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Towards a comprehensive safety evaluation of cycling infrastructure including objective and subjective measures

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ABSTRACT

Cycling infrastructure has been implemented worldwide to promote bicycle use and to minimize injury risk. A comprehensive evaluation of such infrastructure is required to assess its success. In terms of safety, assessments ideally focus on both objective and subjective parameters. This study explores the application of a combined objective-subjective safety assessment approach in a pre-post analysis of a left-turning bicycle box in Zurich, Switzerland. A computer-based video technology was used to objectively measure passing distance between bicycles turning left and continuing motor vehicles passing on the right. In an in-situ survey perceived safety while crossing the intersection and a photo-based assessment of the intersection were collected as indicators of subjective safety. Median passing distance between bicycles and motor vehicles did not significantly change after the implementation of the bicycle box, but the shortest distances were increased. Perceived safety while crossing the intersection was significantly higher after marking the bicycle box, which is consistent with safety expectations expressed based on photos with and without left-turning box. Gender and general perception of traffic safety within the city are significant determinants of expected and perceived intersection safety. Women expect greater safety gains from the left-turning box (photo based), but its effect on perceived safety when actually crossing the intersection does not differ between genders. While the applied video technology is not yet practice-ready, it shows great potential to complement cycling safety evaluations, in combination with self-reported perceived safety indicators.

1. Introduction

The promotion of bicycling as a mode of transportation is pursued by cities worldwide for a host of benefits, such as being free of emissions, space-efficient, and healthy. Although health impact assessments of cycling indicate that benefits from increased physical activity outweigh injury risks (Doorley et al., 2015; Mueller et al., 2015) lack of safety in mixed-traffic remains a key issue in cycling promotion. Its negative effect is two-fold: for one, crash victims can suffer severe injuries or worse, second, the (perceived) risk of crashing deters people from cycling more, or from cycling at all (Götschi et al., 2016). Both, objective and perceived traffic safety,

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which are not necessarily correlated (Elvik and Bjørnskau, 2005), have been identified as crucial determinants of the decision to bike (Jacobsen et al., 2009; Sanders, 2015). Equally, road and cycling infrastructure are linked to safety (Reynolds et al., 2009) and bicycle use (Rietveld and Daniel, 2004; Winters et al., 2010).

To allow decision makers to strategically invest in infrastructure to achieve maximum return on investment, the effects of different infrastructure types need to be better understood. Research investigating the effectiveness of measures to increase cycling is growing (Brand et al., 2014; Forsyth and Krizek, 2010; Ogilvie et al., 2004; Yang et al., 2010), but remains challenging. Studies that investigate the safety effects of specific infrastructure are scarce (Dill et al., 2012; Loskorn et al., 2013; Teschke et al., 2012; Zangenehpour et al., 2016, 2013).

Safety assessments of specific (small scale) cycling infrastructure face a set of challenges: a) the outcomes of interest, i.e. safety relevant incidents, are generally rare, b) common outcomes are less relevant than rare ones, e.g. light injuries vs. fatalities, and c) common outcomes, e.g. light injuries and falls, are harder to measure than rare ones. Quantitative safety assessment therefore first of all face a challenging trade-off between focusing on *accurate measures of highly relevant but extremely rare events* vs. *crude measures of less safety relevant proxy-measures that are sufficiently common* to be statistically analyzed. As such, what traffic safety research refers to as the low mean problem (Lord, 2006), is particularly aggravated for cycling. This highlights the importance of alternative methods that are based on surrogate safety and behavioral measures.

A range of indicators can be considered when assessing objective safety of cycling, such as the crude number of crashes, injuries or fatalities; or expressed as rates per inhabitant, trip, distance or time travelled. Each of these indicators has its pros and cons concerning reliability and accuracy (Götschi et al., 2016). Thus, existing data on traffic crashes, in particular minor crashes or injuries and those that do not involve vehicles, might not be accurate enough (Götschi et al., 2016). Hospital and police records often do not completely correspond to each other due to underreporting (Agran et al., 1990; Aptel et al., 1999; Juhra et al., 2012). Both underestimate actual crashes. In contrast, data on fatalities or severe injuries can be more accurate but they lack statistical reliability due to the limited sample size of such rare events. When assessing cycling safety for a specific infrastructure, as compared to a whole city or country, this problem is aggravated because of the low number of crashes. The same challenge applies to determining denominators to derive risk estimates, i.e. crash rates. For large areas, population data or travel surveys can provide denominators to be combined with crash statistics, but for a specific infrastructure project, exposure data is not readily available.

In order to avoid the issue of low numbers of actual crashes, analyses based on conflicts provide an alternative. Surrogate measures of safety such as vehicle speed, distance between conflict-involved vehicles, post encroachment time or time to collision are examples of indicators used in conflict analyses (Gettman and Head, 2003; St-Aubin et al., 2014; Tarko et al., 2008).

Some data required for conflict analysis can be collected by means of manual traffic inspection of video recordings (e.g. Phillips et al., 2011), but this technique is time and resource consuming. In order to improve efficiency computer-based video technologies that automatically recognize road users, classify them by transportation modes (motor vehicle, bicycle and pedestrian), track their paths, and measure conflict indicators have been developed and applied (Zaki and Sayed, 2013; Zangenehpour et al., 2016, 2015). As such, computer-based video technology is promising both with regards to objectively and accurately measuring safety indicators and with regards to capturing sufficiently large samples.

A second objective of comprehensive safety evaluations of cycling infrastructure is to understand the role of (lack of) safety on cycling behavior. Many cyclists are reluctant to cycle on a particular infrastructure or across an intersection if they perceive it as dangerous (Lawson et al., 2013). Therefore, understanding subjective measures of safety plays an important role in cycling promotion. Surveys of infrastructure users are the method of choice to capture safety perceptions. Household surveys have been used for the assessment of traffic safety perception in large areas (e.g. Rissel, et al., 2010), but for the evaluation of specific infrastructures, in-situ surveys promise more accurate information.

Evaluation of cycling safety infrastructure considering a combination of both objective and subjective parameters is rare and is mainly based on injury data and household surveys (Cho et al., 2009; e.g. Winters et al., 2012). The aim of this study was to apply a comprehensive approach to safety analysis of a specific cycling infrastructure. The pre-post evaluation combines objective safety indicators automatically derived by video analysis technology and subjective indicators collected through an in-situ survey. To investigate the feasibility of the suggested approach, it was applied to a left-turning bicycle box in Zurich, Switzerland, marked specifically to increase passing distance between left turning cyclists and motor vehicles on the right (Fig. 1).

The specific research questions addressed were:

- What are the expectations of cyclists with regards to safety improvements due to the bicycle box?
- What is the effect of the bicycle box on the perceived safety of cyclists crossing the intersection?
- What is the effect of the bicycle box on the passing distance between cyclists and motor vehicles?

2. Methodology

2.1. Study setting

The site for the case study was chosen in collaboration with the City of Zurich, based on three criteria: 1) high traffic density of cyclists and motor vehicles, 2) traffic flows potentially leading to conflicts between both types of road users, and 3) feasibility to mark a left-turning box. As a result, the non-signalized intersection of Sonneggstrasse and Universitätstrasse was selected (Fig. 1). This site is located close to the Swiss Federal Institute of Technology and the University of Zurich, which implies a large number of students riding by bicycle. The left-turn maneuver can be challenging for cyclist in light of crossing tram tracks with frequent tram passings

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