Safety Impacts of Bicycle Infrastructure: A Critical Review

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1 INTRODUCTION

Despite the growing concern and effort toward improving the status of non-motorized transportation safety, there is limited research to quantify the impacts of measures used. In the United States, the predominant guide for assessing the effects of safety treatments is the Highway Safety Manual (HSM) [1]. Safety performance in the HSM is a function of a base rate multiplied by a series of crash modification factors (CMFs) that estimate the expected safety effectiveness of a specific treatment. CMFs are estimated by observing changes in crash rates in the presence of a particular treatment using either longitudinal (before/after) or cross sectional (treatment/control) studies. The sample sizes necessary for developing and using CMFs for automobile safety interventions are often available, given the large traffic volumes, significant number of vehicle crashes, and known facility design features. However, cyclist collisions are fairly rare events compared to vehicle crashes and few data sources are available for cyclist exposure data, making the development of CMFs for bicycle safety treatments difficult.

2 SYNTHESIS OF THE LITERATURE

The research team reviewed 81 journal articles and reports, making note of stated safety outcomes, treatment details, study design, sample size, controls, exposure data, and statistical significance of results. Of these, 19 reported quantitative safety outcome measures in the form of crash risk, injury risk, injury severity, or conflicts (Figure 1). The risk ratio on the vertical axis of the figure represents the risk of an event happening with a treatment divided by the risk of that same event happening in the same situation without the treatment. Risk ratios were explicitly reported in the literature or converted from percentages.

Of the 14 treatments with study outcomes presented in Figure 1, only bike boxes, bike lanes, cycle tracks, and roundabout treatment types had more than one quantitative study that described risk ratios associated with implementation. The bike box studies were all conflict-based studies (as opposed to crash-based or injury-based); hence, any reduction in crashes or injuries must be inferred from the reduction in conflicts. The studies associated with bike lanes, cycle tracks, and roundabouts conflicted as to whether the treatment helped or harmed safety outcomes. These differences may be attributable to design differences in the facilities themselves, the way exposure was measured (if at all), crash reporting bias, location characteristics, study controls, and/or possibly even chance. Of the studies reviewed, some used very simple methodologies with few controls, while others developed more rigorous methods to control for certain confounding factors. Without multiple sites in varying locations, controlling for multiple confounding factors, an understanding of the broad safety impacts of a treatment cannot be obtained.

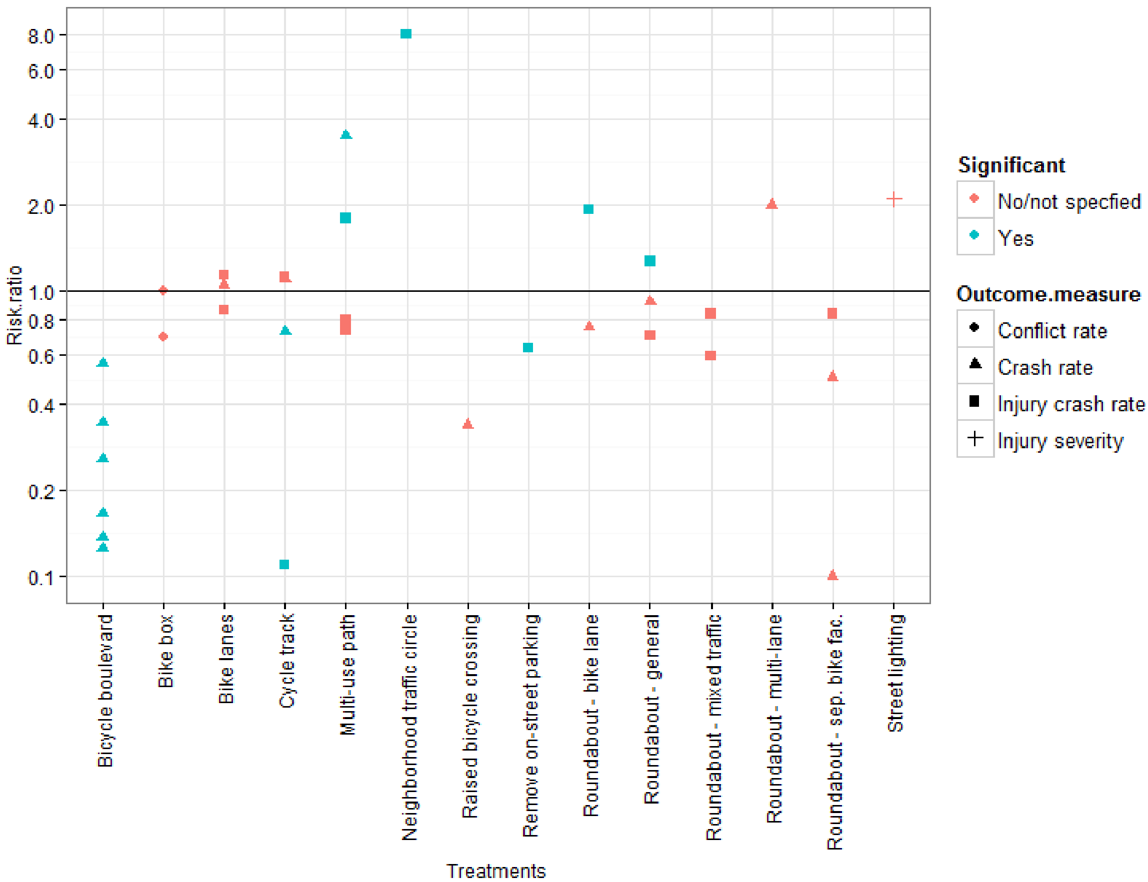

Figure 1: Summary of Risk Ratios in the Literature
Note: Significance stated above is based on the authors' claims in the original studies.

3 DISCUSSION

To develop or use crash modification factors, the HSM requires a significant amount of data for implementation of its quantitative approach. These data needs can be classified into three categories:

1. *Exposure data*; e.g., traffic (vehicular, pedestrian, and bicycle) volume, miles or hours traveled.
2. *Roadway characteristic data*; in this case, pedestrian and bicycle facility characteristics in addition to the standard roadway characteristics
3. *Crash data*, or other surrogate measures

One common theme among the studies in this review was a lack of standardized, transferable exposure data to understand the extent to which users are exposed to risk. For example, if total bicycle crashes increase after a treatment is installed, an actual decrease in risk on a per-cyclist basis might be more than offset by an increase in cyclist activity (i.e., bicycle-miles-of-travel). Unlike motor vehicle networks for which activity data are systematically collected, bicycle activity is only generally known and often not allocated as volumes on routes. Fewer than half of the outcome measures identified in the literature controlled for exposure in any way. Most of the exposure types were bicycle counts and motor vehicle counts, but a few were surveys and percentages.

Infrastructure characteristics data are also needed to select treatment and control locations, to implement systematic data collection and monitoring plans, and understand transferability of the results to other sites. For every potential intervention, the cause-effect relationships at work must be identified and quantified through data collection and analysis before crash modification factors can be developed. For example, widening bicycle lanes is thought to reduce cycling risk by providing a wider separation between bicycle and automobile traffic and improving lines of sight and cyclist visibility. To assess whether such an intervention reduces crash rates, the activity, number, and severity of crashes on 3-foot bicycle lanes and 5-foot bicycle lanes must be tracked separately. Any other factors that may impact these crash rates must be controlled in the data set, such as the presence of heavy-duty truck activity. The larger the number of potential variables that need to be controlled in statistical analyses, the larger the number of sites that need to be monitored. Only 70% of the studies in this analysis used at least 10 treatment locations, and only half of those used more than 20 treatment sites.

Knowing the number, type, and severity of crashes is a significant problem for understanding the effectiveness of pedestrian and bicycle treatments. For automobile crashes, agencies maintain crash databases containing basic information (e.g., time, location, number of vehicles, type of crash, injuries) to help researchers look for patterns in causation and address problem locations. Much of the causation data found in crash reports is less relevant for non-motorized users, leaving critical gaps in information [2]. One significant issue in the understanding of the safety attributed to bicycling is the substantial underreporting of bicycle and pedestrian crashes in official crash records, especially less severe crashes [3,4,5]. To exacerbate the issue of underreporting, bias also exists in crash reporting rates because cyclists in particular are less likely than other users to report crashes. Collecting crash data specific to bicycle crashes might be more feasible now thanks to automated crash reporting technology used by police forces. Furthermore, crowdsourcing is being used in many aspects of transportation data collection [6] and using this citizen science technique for bicycle crash data may be one of the best ways to supplement existing crash databases [7].

Investing in research and actions to work toward finding the answers is critical, and it has the potential to make a substantial difference in the reach of non-motorized safety research and its application to the safety and excellence of cycling infrastructure for future generations.

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