147
U060-01	60	Southern	North Street, Toowoomba, at property no.88
U060-02	60	Southern	Stenner Street, Toowoomba, west of Ramsey Street
U060-03	60	Brisbane	London Road, Chandler, outside property no.823
U060-04	60	Brisbane	Alperton Road, Burbank, outside property no.60
U060-05	60	Central	George Street, Bundaberg, outside property no.55
U060-06	60	Central	Burrum Street, Bundaberg, outside Showgrounds
U060-07	60	South Eastern	Between Norman St & Scarborough St
U060-08	60	South Eastern	Between Marsupial Dve & Lae Dve
U060-09	60	Central	Abut A North Maroochy River
U060-10	60	Central	Between School Road & Rd 1305
U060-11	60	Central	North of Lake Kawana Blvd
U060-12	60	Central	Sth Moores Creek on Musgrave Street
U060-13	60	Central	Rton - Ridgelands 50m east of Jardine St
U060-14	60	Central	WiM Site Harbour Road
U060-15	60	Brisbane	WiM Site Brisbane Port
U060-16	60	Brisbane	Ross Ct North of
U060-17	60	South Eastern	Between Sunlight Dr and Billabong Pl
U060-18	60	Central	G'stone-Benaraby Rd 150m E Reef St
U060-19	60	Northern	Boundary St (Adjacent Civic Theatre)
U060-20	60	Brisbane	Ross Ct North of

ID	Lim it	(July 2013)	Location
R060-01	60	South Eastern	240 metres north of Hayes Rd
R060-02	60	South Eastern	220 meters north of Tamborine School Pk
R060-03	60	Central	50m east of Blackbutt St
R060-04	60	Central	West of Samantha Dr east
R060-05	60	Southern	200m form E Conn of 18B Td 0.2
R060-06	60	Southern	At Showgrounds on 35A Td0.5 km
R060-07	60	Southern	200m Sth Of Dalby-Cooyar Rd Td 1.7 Km
R060-08	60	Southern	0.67km North of Mitchell Hwy - Bollon Rd
R060-09	60	Southern	West of Feather Street
R060-10	60	Southern	At O O Madsen Bridge
R060-11	60	Southern	At Backhouse Bridge in Killarney
R060-12	60	Central	Dawson Hwy at Police Ck (Auckland Ck)
R060-13	60	Central	Burnett Hwy 500m South of Dawson Hwy
R060-14	60	Southern	Near truck pull-over area in Longreach
R060-15	60	Central	Bemborough Avenue - City Gates
R060-16	60	Northern	Adj to Catholic Church Cardwell
R060-17	60	Northern	100m West of the Bruce Hwy.
R060-18	60	Central	Broadhurst St (Childers) T/dist 0.862
R060-19	60	Central	Childers Rail Xing T/dist 56.00
R060-20	60	Brisbane	At Browns Rd
R060-21	60	Southern	At Sandy Creek
R060-22	60	Brisbane	South of Deakin Street
R060-23	60	Northern	Home Hill between 11th and 12th Street
R060-24	60	South Eastern	1km North of McInnes Court
R060-25	60	Southern	0.20km South of Roma Airport Turn Off
U080-01	80	Southern	Goombungee Road, Toowoomba, 50m west of water treatment plant
U080-02	80	Southern	Hermitage Road, Toowoomba, outside property no.276
U080-03	80	Southern	Drayton Connection Road, Toowoomba, 50m north of rail cossing
U080-04	-		-
U080-05	80	Central	Elliott Heads Road, Bundaberg, 1.1km east of Ashfield Road
U080-06	80	South Eastern	500 metres south of Bahrs Scrub Rd
U080-07	80	South Eastern	100 metres east of Schneider Rd
U080-08	80	Southern	north of Burpengar creek
U080-09	80	Central	near start of raod
U080-10	80	Central	Slade Point Road - South of Keeleys Road
U080-11	80	Brisbane	150m North of Freight Trade St
U080-12	80	Brisbane	East of Torbay Road
U080-13	80	Central	Holts Road - Habana Road
U080-14	80	South Eastern	300m north of Ross St Bridge
U080-15	80	South Eastern	900m East of Ross St
U080-16	80	South Eastern	Park Ridge Road Park Ridge @ # EP 35508
U080-17	80	Brisbane	Johnson Road Heathwood 1.1km east of Woogaroo Road
U080-18	80	Brisbane	Johnson Road Heathwood 1.1km east of Woogaroo Road
U080-19	80	Central	1.1km East Of Cooney Rd
U080-20	80	South Eastern	Norwell Road Norwell , 1km south of Fischers Road
U080-21	80	South Eastern	Pimpama Jacobs Well Road Pimpama , 1.2km east of Wharf Road
U080-22	80	Central	Bundaberg Ring Road Bundaberg 1.1km west of Lovers Walk
U080-23	80	Central	Booral Road Hervey Bay , 1.1km south of Don Adams Dr
U080-24	80	Central	Between School Road & Rd 1305
U080-25	80	Central	At LA Boundary Maroochy/Caloundra
U080-26	80	Northern	University Rd 200m east Mark Reid Dr

ID	Limit	(July 2013)	Location
R080-01	80	South Eastern	260 metres north of Calgiraba Rd
R080-02	80	South Eastern	640 metres south of Nixon Ck Bridge
R080-03	80	Central	east of Camp Flat Road
R080-04	80	Central	South of Reesville Rd
R080-05	80	Southern	At 80km Sign Td 0.70
R080-06	80	Southern	0.57km West of Roma Downs Rd
R080-07	80	Southern	0.20km South of Roma Airport Turn Off
R080-08	80	Southern	Wallangarra Rd 300m North of N E Hwy
R080-09	80	Southern	200m East of Parker Street
R080-10	80	Central	Dawson Hwy 900mts W Burnett Hwy(41E)
R080-11	80	Central	Dawson Hwy 400m west of Leichhardt Hwy
R080-12	80	Central	East of BSES
R080-13	80	Northern	400m from Inter with 98C (New Queen Rd)
R080-14	80	Northern	200m East of Bruce Hwy
R080-15	80	Northern	300m Sth of El Arish - Mission Bch Rd
R080-16	80	Northern	Kurrimine Beach
R080-17	80	Central	Nth side Tiaro Township T/dist 61.069
R080-18	80	Central	150m East of Rehbein Ave T/dist 9.914
R080-19	80	Brisbane	North of Double Jump Rd
R080-20	80	Brisbane	South of Giles Rd
R080-21	80	Brisbane	WiM Site Port of Brisbane Mwy
R080-22	80	Brisbane	Linkfield Rd west of Carseldine Rd
R080-23	80	Central	Clermond Connection Rd 120m E Sandy Creek
R080-24	80	Central	Marian Permanent Counter
R080-25	80	Central	Rockhampton - Emu Park Rd - West of Emu Park Golf Club
R080-26	80	South Eastern	260 metres north of Calgiraba Rd
R080-27	80	South Eastern	640 metres south of Nixon Ck Bridge
U100-01	100	Southern	Gowrie Junction Road, Toowoomba, 100m north of property no.177
U100-02	100	Southern	Drayton Connection Road, Toowoomba. 200m north of Love Road
U100-03	100	Southern	Cunningham Highway, Dinmore
U100-04	100	Southern	Cunningham Highway, Willowbank (South of Champions Way)
U100-05	100	Central	Sunshine Motorway, Yandina
U100-06	100	Southern	Daguilar Highway, Caboolture
U100-07	100	Central	Isis Highway, Bundaberg, 100m south of La Roccos Lane
U100-08	100	Central	Maryborough- Hervey Bay Road, Bundaberg, @ Susan River Bridge
U100-09	100	South Eastern	North of Robina Parkway overpass on M1
U100-10	100	South Eastern	500mtrs west of Clagiraba Rd, Clagiraba
U100-11	100	South Eastern	1.5km west of Olsen Ave Interchange
U100-12	100	Central	At LA Boundary Maroochy/Caloundra
U100-13	100	Southern	east of Hickey Road
U100-14	100	Central	Mackay - Bucasia Road to Richmond Road
U100-15	100	Southern	Sandy Ck Bridge
U100-16	100	Northern	TSV Ring Rd adj Beck Dr Opass
U100-17	100	Central	Burnett Heads Road, Bundaberg, 1km South of Grange Road

ID	Lim it	(July 2013)	Location
R100-01	100	South Eastern	WiM Site Cyrus Creek
R100-02	100	South Eastern	150 metres south of Plunkett Rd
R100-03	100	South Eastern	900 mtrs east of Alberton Rd UBD 285 N2
R100-04	100	Central	west of Rocky Creek Culvert
R100-05	100	Central	Abut A Mary River Bridge
R100-06	100	Southern	1Km East of Murphy Ckeek Rd
R100-07	100	Southern	WiM Site Condamine1.72kmSouth Int 345Rd
R100-08	100	Southern	2.57km West of Mitchell - StGeorge Rd
R100-09	100	Southern	WiM Site Freestone
R100-10	100	Southern	WiM Site Spring Creek CLASSIFIER ONLY
R100-11	100	Central	R'ton-Yeppoon Rd East of Ironpot Ck
R100-12	100	Central	Dawson Hwy 250m W Chamberlain Rd
R100-13	100	Central	WiM Site Midgee
R100-14	100	Southern	5.45km north of Winton
R100-15	100	Southern	3.0km north of Barcaldine
R100-16	100	Central	WiM Site Koumala
R100-17	100	Central	East of Coppabella
R100-18	100	Northern	WiM Site Cardwell
R100-19	100	Northern	WiM Site Greenacres
R100-20	100	Northern	WiM Site Mt Isa
R100-21	100	Northern	WiM Site 40 Mile Scrub
R100-22	100	Northern	WiM Site Davies Creek
R100-23	100	Central	Nth of Stehbens Road T/dist 4.892
R100-24	100	Southern	Warrill View Rd at Bremier Rv
R100-25	100	Southern	Ipswich/Rosewood Rd Wst of Rail Bridge
R100-26	100	Southern	WiM Site Bremer River
R100-27	100	Southern	100m North of Swanbank Road at creek
R100-28	100	Southern	WiM Site Southbrook

Red light speed camera synergy

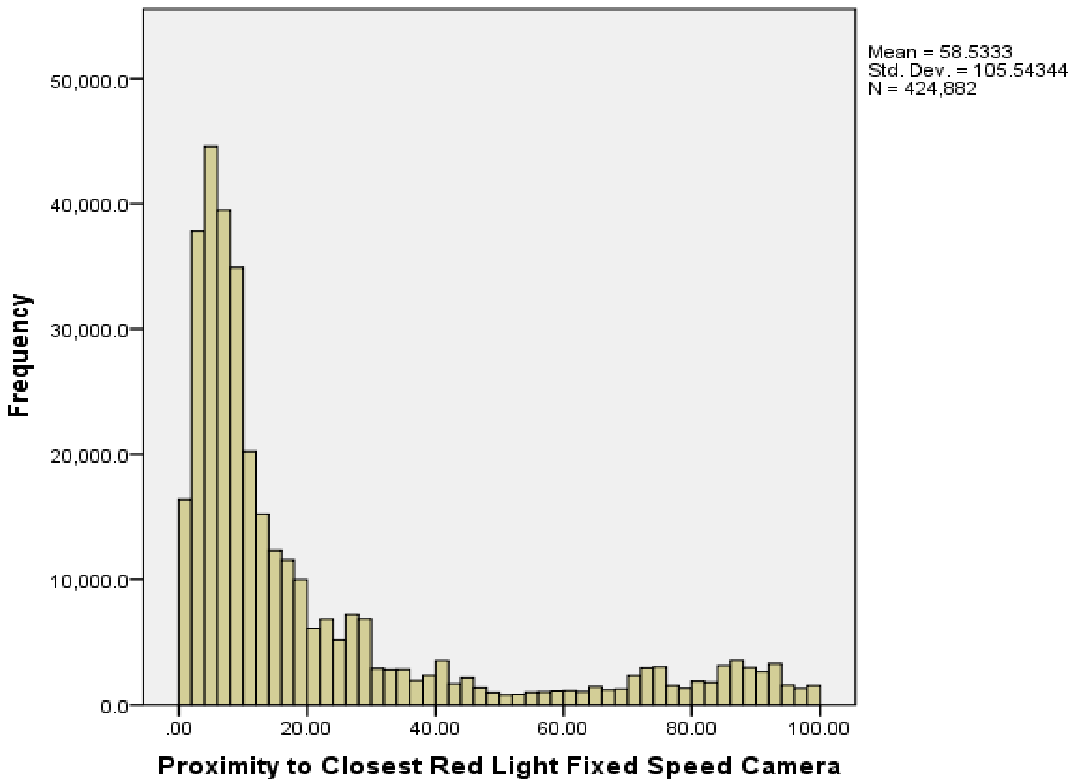
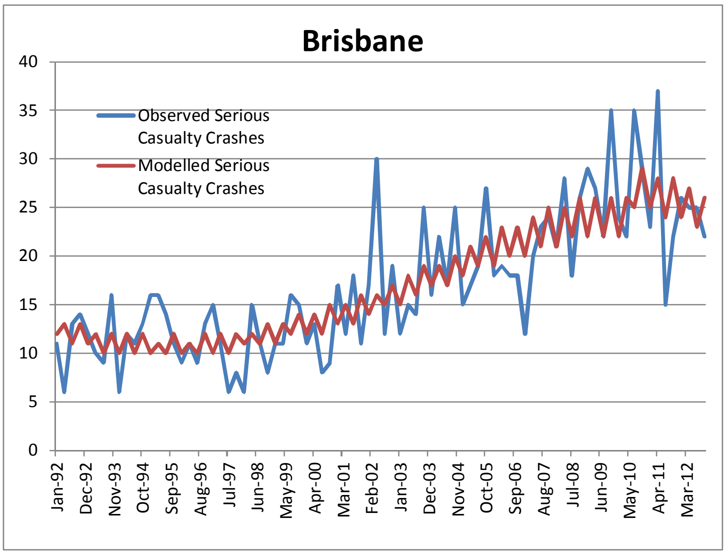
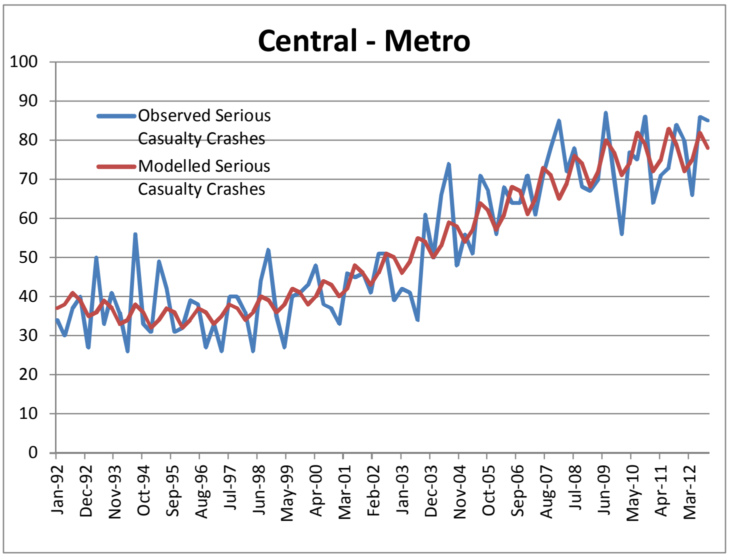
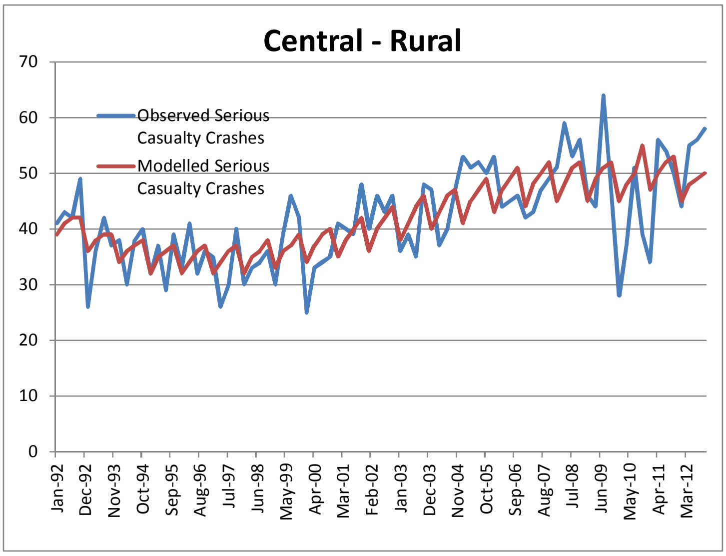


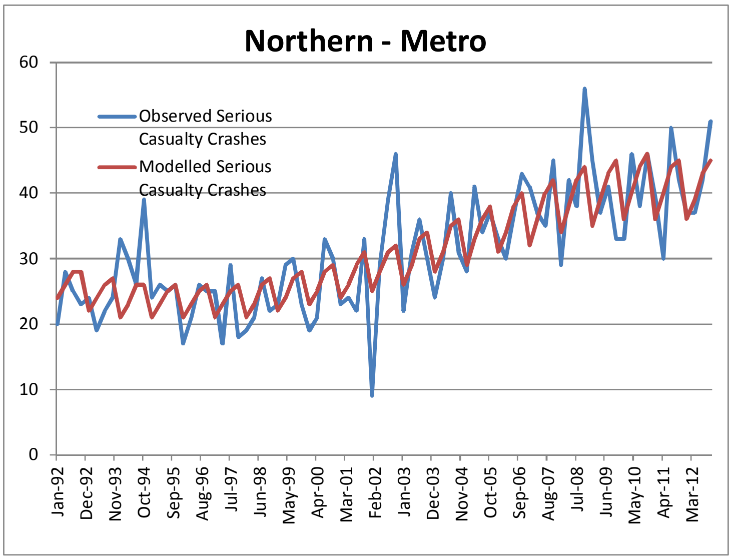
Figure 6
The proximity of crashes to Red Light speed Cameras (km)

8.6. MOBILE SPEED CAMERA CONTROL SERIES INTERVENTION TIME SERIES MODEL FITS








Northern - Metro
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
60
50
40
30
20
10
0
Jan-92
Dec-92
Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
Mar-01
Feb-02
Jan-03
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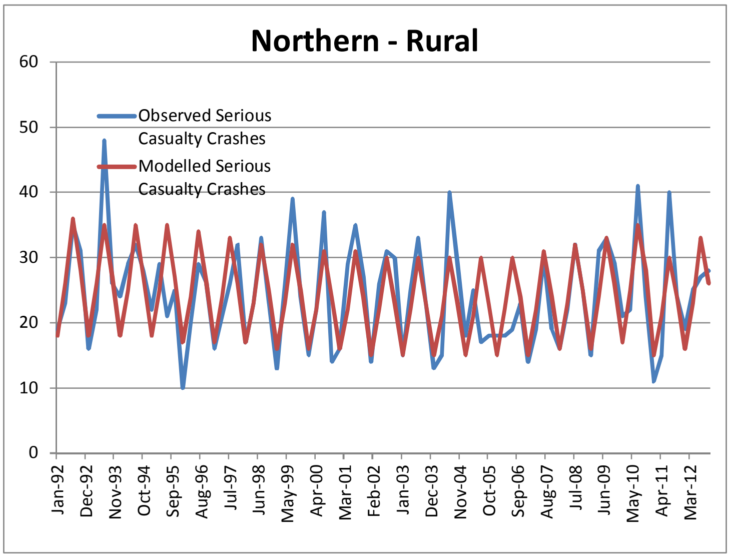
May-10
Apr-11
Mar-12


Northern - Rural
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
60
50
40
30
20
10
0
Jan-92
Dec-92
Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
Mar-01
Feb-02
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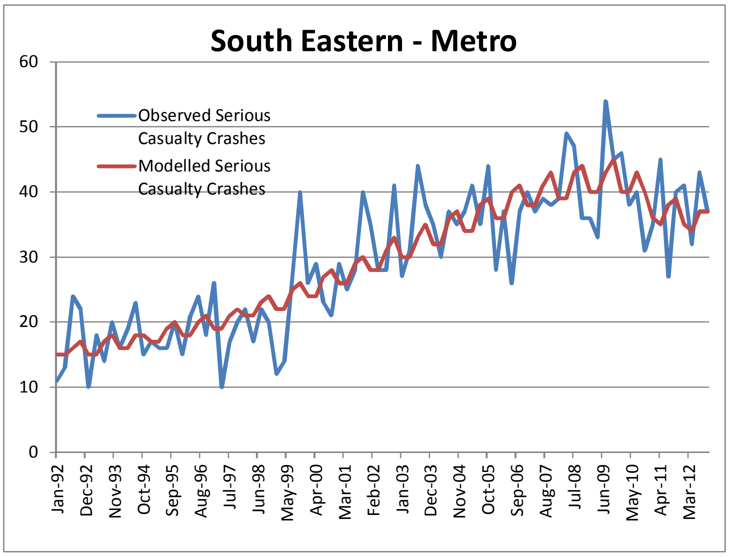
May-10
Apr-11
Mar-12


South Eastern - Metro
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
60
50
40
30
20
10
0
Jan-92
Dec-92
Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
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Feb-02
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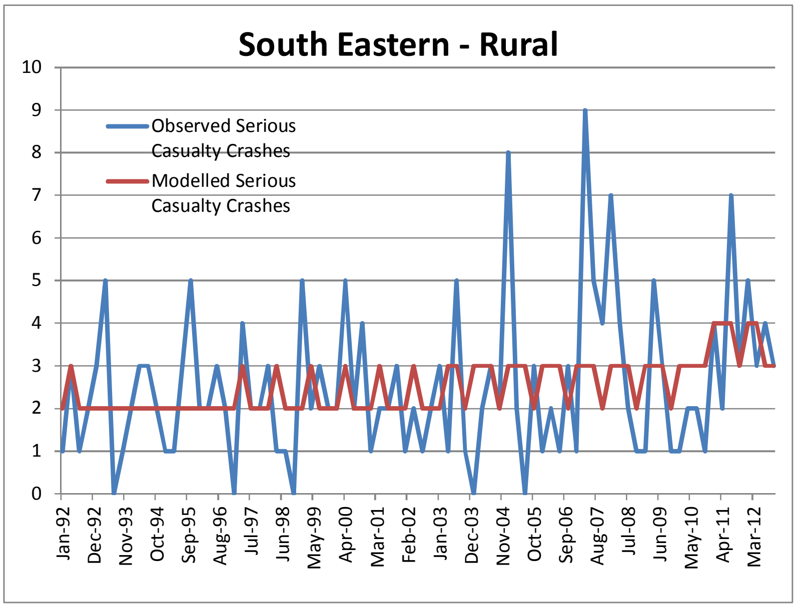
South Eastern - Rural
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
0
1
2
3
4
5
6
7
8
9
10
Jan-92
Dec-92
Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
Mar-01
Feb-02
Jan-03
Dec-03
Nov-04
Oct-05
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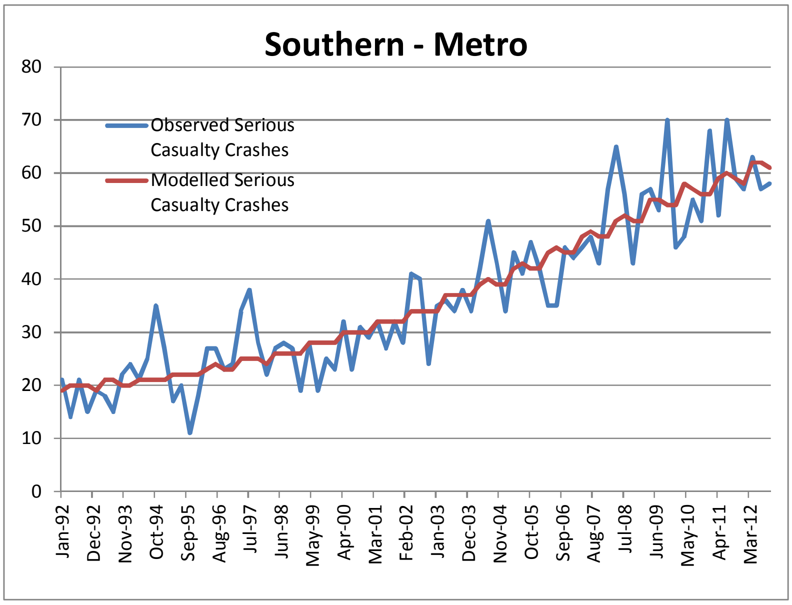
Jun-09
May-10
Apr-11
Mar-12


Southern - Metro
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
0
10
20
30
40
50
60
70
80
Jan-92
Dec-92
Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
Mar-01
Feb-02
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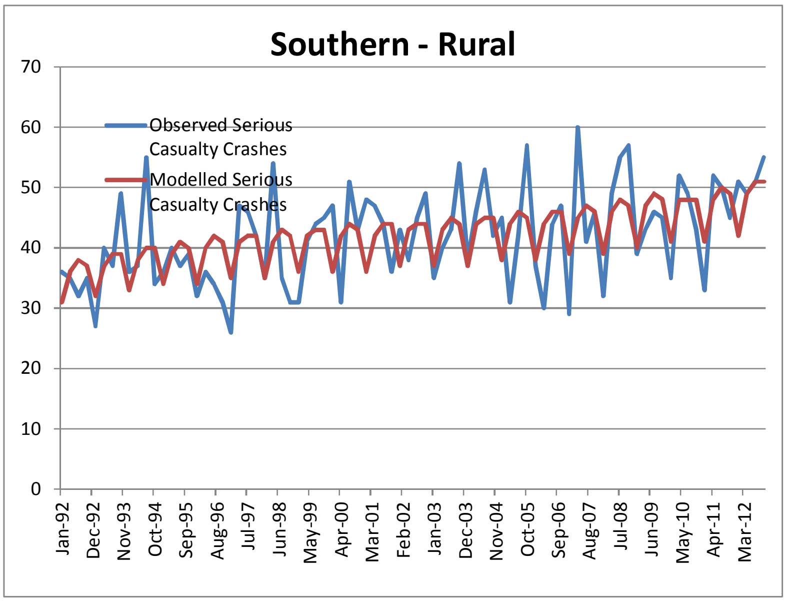
Apr-11
Mar-12


Southern - Rural
Observed Serious Casualty Crashes
Modelled Serious Casualty Crashes
0
10
20
30
40
50
60
70
Jan-92
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Nov-93
Oct-94
Sep-95
Aug-96
Jul-97
Jun-98
May-99
Apr-00
Mar-01
Feb-02
Jan-03
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Nov-04
Oct-05
Sep-06
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Apr-11
Mar-12