Red light cameras

Please refer to this document as follows: **Goldenbeld, Ch (2017), Red light cameras, European Road Safety Decision Support System, developed by the H2020 project SafetyCube. Retrieved from www.roadsafety-dss.eu on DD MM YYYY**

Please note: The studies included in this synopsis were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides *a quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

1 Summary

Goldenbeld, Ch., July 2017

1.1 COLOUR CODE: LIGHT GREEN

Studies indicate that red light cameras decrease right-angle crashes, but at the same time increase rear-end and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive.

1.2 KEY WORDS

Red light cameras, Signalised intersections, Red light running, motorised vehicles, crashes

1.3 ABSTRACT

Red light cameras (RLCs) are one of several possible countermeasures against red light running. Red light running is a risky traffic violation since it is associated with very serious, high injury crashes. Besides red light cameras, other countermeasures may include improving the driver's view of the intersection, converting intersection to roundabout, producing a raised intersection or improving the traffic signal phasing. A 2013 meta-analysis indicated that RLCs decrease right-angle injury collisions by 33%, but at the same time increase injury rear-end collisions by 19%. Several North-American studies after the meta-analysis, one European study and one Korean study, have confirmed that RLCs reduce right-angle crashes, but at the same time increase rear-end crashes and other types of crashes. Since rear-end crashes are often associated with less severe injury than right-angle crashes, it may be assumed that the net effect on road safety is positive. RLCs have been found to achieve larger road safety effects when red light violations are deliberate, when intersections have a high proportion of right-angle crashes and a lower proportion of rear-end crashes, when cameras are signposted, and when cameras are in continuous operation rather than rotational.

1.4 BACKGROUND

What is a red light camera?

As part of general traffic enforcement strategy, red-light cameras (RLCs) are used to automatically detect and record red light running by vehicles at intersections. Frequently, RLCs combine speeding and red light detection.

How do red light cameras affect road safety?

The main purpose of RLCs is to prevent red light running and thus to prevent collisions that result from red light running. The combined speed/red light cameras may also serve to reduce speed in approaching an intersection. Basically red light running causes two main traffic conflicts that may result in a (serious) crash: right-angle and left turn-opposed conflicts (Bonneson & Zimmerman, 2004).

How do red light cameras work?

Red-light speed cameras detect and record the position and speed of a vehicle by using vehicle tracking radar or electronic detectors embedded in the road's surface. RLC systems typically include at least one camera, at least one trigger, and a computer (Harris, 2001). The red-light detection function of the camera is connected to the traffic lights and is activated when a vehicle crosses the white stop line after the lights have turned red. Typically, the camera takes two photographs, one when the vehicle crosses the stop line and a second when the vehicle is in the intersection. The photographs include the date, time and place, vehicle speed, and elapsed time from the light turning red to the time the photograph was taken. The camera is not triggered by vehicles crossing the stop line on amber (yellow) or green lights. Digital cameras have improved the effectiveness of the systems and are the most common camera used for red light running detection.

When to use red light cameras?

RLCs are generally used if an intersection has a red light running problem. In that case there are several possible countermeasures of which the use of red light camera is only one. The red light running problem may be due to the view on the approach to the intersection or to the traffic light phasing. In such situations RLC enforcement is likely not to be the best solution, and other solutions should be considered first. When red light running is a deliberate violation, and is not caused by the view or the signal phasing, then RLCs may be considered as a viable countermeasure.

Which factors influence the effect of red light cameras on road safety?

RLCs have been found to achieve larger road safety effects when red light violations are deliberate, when intersections have a high proportion of right-angle crashes and lower proportion of rear-end crashes, when RLCs are signposted, and are in continuous operation, rather than rotational.

How is the effect of red light running on road safety measured?

The effectiveness of RLCs has been measured by the number or rate of collisions, right-angle crashes, rear-end crashes, crash severity measures, and the prevalence of red-light violations .

1.5 OVERVIEW OF RESULTS

- A 2013 meta-analysis concluded that red light cameras significantly reduced right-angle injury collisions (−33%) but at the same time significantly increased rear-end injury collisions (+19%).
- Several USA studies, one European and one Korean study, confirmed this pattern of results.
- Overall a positive safety effect of red light cameras is to be expected since rear-end crashes are often less serious than right-angle crashes.
- A positive safety effect of red light cameras can be expected especially at intersections where relatively many right-angle crashes related to deliberate red light running take place, and where relatively few rear-end crashes occur.
- The safety effects of red light cameras are greater when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.
- Red light cameras are not a suitable measure for solving problems that arise from a bad view of the intersection, problems with unintentional red light running or problems with signal phasing.
- There is still a considerable lack of knowledge about the type of intersections where red light cameras are most effective.
- Most studies have been performed in the USA and results are not easily transferable to European intersections which have different designs, traffic volumes and traffic composition

(e.g. larger share of cyclists and/or moped riders). However, two non-USA studies, one European and one Korean, show results that are in line with several American studies.

2 Scientific Overview

This scientific overview on the safety effect of red light cameras first describes knowledge on red light cameras and traffic safety from the general literature (Section 2.1), it then describes characteristics of coded studies on red light cameras (Section 2.2), major results of the coded studies (Section 2.3) and it ends with main conclusions (Section 2.4).

2.1 GENERAL LITERATURE

Red light cameras are a possible countermeasure against red light running. Studies show that the rate of red light violation per 1000 vehicles varies between 1.3 and 5.3 in USA and Australia (Attawi, 2014). Red-light violation frequency among car drivers is correlated with the following (intersection) factors: traffic volume, cycle length, advance detection for green extension, speed, signal coordination, approach grade, amber interval duration, proximity of other vehicles, presence of heavy vehicles, delay, intersection width, and signal visibility (Bonneson & Zimmerman, 2004).

If at an intersection there is a lot of red light running this may be due to the driver's view of the intersection or the traffic light phasing. In such cases camera enforcement may not be the best solution. Red light cameras are not the only countermeasure for reducing crashes at signalised intersections. Other solutions may work better. Converting traditional intersections to roundabouts eliminates the need for traffic signals as well as cameras. Raised intersections can reduce the approach speed and subsequent red light running (Fortuijn et al., 2005).

Red light running is an especially risky traffic violation since it is associated with very serious, high injury crashes (ATS, 2013; IIHS, 2014). Many of the victims are pedestrians, bicyclists and people in other vehicles who are hit by the red light runners. In European cities, the large number of red light cameras attest to the red light running problem. For example, in 2009 more than 850 red light and speed cameras were operational in London alone (ETSC, 2009).

Modifying conditions

According to Burkey (2005), traffic volume may affect the impact of red light cameras. At intersections with high traffic volumes he found less favourable effects than at intersections with low traffic volumes. Effects of red light cameras may change over time (Høye, 2013). For example, it is possible that drivers get used to both red light cameras and to other drivers braking at red (or amber) lights. As a consequence, rear-end collisions might therefore increase only initially, but decrease over time, while right-angle collisions continue to decrease.

Langland-Orban et al. (2011) specifically point out that red light cameras are not a solution to the problem of unintended red light running, i.e. when people unintentionally go through a red light. They advise that an analysis of the problem, which shows the cause of red light running at an intersection, is to be carried out before making a decision about deployment of a red light camera.

Council et al. (2005) performed an exploratory analysis and found that red light cameras were most effective when sites were highly publicised with public information programmes, when the detected violations were enforced with higher fines, when the traffic light had one or more left turn protected phases, shorter signal lengths and inter-green periods, when the intersection had a reduced speed limit, a high proportion of traffic in the major road, and a high ratio of right-angle to rear-end crashes.

Pulugurtha et al. (2014) analysed red light camera data from thirty-two signalised intersections in the city of Charlotte, North Carolina. The empirical Bayes (EB) method was used to assess the effectiveness of a red light camera enforcement programme in reducing crashes. They estimated that the road safety benefits of red light cameras were higher if cameras are employed at signalised intersections with: 1. total entering vehicles per day less than 40,000; 2. fewer than 20 rear-end crashes per year, or 3. fewer than 5 sideswipe crashes per year.

Høye (2013) found that the safety effects of red light cameras are greater when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.

In a Canadian study, Tay & de Barros (2011) compared red light running violation levels when cameras were either operating continuously or rotated amongst locations. The fixed camera scheme clearly produced lower violation levels than the two rotational schemes that were studied (cyclical and random).

2.2 METHODOLOGY

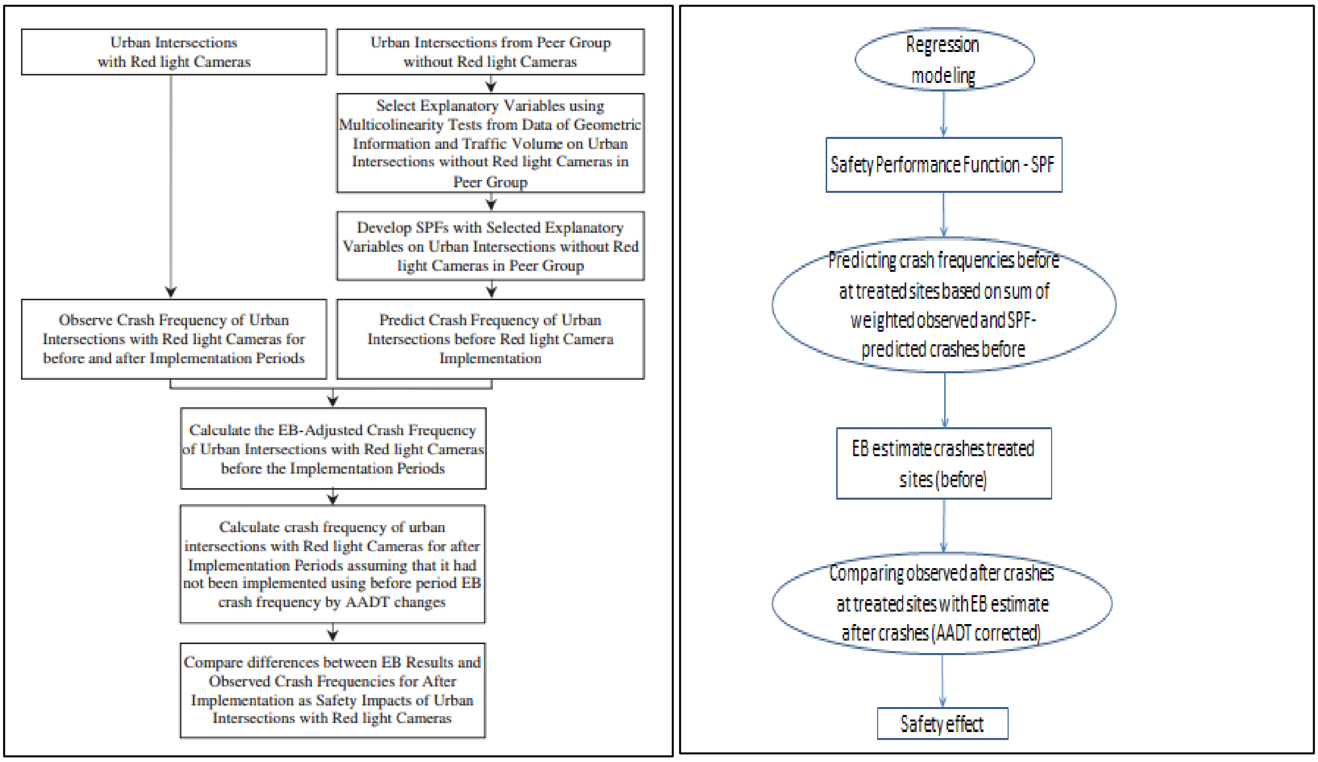
A systematic literature study was undertaken to identify scientific studies on the relationship between red light cameras and crashes. A total of 16 studies were identified and coded. Starting point was a 2013 meta-analysis (Høye, 2013). One relevant study previous to the meta-analysis was coded; the remaining 14 studies were published after the meta-analysis, and hence not included.
It should be noted that most of the (coded) studies on red light cameras were done in the USA. The differences in intersection design and road user composition between USA and Europe prompt caution in generalising from these results to other parts of the world. Studies in Europe are scarce. Most of the USA red light camera studies did not assess the precise injury levels associated with red light running crashes and the expected road safety benefits from cameras, and most of them were not able to identify static or dynamic intersection characteristics that interact with camera effectiveness.

The main methodology for estimating the safety effects of red light cameras was a before-after Empirical Bayes with a reference (or control or peer) group. Several coded studies have used this method (Ahmed-Aty & Abdel-Aty, 2014; Ko et al., 2013; Lee et al., 2016; Llau et al., 2015; Pulugurtha & Otturu, 2014). The methodology basically consists of three steps (Lee et al., 2016):

1. Acquiring data from different sources and processing that data for treated and untreated (reference) intersections.
2. Modelling Safety Performance Functions using untreated intersection data, including geometric information, crash data, and traffic volume data.
3. Conducting Empirical Bayes analysis for safety impacts at intersections before and after the deployment of red light cameras.

In Figure 1, the left Panel presents a schematic, stepwise presentation of the method. The right Panel presents a simplified schematic representation of the method.

Figure 1: *Left panel*: Analysing safety impacts of urban intersections with red light cameras using Empirical Bayes approach (source: Lee et al., 2016); *Right panel*: alternative (simplified) representation of left panel (by synopsis author). (Abbreviations used: AADT = Annual Average Daily Traffic; EB = Empirical Bayes; SPF = Safety Performance Function)



For analysing the safety impact of red light cameras by the Empirical Bayes approach, a first step is the development of Safety Performance Functions (SPFs) based on data of untreated intersections (Lee et al., 2016). Lee et al. (2016) define SPFs as statistical and probabilistic models for the prediction and interpretation of vehicle crashes using variables that are related to vehicle crash frequencies. For SPF development, an appropriate set of dependent and independent variables is needed, as well as a statistical model that adequately accounts for the relationship between dependent and independent variables. Independent variables for modelling SPFs may include geometric information, vehicle crash data, and traffic volume data.

A few studies on red light cameras have used a distinct method for assessing their safety impact:

- Chai et al. (2015) used a cellular automata simulation model to estimate safety impacts of RLC.
- Chin & Haque (2012) used the quasi-induced exposure method to estimate the crash vulnerability and at-fault crash proneness of motorcyclists at intersections
- Polders et al. (2015) used a combination of video observations and driving simulator to better understand chances of and reasons for rear-end collisions at intersections
- Porter et al. (2013) used a design where effects of RLC were also studied after cameras were set off.

2.3 ANALYSIS AND RESULTS

16 studies on the effects of red light cameras on crashes or red light running were coded, including one meta-analysis.

Meta-analysis

Based on a meta-analysis on 29 international red light camera studies (of which 17 in USA), Høye (2013) found the following main results:

- A non-significant decrease of all injury crashes by 13% and a non-significant increase of all crashes by 6%.
- Right-angle collisions were found to decrease by 13% (NS) and rear-end collisions were found to increase by 39% (statistically significant).
- For right-angle injury collisions a far larger decrease was found (−33%, statistically significant) and for rear-end injury collisions a smaller increase was found (+19%, statistically significant).

Additional crash studies not covered by meta-analysis

After the meta-analysis by Høye several American studies have confirmed that red light cameras reduce right angle crashes but at the same time increase rear-end crashes and other types of crashes complicating the estimate of the net/total safety effect (Ahmed & Abdel-Aty, 2015; Claros et al., 2016; Lord & Geedipally, 2014; Pulugurtha & Otturu, 2014; Wong, 2014). One European study of safety effects of red light cameras (in Belgium) confirmed the pattern of results from American studies: a significant increase in rear-end crashes combined with significant decrease in severe side crashes (DePauw et al. 2014). An Asian study (South Korea) was partly in line with previous findings (Lee et al., 2016). This study indicated that red light cameras would reduce fatal injury angle crashes, but at the same time they would substantially increase injury crashes, both injury sideswipe and rear end crashes and angle injury crashes.

McCartt & Hu (2013) found some evidence for spill-over effect of red light cameras but the effects were observed only for nearby intersections on travel corridors with cameras and were not always significant.

A study by Chin et al. (2012) focused on effects of red light cameras on the exposure of motorcylists to right-angle conflicts. They found that the presence of red light cameras reduced (observed) right angle conflicts of motorcyclist, and reduced the crash vulnerability of motorcyclists at right angle collision.

Additional studies on red light running

Studies on the effects of red light cameras on red light running indicate that the installation of red light cameras reduce red light running (McCartt & Hu, 2013; Polders et al., 2015), whereas the removal of red light cameras increase red light running (Porter et al., 2013). In several simulation and observational studies further evidence is found of how and the extent to which red light running violations lead to increased traffic conflict situations (Chai et al, 2014; Polders t al., 2015; Chin & Haque, 2012). For example, Chin & Haque (2012) based on video-observations found that motor-cycles at RLC sites compared to non-RLC sites had a lower exposure to red light runners by about 10% during the first second of green and 13% in the first 2.5 seconds of green. This improvement was due to two behavioural mechanisms; first, at RLC sites, motorcyclists were less willing to queue beyond the stop line, thereby reducing the number of motorcycles discharging ahead of other vehicles; second, the motorcyclists were also less likely to jump start prior to gaining the right of way. Based on video-observations Polders et al. (2015) found evidence that red light cameras influence stopping behaviour of vehicles so that they stop earlier and also stop at the onset of yellow when they are closer to the stop line. Also, the influence on behaviour appeared stronger for truck driver than for other vehicles. Using a simulation model, Chai et al. (2014) found evidence that the safety impact of RLCs on right-turn conflicts was strongest for right angle conflicts (85% and 86% reduction for TTC < 2 s during peak and off-peak hours, respectively) and was more prominent during amber–red signal phases. Apparently, the installation of RLCs reduces red light running from opposing straight-through vehicles and thereby reduces the occurrence of this type of conflict.

2.4 CONCLUSIONS

From the coded studies and from the literature review the following conclusions can be derived:

- A 2013 meta-analysis concluded that red light cameras significantly reduced right-angle injury collisions (−33%) but at the same time significantly increased rear-end injury collisions (+19%).
- Several USA studies, one European and one Korean study, confirmed this pattern of results.
- Overall a positive safety effect of red light cameras is to be expected since rear-end crashes are often less serious than right-angle crashes.
- A positive safety effect of red light cameras can be expected especially at intersections where relatively many right-angle crashes related to deliberate red light running take place, and where relatively few rear-end crashes occur.
- The safety effects of red light cameras are larger when red light camera warning signs are posted at main entrances to areas with red light camera enforcement rather than when each camera-controlled intersection is signposted.
- Red light cameras are not a suitable measure for solving problems that arise from a bad view on the intersection, problems with unintentional red light running or problems with signal phasing.
- There is still a considerable lack of knowledge about the type of intersections where red light cameras are most effective.
- Most studies have been performed in the USA and results are not easily transferable to European intersections which have different designs, traffic volumes and traffic composition (e.g. larger share of cyclists and/or moped riders). However, two non-USA studies, one European and one Korean, show results that are in line with several American studies.

3 Supporting document

This supporting document describes the main characteristics of coded studies (Section 3.1), it presents a schematic overview of study outcomes (Section 3.2), it describes the literature search strategy, and it presents references on coded studies, and general literature (Section 3.4).

3.1 DESCRIPTION OF STUDIES

Table 1 presents information on the main characteristics of the coded studies.

Table 1: Overview of main characteristics of coded studies of the effects of red light cameras (RLC)

Author, Year, Country	Study type	Sample/Measurement	Analysis
1. Chin & Haque, 2012, Singapore	Crash analysis	This study evaluated the effectiveness of RLCs on motorcycle safety in Singapore by comparing their exposure, proneness of at-fault right-angle crashes as well as the resulting right-angle collisions at RLC with those at non-RLC sites. For this study, the Singapore crash data from 1998 to 2002 were used. During this 5-year period, there were 8880 2-vehicle crashes at intersections of which about 74.9% crashes were right-angle collisions. To simplify the assignment of fault in a crash, the analysis was restricted to two-vehicle collisions at intersections.	The researchers estimated relative right angle crash vulnerability and relative crash proneness for red light camera sites and non-camera sites to explore the effect of red light cameras for motorcyclists.
2. Høye, 2013 International	Meta-analysis	Total of 29 before-after studies (17 from USA, 6 from Australia, 3 from UK, 1 from Norway and 1 from Singapore). Studies were classified in 4 groups: - Studies that controlled neither for regression to the mean (RTM) nor for spill-over effects (8 studies) - Studies that controlled for spill-over effects, but not for RTM (7 studies) - Studies that controlled for RTM, but not for spill-over effects (5 studies). - Studies that controlled for both RTM and spill-over effects (9 studies)	A meta-analysis was performed. A moderator analysis investigated effects of: - the approach to controlling for spill-over effects - the approach to controlling for RTM - the location of RLC warning signs (at intersections or main entrances to cities with RLC) - the unit of analysis (intersections with vs. without RLC or cities with vs. without RLC programme). Sensitivity analyses evaluated outlier bias, publication bias, statistical weighting.
3. Ko et al., 2013, USA, Texas	A before–after Empirical Bayes study with comparison group	The researchers collected crash data at 245 red light camera intersections in Texas. The data covered periods	To overcome a regression to the mean bias the Empirical Bayes method was used. Safety performance functions were

Author, Year, Country	Study type	Sample/Measurement	Analysis
		from 1 to 4 years before (516 intersection years) and after (663 intersection years) RLC installation.	developed by the use of crash, traffic, and geometric data from the reference sites and the negative binomial regression models for red light running crashes of all types and of right-angle and rear-end crashes.
4. McCartt & Hu, 2013, USA, Virginia	Observational study. The effects of the camera enforcement on red light violations were examined.	In June 2010, Arlington County, Virginia, installed red light cameras at four heavily travelled signalised intersections. Traffic was videotaped during a 1-month warning period and 1 month and 1 year after ticketing began at 4 camera intersections, 4 "spill-over" intersections without cameras, and 4 "control" intersections without cameras in an adjacent County.	At each intersection, the amount of red light running per 10,000 vehicles was calculated for each of the three observation periods by seconds elapsed after the signal light turned red (≥0.5 second, ≥1 second, and ≥1.5 seconds). Percentage changes were calculated for violation rates 1 month after ticketing began compared with the warning period and for rates 1 year after ticketing began compared with the warning period. Logistic regression models were used to estimate the effects of RLC on the probability of red light running at the camera intersections.
5. Porter et al., 2013, USA, Virginia	An observational study at treated and untreated intersections	Observations were done at 4 camera intersections, and 2 control non-camera intersections in one city (Virginia Beach). As a second control group 2 intersections in a nearby city were used (Newport News). Red light running was observed at intersections before (2 phases), during (5 phases) and after RLC enforcement (4 phases). The intersections in Virginia Beach varied from 4 x 4 lanes to 7 x 7 lanes; the two intersections in Newport News were chosen as control sites based on comparable size (6 x 2 lanes and 6 x 4 lanes). More than 2700 direct observations were made in these time periods.	The study was limited to behavioural data; no crash data provided. Relative risk estimates were based on frequencies of red light running before and after camera installation.
6. Chai et al. 2014, Singapore	A simulation study. In this study, a model was applied to estimate safety impacts of RLCs.	Using conflict occurrences generated in simulation allowed analysts to control regression to the mean and spill-over effects. Conflict occurrences were generated through simulating vehicular interactions based on a cellular automata (CA) model. The CA model was calibrated and validated against field observations at approaches with and without RLC. Simulation experiments were conducted for RLC and non-RLC intersections.	Average times-to-collision and post-encroachment times of 200 simulated conflicts were compared against 200 observed vehicle conflicts from video extraction at 4 approaches.
7. De Pauw et al., 2014, Belgium	Before-and-after Empirical Bayes comparison of the number of injury crashes	This study concerns combined speed/red light cameras (SRLC) in Flanders, Belgium. All crashes from2000 until 2008 were included. As the first cameras were installed in	The effectiveness of the installation of SRLC was first calculated per intersection, and was expressed in an index of effectiveness. The database with all crashes in Flanders was selected as the

Author, Year, Country	Study type	Sample/Measurement	Analysis
		2002, for any location at least 2 years of data in the before period and 1 year of data in the after period were available. The before period amounted on average to 3.13 years, the after period to 3.7 years. The injury crashes in the treated group decreased from 800 in 2000 to 618 in 2008, with an average of 713 crashes per year. The severe crashes had a range from144 in 2000 to 58 in 2008, with an average number of 90.	comparison group, as this gives a good estimation of the general trend. An Empirical Bayes estimation of regression-to-the-mean was executed, based on the crash frequencies in the treated group.
8. Lord & Geedipally, 2014, USA, Chicago	Before-after Empirical Bayes study with treatment and reference group. .	Crash, geometric and traffic flow data were collected at 90 4-legged signalised intersections for three years before and for three years after the installation of the cameras as well as at 59 intersections where no camera was installed. Three years of data were collected for the before (2005-2007) and after (2010-2012) periods (for both treatment and reference group).	Three types of before-after studies were conducted: 1) the naïve or simple before-after; 2) the before-after study with reference group; and, 3) the before-after study with the Empirical Bayes method (these results most relevant and coded). For the Empirical Bayes method Safety Performance Functions were developed using Negative Binomial regression models.
9. Pulugurtha & Otturu , 2014 USA, North Carolina	Data from January 1997 to December 2010 for 32 signalised intersections in Charlotte, North Carolina, where RLCs were installed between August 1998 and August 2000 and terminated in fall 2006, were gathered, analysed, and compared for "before the installation", "after the installation", and "after the termination" periods.	Data from January 1997 to December 2010 for 32 signalised intersections in Charlotte, North Carolina, where RLCs were installed between August 1998 and August 2000 and terminated in fall 2006, were gathered, analysed, and compared for "before the installation", "after the installation", and "after the termination" periods.	Descriptive analysis and paired t-tests were performed using rear-end, sideswipe, left-turn, angle, and right-turn crashes as well as the number of total crashes. The expected number of total crashes, had RLC enforcement program not been implemented, was computed using the Empirical Bayes (EB) method and compared to the actual number of total crashes for "after the installation" and "after the termination" periods.
10. Vanlaar et al., 2014, Canada	A time-series analysis on red light running-related crashes	Crashes were grouped into right-angle and rear-end. First set of 12 cameras was installed Jan 2003, second 12 August 2003, third set July/August 2004; fourth set July/August 2005. The analysis covered crashes in the period 1994-2008 on 48 intersections in City Winnipeg.	Four dummy variables were created to indicate when each set of cameras was installed. ARIMA times series design was used to rule out regression to the mean. Data from the province of New Brunswick were used as a comparison group in the time series analysis. Monthly count data were used. % change in crashes was calculated from coefficient ω as: 100 × (e^ω −1).
11. Wong, 2014, USA, Los Angeles	Before-after observation study with treatment and control sites.	The average number of months observed before a treated intersection received a RLC was 16.46 months, while the average number of months observed after a treated intersection received a camera was 42.53 months. For each	A Poisson panel data model with random coefficients was applied to these data and estimated using Bayesian methods. In the statistical model, the Poisson distribution was "mixed" with a log-normal distribution to form the Poisson-log-normal model. This mixing

Author, Year, Country	Study type	Sample/Measurement	Analysis
		of the 32 treated intersections, the researcher selected 4 nearby intersections, one each to the north, south, east and west of the treated intersection as controls for that treated intersection. These control intersections were also selected by matching on three observable characteristics: type of intersection (i.e. four-way), presence of a traffic light, and number of lanes. If no intersection with a common street fulfilled the matching criteria, it was replaced with the closest intersection that does match the observable characteristics.	distribution relaxes the assumption of equidispersion and allows for error correlations across observations.
12. Ahmed & Abdel-Aty 2015 USA, Florida	A before-after Empirical Bayes crash analysis comparing treatment and control intersections	Intersections with active red-light cameras and at least three year of crash data in the before and after periods were considered for inclusion in the study. 25 RLC intersections were compared with 50 non camera intersections. Evaluation performed at 3 levels: 1. only target approaches where RLCs were installed, 2. all approaches on RLC intersections, and 3. non-RLC intersections located on the same travel corridors as the camera equipped intersections.	The observational Before-After EB method was applied on the 25 RLC intersections. The aggregate safety effectiveness over all RLC intersections was estimated and the Poisson test of significance was performed on all target approaches and all approaches combined.
13. LLau et al. 2015, USA, Florida	A before–after EB crash analysis using a comparison group along with traffic control correction	20 signalised intersections with RLC were matched to two comparison sites located at least 2 miles from camera sites (to minimize spill-over effect). Crashes were analysed for 3 years before (2008–2010) and 2 years after camera enforcement (2011 and 2012). Crashes at intervention and comparison sites were included if they occurred within 150 feet (± 46m) from the centre of an intersection.	An Empirical Bayes analysis was used to account for potential regression to the mean effects. An index of effectiveness along with 95% confidence intervals were calculated based on the comparison between the estimated and actual number of crashes in the after period.
14. Polders et al., 2015, Belgium	A combination of before-after observations and a driving simulator experiment (feeding into a Monte Carlo simulation)	Two signalised intersections where combined speed/red light cameras were about to be installed were selected for an on-field behavioural observation study in a before-and-after design. One of the intersections was rebuilt in a driving simulator where two test conditions (i.e., speed/red light cameras and speed/red light cameras with a warning sign) and one control condition (i.e., no speed/red light camera) were examined to provide input parameters for a Monte Carlo simulation of risk of rear-end collisions.	The odds of rear-end collisions for each condition are estimated by means of a Monte Carlo Simulation using a normal distribution. The Monte Carlo Simulation was performed with 100,000 iterations for each condition. The stopping distance was calculated for both the following and leading vehicle. A rear-end collision will occur when the sum of the stopping distance of the following vehicle and the distance headway is larger than the stopping distance of the leading vehicle

Author, Year, Country	Study type	Sample/Measurement	Analysis
15. Claros et al., 2016, USA, Missouri	A before-after/treatment-control Empirical Bayes estimation	A total of 24 four-leg urban intersections were randomly selected from a list of RLC intersections in Missouri from 2006 to 2011. Additionally, 35 comparable non-treated intersections were selected for the analysis. The data collection included intersection geometry, signal control operation, traffic volume, surrounding features, and crash data.	The predicted crashes were obtained using Safety Performance Functions, Crash Modification Factors, Calibration factors, and crash type distribution by facility and severity type. All these functions and factors account for local site characteristics, refining the prediction of crashes. The comparison (unbiased odds ration) of expected and observed crash frequency for the after period formed the basis for deriving the safety effectiveness.
16. Lee et al., 2016, South Korea	A before-after Empirical Bayes method with treated and untreated intersections	In years 2008, 2009, 2010, 2011, 2012 there were 2, 18, 26, 40, 40 urban intersections with a RLC. In 2007, 2008, 2009, 2010, 2011, 2012, there were 101, 99, 83, 75, 61, 61 (untreated) intersections in the reference group.	The method for assessing the safety impact of RLC consisted of 3 steps: 1. Acquiring data from different resources and processing that data for treatment and reference intersections 2. Modelling Safety performance functions using untreated intersection data, including geometric information, vehicle crash data, and traffic volume data; 3. Conducting an Empirical Bayes analysis for assessing the safety impacts

3.2 STUDY OUTCOMES

Table 2 summarises the main results per study.

Table 2: Results of coded studies on the effects of red light cameras (RLC) on crashes or risk (↙ = expected decrease in road safety; ↗ = expected increase in road safety).

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
1. Chin, 2012, Singapore	The crash vulnerability or crash-involved exposure of motorcycles at right-angle collisions	↗	The crash-involved exposure of motorcycles at right-angle collisions was significantly reduced from non-RLC sites with relative crash vulnerability (RCV) = 0.532 to RLC sites with RCV = 0.414.
	Observed exposure of motorcycles to vehicles in conflicting stream (at intersection)	↗	Motorcycles at RLC sites compared to non-RLC sites had a lower exposure by about 10% during the first second of green and 13% in the first 2.5 seconds of green.
	Light motor cycles proneness of at-fault right -angle collisions (Odds Ratio)	↗	For light motor cycles, the Odds Ratio of at-fault right-angle collisions to collide with not-at-fault motorcycles was lowered from 9.14 at non-RLC sites to 4.03 at RLC sites.

Author, Year, Country	**Indicator**	**Expected effect on safety**	**Safety/Crash reduction percentage (type crash)**
	Heavy motor cycles proneness of at-fault right-angle collisions (Odds Ratio)	↗	The Odds Ratio for at-fault heavy motor cycles was lowered from 6.26 at non-RLC sites to 2.34 at RLC sites.
2. Høye, 2013 international	Right-angle injury crashes	↗	33% decrease
	Rear-end injury crashes	↙	19% increase
	Rear-end crashes	↙	39% increase
3. Ko, 2013, USA, Texas	Red light running crashes	↗	20% decrease
	Right-angle red light running crashes	↗	24% decrease
	Rear-end red light running crashes	↙	37% increase
4. McCartt, 2013, USA	Odds of red light running after 0.5 second red signal phase	↗	At the camera intersections, 1 year after the start of enforcement the odds of red light violations occurring at least 0.5 second into the red signal phase decreased by 39%.
	Odds of red light running after 1.5 seconds red signal phase	↗	The odds of red light violations occurring at least 1.5 seconds into the red signal phase decreased by 86 %, relative to what would have been expected without the cameras.
5. Porter, 2013, USA, Virginia	Relative risk (RR) of red light running at the camera locations	↗	In the immediate months after the cameras were turned off RR at the camera locations was 2.96 times higher than in the months before the law's expiration.
	Relative risk (RR) of red light running at the camera locations	↗	One year later , RR at former camera locations, that still had cameras turned off, had risen to 4.06 times higher than when cameras were last active.
6. Chai, 2014,	Right-angle conflicts	↗	40 to 80% decrease
	Rear-end conflicts	↙	10 to 45% increase
7. De Pauw, 2014, Belgium	Severe right-angle crashes	↗	24% decrease
	Rear-end crashes	↙	44% increase
8. Lord, 2014, USA, Chicago	Angle and turning injury crashes	↗	15% decrease
	Rear-end crashes	↙	22% increase
9. Pulugurtha, 2014, USA,	Total crashes	↗	50% decrease (contrasting "before the installation – after the installation")

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
North Carolina	Total crashes	↗	16% decrease (contrasting "before the installation – after the termination" scenario)
10. VanLaar, 2014, Canada	Right angle crashes	↗	46% decrease after installation of the second set of 12 cameras.
	Rear-end crashes	↙	42% increase in crashes after the installation of first set of cameras
11. Wong, 2014, USA, Los Angeles	Total crashes	↙	17% increase
	Injury crashes	↙	22% increase
	Red light running crashes	—	No significant effect
	Right-angle crashes	↙	24% increase
	Rear-end crashes	↙	34% increase
12. Ahmed 2015, Florida	Angle and left-turn crashes on target approaches	↗	24% decrease
	Angle and left-turn fatal and injury crashes on target approaches	↗	26% decrease
	Rear-end crashes on target approaches	↙	32% increase
	Rear-end fatal and injury crashes on target approaches	↙	41% increase
13. LLau, 2015	Injury crashes first yr.	↗	19% decrease
	Red light running related injury crashes 1st yr.	↗	24% decrease
	Red light running related injury crashes 2nd yr.	↗	17% decrease
	Rear-end crashes 1st yr.	↙	40% increase
	Rear-end crashes 2nd yr.	↙	51% increase
14. Polders, 2015, Belgium	Odds Ratio of compliance with red lights	↗	Odds Ratio compliance 1.2 times higher in the presence of a speed/red light camera.
	Odds Ratio of rear-end accident in camera condition	↙	Odds Ratio was 6.42 in the speed/red light camera condition compared to no-camera condition.
	Odds Ratio of rear-end accident in camera/sign condition	↙	Odds Ratio was 4.01 in the speed/red light camera + warning sign condition compared with no-camera condition

Author, Year, Country	Indicator	Expected effect on safety	Safety/Crash reduction percentage (type crash)
15. Claros, 2016, Missouri	Right-angle fatal and injury crashes	↗	14.5% decrease
	Rear-end crashes	↙	16.5% increase
	Rear-end fatal and injury crashes	↗	10.9% decrease
16. Lee, 2016, South Korea	Total crashes	↙	50.8% increase
	Injury sideswipe and rear-end crashes	↙	73.4% increase
	Sideswipe and rear-end crashes	↙	68.7% increase
	Injury crashes	↙	52.5% increase
	Fatal angle, sideswipe, rear-end and head-on crashes	↗	22.5% decrease

3.3 LITERATURE SEARCH

The literature on red light cameras and traffic risk was searched for in the international database Scopus on 16 December 2016. Scopus is the largest international peer-reviewed database. A meta-analysis by Høye in 2013 covered studies in the period 1995-2011. In view of this, the literature was searched over the period 2012-2016; the search terms were searched in title, abstract and keywords. Table 3 describes the search terms and logical operators and the number of hits for three searches on red light running and accidents.

Table 3: Used search terms and logical operators

no	Search terms/logical operators/combined queries	hits
1	The search for red light running and drivers used the following combination of key words: TITLE-ABS-KEY ("red light camera" AND (safety OR crash OR accident)) AND PUBYEAR > 2011	30

The search resulted in 30 hits. In a first screening round, these 30 references were screened on potential relevance for coding based on title and abstract. The main exclusion criteria were: no effects of red light camera studied, other than English language, duplication, general review like text instead of specific study. Also references were screened for additional studies. Table 4 shows the results.

Table 4: Initial selection of studies after the first screening round

Selection steps	Not selected first round	Selected first round
Excluded: No actual crash reduction studied	10	

Excluded : Duplication	1	
Excluded: General review-like text	3	
Selected after initial screening		16
Added after screening references (VanLaar, Lord, Porter)		3
Total selected after first round		19

The 19 selected studies were further screened on relevance for coding in a second screening round. In the second round the same criteria were used but now the full-text copies of the papers were checked. Table 5 presents the results of this second screening round and describes the final decisions.

Table 5: Selection of studies to be coded in second screening round

	Reference	Relevant	Coded
1	Ahmed, M.M. & Abdel-Aty, M. (2014). Evaluation and spatial analysis of automated red-light running enforcement cameras. Transportation Research Part C: Emerging Technologies. Article in Press.	Yes	1. Yes
2	Chai, C., Wong, Y.D., & Lum, K.M. (2015). Safety Impacts of Red Light Cameras at Signalized Intersections Based on Cellular Automata Models. Traffic Injury Prevention, 16, 374-379.	Yes	3. Yes
3	Chin, H.C. & Haque, Md.M.(2012). Effectiveness of red light cameras on the right-angle crash involvement of motorcycles. Journal of Advanced Transportation, 46 , 54-66.	Yes, but study in Singapore concentrating on motorcycles makes it hard to compare with any of the other studies	4. Yes
4	Claros, B., Sun, C. & Edara, P. (2017). Safety effectiveness and crash cost benefit of red light cameras in Missouri. Traffic Injury Prevention, 18, 70-76.	Yes	5. Yes
5	De Pauw, E., Daniels, S., Brijs, T., Hermans, E. & Wets, G. (2014). To brake or to accelerate? Safety effects of combined speed and red light cameras. Journal of Safety Research, 50, 59-65	Yes	2. Yes
6	*Meta-analysis starting point:* Høye, A. (2013). Still red light for red light cameras? An update. Accident Analysis and Prevention, 55, 77-89.	Yes	6. Yes
7	Ko, M., Geedipally, S. & Walden, T. (2012). Effectiveness and site selection criteria for red light camera systems. Transportation Research Record, 2327, 53-60.	Yes	7. Yes
8	Langland-Orban, B., Pracht, E.E., Large, J.T., Zhang, N. & Tepas, J.T. (2014). Explaining Differences in Crash and Injury Crash Outcomes in Red Light Camera Studies. Evaluation and the Health Professions, 39, 226-244.	This study is a brief methodological review of earlier studies (2000-2013) that analyses how findings are associated with data and method characteristics. Certainly relevant for understanding the research, but not suitable for coding.	No
9	Lee, S.H., Lee, Y.D. & Do, M. (2016). Analysis on safety impact of red	Yes	10. Yes

	Reference	Relevant	Coded
	light cameras using the Empirical Bayesian approach. Transportation Letters, 8, 241-249.		
10	Llau, A.F., Ahmed, N.U., Khan, H.M.R.U., Cevallos, F.G. & Pekovic, V. (2015). The Impact of Red Light Cameras on Crashes Within Miami–Dade County, Florida. Traffic Injury Prevention, 16, 773-780.	Yes	11. Yes
11	Lord, D. & Geedipally, S.R. (2014).Safety Effects of the Red-Light Camera Enforcement Program in Chicago, Illinois. Research report prepared for the Chicago Tribune, College Station, TX.	Yes	12. Yes
12	McCartt, A.T. & Hu, W. (2013). Effects of Red Light Camera Enforcement on Red Light Violations in Arlington County, Virginia. Insurance Institute for Highway Safety, Arlington.	Yes	8. Yes
13	Polders, E., Cornu, J., De Ceunynck, T., Daniels, S., Brijs, K., Brijs, T., Hermans & E., Wets, G. (2015). Drivers' behavioral responses to combined speed and red light cameras. Accident Analysis and Prevention, 81, 153-166.	Real-world observations and driving simulator-based observations are combined.	13. Yes
14	Porter, B.E., Johnson, K.L. & Bland, J.F. (2013). Turning off the cameras: Red light running characteristics and rates after photo enforcement legislation expired. Accident Analysis & Prevention, 50, 1104–1111.	Yes	9. Yes
15	Pulugurtha, S.S. & Otturu, R. (2014). Effectiveness of red light running camera enforcement program in reducing crashes: Evaluation using "before the installation", "after the installation", and "after the termination" data . Accident Analysis and Prevention, 64, 9-17.	Yes	14. Yes
16	Stevenson, M., Faruque, S., Almajil, A., Farhan, M., Fildes, B, & Lawrence, B. (2016). An evaluation of the red-light camera programme in the city of Dammam, the Kingdom of Saudi Arabia. International Journal of Injury Control and Safety Promotion, 1-5. Article in Press.	Study in Saudi-Arabia. The small crash numbers observed prevented rigorous statistical analysis which is a limitation of the current study. Other limitations were: - insufficient details on the crash type (.e.g. whether crash was right angle type) - limited data available on the timing of the installation of the cameras, and the site of the cameras	No (too limited data quality)
17	Testerman, G.M., Al-Balbissi, L.A., & Quillen, O.D. (2013). Red light cameras reduce right-angle and rear-end crashes. American Surgeon, 79 (12), pp. E347-348.	Only 2 pages, perhaps letter or comment. Not relevant.	No
18	Vanlaar, W., Robertson, R. & Marcoux, K. (2014) An evaluation of Winnipeg's photo enforcement safety program: Results of time series analyses and an intersection camera experiment. Accident Analysis and Prevention, 62, 238-247.	Yes	15. Yes
19	Wong, T. (2014). Lights, camera, legal action! The effectiveness of red light cameras on collisions in Los Angeles (2014) Transportation Research Part A: Policy and Practice, 69, 165-182.	Yes	16. Yes

3.4 REFERENCES

Coded studies

Ahmed, M.M. & Abdel-Aty, M. (2014). Evaluation and spatial analysis of automated red-light running enforcement cameras. *Transportation Research Part C*, *50*, 130–140.

Chin, H.C. & Haque, Md.M.(2012). Effectiveness of red light cameras on the right-angle crash involvement of motorcycles. *Journal of Advanced Transportation*, *46*, 54-66.

Chai, C., Wong, Y.D. & Lum, K.M. (2015). Safety Impacts of Red Light Cameras at Signalized Intersections Based on Cellular Automata Models. *Traffic Injury Prevention*, *16*, 374-379.

Claros, B., Sun, C. & Edara, P. (2017). Safety effectiveness and crash cost benefit of red light cameras in Missouri . *Traffic Injury Prevention*, *18*, 70-76

De Pauw, E., Daniels, S., Brijs, T., Hermans, E. & Wets, G. (2014). To brake or to accelerate? Safety effects of combined speed and red light cameras. *Journal of Safety Research*, *50*, 59-65

Høye, A. (2013). Still red light for red light cameras? An update. *Accident Analysis & Prevention*, *55*, 77– 89.

Ko, M., Geedipally, S. & Walden, T. (2013). Effectiveness and site selection criteria for red light camera systems. *Transportation Research Record, 2327*, 53-60.

Lord, D. & Geedipally, S.R. (2014).Safety Effects of the Red-Light Camera Enforcement Program in Chicago, Illinois. Research report prepared for the Chicago Tribune, College Station, TX.

Llau, A.F., Ahmed, N.U., Khan, H.M.R.U., Cevallos, F.G. & Pekovic, V. (2015). The Impact of Red Light Cameras on Crashes Within Miami–Dade County, Florida. *Traffic Injury Prevention, 16*, 773–780.

Lee, S.H., Lee, Y.D. & Do, M. (2016). Analysis on safety impact of red light cameras using the Empirical Bayesian approach, *Transportation Letters*, DOI: 10.1080/19427867.2015.1121009

McCartt, A.T., & Hu, W. (2013). *Effects of Red Light Camera Enforcement on Red Light Violations in Arlington County, Virginia*. Arlington: Insurance Institute for Highway Safety.

Polders, E., Cornu, J., De Ceunynck, T., Daniels, S., Brijs, K., Brijs, T., Hermans, E. & Wets, G. (2015). Drivers' behavioral responses to combined speed and red light cameras . *Accident Analysis & Prevention*, *81*, 153-166.

Porter, B.E., Johnson, K.L. & Bland, J.F. (2013). Turning off the cameras: Red light running characteristics and rates after photo enforcement legislation expired. *Accident Analysis & Prevention*, *50*, 1104– 1111.

Pulugurtha, S.S. & Otturu, R. (2014). Effectiveness of red light running camera enforcement program in reducing crashes: Evaluation using “before the installation”, “after the installation”, and “after the termination” data. *Accident Analysis & Prevention*, *64*, 9– 17.

Vanlaar, W., Robertson, R. & Marcoux, K. (2014) An evaluation of Winnipeg's photo enforcement safety program: Results of time series analyses and an intersection camera experiment. *Accident Analysis & Prevention*, *62*, 238-247.

Wong, T. (2014). Lights, camera, legal action! The effectiveness of red light cameras on collisions in Los Angeles. *Transportation Research Part A: Policy and Practice*, *69*, 165-182.

Additional references

Attawi, A.M. (2014). Characteristics of red light running violations in urban areas in Tabuk, Kingdom of Saudi Arabia*. IATSS Research 37*, 119–123.

ATS (2013). *Red-Light Running Dangers in the United States.* American Traffic Solutions. https://www.atsol.com/wp-content/uploads/2013/10/ATS-RLR-Dangers-Cutsheet-201309-v03.pdf, accessed July 12th 2016

Bonneson, J. & Zimmerman, K. (2004). *Red-Light-Running Handbook: An Engineer's guide to reducing red-light-related crashes*. College Station: Texas Transportation Institute.

Burkey, M.L. (2005). A response to unfounded criticisms of Burkey and Obeng (2004) made by the IIHS., Greensboro, NC: Department of Economics and Transportation/Logistics, NCA&T State University. https://mpra.ub.uni-muenchen.de/36369/1/MPRA_paper_36369.pdf, accessed April 13th 2017.

Council, F.M., Persaud, B.N., Eccles, K.A., Lyon, C., Griffith, M.S., Zaloshnja, E. & Miller, T. (2005). Implementing red light camera programs: guidance from economic analysis of safety benefits. *Transportation Research Record*, *1922*, 38-43.

ETSC (2009). *2010 on the Horizon. 3rd Road Safety PIN Report*. Brussels: European Transport Safety Council.

Fortuijn, L.G.H., Carton, P.J. & Feddes, B.J. (2005). *Veiligheidseffect van kruispuntplateaus in gebiedsontsluitingswegen*. Verkeerskundige Werkdagen 2005*.* Ede: CROW.

Harris, T. (2001). How red-light cameras work. http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/red-light-camera.htm, accessed February 9th 2017

IIHS (2015). Red light running. Camera enforcement works to curb this dangerous behavior. Insurance Institute for Highway Safety. http://www.iihs.org/iihs/topics/t/red-light-running/topicoverview, accessed July 12th 2016

Langland-Orban, B., Large, J.T. & Pracht, E.E. (2011). An update on red light camera research: The need for federal standards in the interest of public safety. *Florida Public Health Review, 8*, 1-9.

Llau, A.F., & Ahmed, N.U. (2014). The Effectiveness of Red Light Cameras in the United States-A Literature Review. *Traffic Injury Prevention*, *15*, 542-550.

Retting, R.A., Ferguson, S.A. & Hakkert, A.S. (2003). Effects of red light cameras on violations and crashes: a review of the international literature. *Traffic Injury Prevention*, *4*, 17–23.

Tay, R. & Barros, de A. (2011). Should traffic enforcement be unpredictable? The case of red light cameras in Edmonton. *Accident Analysis and Prevention*, *43*, 955–961.

References in 2013 meta-analysis Høye

Andreassen, D. (1995). *A long term study of red light cameras and crashes. Research report ARR 261.* Victoria: Australian Road Research Board.

Bradbury, K.E. (2010). *The effectiveness of red light cameras in Washington and Oregon*. Oregon: Thesis submitted to Oregon State University, University Honors College.

Budd, L., Scully, J., & Newstead, S. (2011). *Evaluation of the crash effects of Victoria's fixed digital speed and red-light cameras. Report no. 307.* Victoria: MONASH University, Accident Research Centre.

Burkey, M.L., & Obeng, K. (2004). *A detailed investigation of crash risk reduction resulting from red light cameras in small urban areas. Updated Final Report*. North Carolina: Urban Transit Institute, North Carolina Agricultural/Technical State University.

California State Authority (2002). *Red light camera programs. Report 2001-125*. Sacramento: California State Authority.

Charlotte, City of (2001). SafeLight crash analysis 2001. http://www.charmeck. org/Departments/Transportation/Special+Programs/SafeLight+Crash+Analysis+2001.htm (accessed 17.9.07).

Council, F.M., Persaud, B., Eccles, K., Lyon, C., & Griffith, M.S.(2005). *Report FHWA-HRT-05-048*. Washington: Federal Highway Administration.

Cunningham, C.M., & Hummer, J.E. (2010). Evaluating the effectiveness of red-light running camera enforcement in Raleigh, North Carolina. *Journal of Transportation Safety & Security, 2*, 312–324.

Dahnke, R.A., Stevenson, B.C., Stein, R.M., & Lomax T. (2008). *Evaluation of the city of Houston digital automated red light camera program*. Texas: Rice University, Center for Civic Engagement and Texas Transportation Institute, Texas A&M University.

Fitzsimmons, E.J., Hallmark, S., McDonald, T., Orellana, M., & Matulac, D. (2007). *The effectiveness of Iowa's automated red light running enforcement programs. Report No. CTRE Project 05-226.* Ames, Iowa: Center for Transportation Research and Education Iowa State University.

Fox, H., (1996). *Crashes at Signal Controlled Junctions and Pelican Crossings in Glasgow*. Glasgow: Scottish Office Central Research Unit.

Garber, N.J., Miller, J.S., Abel, R.E., Eslambolchi, S., & Korukonda, S.K. (2007). *The impact of red light cameras (photo-red enforcement) in Virginia. Final report VTRC 07- R2*. Charlottesville, Virginia: Virginia Transportation Research Council.

Giæver, T., & Tveit, Ø. (1998). *Erfaringer med automatisk rødlyskontroll – vurdering av videre drift*. SINTEF rapport STF22 A97067. Trndheim: SINTEF.

Golob, J.M., Cho, S., Curry, J.P., & Golob, T.F. (2002). *Impacts of the San Diego photo red light enforcement system on traffic safety. Report UCI-ITS-WP-02-11*. Irvine, California: Institute of Transportation Studies.

Hillier, W., Ronczka, J., & Schnerring, F. (1992). *An evaluation of red light cameras in Sydney*. New South Wales: Roads and Traffic Authority, New South Wales.

Hooke, A., Knox, J., & Portas, D. (1996). *Cost benefit analysis of traffic light & speed cameras. Police Research Series Paper 20*. London: Police Research Group.

Hu, W., McCartt, A.T., & Teoh, E.R. (2011). Effects of red light camera enforcement on fatal crashes in large US cities. *Journal of Safety Research, 42*, 277–282.

Kloeden, C.N., Edwards, S.A., & McLean, A.J. (2009). *Evaluation of South Australian red light and speed cameras. Report CASR011*. Adelaide: Centre for Automotive Safety Research, University of Adelaide.

Malone, B., Hadayeghi, A., & White, C. (2010). *Red light cameras: surprising new safety results*. ITE 2010 Annual Meeting and Exhibit. Vancouver, Canada.

Mann, T.S., Brown, S.L., & Coxon, C.G.M. (1994). *Evaluation of the effects of installing red light cameras at selected Adelaide intersections*. Walkerville: South Australian Department of Transport Office of Road Safety.

MVA Consultancy (1995). Running the red: an evaluation of Strathclyde Police's red light camera initiative. http://www.scottishexecutive.gov.uk/Publications/1999/01/47e3bf41-bf11-470a-83bf-7f57095d0f0f (accessed 17.9.07).

Ng, C.H., Wong, Y.D., & Lum, K.M. (1997). The impact of red-light surveillance cameras on road safety in Singapore. *Road & Transport Research, 6*, 72–81.

Persaud, B., Council, F.M., Lyon, C., Eccles, K., & Griffith, M. (2005). Multijurisdictional safety evaluation of red light cameras. *Transportation Research Record, 1922*, 29–37.

Retting, R.A., & Kyrychenko, S.Y. (2002). Reductions in injury crashes associated with red light camera enforcement in Oxnard, California. *American Journal of Public Health, 92*, 1822–1825.

Richardson, K.(2003). Red light camera study. *Transport Engineering in Australia, 9*, 13–23.

Shin, K., & Washington, S. (2007). The impact of red light cameras on safety in Arizona. *Accident Analysis and Prevention, 39*, 1212–1221.

South, D., Harrison, W., Portans, I., & King, M. (1988). *Evaluation of the red light camera program and the owner onus legislation. Report No SR/88/1*.Hawthorne, Australia: Road Traffic Authority.

Vinzant, J.C., & Tatro, B.J. (1999*). Evaluation of the effects of photo radar speed and red light camera technologies on motor vehicle crash rates*. Arizona: Prepared forth City of Mesa Police Department, Arizona State University, and B.J. Tatro Consulting.

Walden, T.D., Geedipally, S., Ko, M., Gilbert, R., & Perez, M. (2011). *Evaluation of automated traffic enforcement systems in Texas*. Texas: Crash Analysis Program of the Center for Transportation Safety, Texas Transportation Institute, Texas A&M University.

Yaungyai N. (2004). *Evaluation update of red light camera program in Fairfax county, Virginia*. Virginia: Masters Thesis, Virginia Tech.