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Cyclists and Left Turning Drivers: A Study of Infrastructure and Behaviour at Intersections

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Abstract

Cycling is a legitimate mode of transport for a proportion of the population in Australia. Interactions between drivers and cyclists at intersections are complex, particularly left turn negotiations when a cyclist is travelling straight and a driver intends to turn left. Current understanding of safe and unsafe interactions involving these types of left turn negotiations is limited. This study employed a mixed method investigation into the factors involved in driver-cyclist left turn negotiations including desk-based analysis of police reported cyclist crash data and a cross-sectional observational study using a roadside mounted video camera. Video analysis included observed driver/vehicle and cyclist behaviour across different infrastructure types and implications for road rules. Crash data indicates left turn negotiation incidents are proportionally less severe when compared to all cyclist crashes, gender distributions align with that for work-related bicycle trips, and site traffic control type may influence crash risk. Future studies could extend the methods used across additional sites to gain a representative understanding of the types of road design that maximises safe left turn negotiations between drivers and cyclists.

1. Introduction

In 2015, the National Cycling Participation Survey showed that 17.4 percent of Australians had ridden a bicycle in the past week (ABC, 2015), indicating that almost a fifth of Australians use bicycles as a transport mode. Facilities for cyclists vary from dedicated off-road paths usually shared with pedestrians, designated on-road bicycle lanes, and, frequently cyclists share road space with motor vehicles. Sharing the road, whether in shared traffic lanes or bicycle lanes, can result in confusion and at times conflict that can cause serious or fatal injury. The potential for conflict is particularly high at intersections where a number of vehicle movements occur in close proximity and travel paths cross.

Over one in 20 (6 %) of crashes involving cyclists in Victoria can be attributed to incidents that occur when a driver makes a left turn and causes a collision with a cyclist travelling straight ahead (Tierney, 2015). This type of manoeuvre is considered to be a negotiation between a left turning driver and a forward-travelling cyclist. For a safe interaction to occur, there must be a mutual understanding of who must give way. A naturalistic cycling study that investigated driver/cyclist interactions through a variety of road environments, identified left turn side swipe in 40.7 percent of all near-collision events (Johnson et. al, 2010).

The factors that influence left turn negotiation events are not well understood by researchers and practitioners (Johnson, 2010; Cumming, 2012). Australian/Victorian road design standards provide limited guidance on managing left turn negotiations using infrastructure treatments. As a result, cycling infrastructure at intersections varies greatly across the state.

There is a need to investigate the behaviour of both motorists and cyclists when approaching a left turn intersection, and understand the effects of infrastructure on left turn negotiations. The elements of the study undertaken reported here are:

1. Identify characteristics and behaviours of drivers and cyclists that cause or mitigate conflict between cyclists and drivers during driver left turn negotiation;
2. Analyse frequency and severity of conflicts and near collisions between cyclists and left turning drivers at a sample of intersections, and relate frequency and severity of conflicts and near collisions to local conditions; and
3. Identify best practice approaches in managing conflicts between cyclists and left turning drivers in terms of road rules and infrastructure.

The structure of this paper is as follows. Section 2 summarises insight from the literature. Section 3 outlines the methodology and the results are presented and discussed in Section 4. Finally the conclusions of the study are presented in Section 5.

2. Literature review

2.1 Infrastructure and road environment treatments

Common infrastructure treatments to manage left turn conflicts were identified within the literature and are presented in Table 1, and are discussed in the sections which follow.

Table 1. Infrastructure to mitigate conflict during left turn negotiation between cyclists and drivers

Infrastructure type	Aim of infrastructure
Advanced stop box (ASB)	Permit head start position for cyclists in front of a traffic lane
Advanced stop line (ASL)	Permit head start position for cyclists to the left or right of a traffic lane
Continuous bicycle lane (CBL)	Direct cyclists through intersection
Sharrow	Merge cyclists with motor vehicle traffic prior to intersection

2.1.1 Advanced stop boxes and lines

ASB and ASL treatments are well understood to function best when cyclists and drivers are moving from a stationary position. Further to this, the use of ASB and ASL treatments to mitigate conflict when negotiating a left turn have been effective. Comprehension of bike boxes (ASBs) by both cyclists and drivers was considered to be acceptable by Dill et. al (2012), while safety perceptions from both road users were shown to be improved over no treatment. However, the analysis showed that encroachments into bike boxes by motorists increased when making a right turn (USA context) at some intersections, which may have implications for safety.

Research by Koorey and Mangundu (2009) in Christchurch, New Zealand assessed compliance with coloured and uncoloured ASB/ASL treatments. The analysis of all sites (ASB and ASL) showed statistically significant reductions in lane encroachment when coloured treatments were applied. Coloured treatments applied at ASB and ASL sites was reported to improve riding conditions for cyclists. While ASB and ASL treatments appear to be understood and reduce lane encroachment, arguably improving safety in general, research is lacking regarding their influence on left turn negotiations.

2.1.2 Continuous bicycle lanes

Analysis of the effect of continuous lanes indicates that the increased level of awareness for cyclists' presence reduces the number of conflicts. A review of literature by Weigand (2008) reported that a Portland, USA study (Hunter, 2000) into continuous lane safety showed a significant improvement in drivers yielding to cyclists in the presence of continuous lanes compared to no treatment, however signalling of intended travel path from cyclists reduced. Research conducted by Johnson et. al (2010) in Melbourne, Australia indicated a high level of compliance from both cyclists and drivers with coloured, continuous lanes, significantly more than observed at ASB sites. The use of buffer zones, being either a painted or physical buffer between a bicycle lane and a traffic lane, was not included in this literature review.

Continuous lanes are comprehended well by cyclists and drivers alike, and seem to reduce conflicts over untreated sites. There is however a lack of research into the effect on the conflict between cyclists and drivers negotiating a left turn.

2.1.3 Sharrows

The theory of merging motor vehicle and bicycle traffic prior to a conflict zone has become more popular in recent years. According to Furth et. al (2011), sharrows are appropriate in locations where the road width is limited and bicycle lanes cannot be provided. Comprehension of sharrow treatments was assessed in a study by Furth (2009), by observing the positioning of cyclists on a length of road before and after sharrow treatment in Portland, USA. Results indicated that cyclists used the centre of the lane more often when there was a treatment presented.

Monsere et. al (2015) attempted to understand user preferences regarding sharrows in a right turn lane (US context), among other treatments, through video and survey data in Portland, USA. Analysis of video data indicated that sharrows resulted in the lowest percentage of cyclists riding in the correct location (30%), while the same treatment resulted in the lowest percentage of drivers merging at the intended location (48%). In addition, comprehension of the intended use by cyclists when cycling straight through was lower (79%) compared with through bike lane treatments (93% and 94%) (Monsere et. al, 2015). The influence of sharrows on cyclists and drivers is not clear, and their use in turn lanes is not well understood.

2.2 Conflict points, paths and behaviours

Common safety critical events between cyclists and drivers that result in conflict were investigated in Germany using a naturalistic cycling study (Schleinitz et. al, 2015). From 372 hours of data, 31 safety critical events were identified, 9 were due to a driver failing to give way when cyclist and driver trajectories intersected; and 7 were classified as a driver entering the path of a participant cyclist during turning or parking. A semi-naturalistic study by Goode et. al (2014) using a pre-determined route in Melbourne, Australia identified 17 near collisions, 13 of which involved a driver overtaking a cyclist and 12 of which involved a cyclist either approaching or moving through an intersection. However, neither authors directly addressed the left turn conflict.

Cumming (2012) used 'conflict path analysis' to address several common road user conflict scenarios, including a left turn negotiation at intersections with a dedicated left turn lane, in the Australian context. The negotiation can be presented as a two-stage event: (1) a driver turns left from a place to the right of through cyclist traffic; and (2) the driver is unaware of a cyclist's presence (Cumming, 2012). A solution is proposed by staging the turn in two steps, the first being to check for cyclists before merging into a dedicated left turn lane, then completing the turn.

Conflict and near conflict point frequency for left turn negotiations has been measured in a controlled experimental study by Abdul Rahimi et. al (2013). A combination of video recording, eye movement recording and surveys were used to understand the effect of infrastructure types on the safety of left turn negotiations. Due to the small sample size (n=14), closed track test site and potential for test subject bias, the findings of this study were not considered conclusive; however, the study indicates the value of using video data to obtain conflict point frequency data.

2.3 Summary

The studies above indicate that current behaviours from drivers, and to a certain degree cyclists, may be influencing the occurrence of conflicts. Current intersections designs in Australia may not be optimal in managing the left turn negotiation between road users.

3. Methodology

This study used a mixed method approach to investigate current and past conflicts involving a left turn negotiation between cyclists and drivers. Police reported crash data and roadside observation video data were analysed.

3.1 Crash data collection and analysis

In Victoria, the crash types are coded using the Definitions for Classifying Accidents, or DCA codes. The codes related to left turn negotiations are DCA 135 (lane change left) and DCA 137 (left turn side swipe). Figure 1 presents the crash diagrams for each type. This includes the full range of situations where these DCA codes are applied, including some non-intersection sites.

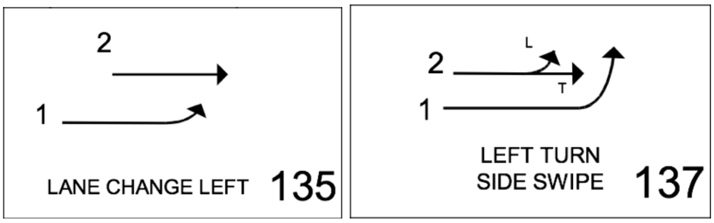

Figure 1. Left turn conflict crash types (VicRoads, 2016)

Data reported on incidents classified as DCA 135 and DCA 137 that occurred between January 2011 and December 2015 were analysed including: demographics, date and time of incident, type of vehicle involved and reported intentions of the cyclist and driver.

3.2 Site selection

Roadside video observations were recorded at five sites within inner Melbourne . Sites were selected based on the variety of: bicycle infrastructure installed; and location relative to the Melbourne CBD. The different bicycle infrastructure types at the selected sites are detailed in Table 2. Street 1 refers to the street on which the cyclist is travelling; Street 2 refers to the street into which the driver will turn left. Relative location indicates the site's position relative to the Melbourne CBD; and bicycle facilities refer to the infrastructure provisions specific to cyclists on Street 1. Configuration of all sites are diagrammatically represented below. Coloured pavement treatment (indicating cycling infrastructure) was installed at all locations except for Site 5. Four of the five involved locations with dedicated left turning lanes.

Table 2. Video data collection site list

Site	Characteristics: Street 1	Street 2	Relative location	Bicycle Facilities	Dedicated Left Turn	Signal Controlled
1	Albert St	Clarendon St	East	ASB coloured, bicycle lane terminating prior to intersection	Yes	Yes
2	Albert St	Lansdowne St	East	ASB coloured, bicycle lane terminating prior to intersection	Yes	Yes
3	Faraday St	Lygon St	North	ASL coloured, bicycle lane continuous to intersection	Yes	Yes
4	Peel St	Franklin St	Northwest	CBL coloured with linemarked buffer zone, continuous through intersection	No	No
5	Glenlyon Rd	Lygon St	North	Sharrows	Yes	Yes

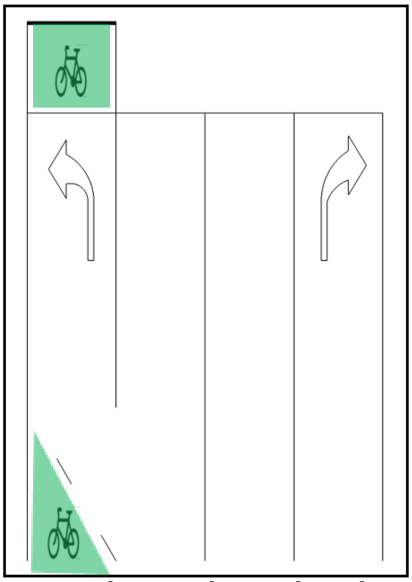

Figure 2. Advanced stop box (ASB) arrangement at Sites 1 and 2 with sign permitting cyclist through movements within left turn lane.

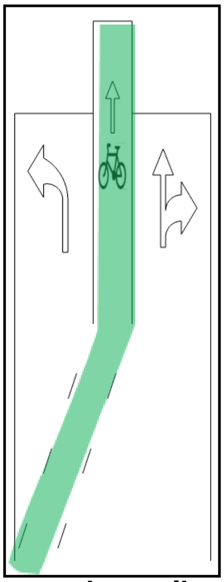

Figure 3. Advanced stop line (ASL) arrangement at Site 3.

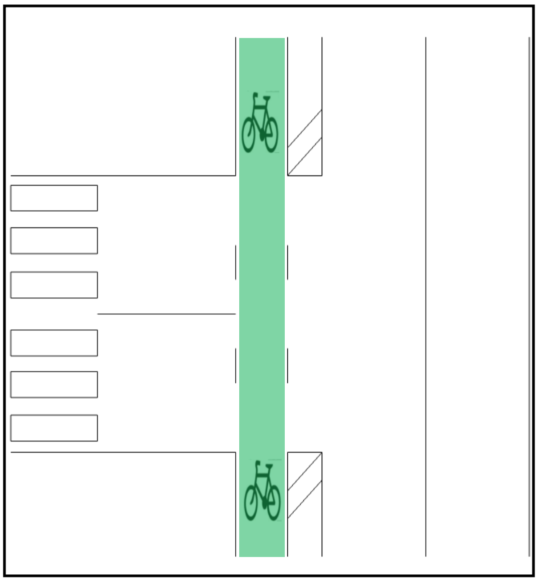

Figure 4. Continuous bicycle lane (CBL) arrangement with buffer zone at Site 4.

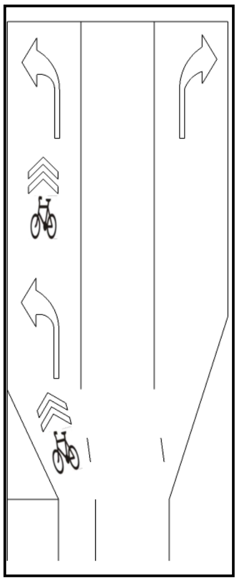

Figure 5. Sharrows arrangement at Site 5 with sign permitting cyclist through movements within left turn lane.

3.3 Video data collection and analysis

Data was collected during the peak morning and evening commuter traffic times, when a high number of cyclists are present on the roads. Video footage was collected at each site for one hour in the morning (07:30-08:30) or evening (17:00-18:00) to correlate with commuter travel periods, over a period of three days per site. The video data collection was conducted during May 2016. The camera, an ATC-900 action camera (Sites 1, 3, 4 and 5) or a Brinno TLC200 (Site 2), was placed within a securely locked box attached to a standard diameter roadside pole. The pole was required to be a suitable distance back from the intersection, in the order of 10 metres or greater, for the site to be considered suitable. The position of the camera on the pole was approximately two metres above ground level, to ensure pedestrians and tall parked vehicles would not affect the data collection process, shown in Figure 6.

Footage was manually reviewed using Quicktime Media Player by a single researcher (HN). The aim was to identify left turn negotiations, conflicts and/or collisions. Negotiations were defined per cyclist arriving behind a left turning vehicle, and travel path was coded dependent on the positioning of the cyclist relative to the turning vehicle. Conflicts were defined by a negotiation that required a minor deviation from the intended path. Near collisions were defined by a negotiation that required more severe evasive action (braking or swerving).

Figure 6. Indicative camera positioning relative to roadway at Site 4, with camera circled in red.

4. Results and analysis

4.1 Insights from crash data

A total of 500 incidents across Victoria were identified between 2011 and 2015 associated with the two crash classifications chosen, including one incident involving two cyclists, with 70 lane change left (DCA 135) and 431 left turn sideswipe (DCA 137) incidents.

4.1.1 Crash severity

Cyclist injury severity outcomes for the 500 left turn negotiation crashes analysed is presented in Table 3. In the five years analysed, there was one fatal crash as a result of a left turn negotiation, the majority were 'other injury' outcomes (injuries not requiring hospitalisation)(81.2%). Serious injuries to cyclists (requiring hospitalisation) were experienced in approximately one fifth of all left turn crashes. In comparison to the total number of crashes in Victoria over the same period (2011-2015), left turn negotiation events experience a lower proportion of serious and fatal injuries (VicRoads, 2016).

Table 3. Crash severity of left turn conflict incidents compared to all incidents involving cyclists in Victoria

Severity	Left turn negotiation incidents (%)	All incidents involving cyclists (%)
Other Injury	407 (81.2%)	5365 (71.0%)
Serious Injury	93 (18.6%)	2148 (28.4%)
Fatal Injury	1 (0.2%)	42 (0.6%)
Total	500	7555

From the crash data analysed, left turn negotiation crashes result in primarily minor or non-hospitalisation injuries for cyclists. This may be due to the angle of the conflict; although the DCA diagrams seen in Figure 1 indicate that the trajectories can cross at right angles (DCA 137), the actual angle of impact may be less, contributing to reduced severity.

Conversely, the reduced proportion of high severity incidents may be due to the speeds at which these incidents occur. A driver intending to turn left will generally slow prior to beginning the manoeuvre, which in turn will reduce the speed at impact. Further investigation into the factors behind reduced severity of left turn negotiations is required.

In addition to these contributing factors, perceptions of safety, both by cyclists and drivers is an important factor to consider in left turn negotiations. Cyclist and driver perceptions of safety do not always correlate with the safest infrastructure according to conflict frequency (Abdul Rahimi et. al, 2013; Monsere et. al, 2015), and cyclists will choose infrastructure perceived as safer (Koorey et. al, 2010). Investigation into perceived safety factors is recommended.

4.1.2 Gender and time distributions

The gender distribution of left turn negotiation incidents, in comparison to the gender distribution of the total number of cycling trips and work trips in Melbourne (VicRoads, 2014), is presented in Table 4. The proportion of female cyclists in left turn negotiation incidents is observed to be lower than that seen across the total number of trips made by bicycle. No investigation into gender proportions per time of day was conducted. However, it can be seen that the gender differences between left turn negotiations and trips to work by bicycle were in the order of one to three percent.

The largest proportion of left turn negotiation incidents occurred in the morning peak travel times, between 7:00-9:59am (38.8%) including 20.6 percent between 8:00-8:59am. Thursday was observed to be the day with the highest proportion of incidents (23.8%).

Table 4. Gender distribution of left turn negotiation incidents compared to census data gender distribution

Gender	Left turn negotiation incidents (%)	All trips made by bicycle (%)	Work trips made by bicycle (%)
Male	371 (74.0%)	55%	73%
Female	124 (24.8%)	45%	27%
Unknown	6 (1.2%)	-	-

These patterns may indicate that work-related bicycle trips are represented in a high proportion of left turn negotiation incidents, which may be supported by the high number of incidents occurring within Melbourne City Council (n=128, 25.5%). Whether this is due to a large volume of cyclists during the commuter travel period, increased vehicle traffic volumes, and/or the impact of congestion on cyclist and motorist behaviour is not known. In addition, the factors behind weekday proportions is difficult to ascertain from the current data.

It is likely that a combination of the above factors influences the proportion of incidents, however investigation into the gender, time of day and day of week distributions would provide further insight.

4.1.3 Age distribution

The age distribution the cyclists and drivers involved in the incidents is presented in Figure 3. The largest proportion of incidents involved road users aged 30-59 year for both cyclists (61%) and drivers (48%). A higher proportion of 19-29 year old cyclists compared to drivers were involved in left turn negotiation incidents (29% vs. 21%). In contrast, a higher proportion of elderly (60-80+) drivers were involved compared to cyclists (11% vs. 6%). Data for 13-18 year old drivers and cyclists is shown, however is not considered appropriate for comparison, as persons under the age of 17 are not able to drive in Victoria. Furthermore, given that 11% of drivers' age was unknown, it is difficult to determine whether a particular age group of drivers was represented the most within the data. For cyclists however, it was evident that adult cyclists aged 30-59 years were the highest proportion, this is likely to reflect the high representation of this age group in the current Victorian cycling population.

Census data published by Loader (2014) indicates that a spike in cycling mode share occurs for males aged 30-40 years, while for females the spike occurs between 28-32 years. The crash data indicates a similar pattern, showing no clear over or underrepresentation of certain age groups. For drivers, no such conclusion is able to be drawn; however, insight into the most representative age group could be achieved with more stringent recording of driver age at the time of the event.

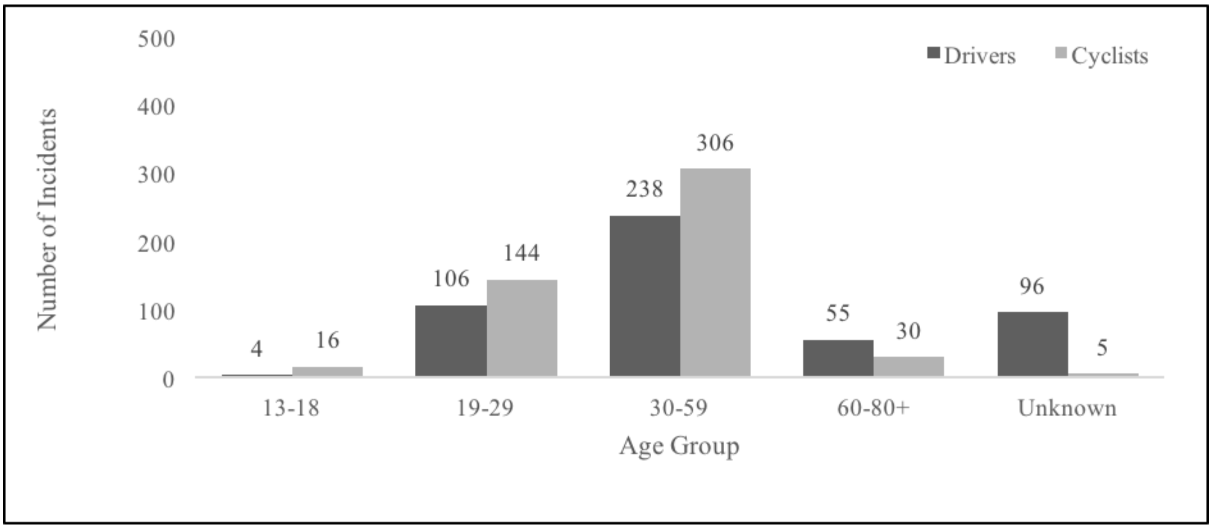

Figure 7. Distribution of ages for left hand turn crashes involving cyclists and drivers

4.1.4 Crash site traffic control

Figure 8 indicates the relative proportion of sites with controlled and non-controlled traffic movements. A total of 456 events occurred at an intersection, while 45 events occurred at non-intersection sites. Sites classified as 'Other' included pedestrian crossings, pedestrian-only signals, school crossings and stop signs.

Sites with no traffic control were represented in the highest number of events (n=316, 63%). Of the sites with control, signalised sites had the highest number of incidents (n=136, 27%), followed by roundabouts (n=28, 5%). Sites without traffic control may have a higher potential for incidents to occur – both drivers and cyclists require a certain level of guidance when travelling in a road environment. An absence of control requires individual road users to decide the appropriate action to take, which may not be understood by the other road user involved in the left hand turn negotiation. In the situation of a cyclist-driver negotiation at a non-controlled site, a driver's decision may be considered to have more influence given the size and presence of a motor vehicle compared with a bicycle.

The representation of signalised intersections may also be attributable to the number of such sites across Victoria and may influence left turn negotiations. In the absence of cycling facilities, which represent the majority of signalised intersections in Victoria, signalised intersections do not provide guidance for cyclists to travel through, while driver awareness of cyclists can be low. Conversely, a high number of events occurred in Melbourne City Council, where cycling facilities are widespread at signalised intersections.

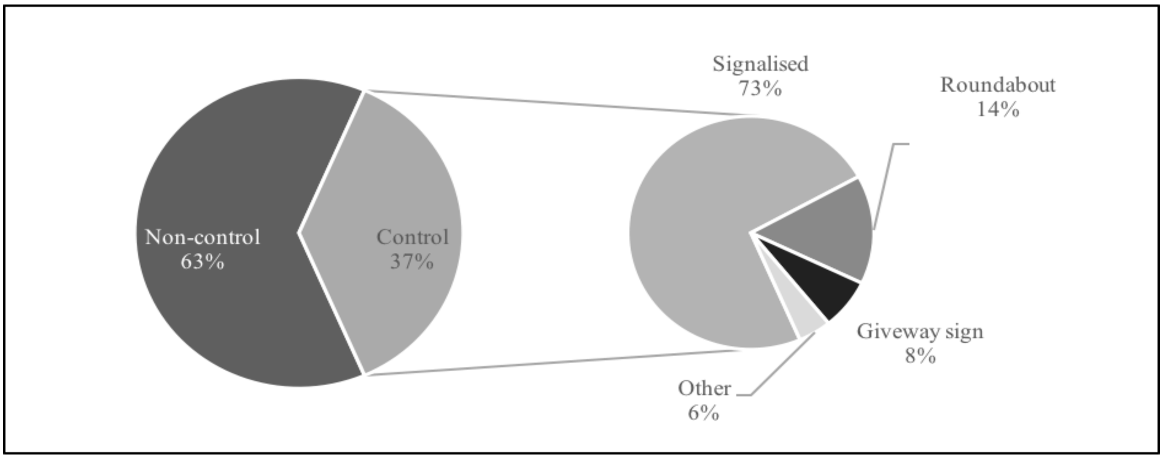

Figure 8. Proportion of crashes with non-controlled vs. controlled traffic movements.

The lower proportion of roundabout-related left turn negotiations may be explained by the comparatively low number of roundabouts in comparison to signalised intersections, or may indicate cyclist route choice, with some cyclists preferring to avoid roundabouts.

A low proportion of crashes occurred at intersections controlled by give way signs. This may be because such controls are applied to minor legs of intersections, at which both drivers and cyclists intend to turn onto a major road, and hence a left turn negotiation is not required.

4.1.5 Summary

For crashes analysed, a missing component is exposure data. Provided with information regarding the number of non-controlled and signalised, roundabout and give way controlled sites encountered by an average cyclist, a more in-depth understanding of the effect of traffic control could be obtained. Furthermore, investigation into the proportion of all cyclist incidents occurring at non-control versus control sites and comparison with the data presented may indicate whether left turn negotiation events are over or underrepresented at certain site types.

The left turn negotiation crash data provides some insight into the factors that contribute to the frequency and severity of conflicts. Current literature does not address a number of proposed factors, and a lack of exposure data means any conclusions drawn have limited application.

What is also clear is that crash data alone does not provide sufficient detail to understand behaviours of cyclists and drivers, nor to understand the role of infrastructure in such events. For that reason this study included video data collection of actual behaviour of cyclists and motorists.

4.2 Insights from video data

A total of 15 hours of data was collected across the sites, however the three hours from Site 2 were deemed to be unsuitable given the capture rate of the Brinno TLC200 was not considered adequate for data analysis. The results of the analysis of 12 hours of video have been presented, including a detailed analysis of the left turn negotiations and near collisions observed.

4.2.1 Negotiations and conflicts overview

Negotiations were classified by the path chosen by the cyclist relative to the left turning vehicle, being to the left of the vehicle, behind the vehicle and to the right of the vehicle.

Figure 5 indicates the distribution of travel path chosen across the different infrastructure types. Distinct behaviours were observed at each site for each travel path.

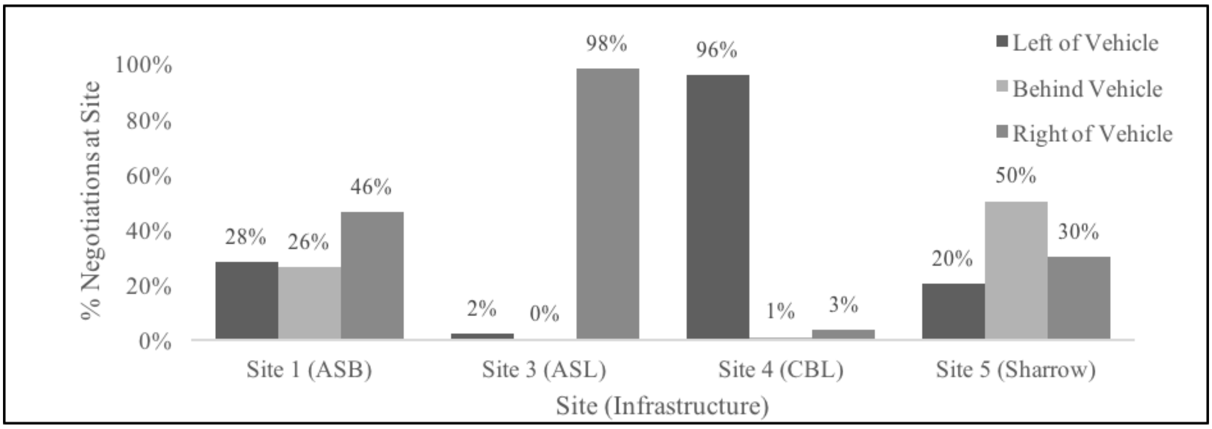

Figure 9. Percentage of left turn negotiations per travel path taken across different bicycle infrastructure.

A total of 702 left turn negotiations were observed across Sites 1, 3, 4 and 5, with the distribution shown in Table 5. It was evident that a larger number of negotiations took place at Sites 3 and 4, most likely due to a larger volume of cyclists and left turning traffic in comparison to Sites 1 and 5. Conversely, Site 5 was observed to have a very low number of negotiations, due to a low number of cyclists and left turning traffic volumes. As such, findings from the latter site have limited application.

Table 5. Number of left turn negotiations per bicycle facility.

Site	Infrastructure types	Negotiations
Site 1	Advanced stop box (ASB)	50
Site 3	Advanced stop line (ASL)	226
Site 4	Continuous bicycle lane (CBL)	416
Site 5	Sharrow	10
TOTAL		702

4.2.2 Site 1 (ASB) behaviours

The most often chosen path by cyclists involved in a left turn negotiation was to the right of the vehicle, followed by left of the vehicle, then behind the vehicle. A much more distributed pattern of behaviours was observed at the ASB site in comparison to the other sites (also observed within the limited data at the sharrows site) and it is possible that this was influenced by the infrastructure present. As indicated in Figure 2, guidance for cyclists is absent before the intersection stop line and ASB. Cyclists have been provided with a protected, coloured lane prior to this point. This lack of guidance requires cyclists to make individual decisions regarding travel path, based on their perceptions of safety.

Further, the variation of cyclist travel paths is likely to increase a driver's sense that cyclists are unpredictable. This lack of certainty may also contribute to either miscommunication or misunderstanding between driver and cyclist during the left turn negotiation. Two qualitative insights were obtained: (1) Drivers approaching the left turn negotiation at a red light often provided a gap on the left side of the vehicle; and (2) Drivers approaching the left turn negotiation at a green light often turned from a position straddling the lane dividing line of the left turn and through lanes, as opposed to the left turn lane only.

It could be inferred that behaviours were enacted to leave road space for cyclists approaching the intersection. In addition, due to a lack of visual aid from the infrastructure for drivers, give way tendencies were made on an individual basis. Again, investigations into the factors behind these decisions using larger samples would provide further insight.

4.2.3 Site 3 (ASL) behaviours

At the ASL site, cyclist behaviours were very consistent. The majority of cyclists involved in a left turn negotiation were observed to travel to the right of a left turning vehicle. This behaviour follows the guidance provided by the infrastructure, being to follow the path of the bicycle lane to the right of the left turn lane. During periods of congestion, vehicles queueing to turn left blocked the bicycle lane, consequently cyclists were not able to follow the lane, and were required to make individual choices. Even during congested periods, cyclists mostly chose to travel to the right of vehicles. It was observed that when infrastructure is provided, cyclists will attempt to follow the designated path, even if the intended route is not immediately available.

Driver behaviour was difficult to analyse as behaviour appeared to be influenced by high levels of congestion, lower travel speeds and queueing. No observable pattern was recorded regarding the decision for a driver to obstruct the bicycle lane rather than to allow a gap, while give way tendencies were difficult to record. Future investigation of ASL sites with differing levels of congestion and vehicle speeds may provide more insight into driver behaviour.

4.2.4 Site 4 (CBL) behaviours

At the CBL site, which had no traffic lights, a buffer zone running along the edge of the bike lane and a shared left turn and through traffic lane, cyclists involved in negotiations most often chose to travel to the left of the driver, with a small number choosing to travel right around turning traffic. The infrastructure in place intends to guide cyclists to the left side of the vehicle, leading to predictable or more intuitive behaviours.

Patterns were identified regarding the road user priority at the intersection. Left-turning drivers were observed most often to give way to straight-travelling cyclists, although the presence of a pedestrian crossing immediately after the negotiation point may influence this behaviour. In the event that a cyclist was observed giving way to a driver, the negotiation was normally defined by hand signals from the cyclist, and slowing of travel speed from both users. It could be stated that this intersection provided the highest potential for conflict, given the higher level of cognitive load required from three tasks: to check for a cyclist; to complete a left turn; and to give way to pedestrians. This potential was realised in a near collision and several conflicts.

Conflicts were observed in five negotiations at the CBL site. It was clear that the commonly-enacted negotiation of drivers giving way to cyclists was not mutually understood by both users in each of the conflicts. Instead, all events saw a driver turning left in front of a cyclist travelling straight, resulting in action from the cyclists including minor evasive manoeuvre (braking and/or changing trajectory) and/or a physical response (raised hand and/or shaking of head). This site provides some potential insight into the role of prior experience at a given site. It is probable that frequent users of the roadway understand the accepted negotiation, whereas infrequent users do not. Furthermore, an infrequent user should be able to approach a road environment negotiation and be able to clearly understand the intended approach. Evidently, this does not occur at this particular site – a larger sample size of CBL sites may indicate whether this is an infrastructure related factor.

4.2.5 Site 5 (Sharrow) behaviours

Sharrow infrastructure at Site 5 produced varied results, showing a majority of cyclists chose to travel behind the vehicle. Findings from this site are limited, given the low number of negotiations observed (n=10). Behaviours were generally observed to follow the intended use of the sharrow, being to merge single file with vehicle traffic. In future, additional sites with sharrow treatments should be observed to gain insight into the role of infrastructure and guidance.

4.3 Strengths and limitations

While the scale of this study means that it represents a starting point in establishing an evidence base in this field, it has never-the-less provided important new insights into the complex left turn negotiations between cyclists and drivers. The use of two distinct data sources, crash and video data, allowed the investigation to account for a number of factors relating to left turn crash events and a left turn negotiation. Observed sites included a range of infrastructure types that enabled analysis of the varied behaviours by infrastructure types.

However, this study was also limited by the small number of sites investigated and technical difficulties with one camera further limited the available data. The influences of other site characteristics such as signal phase, posted speed limit and traffic volumes were not investigated. Future studies should investigate a larger number of sites, including a control with no bicycle infrastructure installed, more non-signalised sites, more sites with no dedicated left turning lane, and collect data using a single camera type.

5. Conclusions

This study provides initial insight into the factors at play in left turn negotiation between cyclists and drivers in an urban environment across a range of cycling facilities at intersections, most involving dedicated left turning lanes. Overall crashes were less severe than total cyclist incidents, while gender distributions were similar to work-related trips. Cyclists and drivers aged between 30-59 years were most commonly present, while morning incidents were most common. The collection of exposure data would enrich further investigation of these patterns.

From the video observations, it was evident that infrastructure plays a role in driver and cyclist behaviour. It could be expected that guidance for cyclists allows a more predictable travel path, however intended behaviour messages to drivers provided by infrastructure may be unclear. The two near collisions observed were thought to occur as a result of a lack of mutual understanding between users, potentially influenced by site characteristics. Larger sample sizes in future studies would be valuable to increase the confidence in the conclusions.

Based on the observed driver and cyclist behaviours across the four site types, Site 3 (ASL, continuous bicycle lane to intersection) could be considered the most appropriate bicycle facility in addressing the left turn negotiation conflict where a dedicated left turn lane exists, as cyclists were observed to travel most consistently to the right of drivers, following the designated bicycle lane. This layout follows the two stage approach as described by Cumming (2012), which could be considered to reduce cognitive load for drivers, whilst the continuous bicycle lane provides clear guidance for cyclists (supported by the observation data).

Site 4 (CBL, continuous lane through intersection) could be considered an appropriate intersection layout, with cyclist behaviours observed as being consistent (being to the left of the driver) and therefore predictable from a driver’s perspective. However, the point at which drivers must negotiate with cyclists remains at the intersection, where cognitive load for drivers could be considered greater, and therefore their awareness of cyclists approaching the intersection may be reduced.

Site 1 (ASB, terminating bicycle lane before intersection) could be considered the least appropriate in addressing the left turn conflict, as behaviours were not consistent at this location, with cyclists travelling to the left, directly behind or to the right of drivers. Arguably this can be attributed to the termination of the bicycle lane prior to the intersection.

Site 5 (Sharrows, terminating bicycle lane before intersection) could also be considered as a less appropriate treatment for a left turn negotiation, given the unpredictable travel path of cyclists relative to drivers. However, it is again noted that a limited number of negotiations were observed, and therefore definitive conclusions for this infrastructure layout are difficult to make.

Further research that expands this study could provide greater insights into how the built environment influences cyclist and driver behaviours. Such further research could also inform the implementation of more intuitive infrastructure treatments and increase predictability for cyclists and drivers, which would lead to improved safety for cyclists.

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