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A comparison of collision-based and conflict-based safety evaluations: The case of right-turn smart channels

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ABSTRACT

This study presents the results of a collision-based full Bayes (FB) before–after (BA) safety evaluation of a newly proposed design for channelized right-turn lanes. The design which is termed "Smart Channels" decreases the angle of the channelized right-turn to approximately 70°. Its implementation is usually advocated to afford drivers a better view of the traffic stream they are to merge with and to allow also for safer pedestrian crossing. The evaluation used data for three treatment intersections and several comparison sites in the city of Penticton, British Columbia. The evaluation utilized FB univariate and multivariate linear intervention models with multiple regression links representing time, treatment, and interaction effects as well as the traffic volumes effects. As well, the models were extended to incorporate random parameters to account for the correlation between sites within comparison-treatment pairs. The results showed that the implementation of the right-turn treatment has resulted in a considerable reduction in the severity and frequency of collisions.

Another objective of the paper was to compare the results of the collision-based evaluation with the results of a traffic conflict-based evaluation of the same treatment intersections. The comparison showed remarkable similarity between the overall and the location specific reductions in conflicts and collisions which provides support for using traffic conflicts in BA studies. The results also provide positive empirical evidence that can support the validity of traffic conflict techniques.

1. Introduction

A significant volume of right-turning vehicles at intersections can have adverse operational and safety effects. Therefore, channelized right-turn lanes are usually implemented at intersections with high right-turn traffic volumes to reduce vehicle delay and improve safety. Studies have shown that the provision of these lanes provides significant safety benefits (Agent et al., 1996; Harwood et al., 2002).

To further improve the safety of channelized right-turn lanes, an alternative right-turn design has recently been proposed (Zegeer et al., 2002) that is more pedestrian-friendly and that supports improved traffic operations. The new design, termed "Smart Channels", decreases the angle of the channelized right-turn to approximately 70°. The design reduces the pedestrian crossing distance which can lead to shorter distance exposure, shorter signal cycles, and reduced potential for pedestrians to be in conflict with vehicles (Zegeer et al., 2002; The City of Ottawa, 2009). As well, smart channels provide drivers with a better view of the traffic stream they are to merge with (Fig. 1).

Conventional channelized right-turn lanes can require head turns of as much as 150°. However, guidelines such as the Transportation Association of Canada's (TAC) guidelines require that drivers should not have to look more than 120° back to check approaching traffic (Transportation Association of Canada, 1999). This is advocated because of the difficulty of older drivers to turn their head more than 90° to view intersecting traffic and the importance for drivers to clearly see potential conflicting vehicles at the end of an auxiliary right-turn (Staplin et al., 2001). Smart channels can accommodate both issues by widening the visibility cone of drivers (light-gray areas in Fig. 1).

In 2009, the Insurance Corporation of British Columbia (ICBC), in partnership with the British Columbia Ministry of Transportation and Infrastructure, initiated a pilot project to evaluate the safety performance of smart channels. The evaluation of the conversion of right-turn lanes to smart channels was carried out for 3 intersections in the city of Penticton, British Columbia. A before-and-after (BA) analysis of the safety impact was performed using automated detection and analysis of traffic conflicts with computer vision techniques (Autey et al., 2012). The results showed that the conversion

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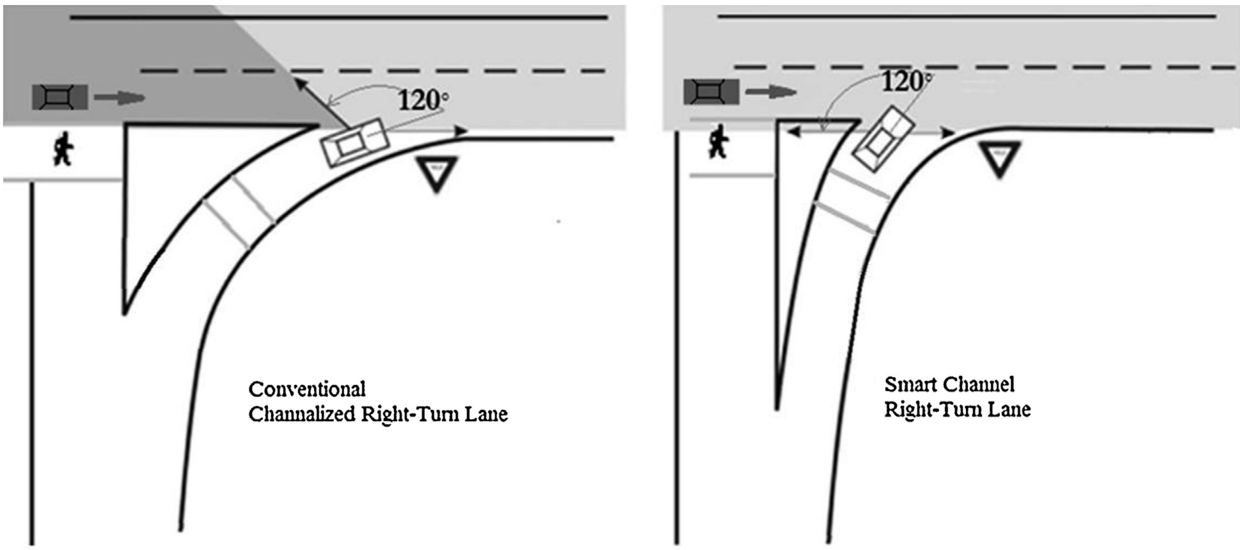

Fig. 1. Visibility conditions: conventional versus smart channelization.

of channelized right-turn lanes to smart channels can lead to a considerable reduction for both conflict frequency and severity. The overall reduction in total conflicts was estimated at approximately 51%. The total severity of all conflicts, normalized to traffic volumes, was observed to decrease by approximately 41% following the treatments (Autey et al., 2012). One main advantage which supported the use of traffic conflicts for the evaluation was that traffic conflicts are much more frequent than road collisions and BA studies based on traffic conflicts can be conducted over much shorter periods. Moreover, the use of automated video-based conflict analysis considerably facilitates the collection of traffic conflict data and overcomes the reliability and repeatability problems usually associated with manual traffic conflict observations.

However, although the use of collision surrogates such as traffic conflicts can offer several advantages for BA studies, the link between conflict reduction and potential collision reduction still needs to be clearly established before a wider application of the traffic conflicts technique in BA studies. In fact, establishing the linkage between conflicts and collisions is still a challenging subject in today's road safety research as witnessed by many studies (Gettman et al., 2008; Davis et al., 2008; El-Basyouny and Sayed, 2013). As well, BA studies based on collision data rely on more solid statistical techniques which were developed over many years of research compared to the automatic detection and analysis of traffic conflicts. Therefore, the main objectives for this study are to:

(a) Supplement the conclusions from Autey et al.'s 2012 evaluation by conducting a BA study using collision data and state-of-the-art full Bayes (FB) statistical technique. Collision and traffic volume data for the same treated intersections in Penticton are considered in addition to data for a set of control/comparison sites;
(b) Compare the results of the FB collision-based evaluation and the conflict-based evaluation conducted earlier to further strengthen the validity of using the traffic conflict technique. This validation should lead to a wider application of the traffic conflicts technique and better understanding of the link between road safety, driver behavior, and dynamic traffic interactions.

2. Collision-based before–after studies

Several methods are available to analyze collision data and to determine the effectiveness of safety treatments. Generally, these methods can be classified into conventional and Bayesian techniques.

Conventional methods assume that the collisions observed at a location can be used to directly provide an estimate of the true collision frequency. Examples of conventional evaluation techniques include the simple BA studies and simple BA studies with a control group (Hauer, 1997; Highway Safety Manual, 2010).

However, it can be argued that the observed accident frequency alone is not a reliable measure to estimate road safety since collision frequency is a stochastic variable of which the observed collision frequency is but one realization. Bayesian methods treat collision frequency as a random variable with its own probability distribution. The probability distribution is obtained in two steps. The first step involves determining a prior distribution and the second step involves using Bayes theorem to convert the prior distribution into a posterior distribution with observed data. Examples of Bayesian evaluation techniques include the empirical Bayes (EB) and full Bayes BA studies. The EB technique is considered the current most popular road safety evaluation approach (Hauer, 1997; Sayed et al., 2004; Persaud and Lyon, 2007; Sayed et al., 2010).

However, it is important to recognize that despite being the current state-of-the-practice, the EB method suffers from several limitations. These limitations make the use of the FB technique more appealing for conducting before and after safety studies. Researchers have shown that the FB technique: (i) accounts for more uncertainty in the data and model parameters; (ii) provides more detailed inference (credible intervals and parameter distributions); (iii) adds more flexibility in selecting collision distributions; (iv) allows inference at more than one level; (v) efficiently integrates the estimation of the SPF and treatment effects in a single step, reducing the need for a large data set; and (vi) conducts multivariate analysis (Li et al., 2008; Persaud et al., 2010; El-Basyouny and Sayed, 2009a,b, 2010, 2011). Therefore, the FB approach will be used in this study to estimate the effectiveness of the proposed design for channelized right-turn lanes (smart channels).

2.1. Fully-Bayesian approach

If we consider a BA study where collision data are available for a reasonable period of time before and after the intervention and, in addition, we also consider the availability of a comparison/control group for the before and after period of the intervention at treatment sites, it is possible to write the foundational model for FB