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Lesson learned from the application of intersection safety devices in Edmonton

Laura Contini*, Karim El-Basyouny

Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, T6G 2W2, Canada

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ABSTRACT

The City of Edmonton began its intersection safety device (ISD) program in 2009 with the installation of 50 cameras throughout the city. The ISDs are approach-specific and combine automated enforcement of red-light running and speed violations during the red and green phases of the intersection control. The goal of this study is to evaluate the safety performance of ISDs within the city of Edmonton, Canada and to identify factors that can lead to successful selection of future ISD sites. A before-and-after Empirical Bayes (EB) method is used to account for regression-to-the-mean and other confounding factors. A safety performance function and yearly calibration factors are developed using data from a set of reference intersections within Edmonton. The before-and-after analysis is applied at the overall intersection level and for each approach of the ISD intersections. The results showed significant reductions that ranged from 12% to 25% for total collisions, and from 33% to 43% for angle collisions. No significant reduction was observed for severe collisions at the intersection level, however significant reductions were found at the approach level at locations with a relatively higher collision history. The impact of site selection criteria on collision reduction was also evaluated. Greater reductions were found at sites with a higher collision frequency. Additionally, the impact of intersection characteristics on collision reduction was investigated. Speed limits, presence of separated right turn lane and the number of lanes were found to impact ISD collision reduction.

1. Introduction

The City of Edmonton, in Alberta, Canada, introduced Intersection Safety Devices (ISD), which combine red-light running enforcement and speed enforcement at intersections in 2009. Both red-light running and speeding are major contributors to collisions at intersections. In 2014 there were nearly 25,000 collisions in the city of Edmonton including over 2900 injuries and 23 fatalities. Collisions at intersections accounted for 55% of the total number of collisions and 68% of injury collisions. The two main causes of injury collisions at intersections were rear-end collisions and left-turn cross path collisions (Motor vehicle collisions, 2014).

Angle collisions and rear-end collisions are the commonly identified collisions related to red-light running (Council et al., 2005). Angle collisions occur when a vehicle enters the intersection after the onset of the red phase and collides with a vehicle with the right of way entering from a perpendicular roadway. In the literature, red-light cameras (RLC) are commonly found to be associated with an increase in rear-end collisions. The increase in rear-end collisions can be attributed to drivers stopping suddenly or slowing at the onset of the yellow phase to avoid RLC ticketing, while the following vehicle speeds up as it plans to proceed through the intersection.

The effectiveness of RLCs has been extensively investigated in the literature. However, the safety impacts of ISDs have not been as widely studied. Although ISDs are similar to RLCs, the addition of speed enforcement should have an influence on the intersection's safety performance. Speeding increases both the odds of being involved in a collision as well as the risk of injury or fatality resulting from a collision (Elvik, 2005). This could be attributed to the fact that when driving at higher speeds, drivers have less time to react to changing conditions, and stopping distances are increased. Furthermore, the criteria used to determine ISD locations had not been well defined or studied. ISD performance is likely affected by various intersection characteristics. Understanding the factors that impact ISD performance will help when developing future ISD programs.

Previous studies have been mainly focused on RLCs. RLC target collisions related to red-light running violations, but not specif-

* Corresponding author.
E-mail addresses: contini@ualberta.ca (L. Contini), basyouny@ualberta.ca (K. El-Basyouny).

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ically speed. The results of these RLC studies have varied, but generally show a decrease in angle collisions and an increase in rear-end collisions. A *meta*-analysis (Høye, 2013) looked at the impact of RLC cameras across 28 RLC studies. Overall the results showed a 39% increase in rear-end collisions, a 19% increase in rear-end injury collisions and a 33% decrease in right-angle collisions. A study by (Sayed and de Leur, 2007) evaluated the performance of RLC in the city of Edmonton. The study included 25 intersections with RLCs installed between 1999 and 2003. Significant reductions were observed in all collision categories, including an 11% reduction in total collisions, 17% reduction in angle collisions and 12% reduction in rear-end collisions. The temporal changes of collision reductions following RLC installation was observed by Wang et al. (2015). The changes in collision modification factors (CMF) were predicted using ARMA time series analysis. The CMFs were determined for a period of 36 months. It was observed that CMFs for total collisions were lower in the first 9 months and then started to increase. Similar trend was observed for Fatal+Injury collisions, the CMF was lower for the first 18 months compared to the entire 36 months.

A study of ISDs in Victoria, Australia was conducted by (Budd et al., 2011). Their study included 77 intersection locations in Victoria. Warning signs were posted at all intersection approaches however cameras were limited to only 1 or 2 approaches per intersection. A 44% reduction was found in target collisions (right angle as well as right turn collisions) and no significant change in rear-end collisions. The study also found there was a strong effect on the targeted approaches; there was a 26% reduction in fatality collisions at intersections and a 47% reduction at target approaches.

A study of Winnipeg's intersection photo enforcement program which captured speed on green and red-light-running was conducted by (Vanlaar et al., 2014). The study looked at both the changes in collisions as well as speeding and red-light running violations. There was a drop in both speed and red-light running violations, however the reduction in speeding violations were greatest for less severe violations (1–13% over the speed limit) and less effective at reduction serious speeding violations (more 13% over the speed limit). Right angle collisions were found to decrease 46% but there was no change in collisions relating to speeding. Rear-end collisions were found to increase by 42% however time series analysis suggested that rear-end collisions may decrease over time.

A study by Alberta Transportation evaluated the safety performance of 54 ISD equipped intersections in four municipalities in Alberta (Zarei and Izadpanah, 2014). A before-and-after evaluation was conducted using the EB method. The study investigated the change in collisions and collision severity following ISD installation. Overall the study found a 1% increase in total collisions. The largest reductions were in severe and angle collisions (32% and 31% respectively). The study also found increases in the number of PDO and rear-end collisions (11% and 9%).

(De Pauw et al., 2014) analysed the change in injury collisions after the installation of ISDs in Flanders, Belgium using a before-and-after Empirical Bayes methodology. The study included 253 intersections and a comparison group which included all collisions in Flanders. The total injury collisions increased 5% to 9% after the installation of the cameras. The results also indicated a 14% to 18% reduction in severe side angle collisions and a 44% increase in rear-end collisions. The increase in rear-end collisions was much greater in urban areas than rural areas. The study also found that the proximity of ISDs impact the safety effectiveness; when there were 2 or more ISDs within 1500 m the collisions reductions were smaller.

Overall, the current literature suggests that ISDs are effective in reducing angle collisions. The changes in rear-end collisions have varied, from large increases to non-significant decreases. However, there are still a few issues regarding the safety of ISDs that need to investigated. Consequently, the first objective of this study is to

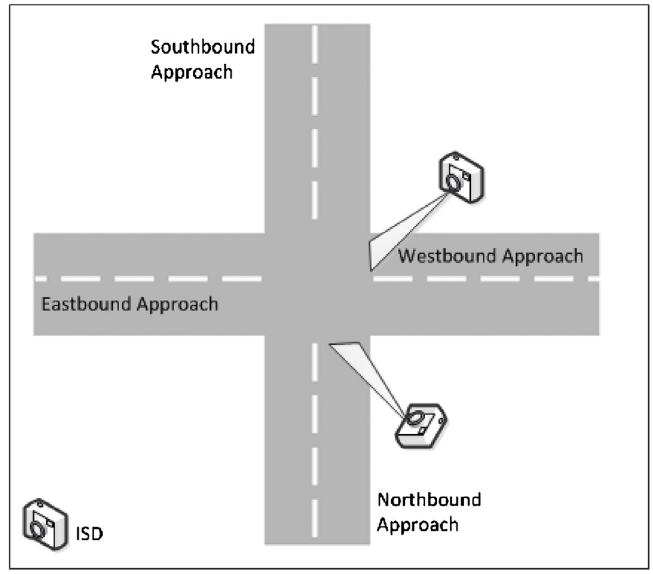

Fig. 1. Sample ISD intersection.

estimate the traffic safety impact of ISDs using data about the City of Edmonton's ISD program. The safety evaluation is conducted using the Empirical Bayes (EB) before-and-after analysis technique, as outlined in the Highway Safety Manual (2010). The EB method is considered the state-of-the-art technique to evaluate safety countermeasures. Since ISDs are installed on specific approaches, the safety evaluation is repeated twice, once at the approach level (i.e., each leg of the signalized intersection is analyzed separately) as well as the intersection level as a whole. For the approach level analysis, collisions are aggregated for each leg of the intersection. It is important to note that ISD are installed separately at each approach. For example, some intersection might have an ISD on only one of its four legs, or ISD could be available on all four legs. Fig. 1 shows an example of an intersection with ISDs installed on two approaches. For the intersection level analysis, collisions are aggregate for the whole intersection. Most ISD intersections have enforcement signs installed on all four legs. One of the advantages of conducting an approach level analysis is being able to examine the safety effects of approaches with signs only versus approaches with both signs and ISDs.

The second objective of this study is to identify factors that can lead to a successful selection of future ISD sites. Current studies do not differentiate between successful and ineffective ISD implementations. It is to be expected that ISD performance will not be the same for all sites. There may be other traffic and geometrical factors that contribute to a successful ISD application. If a relationship between collision reductions and intersection characteristics can be established at enforced sites it can be used to refine the selection of future ISD sites.

2. Program and data description

The first ISDs were installed at three intersections in 2009 and expanded to 50 approaches at 30 arterial intersections in the following years. ISDs are not always located on every approach to an intersection; some intersections have only one approach with an ISD and some have multiple. Drivers are made aware of the presence of ISDs, all intersection approaches with an ISD have a sign posted warning of automated enforcement. Additionally, drivers can view a list of all ISD equipped intersections that is available on the City of Edmonton website. The locations for ISD sites were cho-