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Still red light for red light cameras? An update

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ABSTRACT

The present study has replicated the results from a previous meta-analysis by Erke (2009) [Erke, A., 2009. Red light for red-light cameras? A meta-analysis of the effects of red-light cameras on crashes. Accident Analysis & Prevention 41 (5), 897–905.] based on a larger sample of RLC-studies, and provides answers to the criticisms that were raised by Lund et al. (2009) [Lund, A.K., Kyrychenko, S.Y., Retting, R.A., 2009. Caution: a comment on Alena Erke's red light for red-light cameras? A meta-analysis of the effects of red-light cameras on crashes. Accident Analysis and Prevention 41, 895–896.] against the previous meta-analysis. The addition of recent studies to the meta-analysis and a more thorough investigation of potential moderator variables lead to a slight improvement of the estimated effects of RLC in the previous meta-analysis. The present study found a non-significant increase of all crashes by 6% and a non-significant decrease of all injury crashes by 13%. Right-angle collisions were found to decrease by 13% and rear-end collisions were found to increase by 39%. For right-angle injury collisions a decrease by 33% was found and for rear-end injury collisions a smaller increase was found (+19%). The effects of RLC are likely to be more favorable when RLC-warning signs are set up at main entrances to areas with RLC enforcement than when each RLC-intersection is signposted. The effects of RLC may become more favorable over time, this could however not be investigated empirically. Several results indicate that spillover effects may occur for right-angle collisions, but most likely not for rear-end and other crashes. If spillover effects do not occur for rear-end crashes, which increase at RLC intersection, this would be a positive result for RLC. However, the results seem to be affected to some degree by publication bias and the effects may therefore be somewhat less favorable than indicated by the results from meta-analysis.

1. Introduction

Red light cameras (RLC) are a controversial safety measure. They aim at reducing red-light running (RLR) at signalized intersections and crashes resulting from RLR. While several studies have shown that RLC are successful in reducing RLR (Arup, 1992; Chin, 1989; Retting et al., 1999a,b, 2003), the results for crashes are not equally positive. Only right-angle collisions are in most (but not all) studies found to decrease. Right-angle collisions are the target crashes for RLC. They are on average more severe than other types of intersection crashes and are often associated with RLR. Rear-end collisions on the other hand are consistently found to increase at RLC-intersections. Results for the total number of crashes are inconsistent. Many studies found decreases of the total number of crashes. A number of studies found however unchanged or increased total crash numbers and conclude that the increase of rear-end collisions offsets, or more than offsets, the decreasing right-angle collisions (e.g. Burkey and Obeng, 2004; Cunningham and Hummer, 2010; Garber et al., 2007; Kloeden et al., 2009; Vinzant and Tatro, 1999). The unfavorable results were by several authors attributed to methodological flaws (Lund et al., 2009; Kyrychenko and Retting, 2004; Persaud et al., 2008).

A previous meta-analysis (Erke, 2009) showed that study methodology indeed affects the results form RLC studies. A lack of control for regression to the mean (RTM) generally leads to an overestimation of the favorable effects of safety measures. RTM occurs when safety measures are implemented at high-crash sites. When large numbers of crashes have wholly or partly been due to random variation, decreasing crash numbers can be expected even without any (effective) safety measure (Elvik, 1997; Hauer, 1997). RLC are often installed at intersections for the very reason that there have been large numbers of crashes, especially right-angle collisions (Shin and Washington, 2007), and their introduction is therefore inclined to be accompanied by RTM effects. Spillover effects may also affect the results from RLC studies. Spillover effects are those effects on crash numbers at untreated sites that are close to a site where a certain measure has been implemented. Drivers may for example become generally more inclined to stop when lights are changing to red. Spillover effects may lead to an underestimation of the effects of RLC, both favorable and unfavorable, when

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intersections proximal to RLC-intersections are used as a comparison group. Evidence for the existence of spillover effects is however not consistent (Burkey and Obeng, 2004).

Based on studies that have controlled for both RTM and spillover effects, Erke (2009) concluded that RLC do not have any favorable effect on the total number of crashes. For all crashes an increase by 15% was found, right-angle collisions were found to be reduced by 10% and rear-end crashes were found to increase by 40%. According to Lund et al. (2009), two of the studies included in the meta-analysis have been misclassified as having controlled for both RTM and spillover effects and should not have been included in the final results. The aim of the present study is to replicate the results from the study by Erke (2009) based on a larger sample of RLC-studies, and to investigate more thoroughly the effects of study methodology. A closer look is especially taken at those studies than have been critized by Lund et al. (2009) and several analyses are performed to test if these or other studies can be regarded as outliers. Additionally the effects of signposting all RLC-intersections are investigated. RLC are often signposted, either to increase the deterrence effect or because of data privacy. It is assumed that the effects of RLC are different, depending on whether or not all RLC-intersections are signposted.

2. Log-odds method of meta-analysis

The estimated effects of RLC on crashes from different studies are summarized using the log-odds method of meta-analysis (Christensen, 2003; Elvik, 2005b; Fleiss, 1981). The effects of RLC on intersection crashes are estimated as percentage reductions in the number of crashes at intersections with RLC, compared to intersections without RLC. Effect estimates are expressed as odds ratios, i.e. as the ratio of the odds of a crash at intersections with RLC against the odds of a crash at intersections without RLC. Summary effects are calculated as weighted means of the natural logarithms of the effect estimates (odds ratios), and then rescaled from the logarithmic scale. The statistical weights are in a Fixed Effects (FE) model inversely proportional to the variance of the logarithms of the odds ratios. In a FE model the variance of effect estimates is assumed to arise only from random variation of the effect estimates around one "fixed" mean effect. In a random effects (RE) model the variance is assumed to arise additionally from random variation of the mean effects of each of the studies. The statistical weights are computed according to Christensen (2003) as a function of the logarithm of the effect estimates and weights in a FE model, and Cochran's Q statistic. A RE model of meta-analysis is more adequate than a FE model when there is heterogeneity in the results, i.e. when the effect estimates are not varying randomly around one common "fixed" mean effect. When there is no significant amount of heterogeneity, a RE effects model can also be applied and the results will be similar to those of a FE model. The RE model is therefore applied in the meta-analysis except when too few effect estimates are available to compute RE weights. For a more detailed description of the log-odds method of meta-analysis it is referred to Erke (2009) and the publications cited above.

3. Studies included in the meta-analysis

Studies that have investigated the effect of RLC on numbers of intersection crashes were included in the meta-analysis when enough information was provided to compute effect estimates and statistical weights. All studies that were included in the previous meta-analysis are also included in the present analysis. Additional (more recent) studies were identified by searching ScienceDirect (an online collection of over 2000 peer reviewed scientific journals), TRID (a database that combines the records from the Transportation research Board, TRIS, and the OECD's Joint Transport Research Centre's International Transport Research Documentation Database, ITRD, which includes over 940,000 records), the ISI Web of knowledge, and the internet (mainly by Google Scholar). Reference lists of relevant studies have also been checked.

A total of 28 before-after studies were found that gave sufficient information to compute effect estimates and statistical weights (29 if one includes the study by Persaud et al., 2005). 19 of these had been included in the previous paper, while 9 are more recent studies. The studies are listed alphabetically in Table 1. According to the study methodology, all studies have been classified as belonging to one of the following four categories: (1) *Studies that have controlled neither for RTM nor for spillover effects* (8 studies). These studies are before-after studies with comparison groups. The results may be affected by RTM because RLC were not randomly assigned to study and comparison intersections, and intersections with and without RLC were not matched with respect to crash frequencies. Spillover effects may affect the results because comparison intersections (or approaches) include intersections close to the RLC-intersections. (2) *Studies that have controlled for spillover effects, but not for RTM* (7 studies). Some of these studies are before-after studies without comparison groups and therefore not likely to be affected by spillover effects. Among the remaining studies, two have used crashes not related to RLR at RLC-intersections as a comparison group (Fox, 1996 in a part of the results; Walden et al., 2011), and one has used only non-RLC signalized intersections that are not close to the RLC intersections as a comparison group (Malone et al., 2010). (3) *Studies that have controlled for RTM, but not for spillover effects* (5 studies). These studies are before-after studies with comparison groups. In contrast to the studies in group (1), intersections with and without RLC are matched with respect to crash frequencies (and other intersection characteristics), or RLC are randomly assigned to intersections. One of the studies has applied the Empirical Bayes (EB) technique for controlling for RTM (Richardson, 2003). (4) *Studies that have controlled for both RTM and spillover effects* (9 studies). These studies have used a variety of different approaches to controlling for RTM and spillover effects. These studies are discussed in more detail in Section 4.2.[1]

Most studies have been conducted in the USA. A total of 134 effect estimates has been obtained or computed from these studies. Multivariate studies are not included in the meta-analysis because the results are not necessarily an indication of the effects of RLC on crashes, but may be affected by a selection bias, i.e. the installation of RLC at intersections with high crash numbers. Two multivariate studies (Chin and Quddus, 2003; Helai et al., 2008) are discussed in Erke (2009). Two more recent multivariate studies (Haque et al., 2009, 2010) have investigated the effects of RLC on motorcycle crashes in Singapore. Both studies found fewer motorcycle crashes at intersections with RLC than at intersections without RLC.

4. Results of meta-analysis

4.1. Effects of RLC on crashes at RLC-intersections

Summary effects were computed separately for different crash types (all crashes, right-angle collisions, rear-end collisions, RLR-related collisions RLR-related collisions and head-on/left-turn collisions) and for different degrees of severity (fatal, injury, unspecified). Summary effects for all crashes are based on effect estimates that refer to all intersection crashes (or calculated as summary effects if only results for several types of intersection crashes are reported in a study). Effect estimates for unspecified crash

[1] Two studies in this group were classified differently than in the previous analysis (South et al., 1988; Yaungyai, 2004).