Enhancing Cycling Safety at Signalized Intersections: 
An Analysis of Observed Behavior

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ABSTRACT

Urban transportation systems tend to operate most effectively when there exist common expectations of all users’ travel behavior under various conditions. A wide range of behavior amongst cyclists presents a significant challenge in achieving safer and improved designs at intersections. In this research, cyclists are observed (using video from fixed camera locations) making left turns at six intersections in the City of Toronto. The intersections are classified into five types based on their physical designs and operational characteristics. Cyclists’ behavior is assessed to determine the propensity to traverse the intersection legally - designated as “rule compliance.” Further, the analysis determines the likelihood of a cyclist traversing the intersection using a path that is consistent with the design; this outcome is defined as “facility compliance.”

The results reveal that the presence of bike boxes, two-phase lefts, and turning lanes with advance green phases positively influence cyclists by increasing the likelihood that left turns will be legal, and consistent with the behavior intended through the design. The results also suggest that the highest rates of rule and facility compliance exist in the condition where cyclists approach an intersection during a green signal. Based on the observations made in the research, design recommendations are made that have the potential to better accommodate cyclists and produce more consistent behavior that presumably enhances safety.
INTRODUCTION

Contemporary transportation professionals seek to achieve “balanced transportation” – where multiple modes such as public transport, walking, cycling and personal auto serve appropriate urban trips. Important to balanced transportation is the promotion of cycling as a viable and more frequently utilized method of transportation in urban centers. The benefits of cycling are well understood. Increased cycling can improve cyclists’ health, and decrease cyclists’ costs of travel. When auto travelers shift modes to become cyclists, congestion and the need for parking can both be reduced. More generally, increased cycling mode share can produce improved environmental conditions.

Despite the benefits, many cities have struggled to achieve meaningful mode shares by cycling. One oft-cited concern [1] is that the interactions between cyclists and motor vehicles create real and perceived safety issues, deterring potential cyclists. Of critical concern are signalized intersections. The City of Vancouver, for example, found that between 2007 and 2015, 72% of high cyclist collision locations were signalized intersections, and 14.9% of all cyclist-vehicle collisions were during left turn maneuvers [2]. The safety of these intersections, both real and perceived, can be improved if drivers and cyclists have well-established, common expectations of behavior as both modes traverse the intersection. The range of cyclists’ behaviors can be quite extensive, depending on both characteristics of the cyclists – confidence and experience – as well as the design and operation of the intersection.

The overarching question this research intends to answer is if more consistent cycling behavior can be achieved through best practices in design and operation of signalized intersections. In the paper, consistent behavior is bound by two concepts. There exists a range of behaviors that are legal in terms of the cyclists’ path through the intersection and interactions with pedestrians. There also exists a more narrow range of behaviors that are consistent with the design of the intersection. When a cyclist traverses the intersection legally, we identify this outcome as being “rule compliant.” When a cyclist chooses the preferred path through the intersection (presumed to be the path that the designer intended and that vehicle operators would most likely anticipate), we label that outcome as “facility compliant.” Our assumption is that designs and operational characteristics that promote rule and facility compliance tend to produce less variance in behavior and greater safety for cyclists.

Using these two concepts, cyclists’ behavior in making left turns was analyzed at six intersections in the City of Toronto. The intersections were selected to capture the effects of different designs, including bicycle lanes, left turn lanes, and bike boxes, as well as different signal timings, including advanced greens and two-phased lefts. The analysis method included the placement of video cameras to record cyclists’ actual paths through the intersection and determine the rate of rule and facility compliance. The video recordings also allowed for the analysis of these rates as a function of other attributes, particularly the impacts of the signal phase during which the cyclist arrived at the intersection. The results clearly demonstrate that the presence of well-designed intersections, with cycling-friendly signal operations can generate much higher compliance rates, promoting expected behaviors. These observations suggest that upgrading intersections may reduce some barriers to cycling and increase mode share. Based on the results of the research, design options are presented that have the potential to match cyclists’ natural path choices.

The remainder of the paper includes a literature review followed by a more detailed description of the data collection methods. Then, the results of observed left turn behaviors are described and discussed. Recommendations are presented based on the results, matching
LITERATURE REVIEW

The goals of this research are to understand how intersection design and operation influence cyclists’ behavior and, as a result, if designs can be improved to achieve fewer conflicts amongst intersection users. In this section, results of previous literature—both academic and professional—are reviewed to summarize the state of knowledge to which this paper intends to contribute. Of particular interest are those studies that identify perceived safety risks as barriers to increased cycling and research that systematically evaluates facility safety as a function of design and operation.

Perceived Safety Risks as a Barrier to Cycling

The literature on the relationship between safety perceptions and propensity to cycle is vast and global. In North America, a 2003 study [3] identified the variables that affect the propensity to cycle multiple cities. Several stated preference surveys were conducted, the results of which indicated that better infrastructure would generate increased cycling. To augment the stated preference results, the study also used data from 43 cities to conduct a multi-variate regression that tested the correlation between (amongst other variables) the presence of cycling infrastructure and the cycling mode share for commuting trips. The results reinforced the positive relationship between infrastructure and bicycle commuting.

Similar research has been conducted in various locations outside of North America. Several studies from Australia [4, 5, 6], the UK [7, 8], and Spain [9] have reached similar conclusions—that cycling activity is limited by perceived safety risks. Interestingly, research from Copenhagen [10], a globally recognized leader in cycling, suggests that cyclists in that city have significantly fewer concerns about their safety, potentially given experience levels of both cyclists and drivers.

Other researchers have attempted to identify the role of parents/guardians in limiting children’s cycling activity. Concerns arise around the built environment [11] as well as neighborhood safety [12]. For a comprehensive and up-to-date literature review of factors influencing cycling rates, particularly for commuting, the reader is directed to [13].

Observations on Design, Operations and Cycling Safety

Research involving empirical evidence of cyclists’ behavior, safety and facility design can also be found in the literature. Harris et al. [14] studied rates of accidents occurring at and away from intersections. The research concluded that crashes were significantly more frequent at multi-lane intersections than at single lane configurations. Away from intersections, accident rates were exceptionally low when cycle tracks—protected cycle lanes—were provided. Similar research [15], also from Canada, compared safety rates using crash data for various facilities: cycle tracks, major roads (with and without parking), and local roads. The results confirm traditional understandings, with cycle tracks producing the safest conditions, while major roads with parking were least safe. This study found that safety rates were not sensitive to proximity of intersections.

Moreno et al. [16] studied intersections in Montreal. In their research, the authors identified traffic volume, particularly right turning volumes, as strongly correlated to bicycle crash rates. This study found no strong statistical correlation between certain intersection properties and cycling safety.

One European study was significant in providing motivation for the current research. Left turning cyclists at a high volume intersection in Copenhagen were observed [17] to compare actual...
paths to the intended path. The intersection studied was designed with a two-phased left turn box. Results revealed that 86.5% of cyclists turned left using the facility as designed. Of the remaining 13.5%, only 2.2% used the same maneuver as a left turning automobile, while 11.3% performed a “snake” crossing – essentially mimicking pedestrian movements through the intersection. In order for the snake crossing to be legal, cyclists should dismount and walk their bikes through the intersection. In this study, 63% completed the crossing legally.

This high rule compliance is common across cities with highly developed cycling networks. In cases like Copenhagen, where the cycling domain is well-defined and the network is complete, there is little incentive to break the rules for safety or convenience reasons, and doing so would result in high risk of collision and may result in expressed dissatisfaction from other travelers. In this research, we attempt to replicate this study to determine which facility designs and operational strategies lead to consistent, intended behavior for cyclists. The methods employed are described in the next section.

METHODS
Left-turn behavior of cyclists at different types of intersections in the City of Toronto was determined by collecting and analyzing digital video footage gathered over several days. The goals of the research were to determine the degree to which cyclists who traveled through the intersections:

1. did so legally (in compliance with the Highway Safety Act).
2. did so in a way that is consistent with users’ expectations as guided by the intersection design.

The City of Toronto
The City of Toronto is the largest metropolitan area in Canada and the 4th most populous city in North America. The City’s 2013 population of 2.77 million is forecasted to grow to 3.74 million by 2041. Like many North American cities, Toronto and the Province of Ontario have established policies to deter outward growth and catalyze intensified land uses, particularly in existing high density areas. From a transportation perspective, the City perceives cycling as an important mode to address growing travel demand and, as such, hopes to accelerate growth in cycling activity. From 1999 to 2009, the number of city residents who self-identified as cyclists grew by about 6%, from 48 to 54% [18]; the number of utilitarian cyclists rose from 20% to 29%. More locally, in high volume cycling areas in downtown, like the intersection of Spadina Avenue and College Street, the number of cyclists has increased by 74% in the past three years [19]. The City adopted a new cycling network plan in June of 2016 [20] that establishes priority corridors and intersections for investment over the next 10 years.

Study Intersection Criteria
The foundation of the research conducted here is that bicycle facilities, when designed correctly, will promote legal activity by cyclists. Further, well-designed intersections produce more predictable behavior from cyclists. In contrast, inadequate intersection designs are more likely to motivate illegal or unsupported travel patterns by cyclists. The expectation is that the former will generate more cycling-friendly intersections while the latter will increase uncertainty and not promote expected behaviors.

We gathered empirical data on the propensity to traverse intersections legally and as the design intends at six intersection in the City of Toronto. The choice of intersections for the study
was based on the following criteria:

1. The intersection involved the meeting of two bicycle routes (defined by the presence of a bike lane, shared lane, or cycle track);
2. The intersection had at least one through lane for vehicle traffic in each direction (with the exception of one subject intersection);
3. The intersection had at least one left turn lane for vehicle traffic; and
4. The total set of intersections contained a variety of cycling treatments, including:
   a) No treatment
   b) Two-phased left turn
   c) Bike Box

The six intersection locations and designs are detailed in Table 1. Intersections A and B have the same configuration and designs, so in subsequent analyses they are coupled into intersection Type 1. The remaining four intersections have unique designs; they are labeled as intersection Types 2-5 in subsequent analyses.
Table 1 Intersection types and configuration

<table>
<thead>
<tr>
<th>Intersection Type and Naming Convention</th>
<th>Location(s) Studied</th>
<th>Intersection Configuration</th>
<th>Approach Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LTL,1TH,BL</td>
<td>A. Runnymede and Annette (all directions) B. Jones and Dundas</td>
<td>![Intersection Diagram]</td>
<td>• left turn lane (LTL) • one through lane (1TH) • on-street bike lane (BL)</td>
</tr>
<tr>
<td>2 LTL,1TH,CT,TPLB</td>
<td>C. Sherbourne and Wellesley (north and southbound approaches)</td>
<td>![Intersection Diagram]</td>
<td>• left turn lane • one through lane • cycle track (CT) • two-phase left-turn box (TPLB)</td>
</tr>
<tr>
<td>3 LTL,1TH,BL,BB</td>
<td>D. St. George and Hoskin (all directions)</td>
<td>![Intersection Diagram]</td>
<td>• left turn lane • one through lane • on-street bike lane • bike box (BB)</td>
</tr>
<tr>
<td>4 LTL,1TH,BL,BB,AG</td>
<td>E. St. George and College (southbound approach)</td>
<td>![Intersection Diagram]</td>
<td>• left turn lane • one through lane • on-street bike lane • bike box • advanced green left turn signal (AG)</td>
</tr>
<tr>
<td>5 LTL,2TH,BL,TPLB,AG</td>
<td>F. Spadina and Harbord (north and southbound approaches)</td>
<td>![Intersection Diagram]</td>
<td>• left turn lane • two through lanes (2TH) • on-street bike lane • advanced green left turn signal</td>
</tr>
</tbody>
</table>

For reference, the naming convention of intersection types and configurations is sequenced based on reading lanes from left to right, followed by bike lane type, other bicycle facilities and lastly the presence of an advanced left turn signal. For example, intersection Type 4 (LTL,1TH, BL, BB, AG) reads as: left turn lane, 1 through lane, bike lane, bike box, advanced green.

The locations of these intersections within Toronto are shown in Figure 1.
Determining Compliance
As noted earlier, the goals of this research are to determine the frequency and the circumstances under which cyclists complete left turns at these intersections in ways that are legal and consistent with the intended design. The distinction between these two outcomes are demonstrated below (Figure 2). At an intersection with a vehicle left turn lane and no cycling facility (Figure 2.a), the intersection design encourages cyclists to join the vehicle stream, queue in the left turn lane, and complete the left turn as a vehicle. This sequence is shown as Path A. Alternatively, a cyclist may turn left at this intersection by using a two-phase left. This alternative, labeled as Path B, is not consistent with the intersection design but it is legal. As such, this movement would be recorded as non-compliance with design but compliant with the law.
A third alternative in this case is for the cyclist to remain curbside on the northbound approach. If northbound travel is receiving a red signal, the cyclist can join pedestrians crossing from the southeast corner to the southwest corner. When the northbound movement receives green, the cyclist can cross from the southwest corner to the northwest, and continue cycling curbside adjacent to westbound traffic. This path is labeled as Path C. If the cyclist remains on the bike, this option is inconsistent with the preferred path and violates the law, as cyclists are not allowed to use pedestrian crosswalks. If the cyclist dismounts and crosses the intersection as a pedestrian, then the crossing was legal but because it introduces an extra cost (in terms of convenience and delay), it is not the preferred outcome.

For an intersection with a designated cycle lane, and a bike box (figure 2b), the preferred path is shown as the dotted line. Similar assessments for rule and facility compliance were completed for each intersection type.

**Data Gathered**

In this research, cameras were positioned on the approach for each intersection to record cyclists’ paths. For each observed cyclist, both rule compliance (legal activity) and facility compliance (behavior consistent with the design) were recorded. The cameras’ positions also recorded the signal phase – red or green – during which the cyclist arrived at the intersection. The expectation was that cyclists arriving on green would have a higher likelihood to be rule and facility compliant whereas those arriving on red would attempt to minimize delay and, as a result, be less likely to be compliant.

In addition to the signal phasing, the video recordings allowed for estimates of vehicle volumes in the periods of analysis. The expectation was that vehicle volumes may further influence...
behavior, particularly with designs that require cyclists to travel in mixed traffic. To assess this hypothesis, compliance rates were computed as a function of traffic volume using the following three categories: low volume (v/c ratio of 0.3 or less); medium volume (v/c ratios between 0.3 and 0.7); and high volume (v/c ratios greater than 0.7).

Cameras were installed over several dates in September and October of 2014. The duration of video gathered at each intersection was approximately three hours. Video results were processed manually, recording compliance rates as a function of signal phase and vehicle volume at each intersection. In total, 1650 cyclists were recorded in this study of which 322 completed left turn movements. Results are presented in the next section.

RESULTS

The overall compliance rates were approximately 70% and 44% for rule and facility compliance respectively. Figure 3 summarizes the compliance rates for all five intersection types.

![Figure 3 Overall compliance rates by intersection type](image-url)

The intersection with the greatest overall compliance is Intersection Type 4 (LTL,1TH,BL,BB,AG); in this case, the cyclist’s left turn is facilitated by a curbside bike lane, leading to a bike box (Figure 2b). This design accomplishes many of the “best practices” associated with good cycling design. In the bike box, the cyclist can position themselves at the front of the left-turning vehicle queue, prioritizing the cyclist over vehicles. Further, situating the cyclist at the front of the queue enhances the visibility of the cyclist, increasing safety. Finally, the advanced green prevents the cyclist from having vehicle conflicts in completing the left turn. As illustrated,
approximately 90% of all cyclists made the left turn legally and more than 65% did so using the intended design (Figure 2).

The importance of the advanced green in achieving cyclists’ compliance is also demonstrated through a comparison of intersection Types 3 (LTL,1TH,BL,BB) and 4 (LTL,1TH,BL,BB,AG). Intersection Type 3 has the same geometric configurations as Type 4, but is not operated with an advanced green signal timing. As such, the benefit of completing left turns without vehicle conflicts is lost. The resulting compliances – both Rule and Facility – are significantly lower for intersection Type 3 than Type 4; only 61% of left turning cyclists did so legally and approximately 38% followed the intended design.

The second best performing intersection is Type 2 (LTL,1TH,CT,TPLB). Here, the design includes a curbside cycle track, leading to a designed two-phase left turning facility. As described earlier, the two-phase turn is completed by remaining curbside to move through the intersection, then completing the “left” portion of the movement in a second traffic signal phase. In this case, the data suggest that nearly 70% of left turning cyclists do so legally and approximately 54% of cyclists use the two-phase design.

The two intersections with the lowest overall rule compliance are Type 1 (LTL,1TH,BL) and Type 5 (LTL,2TH,BL,TPLB,AG). Both of these intersections have no special facilities that are designed to help facilitate the left turn of cyclists other than the left turn lane, which is designed for automobiles. These intersections also have the lowest facility compliance, indicating that just the vehicle left turn lane is ineffective at promoting a left turn for cyclists. Out of the two, intersection 5 has the lower of both rule and facility compliance. This reduction in compliance can be attributed to the presence of two through lanes at intersection Type 5, which further deters cyclists from using the vehicle left turn lane as compared to only one through lane at intersection Type 1.

Impacts of Signal Phase on Compliance

Here the results of observed rule compliance (Figure 4) and facility compliance (Figure 5) are presented as a function of the signal phase experienced by the cyclist. The presence of a green signal significantly increased rule compliance for cyclists. In fact, in three out of five cases produced 100% compliance rates when cyclists arrive on green. The remaining two intersection types, 1 (LTL,1TH,BL) and 3 (LTL,1TH,BL,BB), generated rule compliance rates of 78% and 93% respectively. For intersection Type 1, the design includes only a left turn lane and no cycling facilities. As a result, in our study, 22% of cyclists arriving on green elected not to join the left turn lane but instead opted for an illegal left turn movement. While we cannot draw this conclusion from the data, our intuition is that the non-compliant cyclists may represent those with only moderate (or lesser) cycling confidence.

When cyclists approach an intersection during a red signal phase, rule compliance is generally poor. This can be interpreted as an unwillingness for cyclists to experience signal delay. The lone exception in the data set is Intersection Type 4 (LTL,1TH,BL,BB,AG), which is unique for having both a bike box and an advanced green phase. This suggests that even when cyclists approach during a red signal, the road rules are likely followed, and cyclists choose not to circumvent legal practices. Since Intersection Type 3 and 4 have the highest rule compliance when arriving on red, it can be concluded that bike boxes motivate cyclists to complete legal left turns regardless of the signal phase.
The data for facility compliance show significantly more variation and less influence of signal phase. For intersection Types 1 (LTL,1TH,BL) and 5 (LTL,2TH,BL,TPLB,AG), signal phase does not appear to influence facility compliance. In both cases, very little variation is observed when cyclists arrive on red or green. For intersection Type 2 (LTL,1TH,CT,TPLB), arriving on green significantly improves (by almost 58%) facility compliance. Recall that intersection Type 2 has a two-phase left turn design that is designed to accommodate cyclists arriving on green, allowing them to complete the first phase of the two-phase crossing without delay.

Intersection Types 3 (LTL,1TH,BL,BB) and 4 (LTL,1TH,BL,BB,AG) both experience much lower facility compliance rates when arriving under green, approximately 30% and 27% respectively. Both these intersection types involve bike boxes, the advantage of which is to allow cyclists to access the front of the queue when arriving on red. It is understandable that cyclists will be less inclined to use bike boxes when arriving on green, thereby producing lower facility compliance rates.
Figure 5 Facility Compliance as a function of signal phase experienced on approach

**Compliance rates as a function of traffic volume**

Table 2 presents both the rule and facility compliance for each intersection type as a function of traffic volume. Unfortunately, few meaningful conclusions can be drawn from the data. Rule compliance rates tend to be quite variable with no observable trends in the relationships. In fact, except for intersection Type 5 (LTL,2TH, BL, TPLB, AG), rules compliance appears to be completely independent of traffic volume. Similarly, the data for facility compliance are also quite noisy, with few discernable trends. Statistically, traffic volume is not correlated to behavior in any significant way.

Table 2 Rule and facility compliance as a function of traffic volume

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Rule compliance rates %</th>
<th>Facility compliance rates %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low volume</td>
<td>Medium volume</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>64</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>86</td>
<td>91</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>31</td>
</tr>
</tbody>
</table>

**RECOMMENDATIONS**

The data suggest that opportunities to provide cyclists with positive attributes – advancement to the front of the queue, greater visibility, and reduced delay through advanced green phases – result in increased likelihood to choosing legal and preferred paths. Generally, rule and facility compliance remain relatively high when cyclists arrive at the signal during a green phase. The rule compliance rates are less positive when cyclists arrive during a red phase, presumably because the red phase introduces a perceived unnecessary delay that can be mitigated by violating either the
law or the intended design of the intersection.

Bike boxes appear to have very strong, positive impacts on cyclists’ behaviors. As such, the two primary design recommendations from this research are to include bike boxes coupled with advanced green phases whenever possible. We are cognizant of the fact that bike boxes may be difficult to justify in areas where very low cycling volumes are currently observed. But, given the observations from the literature that perceived lack of safety is a deterrent to cycling, low volumes do not necessarily reflect a lack of demand.

When cyclists arrive at intersections during a red phase, our results suggest that the preferred (observed) behavior is to cycle on the near-side pedestrian crossing. Currently, this practice is neither legal nor desired. One solution is to encourage cyclists to dismount before entering the pedestrian flow. This outcome may be difficult to implement. A second opportunity exists to potentially accommodate cyclists through design. By defining space beside the pedestrian crosswalk, cyclists could use a crossing method that minimizes their delay without creating conflicts with pedestrians or vehicles. Such facilities – known as a cross-ride – have been implemented in Ottawa (among other cities) and may be supported through inclusion in local engineering design standards. Typical designs are included in Figure 6.

CONCLUSIONS

This paper summarizes research that seeks to understand the relationships between the design and operation of signalized intersections and cyclists’ propensity to travel through these intersections legally, and via a preferred path – a trajectory that is consistent with the intended design. The assumption is that by designing intersections such that cyclists are motivated to travel in expected, legal ways, safety will be improved for all intersection users.

Video recordings were made of cyclists traveling through six intersections (of five different types) in the city of Toronto. For each intersection type, compliance rates were calculated for cyclists making left turns. The results suggest that the presence of a bike box with an advanced green produced the highest compliance rates amongst the intersections observed. Operationally, this configuration allows cyclists to move to the front of the vehicle queue, reducing delay and heightening visibility of the cyclist. The second best intersection studied employed a cycle track – a physically separated bike lane – approaching the intersection, with a two-phase left turn design. This configuration encouraged cyclists to travel legally about 68% of the time; about 55% of cyclists completed left turns using the two phase design. The poorest performing intersection in
this study included the largest number of travel lanes – two through plus a left turn lane – and only minimal cycling infrastructure – an on-street bike lane.

The research provided evidence that investments in infrastructure tend to be correlated with greater consistency and more often legal behavior by cyclists. These outcomes, we expect, could conceivably lead to greater expected behavior and better-utilized cycling facilities in many cities.

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REFERENCES


13. Willis, Devon Paige, Kevin Manaugh, and Ahmed El-Geneidy. Cycling under influence: summarizing the influence of perceptions, attitudes, habits, and social environments on...


