Accident Analysis and Prevention 86 (2016) 161–172

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Are signalized intersections with cycle tracks safer? A case–control study based on automated surrogate safety analysis using video data

Sohail Zangenehpour[a,*], Jillian Strauss[a], Luis F. Miranda-Moreno[b], Nicolas Saunier[c]

[a] Department of Civil Engineering and Applied Mechanics, McGill University, Room 165, Macdonald Engineering Building, 817 Sherbrooke Street West, Montréal, Québec, Canada H3A 0C3
[b] Department of Civil Engineering and Applied Mechanics, McGill University, Room 268, Macdonald Engineering Building, 817 Sherbrooke Street West, Montréal, Québec, Canada H3A 0C3
[c] Department of Civil, Geological and Mining Engineering, Polytechnique Montréal, C.P. 6079, succ. Centre-Ville, Montréal, Québec, Canada H3C 3A7

ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form
21 September 2015
Accepted 22 October 2015
Available online 10 November 2015

Keywords:
Cycle track
Cyclist safety
Video analysis
Surrogate safety measure
Random effects model

ABSTRACT

Cities in North America have been building bicycle infrastructure, in particular cycle tracks, with the intention of promoting urban cycling and improving cyclist safety. These facilities have been built and expanded but very little research has been done to investigate the safety impacts of cycle tracks, in particular at intersections, where cyclists interact with turning motor-vehicles. Some safety research has looked at injury data and most have reached the conclusion that cycle tracks have positive effects of cyclist safety. The objective of this work is to investigate the safety effects of cycle tracks at signalized intersections using a case–control study. For this purpose, a video-based method is proposed for analyzing the post-encroachment time as a surrogate measure of the severity of the interactions between cyclists and turning vehicles travelling in the same direction. Using the city of Montreal as the case study, a sample of intersections with and without cycle tracks on the right and left sides of the road were carefully selected accounting for intersection geometry and traffic volumes. More than 90 h of video were collected from 23 intersections and processed to obtain cyclist and motor-vehicle trajectories and interactions. After cyclist and motor-vehicle interactions were defined, ordered logit models with random effects were developed to evaluate the safety effects of cycle tracks at intersections. Based on the extracted data from the recorded videos, it was found that intersection approaches with cycle tracks on the right are safer than intersection approaches with no cycle track. However, intersections with cycle tracks on the left compared to no cycle tracks seem to be significantly safer. Results also identify that the likelihood of a cyclist being involved in a dangerous interaction increases with increasing turning vehicle flow and decreases as the size of the cyclist group arriving at the intersection increases. The results highlight the important role of cycle tracks and the factors that increase or decrease cyclist safety. Results need however to be confirmed using longer periods of video data.

1. Introduction

In recent years, cities throughout North America have begun to follow Europe and Asia's lead and have started to build bicycle infrastructure. Until recently, some North American cities (e.g., Montreal, Portland, Ottawa, etc.) have been building and expanding their cycle track network but have not carried out many in-depth analyses to quantify their effects on cyclist safety, specifically at intersections where over 60% of cyclist injuries occur (Strauss et al., 2013). Now that cyclist numbers are on the rise, cyclist safety concerns at bicycle facilities have become an important issue. In the US and in Canada, some cities have implemented cycle tracks which are physically separated from vehicle traffic by concrete medians or bollards, as well as bicycle lanes delineated from vehicles by painted lines or simple sharrows (shared lane markings) along the roadway for vehicles and cyclists to share the same road. Facilities of these types can be found in cities like Montreal, Canada. Despite their increasing popularity, few studies have investigated whether or not cycle tracks are the appropriate solution and more specifically, how safe intersections with cycle tracks are for cyclists with respect to intersections without cycle tracks.

Previous studies have investigated the safety effects of cycle tracks using historical cyclist injury data also referred to as motor-vehicle–bicycle crash data (Thomas and DeRobertis, 2013;

* Corresponding author.
E-mail addresses: sohail.zangenehpour@mail.mcgill.ca (S. Zangenehpour), jillian.strauss@mail.mcgill.ca (J. Strauss), luis.miranda-moreno@mcgill.ca (L.F. Miranda-Moreno), nicolas.saunier@polymtl.ca (N. Saunier).

http://dx.doi.org/10.1016/j.aap.2015.10.025

Reynolds et al., 2009; Lusk et al., 2011; Teschke et al., 2012). Overall, the recent literature has identified some safety benefits for corridors with cycle tracks. However, these studies have not been able to fully answer the question of whether or not intersections with cycle tracks are safer than similar intersections without cycle tracks. Given the limitations of the crash data, these studies have not looked at cyclist injuries microscopically focusing on interactions between vehicles and cyclists as well as the geometry of the intersection. Only few studies have used surrogate safety measures or have relied on manual or semi-automated methods (Afghari et al., 2014; Sayed et al., 2013). Also, past surrogate studies have involved one or very few locations (Afghari et al., 2014; Sayed et al., 2013) and most have been carried out in Europe (Laureshyn et al., 2009; Phillips et al., 2011; Vogel, 2003). Overall the previous literature has not investigated the specific question: what is the effect of cycle tracks on cyclist safety and more specifically what effect does building them on the right or left sides of the road have on safety.

In this work, we tackle the shortcomings in the current literature by developing an automated surrogate safety method, based on video data, to characterize cyclist–vehicle interactions. This method begins with video data extraction and ends with modelling cyclist–vehicle interactions. The proposed method is used to investigate the safety effects of cycle tracks at intersections focusing on interactions between turning vehicles and cyclists travelling in the same direction. For this purpose, a sample of intersections with cycle tracks (referred to as treated sites) and without cycle tracks (referred to as control sites) are carefully selected in the city of Montreal, Canada. This study is expected to provide additional insight into the risk of collision (in terms of probability) of bidirectional cycle tracks at intersections. Also, we expect that the proposed method is easily transferable and can be replicated in other cities.

A sample of 23 intersections were selected and categorized into 3 different groups. In total, more than 90 h of video data was collected and processed to obtain the cyclist and vehicle trajectories. From the videos, post-encroachment time (PET) measures are computed automatically for each cyclist as a surrogate safety indicator. It is worth mentioning that among the advantages of surrogate analysis, is that interactions with different levels of severity can be observed, even in the short-term (hours), as opposed to the traditional approach (with crash data), where no or very few accidents are observed over a long period of time (months and years). Another advantage of the video-based surrogate safety method is its ability to extract information about the factors influencing interactions, such as bicycle and motor-vehicle flows at different levels of aggregation (as is desired) (Zangenehpour et al., 2015a,b).

This paper is divided into several sections. First a review of the literature on cyclist safety at cycle tracks, surrogate safety measures as well as automated methods is provided. This is followed by a detailed description of the proposed automated video based methodology. The paper then presents and discusses the modelling results and finally provides the conclusions that are drawn from this study and future work.

2. Literature review

Several studies have been published in recent years on cyclist safety in urban environments. In particular, some of these studies have investigated cyclist injury risk and its associated factors. Given the rising popularity of cycle tracks, few studies have investigated cycle tracks to identify and quantify their safety effectiveness. The majority of recent studies have concluded that corridors with cycle tracks are either safer or at least not more dangerous than corridors without cycle tracks. We can refer to the literature review of Thomas and DeRobertis (Thomas and DeRobertis, 2013) which examined the literature on cycle tracks from different countries mostly in Northern Europe and one study in Canada. Overall, it was found that one-way cycle tracks are safer than bidirectional cycle tracks and that in general, cycle tracks reduce collisions and injuries when effective intersection treatments are also implemented. Another review of the literature by Reynolds et al. (2009), revealed that bicycle-specific facilities, not shared roads with vehicles or shared off-road paths with pedestrians, reduce both the risk of accidents and injuries. Also, of the 23 studies reviewed in (Reynolds et al., 2009), eight examined safety at intersections which were for the most part roundabouts.

To investigate the effectiveness of safety treatments, road safety studies can be divided into: (i) cross-sectional studies in which data from a sample of locations or intersections with different geometry and built environment characteristics are used (Strauss et al., 2013; Miranda-Moreno et al., 2011; Wang and Nihan, 2004), (ii) before-after studies, in which data from before and after treatment implementation is available from a sample of treated and non-treated locations (Dill et al., 2012; Gårder et al., 1998; Jensen, 2008a,b; Zangenehpour, 2013), and (iii) case–control studies in which data from a sample of intersections contains two subsets: a subsample of intersections in which the treatment exists and a subsample of intersections with very similar characteristics (same traffic intensity, geometry) but without treatment (Lusk et al., 2011; Chen et al., 2012).

A case–control study carried out in Montreal (Lusk et al., 2011), compared cyclist injury rates on six bidirectional cycle tracks and compared them to that on reference streets. Bicycle flows were found to be 2.5 times greater on tracks than on the reference streets and the relative risk of injury on tracks was found to be 0.72 compared to the reference streets, supporting the safety effects of cycle tracks. A study looking at bicycle infrastructure in Toronto and Vancouver found that cycle tracks have the lowest injury risk compared to other infrastructure types and with one ninth of the risk of major streets with parked cars and no bicycle infrastructure (Teschke et al., 2012). Overall quiet streets and bicycle facilities on busy streets provide safest passage for cyclists. An older before-after study in Denmark found that cycle tracks increased bicycle flows by 20% while decreased vehicle mileage by 10% (Jensen, 2008a,b). However, overall, injuries were found to increase with the implementation of cycle tracks. While injuries were reduced along links, the increase in injuries at intersections was greater than this decrease. The author identified that cycle tracks which end at the stop line of the intersection are dangerous. A decade prior, Gårder et al. (1994) came to a similar conclusion in Sweden, that physically separated tracks should be cut some short distance before the intersection which would not only improve visibility but also cause cyclists to feel less safe influencing them to pay greater attention at intersections.

In this emerging literature, it is worth highlighting that most empirical evidence about the effectiveness of cycle tracks are based on historical crash data, referred to as the traditional safety approach. Studies using surrogate safety measures are beginning to gain popularity in the bicycle literature (Sayed et al., 2013; Afghari et al., 2014). However, surrogate safety analysis looking specifically at the effects of cycle tracks are rare in the current literature. In addition, most surrogate safety studies consider only one or a small sample of intersections.

Automated methods for surrogate safety analysis have begun to emerge in the literature (Sayed et al., 2013; Kassim et al., 2014; Sakshaug et al., 2010). A recent study in Vancouver presented the use of an automated method to obtain Time-To-Collision (TTC) to identify the severity of cyclist interactions at one busy intersection (Sayed et al., 2013). Another recent study in Ottawa evaluated cyclist–vehicle interactions at signalized intersections based on post-encroachment time (PET) (Kassim et al., 2014). These studies however have not looked at the effectiveness of cycle tracks.