Advancing North American Design Practices *to Mitigate Bicycle Right-Hook Conflicts:*

Multi-city surrogate safety study applying video analytics at signalized intersections

PHASE 1 REPORT

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PREPARED BY: **Craig Milligan, Ph.D., P.Eng., RSP21, MicroTraffic**
Dylan Passmore, MScPl, P.Eng., MicroTraffic
Amanda Pushka, M.Sc., P.Eng., RSP1, MicroTraffic

Executive Summary

Cities across North America have made significant strides in recent years in expanding their protected bike lane networks, and evidence continues to suggest such initiatives can bring with them a long list of benefits, including safer cycling and transport decarbonization. However, intersections continue to be a safety concern for cyclists, with many collisions happening at them every year. Of the various cycling-related collision configurations at an intersection, right hook events are a prominent collision type.

Several guidelines have been developed to support safe intersection design, but these resources have little empirical evidence to help illuminate the impacts of different design alternatives on right hook conflicts. By leveraging AI-powered surrogate safety video analytics techniques, this cross-sectional study aims to evaluate how different features such as roadway and bike lane geometry, traffic signal operation, and volumes of people traveling through an intersection influence the risk profile of right-hook conflicts at signalized intersections.

In Phase 1 of this study, 6,580 hours of video from 116 signalized intersection approaches spanning 10 cities were analyzed, through which the interactions between 173,300 cyclists and 542,200 right-turning vehicles resulted in the identification of 1,455 bicycle-leading conflicts.

Based on the resulting conflict and severity prediction models, this study builds an empirical foundation for the following 10 design principles:

1. **Ensure trade-offs of protected phasing are well vetted, especially for locations with peak-hour right-turning vehicle volumes exceeding 140, as there are significant potential safety benefits**

   Based on cross product alone, results suggest an average 93% reduction in hourly bicycle-leading conflicts in switching from permissive right-turn phasing to protected-only phasing. Extra caution is advised for permissive right-turns where peak-hour right-turn vehicle volumes are expected to be greater than 140 (i.e., more than 2-3 vehicles per cycle) as this is a statistically significant threshold in predicting conflicts. Where peak-hour right-turning vehicle volumes exceed 180 or other factors contributing to elevated risks are present, such as a downhill approach or an environment with few pedestrians and cyclists, then protected-only phasing or turn restrictions should be strongly considered.

   When considering protected phasing, it is recommended that City staff explore running the protected vehicle turn phase after the through phase for bicycles (and pedestrians) because early results suggest that this may result in fewer conflicts.

2. **Enhance visual prominence and yielding requirements at crossbikes with green paint and yield-on-turn signage where permissive right turns are allowed**

   As a minimum, it is recommended that municipalities include green paint in crossbikes and yield-on-turn signage at locations where there are potential right-hook conflicts. The models predict that they help reduce both turning vehicle speeds (1.7 to 2.3 km/h reduction) and bicycle-leading conflicts (33-36% reduction).

3. **Design tight inside effective corner radii where permissive right turns are allowed**

   Larger inside effective corner radii are associated with higher average vehicle right-turn speeds (increase of 0.2km/h to 0.25km/h per metre radius increase). Even in situations with

multiple receiving lanes and the potential for higher speed right turns, the inside radius still has an important influence on turning vehicle speeds and should be designed as small as feasible, which may require revisiting design and control vehicle assumptions or installing features such as truck aprons or turn wedges.

4. Minimize crossing distances / cyclist exposure to right turning vehicles where permissive right turns are allowed

Limiting the distance that cyclists are exposed to right-turning vehicles predicts fewer right hook bicycle-leading conflicts. For example, reducing cyclists' exposure to right-turning vehicles from 10 m to 7 m (i.e., approximately one travel lane width), is predicted to reduce conflicts by roughly 13%.

5. Consider right-turn bays to reduce turning vehicle speeds and provide cyclists additional clarity of driver intentions

The presence of a right-turn bay predicts a reduced average turning vehicle speed of approximately 1.5 km/h, supporting the notion that it helps to take some of the pressure off turning drivers. However, models also suggest that they lead to more bicycle-leading conflicts (67% - 76% increase). Due to reduced turning vehicle speeds, these interactions are potentially less severe and more comfortable than without a turn bay. Further research is needed to unpack this finding.

6. Horizonal deflection in the bike lane approach can reduce conflicts, but be cautious of excessive lateral offsets

Both larger lateral offsets and bend-in geometry are associated with reduced conflicts. Seemingly a contradiction, these results may speak to the benefit of horizontal deflection in the bike lane approach- cyclist conspicuity in a bend-in design, and the improved sightlines of a bend-out design.

Increasing a 3 m lateral offset to a 5 m offset predicts a 28% decrease in hourly conflicts. However, an increasing lateral offset is also associated with higher turning vehicle speeds at the potential conflict point. In an extreme case, an increase from a 3 m to a 15 m lateral offset is predicted to result in a 3 km/h increase in turning vehicle speeds.

7. Provide physical protection between cyclists and motor vehicles on intersection approaches

Despite painted bike lanes often requiring that drivers merge with cyclists to make a right turn from the bike lane (dashed line on approach), many do not. This observed behaviour suggests that the typical painted bike lane merge is not working as intended, resulting in the same potential right-hook conflicts as with a protected approach but with driver and cyclist behaviour being less predictable to one another. For improved cyclist comfort and a more inclusive design, designers are likely better off simply designing for full physical separation up to the intersection, taking the many considerations raised in this study into account.

8. Take extra caution in locations with very low pedestrian (and bike) volumes

In locations where drivers may not expect to encounter a crossing pedestrian, vehicle right-turn speeds are much higher than elsewhere (at least a 3.2 km/h increase). Similarly, in locations where 12-hour bike volumes are below 100, vehicle right-turn speeds are predicted to increase by 1.2 km/h.

9. **Treat downhill approaches with any grade in excess of 2% with extra caution**

   Any downhill grade beyond even a “gentle” 2% is predicted to increase hourly bike-leading conflicts by 47%. Results are even more pronounced when considering only protected bike lane approaches where such downhill grades are associated with a 90% increase in conflicts. Conversely, some models suggest steep uphill grades above 4% reduces conflicts. These findings also hint at the importance of unpacking questions around how street designs and regulations should respond to the rising popularity of e-mobility.

10. **Pursue intersection designs consistent with the prototypical protected intersection design concept**

    Despite models showing an advance stop line (ASL) contributing to increased bicycle-leading conflicts, this geometric feature is often tied to others. In aggregate, the regression results are “net positive” in support of the prototypical protected intersection design approach. For example, if a location that has no ASL nor lateral offset and 14.5 m of exposure to right-turning vehicles were converted to a protected corner with a modest 8 m ASL, 6.5 m of exposure to right-turning vehicles, and a 3 m lateral offset, the model predicts this would reduce hourly bicycle-leading conflicts by approximately 10%.

    Although a lateral offset is predicted to increase turning vehicle speeds, the corner island it enables, in combination with features such as tighter corner radii, truck aprons, corner wedges, or a setback vehicle stopbar on the cross street create opportunities to help reduce exposure and manage vehicle turn speeds.

Through an in-depth look at cyclist right-hook safety, this research effort demonstrates the value of innovative road safety video analytics technology and near miss data for quantifying real-world challenges. These findings are an important step forward in providing empirical support to help guide designers and City officials through the complex trade-offs involved in contemporary bike lane design initiatives. Furthermore, an additional key output of this study is an open-source database that enables future research that can expand on the findings of this study to advance design practices for signalized intersections with bike lanes.