VIASTRADA
TRANSPORT PLANNING AND DESIGN

LEFT TURN TREATMENTS

AT SIGNALISED INTERSECTIONS

Safety review

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Left turn treatments at signalised intersections

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Cover photo

St Lukes Road at Northwestern Motorway, Auckland. Photo by Glen Koorey.

Note this treatment was installed and photographed prior to the cautionary note now included in the TCD Manual that “*visually impaired road users have reported that red and pink colouring between the white marking stripes does not provide adequate contrast*.”

Executive summary

Left turn treatments at signalised intersections can be provided in a variety of forms, ranging from conventional left turns made within the signalised intersection to turns that bypass the signals via a slip lane. Slip lanes are often discussed as though they are a single treatment type, yet the available research demonstrates that their safety performance varies substantially depending on geometric design and the provisions made for pedestrians and cyclists.

This white paper reviews the characteristics and safety performance of the main left turn treatments used at urban signalised intersections, with a particular focus on pedestrians and cyclists. Signalised treatments include left turns from either an exclusive lane or a lane shared with through traffic. For slip lanes, we consider only compact layouts without a dedicated acceleration lane. In these layouts, drivers merge directly into a shared departure lane and may immediately conflict with traffic from other intersection legs. We distinguish between high-entry-angle (HEA) and low-entry-angle (LEA) slip lanes. The review draws on Australian and New Zealand research, published guidance and engineering first principles.

The available evidence does not show that slip lanes are inherently less safe than conventional signalised left turns. Large studies in Melbourne and Auckland found that pedestrian crash rates at slip lanes were generally similar to, and sometimes lower than, those at conventional signalised left turn lanes. However, safety performance varied considerably between slip lane designs. High-entry-angle (HEA) slip lanes consistently performed better than low-entry-angle (LEA) slip lanes. In the Auckland research, HEA slip lanes had the lowest pedestrian injury crash rates of all treatments studied, while LEA slip lanes had the highest.

The research suggests that safety outcomes are strongly influenced by factors including vehicle speed, driver workload, visibility, and the degree to which conflict points are separated. HEA slip lanes typically achieve lower turning speeds, better driver visibility, and improved observation angles compared with LEA designs. Conversely, LEA slip lanes can encourage higher turning speeds and require drivers to look further away from the pedestrian crossing while searching for gaps in traffic, increasing the potential for conflicts.

Evidence regarding cyclist safety is more limited. However, both research and recognised design guidance suggest that safety benefits can be achieved when conflicts between cyclists and turning vehicles are relocated away from the stop line of the signalised intersection and managed in a simpler operating environment. This can be achieved through exclusive left turn lanes or appropriately designed slip lanes.

A key limitation of the available pedestrian safety studies is that none adjusted crash rates for pedestrian or vehicle exposure. Consequently, treatments commonly installed in areas with high pedestrian demand may appear less safe than they are. While this limits the certainty that can be placed on absolute crash rates, the relative differences observed between treatment types are consistent across multiple studies and align with accepted road-design principles.

Overall, the evidence indicates that active-user safety depends less on whether a left turn is signalised or accommodated via a slip lane, and more on whether the treatment promotes low vehicle speeds, good visibility, manageable driver workload, and focused driver attention. Where slip lanes are used, they should be designed as high-entry-angle treatments and incorporate measures that help drivers recognise and respond to pedestrians and cyclists. Low-entry-angle slip lanes should be avoided.

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1 Introduction

Left turn treatments at signalised intersections are widely used to balance safety and operational efficiency, but different treatment types can result in markedly different outcomes for drivers, pedestrians, and cyclists. In particular, slip lanes have attracted notable attention in recent years because of differing views on their safety performance and the role of geometric design in influencing driver behaviour and conflict risk. There is a considerable movement of urban designers, planners and engineers discouraging slip lanes – note, though, that urban design considerations (e.g. the effects on landscaping and public space) are not within the scope of this paper. For example, the *Global Street Design Guide* (NACTO, 2016) recommends to "remove slip lanes where possible" as a means of achieving more compact intersections[1] which are expected to "reduce pedestrian exposure, slow traffic near conflict points, and increase visibility for all users".

On the other hand, there is a growing body of research (including that discussed in Section 3.2 of this paper) that identifies key design components that can achieve safer intersections and better pedestrian environments through good slip lane designs. This led, for example, to SNUG's (2026) update to the *Stops and goes of traffic signals* guide stating that "well-designed slip lanes […] can improve pedestrian safety (by separating conflict points) and reduce pedestrian delay (by providing a priority crossing across the slip lane and reducing the overall intersection cycle time)."

In this white paper we examine the different options of providing left turns at signalised urban intersections including turns made within the signalised intersection and turns that bypass the signals via a slip lane. The signalised treatments include left turns coming from either an exclusive lane or a lane shared with through traffic. For the slip lane treatments, we only consider the more compact options where the slip lane does not have a dedicated acceleration lane on departure, i.e. slip lane drivers merge directly into a common departure lane where they may immediately conflict with drivers coming from other intersection legs. A key distinction for the slip lane treatments is whether they are high-entry-angle (HEA) or low-entry-angle (LEA).

We first describe the key characteristics of these treatment types and then review evidence relating to the safety performance of slip lanes in general and regarding pedestrians and cyclists specifically. Through this, we also identify measures that can improve safety at slip-lane crossings, including geometric design and form of pedestrian crossing provision.

[1] We note that NACTO also recommends "breaking complex intersections into smaller intersections" which is effectively what having slip lanes does. Furthermore, as we discuss later in this paper, excluding slip lanes increases the size of the controlled area.

2 Left turn treatments at signalised intersections

2.1 Overview

The Austroads design framework, particularly Guide to Road Design Part 4A "AGRD4A" (Austroads, 2026) recognises a range of left turn treatments that vary according to traffic volumes, operating speed, design vehicle requirements, intersection control, and the needs of pedestrians and cyclists. The selected treatment influences vehicle path geometry, turning speed, driver observation angles, pedestrian crossing distances, and the degree of traffic separation provided.

2.1.1 Treatments covered

This review considers two main categories of left turn treatments at signalised intersections where slip lane traffic merges directly with cross traffic on the departure, each with two sub-categories:

- Left turns within the signalised intersection aka "conventional lanes" (section 2.2)
  - Exclusive left turn lane
  - Shared left turn lane
- Slip lanes that allow the left turn to bypass the traffic signals
  - High-entry-angle (HEA) slip lanes (section 2.3.1)
  - Low-entry-angle (LEA) slip lanes (section 2.3.2)

2.1.2 Treatments not covered

In this review, we do not specifically consider:

- "free-flow" slip lanes, i.e. those that have a dedicated acceleration lane and merge with through traffic further downstream (e.g. the left turn from Brougham St west to Ensors Rd north, in Christchurch), as shown in Figure 2-1.

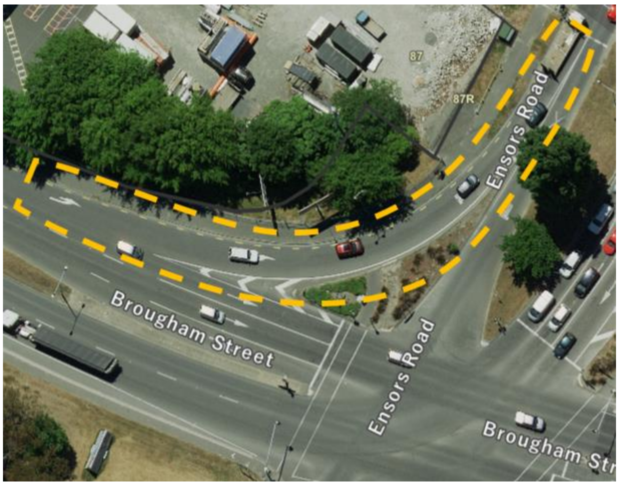


Figure 2-1: Slip lane with a dedicated acceleration lane (source: Canterbury Maps)

- "signalised slip lanes", i.e. left turn lanes with slip-lane-like geometry (sweeping curve, triangle splitter island between the left turn lane and through lane etc) but that are fully signal controlled such that left turners do not have to give way to cross traffic or opposing right turners (e.g. the left turn from Hagley Ave to Riccarton Ave in Christchurch), as shown in Figure 2-2.

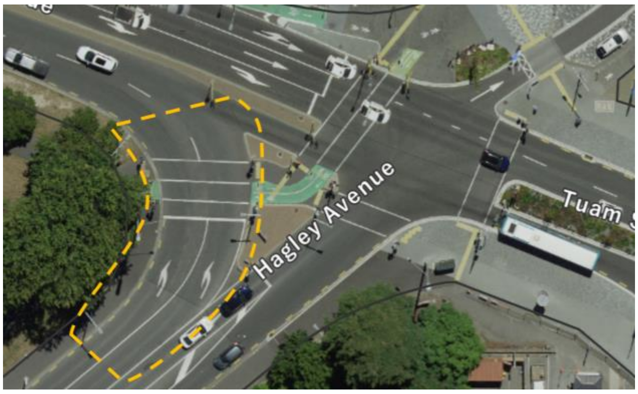
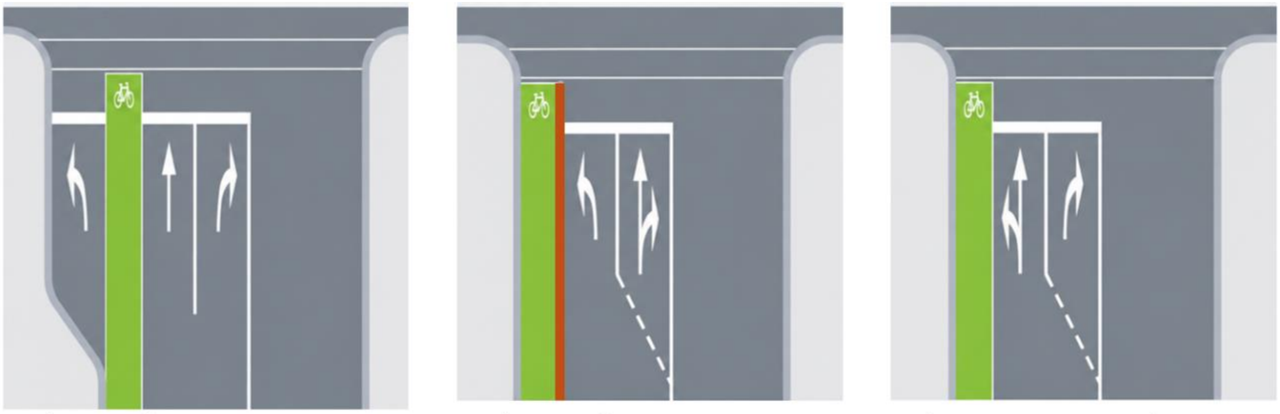


Figure 2-2: Signalised two-lane slip lane (source: Canterbury Maps)

2.2 Left turns within the signalised intersection

Where left turning drivers remain within the main intersection area, they complete the turn directly from a shared left / through lane or from an exclusive left turn lane. These lanes are referred to by some researchers as “conventional lanes” because the application pre-dates slip lanes. The lane designation influences the options for signal operations, which could include protected turns and/or filter turns. These treatments typically have a larger controlled area but a lesser total footprint compared with an intersection with slip lanes.

Figure 2-3 presents three basic concepts for providing for left turners within signalised intersections that also include provision for cyclists. More details including other layouts and the relevant signal operations are available in the TCD Manual Part 4 (NZTA, 2024) and SNUG (2026).



a) Exclusive left turn lane to left of on-road cycle lane | b) Exclusive left turn lane, kerbside cycleway | c) Shared left turn / through lane, kerbside cycle lane

Figure 2-3: Three concepts for providing for left turners and cyclists (source: NZTA, 2026a)

Table 2-1 compares the two main lane designations for left turners at signalised intersections in terms of operation and geometry (safety is covered in Section 3).

Table 2-1: Main operational and geometric benefits (+) and disbenefits (-) of exclusive left turn vs shared left / through lanes

Exclusive left turn lanes	**Shared left turn / through lanes**
+ Better flexibility for operating the through and left turn movements independently, e.g.: • the left turn can have a red arrow for pedestrian (or cycleway) protection, without holding up through traffic; • the left turn can have a green arrow during an exclusive right turn or split approach phase.	**–** Less flexibility for operating the through and left turn movements independently: • a red left turn arrow can result in subsequent through traffic being held up even though there’s a green disc – they may even make unsafe lane change / overtaking manoeuvres; • if a green left turn arrow is applied in conjunction with a red disc, left turners may get stuck behind waiting through traffic.

Exclusive left turn lanes	Shared left turn / through lanes
+ More options for integrating cycle facilities, e.g.: • makes it possible to address the conflict between left turners and cyclists on the approach to the intersection (e.g. part (a) in Figure 2-3) which is safer for cyclists (discussed in Section 3.3); • makes it possible to give adequate protection to a kerbside separated cycleway / cycle path – see part (b) in Figure 2-3.	**–** Trickier to integrate with cycling facilities: • an on-road cycle lane needs to stay at the kerbside, so cyclists will conflict with left turners when travelling through the intersection • a red left turn arrow could be applied when cyclists start, but (as discussed in the point above) this can't continue for long as it will hold up non-conflicting through traffic.
– May require more space in the cross-section: • might not leave enough space for an exclusive right turn lane, requiring a shared through / right turn lane – resulting in similar operational difficulties plus the complication of conflicts with opposing through traffic.	**+** Requires less space in the cross section: • more likely to be able to achieve an exclusive right turn lane, with the associated operational and safety benefits.

2.3 Slip lanes

The key distinction between the two slip lane types is the entry angle, i.e. the angle between the slip lane and the crossroad drivers are turning onto.

2.3.1 High-entry-angle (HEA) slip lanes

A high-entry-angle slip lane is a channelised left turn treatment in which a raised or painted island separates turning traffic from the main intersection and directs vehicles into the receiving road at a relatively steep angle, as shown in Figure 2-4.

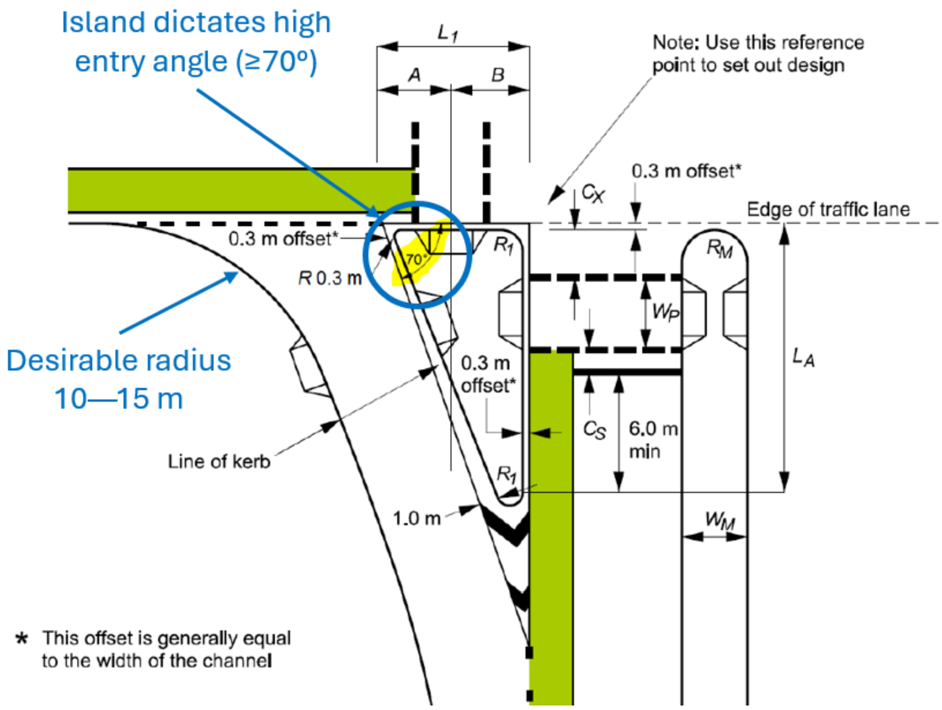


Figure 2-4: HEA slip lane with cycle lanes across entry and exit (adapted from Austroads, 2026, Fig 6.5)

Typical characteristics of a HEA slip lane include:

- Higher entry angle (≥70°, i.e. closer to a right-angle merge than a shallow-angle merge)
- Smaller turning radii (ideally 10–15 m, although tracking of heavy vehicles can complicate this)
- A distinct channelising island

This geometry results in:

- Lower turning speeds than low-entry-angle slip lanes
- Improved visibility to conflicting traffic
- Fewer crashes between drivers exiting the slip lane and cross traffic.

Austroads notes that the key objective of a high-entry-angle layout is to position turning vehicles such that drivers face approaching traffic at an appropriate observation angle while also providing a clear and conspicuous intersection form.

2.3.2 Low-entry-angle (LEA)

For the purposes of this review, low-entry-angle (LEA) slip lanes are those that do not conform to the HEA design standards for entry angle and corner radius. As is discussed in the following section, this results in left turning drivers being able to turn at a faster speed and with decreased visibility to opposing cross traffic. Figure 2-5 shows an example of a LEA slip lane. Historic guidance has included "direct-merge arc" designs that have a low entry angle[2], but Austroads does not currently present a LEA design option other than "free-flow" slip lanes, i.e. with a dedicated acceleration lane and merge with through traffic further downstream (and which, as discussed in section 2.1.2, are not covered in this review).

Figure 2-5: LEA slip lane at Blenheim Rd / Clarence St, Christchurch (base source: Canterbury Maps)

2.3.3 Additional components: pedestrian crossings

Several treatments for pedestrian crossings across slip lanes are available. Crossings can be priority-controlled (e.g. zebra) or signalised crossings, and either may have supporting features such as raised safety platforms ("RSPs").

[2] For example, see Figure 4 of O'Brien *et al*. (2012)

3 Safety performance of left turn treatments

3.1 Factors affecting safety of left turn treatments

Sharobim (2016) analysed the 230 crashes involving left turn movements that occurred at signalised intersections in Auckland in 2014. Figure 3-1 shows that the majority (69%) of these crashes occurred at slip lanes, however Sharobim notes that slip lanes comprised only 41% of left turn treatments in the network. The most common crash type at slip lanes was rear-end crashes. Pedestrian crashes represented only 3% of the total crash sample (7 crashes), with six occurring at shared conventional lanes and one at a zebra-crossing slip lane. Sharobim cautioned that the small number of pedestrian crashes limited the conclusions that could be drawn regarding pedestrian safety and conducted a further study which is discussed in Section 3.2.

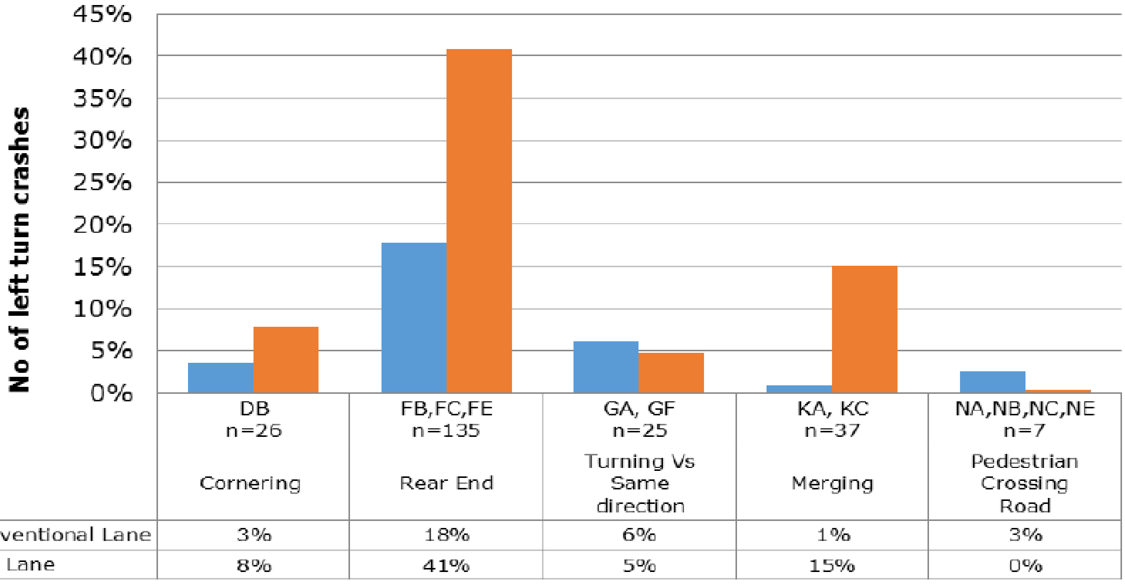


Figure 3-1: Distribution of crashes of slip lane versus conventional lane, by crash group type (Sharobim, 2016)

While the literature reviewed makes a clear distinction about slip lane entry angle, no studies have been identified that specifically compare HEA and LEA slip lanes with exclusive and shared signalised lanes. Several studies have been identified that compare slip lanes in general (i.e. likely a sample that includes both HEA and LEA slip lanes) with exclusive and shared signalised lanes. Sharobim (2016) in a detailed study of left turn crashes at 84 Auckland signalised intersections over 5 years found when accounting for traffic exposure, “the crash rate for slip lanes was marginally less than conventional lanes… (3.17 versus 3.23)” but suggested they have “comparable safety performance overall, but with some notable differences according to the treatment type” and this was statistically verified.

Similarly, Al-Marafi *et al*. (2021) studied 106 intersections in Toowoomba, Australia, and found a modest crash reduction for introducing a slip lane: a crash modification factor (CMF) of 0.97 for adding a slip lane to one major approach and a CMF of 0.94 when adding slip lanes to all major approaches (note though, the sample included both signalised and unsignalised intersections).

When comparing HEA and LEA slip lanes, supporting evidence from related intersection research reinforces the importance of visibility and entry angle. Ukkusuri *et al*. (2020) in a study based in Indiana, US, found that a 1% increase in left turn slip lane turning radius increased crash frequency by 0.22%, suggesting that larger-radius channelised turns, which generally permit higher turning speeds, are associated with higher crash risk.

Schattler *et al*. (2016) evaluated geometric modifications at channelised turning approaches in Peoria, Illinois, US, and found that reducing approach skew and increasing the turning entry angle resulted in a 59.6% reduction in turn-related crashes and a 59.0% reduction in approach crashes. The benefits were even greater for older drivers, among whom turn-related crashes declined by 70%. Significantly elevated crash frequencies were found for sites that had head-turn angles greater than 140°, turn angles less than 45°, and acute intersection angles below 75°. The study concluded that reducing skew and increasing the turn entry angle should be considered a targeted safety treatment where turn-related crashes are occurring.

These empirical findings align with established geometric design guidance. Federal Highway Administration (FHWA, 2024) guidance on older road user safety specifically mentions channelised (i.e. slip) lanes and notes that sharper downstream curvature can reduce vehicle turning speeds, while increasing the angle at which a slip lane joins the receiving roadway improves driver sight lines. These design changes simultaneously enhance driver visibility and pedestrian safety by shortening crossing distances and reducing vehicle entry speeds.

The main influences on the safety of left turn treatments, based on the literature cited above and engineering first-principles, are summarised in Table 3-2, with the colour-coding key presented in Table 3-1. No distinction between exclusive left turn and shared through / left turn lanes has been made because, apart from the flow-on safety effects noted in section 2.2, their main differences are operational and geometric. Note also that safety of pedestrians and cyclists is dealt with in more detail in Sections 3.2 and 3.3 respectively.

Table 3-1: Scale for safety effects

Significant safety hazard[3]	Moderate safety hazard	Slight safety hazard	Neutral	Protective effect

Table 3-2: Comparison of safety influences for left turn treatments

<table>
<tr><th>Aspect / safety factor</th><th>Signalised left turn lane</th><th>High entry angle slip</th><th>Low entry angle slip</th></tr>
<tr><td>Form of control</td><td>Signals</td><td>Give way</td><td>Give way</td></tr>
<tr><td>Entry angle</td><td>High entry angle, typically around 90° for a standard cross intersection.</td><td>High entry angle (70° to 90°).</td><td>Less than 70°.</td></tr>
<tr><td rowspan="3">Left turner give way requirements (affects cognitive workload)</td><td>Can proceed when there is a green disc (without a red arrow) or a green arrow, in which case: not required to give way to any opposing right turners or cross-street traffic.</td><td colspan="2">Can proceed at any time: must check for, and give way to traffic on the departure lane, i.e. cross traffic and right turners from opposite approach.</td></tr>
<tr><td>May have to check for and give way to pedestrians on crosswalk (depending on phasing and level of pedestrian protection).</td><td colspan="2">May have to check for and give way to pedestrians across slip lane, depending on form of pedestrian crossing.</td></tr>
<tr><td>May have to check for, and give way to, cyclists (depending on form of cycle provision) either:
• approaching the intersection to enter an exclusive left turn lane; OR
• travelling the intersection if cyclists are coming from a kerbside facility.</td><td colspan="2">May have to check for, and give way to, cyclists (depending on form of cycle provision):
• when entering the slip lane; AND / OR
• when exiting the slip lane.</td></tr>
</table>

[3] Note the significant safety hazard has not been applied in Table 3-2.

Aspect / safety factor	Signalised left turn lane	High entry angle slip	Low entry angle slip
Location of conflict point relative to others at intersection	Vehicle-vehicle conflict points within signalised intersection, i.e. close to other conflict points.	Vehicle-vehicle conflict points downstream of signals, i.e. further away from other intersection conflict points.	
	Vehicle-pedestrian conflict points within signalised intersection, i.e. close to other conflict points.	Vehicle-pedestrian conflict points outside of signalised area, i.e. further away from other intersection conflict points.	
Vehicle speeds (largely a function of entry angle, form of control, and give way requirements)	Lowest speeds due to tight corner radii. Variance due to whether drivers arrive during a green or a red signal, and whether they have to give way to pedestrians on parallel crosswalk.	Low speeds due to of tight corner radii.	Highest speeds due to larger corner radii.
Visibility to opposing traffic (largely a function of entry angle and form of control)	No opposing traffic to give way to, but good visibility to right turners from opposite approach (required to give way to left turners, but may fail to do so), and cross street traffic (could potentially run a red light).	Reasonable visibility to cross-street traffic road due to the high entry angle – drivers may have to turn their head a bit past their shoulder.	Reduced visibility to cross street traffic as lower angle means drivers have to turn their head further round over their shoulder (difficult for older drivers in particular) and may have to swivel their bodies.
Visibility to pedestrians	Generally good visibility to pedestrians on parallel crosswalk (unless restricted by geometric constraints such as limit line setbacks, narrow footpaths, and high fences / buildings on property boundary). Drivers are able to focus on where they're heading, rather than looking back to find a gap in traffic.	Pedestrian crossing points will be prior to the limit line, i.e. well within the field of vision of forward-facing driver. However, drivers may be focussed on finding a gap in traffic, so turned towards their right and less likely to see pedestrians crossing from the left in particular.	Pedestrian crossing points will be prior to the limit line, but drivers may be focussed on finding a gap in traffic, so turned towards their right and less likely to see pedestrians crossing from the left in particular – exacerbated by having to turn their heads further back due to the low entry angle.

Aspect / safety factor	Signalised left turn lane	High entry angle slip	Low entry angle slip
Likelihood of encountering pedestrians	Parallel pedestrians run in the same phase as left turners, i.e. higher chance of left turners encountering pedestrians.	Encounters between pedestrians and left turners will be random, i.e. much less likelihood of a conflict.	
Effect on level of service (which can lead to driver frustration and increased risk-taking or non-compliance)	Generally lower level of service for the left turn movement, due to delays incurred while the approach / left turn movement has a red signal.	Generally higher level of service than a signalised turn, as left turners have more opportunity to find a gap in traffic. However, this can change depending on relative volumes of various movements within the intersection and the ability to access the left turn slip lane.	Generally highest level of service due to similar operation but faster turning speeds compared to HEA treatment.

3.2 Pedestrian safety at left turn treatments

Pedestrian safety is a key consideration when selecting a left turn treatment because these users are vulnerable (i.e. prone to higher crash severities) and each layout changes how they interact with turning vehicles.

3.2.1 O'Brien *et al*. (2010 & 2012) Melbourne study

O'Brien *et al.* (2010) analysed crashes of left turning vehicles vs pedestrians at 6,978 left turn approaches at 2,284 signalised intersections in Melbourne, Australia, for the period 2004—2008 inclusive, for VicRoads. They later summarised the study findings in the O'Brien *et al.* (2012) journal article. The crash rates at the various types of left turn treatments are shown in Table 3-3; note these are presented as average pedestrian injury crashes per treatment in 5 years, and are not normalised to account for exposure (i.e. volumes of pedestrians and left turning vehicles).

Table 3-3: Melbourne intersection crash data (adapted from O'Brien* et al.*, 2010)

Left turn treatment type		Number of sites	Pedestrian injury crashes	Av. pedestrian injury crashes per treatment in 5 years
Conventional lanes	Exclusive left turn lane	1,407	36	0.026
	Shared lane	3,500	117	0.033
	Sub-total	***4,907***	***153***	***0.031***
Slip lanes	Signals (2-aspect)	115	2	0.017
	Signals (3-aspect)	147	3	0.020
	Unmarked	632	11	0.017
	Zebra	1,142	26	0.023
	Free slip	35	0	0
	Sub-total	***2,071***	***42***	***0.020***
Total		**6,978**	**195**	**0.028**

O'Brien *et al*. (2010) found that slip lanes generally exhibited lower pedestrian crash rates than conventional left turn lanes (0.020 vs 0.031 crashes per site per 5 years). However, pedestrian safety performance varied considerably within the slip lane category, with zebra-crossing slip lanes recording higher crash rates (0.023 crashes per site) than signalised or unmarked slip lanes (0.017-0.020 crashes per site per 5 years). The authors noted that zebra crossings are generally applied in areas with higher pedestrian demand, therefore higher exposure. Furthermore, the authors noted that raised ("wombat") crossings were very rare treatments in Melbourne (at the time – note this study occurred well before the Safe Systems movement in the mid-2010s) although it appears that the sample included at least a couple of raised crossings.

Similarly, the authors noted that conventional signalised left turns can operate with varying degrees of pedestrian protection (i.e. whether left turning vehicles are held on a red arrow while pedestrians cross, and for how long). However, these variations were not separately categorised in the crash analysis, as investigating the signal operation as well as the physical layout of nearly 7,000 approaches would have required substantially more data collection effort. As a result, conventional left turn lanes with differing levels of pedestrian protection were aggregated within the same treatment categories. Overall, while not normalised for exposure, the results of O'Brien *et al*. (2010) suggest that pedestrian safety depends more on the form of the crossing provision than whether it is at a slip lane.

O'Brien *et al*. (2010) did not specifically analyse crashes at high entry angle (HEA) vs low entry angle (LEA) slip lanes, but did further examine the 42 slip lanes that had experienced crashes and found these comprised 27 HEA sites, 14 "direct-merge" (i.e. LEA) sites and one free-flow slip. They found also that compliance with design standards was low. However, even at the 16 HEA slip lanes that "complied or almost complied with current guidelines", each had experienced at least one crash involving a pedestrian coming from the left (note: it is not clear what the split between unmarked vs zebra crossings was for this subset). They concluded "the issue of the driver looking to the right instead of straight ahead appears to be a problem even for slip lanes that meet the current standards" (O'Brien *et al.*, 2012, p119).

O'Brien *et al.* (2010) identified key objectives in slip lane design to: encourage separation of yield to pedestrian and find gap in traffic decisions; improve conspicuity of the pedestrian crossing point to attract driver attention; maximise the safety of pedestrian assertion of the right-of-way; increase pedestrian use of the designated crossing point; and reduce vehicle speeds at pedestrian crossing point to help avoid crashes and to minimise their impact when they do occur. To achieve these objectives, they recommended that new unsignalised slip lanes be of high-entry-angle (HEA) type and incorporate a zebra crossing set back at least 6 m from the limit ("yield") line, together with edge lines to tighten the vehicle path for smaller vehicles, pedestrian fencing to ensure appropriate use of the crossing point, and measures to maintain good sight lines. They further recommended locating the zebra crossing on a raised platform ("wombat" crossing) to reduce vehicle speeds and encourage drivers to look straight ahead toward the crossing; Figure 3-2 shows their sketch incorporating many of these aspects.

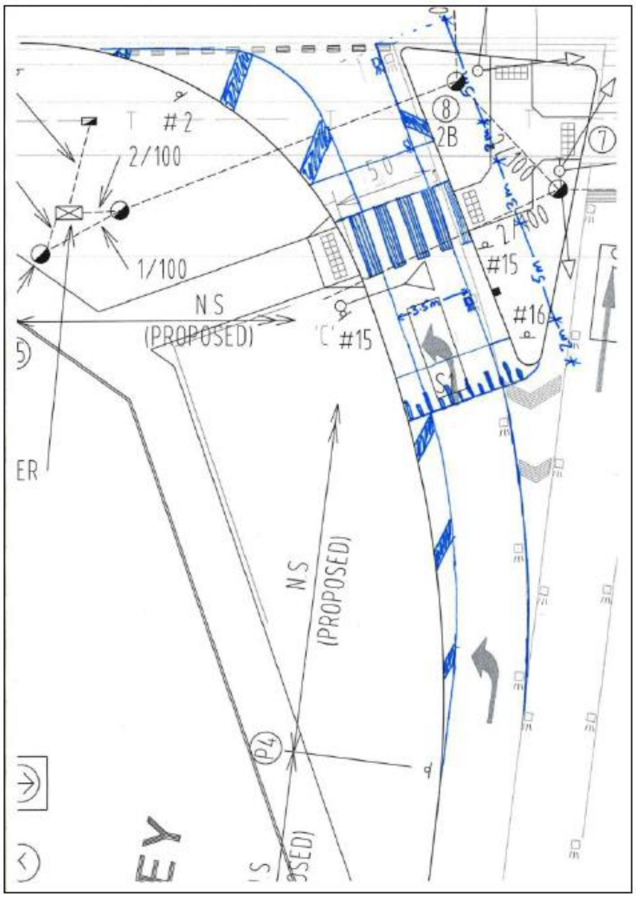


Figure 3-2: Sketch of suggested features for a raised zebra crossing on a HEA slip lane (source: O'Brien et al., 2010)

3.2.2 Sharobim (2016) Auckland study

Sharobim (2016) noted that pedestrian crashes only comprised 3% of all left turn crashes at Auckland signalised intersections in 2014. He then expanded the scope to analyse pedestrian crashes across the entire Auckland network (1,818 treatments at 625 signalised intersections) for the period 2010—2014 inclusive. He found 22% of pedestrian crashes (of any severity, including non-injury) involved left turners. Table 3-4 summarises the pedestrian crash rates at different arrangements of slip lanes and conventional lanes (i.e. left turns from within the signalised intersection) – note, however, these crash rates do not account for exposure, i.e. numbers of pedestrians crossing or left turning vehicles at each site.

Table 3-4: NZ intersection crash data (adapted from: Sharobim, 2016)

<table>
<tr><th colspan="2" rowspan="2">Left turn treatment type</th><th rowspan="2">Number of sites</th><th colspan="2">Pedestrian crashes</th><th colspan="2">Av. pedestrian crashes per treatment in 5 years</th></tr>
<tr><th>Non-injury</th><th>Injury</th><th>All crashes</th><th>Injury-only</th></tr>
<tr><td rowspan="3">Conventional lane</td><td>Exclusive left turn lane</td><td>389</td><td>2</td><td>6</td><td>0.021</td><td>0.015</td></tr>
<tr><td>Shared lane</td><td>688</td><td>4</td><td>14</td><td>0.026</td><td>0.020</td></tr>
<tr><td>Sub-total</td><td>1,077</td><td>6</td><td>20</td><td>0.024</td><td>0.019</td></tr>
<tr><td rowspan="6">Slip lane</td><td>Signalised</td><td>75</td><td>0</td><td>1</td><td>0.013</td><td>0.013</td></tr>
<tr><td>Free flow</td><td>42</td><td>0</td><td>0</td><td>0.000</td><td>0.000</td></tr>
<tr><td>Give way (no marked pedestrian crossing)</td><td>460</td><td>0</td><td>7</td><td>0.015</td><td>0.015</td></tr>
<tr><td>Zebra crossing</td><td>163</td><td>2</td><td>10</td><td>0.074</td><td>0.061</td></tr>
<tr><td>Raised zebra crossing</td><td>1</td><td>0</td><td>0</td><td>0.000</td><td>0.000</td></tr>
<tr><td>Sub-total</td><td>741</td><td>2</td><td>18</td><td>0.027</td><td>0.024</td></tr>
<tr><td colspan="2">Total</td><td>1,818</td><td>8</td><td>38</td><td>0.025</td><td>0.021</td></tr>
</table>

Sharobim’s main analysis focussed on the full pedestrian crash sample i.e. including non-injury crashes. He noted that the crash rate for slip lanes was slightly higher than for conventional lanes (0.027 vs 0.024 crashes per treatment in 5 years) but found they were statistically proven to be “considered similar” (p99). However, this may not be the case for the injury crash subset (added in Table 3-4 based on data given elsewhere in Sharobim, 2016), given the conventional lanes had a lower proportion of injury to non-injury crashes compared with slip lanes.

While Sharobim tested three levels of pedestrian protection in his operational analysis, no such distinction was included in the safety analysis. The two types of conventional left turn treatments, exclusive and shared lanes, showed relatively consistent performance (0.021 vs 0.026 pedestrian crashes per site per 5 years, respectively).

Conversely, there was substantial variation between the five slip lane treatment types. Slip lanes with zebra crossings exhibited the poorest safety performance, with an average crash rate of 0.074 crashes per treatment in 5 years. Sharobim noted that zebra crossings are generally located in areas with high pedestrian demands and therefore high pedestrian exposure, which was not adjusted for. He also posited that raised platforms would likely increase pedestrian safety, but as there was only one raised zebra crossing in the dataset, he was not able to statistically demonstrate this effect. Signalised slip lanes and give-way slip lanes without pedestrian markings recorded much lower rates (0.013 and 0.015 respectively).

Sharobim recommended additional research to further subdivide left turn slip lanes into more categories, with one of these distinctions being high entry angle vs low entry angle slip lanes. The authors of this white paper suggest that further studies should also account for exposure.

Overall, Sharobim’s results indicate that pedestrian safety is influenced less by the presence of a slip lane itself than by the specific crossing treatment and the way pedestrians interact with turning drivers.

3.2.3 O’Brien (2019) Auckland counter-study

Andrew O'Brien (one of the co-authors from O’Brien *et al*. 2012) revisited data first presented by Royce (2019) analysed crashes at 1,696 left turn treatments at signalised intersections in Auckland for the period 2013—2017 inclusive (O’Brien, 2019). The analysis, summarised in Table 3-5, distinguished between HEA and LEA slip lanes and presented sub-categories of each with pedestrian crossings (zebra crossings, without raised safety platforms). However, as for O’Brien (2012) and Sharobim (2016), O’Brien (2019) calculated a crash rate per treatment without normalising for exposure and did not distinguish the level of pedestrian protection applied at the conventional signalised sites.

Table 3-5: NZ intersection crash data (adapted from: O'Brien, 2019)

Site type		**Number of sites**	**Pedestrian injury crashes**	**Av. pedestrian injury crashes per treatment in 5 years**
Conventional lane	Exclusive left turn lane	384	4	0.010
	Shared lane	675	10	0.015
Slip lanes	High-entry-angle (HEA) slip lane	265	1	0.004
	Low-entry-angle (LEA) slip lane	372	19	0.051
	Sub-categories:			
	HEA with pedestrian (zebra) crossing	*50*	*0*	*0.000*
	LEA with pedestrian (zebra) crossing	*100*	*9*	*0.110*

O'Brien (2019) found substantial differences in pedestrian injury crash rates between left turn treatment types, with high-entry-angle (HEA) slip lanes by far the best of all four categories, and LEA clearly the worst (0.004 vs 0.051 crashes per treatment in 5 years respectively) with conventional signalised left turn lanes performing at an intermediate level.

Furthermore, O’Brien showed that none of the HEA slip lanes with pedestrian crossings experienced pedestrian injury crashes and concluded that “using pedestrian crossings on HEAs lip lanes do not make those slip lanes less safe for pedestrians”. Conversely, the LEA slip lanes with pedestrian crossings had the highest rate of all categories presented in Table 3-5.

3.2.4 Jaglal and Wilson (2012) Auckland study

In a study of nine Auckland signalised intersections, Jaglal and Wilson (2012) found little evidence that slip lanes were inherently unsafe for pedestrians. At the Mayoral Drive/Wakefield Street case-study intersection, crash analysis identified only one pedestrian crash involving a slip lane, while most pedestrian crashes involved people crossing outside the marked crossing or against the signal.

Conversely, the study also found that removing slip lanes and increasing the extent of left turn red-arrow protection generally worsened intersection performance, increasing delays, cycle times, and queues. The authors observed broader trends linking longer cycle times with greater pedestrian and driver non-compliance, suggesting that some of the anticipated safety benefits could be offset by increased delay.

They therefore recommended that left turn treatments be selected on a site-specific basis using engineering judgement, rather than applying slip-lane removal or left turn red-arrow protection as blanket policies.

3.2.5 Summary of pedestrian safety at left turn treatments

Overall, the three large-scale studies presented (O’Brien *et al*., 2012; Sharobim, 2016; and O’Brien, 2019) all suggest that well-designed slip lane crossings can be safe for pedestrians, at least to the same degree, if not more so, compared with conventional signalised crosswalks. Slip lane geometry, particularly the slip lane entry angle, is a key determinant of pedestrian safety, with steeper entry angles associated with substantially lower pedestrian injury crash risk.

The outcomes of Sharobim (2016) appear less favourable for slip lanes, especially when the analysis concentrates on injury crashes rather than including non-injury crashes. However, Sharobim did not account for slip lane entry angle and recognised that this would be a useful category to consider. O'Brien (2019) analysed the same Auckland intersections a few years on, but account for the distinction in slip lane angles; he found that HEA slip lanes had the best safety for pedestrians, with further benefits when a marked pedestrian crossing is provided.

As noted above, the fact that these studies did not adjust for pedestrian exposure limits the robustness of their conclusions. It is expected that locations with pedestrian provisions have higher volumes of pedestrians and therefore likely to be safer than what the relative crash rates present.

O'Brien *et al*. (2012) and Sharobim (2016) both found that signalised slip lane crossings are safer than zebra slip lane crossings. Unfortunately, no meaningful distinction between the safety of flush vs raised zebra crossings can be drawn from either paper. Multiple sources show that raised safety platforms (RSPs) increase the safety of zebra crossings in general (i.e. not specifically at slip lanes) because RSPs reduce the chance of a crash happening and the severity of those that do occur (Safe System Solutions, 2021). This is reflected in the Crash estimation compendium (NZTA, 2026b) which gives a crash reduction factor of 0% for a zebra crossing on a two-lane road, but a crash reduction factor of 20% for a raised platform.

There seems to be a discrepancy between O'Brien *et al*. (2010) and O'Brien (2019) in that the former observed a pattern of crashes involving pedestrians coming from the left at HEA slip lanes (assumedly comprising both unmarked and zebra crossings) whereas the latter noted no pedestrian injury crashes on HEA slip lanes with zebra crossings. This could be due to the different locations (Melbourne vs Auckland) or the different analysis periods (2004—2008 vs 2013—2017) when the latter may have benefited from almost a decade of improved industry guidance. While the 2019 paper is arguably more pertinent to current intersection design in New Zealand, designers should be mindful of the caution from the 2010 study and its recommendations for how to mitigate this by helping drivers focus on looking forwards while approaching the pedestrian crossing rather than prematurely looking to the right towards conflicting traffic.

Jaglal and Wilson (2012) add a useful cautionary note: where a treatment compromises intersection efficiency, users may respond by making risky or non-compliant choices.

Overall, the evidence indicates that active-user safety depends largely on whether the left turn treatment supports low turning speeds, good visibility and focused driver attention. HEA slip lanes generally perform well against these criteria, while LEA slip lanes perform poorly because their geometry encourages higher speeds and more complex gap-assessment tasks.

3.3 Cyclist safety at left turn treatments

The following is a relevant excerpt from NZTA's Cycling Network Guidance "CNG" (NZTA, 2026a) section on left turning conflicts at signalised intersections, with some clarifying adaptations added in [*square brackets*]:

> Slip lanes and exclusive left turn lanes are safer than shared through and left lanes for cyclists. [*This is based on data from the Austroads Research Report AP-R380/11 Effectiveness and selection of treatments for cyclists at signalised intersections (Turner et al., 2011). The project manager of AP-R380/11 was Tim Hughes (at the time a senior NZTA employee); he further examined the data and found that*] it is on average four times safer to resolve this conflict in a midblock location compared to a location at the limit line of an intersection [*(Hughes, 2014 pers comm).*] This is because there is less demand on the cognitive ability of drivers at the midblock, i.e. they can make a decision based on what is happening ahead of them, rather than having to observe what happens to the left of their vehicle or behind them once they reach the limit line.
>
> [*Turner et al. (2011)*] did not distinguish between layouts with slip lanes and layouts with exclusive left turn lanes in terms of risk to people cycling. However, the critical risk factor for these two layouts

is the speed differential between the conflicting movements. In general, the greater the distance of the conflict point from the limit line, or the less physical constraint is imposed by a slip lane layout, the higher the speed differential between a motor vehicle and a cyclist. A higher speed differential usually results in less safe conditions for cyclists.

Following on from the CNG content, it is noted that while Turner *et al*. (2011) included all crashes within 50 m of the intersections studied, the modelling method focussed on cycle provisions on the intersection approaches, and while it distinguished various crash types, it didn't specifically consider where those crashes occurred (i.e. on the approach, within the intersection, or on the departure). Therefore, they do not provide an analysis of the safety of slip lane exits. The CNG (NZTA, 2026a) also encourages the use of high-entry-angle slip lanes and notes "Consideration should also be given to cyclists travelling past the slip lane exit on the cross road... Slowing the speed of vehicles turning out of the slip lane will improve safety for these cyclists, and for other road users."

4 Conclusions

The term slip lane is often used as though it describes a single treatment type. However, the research reviewed in this paper demonstrates that slip lanes encompass a wide range of designs with markedly different safety characteristics. A key consideration is the interaction between pedestrians and left turning traffic, and it is often assumed that these conflicts can be better managed by conventional signalised turns. The evidence reviewed suggests that this perception may have been influenced by the safety performance of older or less desirable slip-lane designs. While some slip lanes are associated with poor pedestrian safety outcomes, others perform as well as, or better than, conventional signalised left turn treatments. The research therefore suggests that pedestrian safety depends less on whether a slip lane is present and more on how the slip lane is designed.

The safety performance of any left turn treatment is strongly influenced by how it affects vehicle speed, driver workload, visibility, and the separation of conflict points. Conventional signalised left turns benefit from relatively low turning speeds and allow drivers to focus on pedestrians and cyclists ahead of them, but they place pedestrian conflicts within the complex environment of the signalised intersection and often result in frequent interactions between turning traffic and parallel pedestrian movements. Slip lanes separate these conflicts from the main intersection and reduce the likelihood of pedestrian encounters but require drivers to assess gaps in cross traffic which they might focus on before checking for pedestrians crossing the slip lane. The success of a slip-lane design therefore depends on whether its geometry helps drivers manage these competing tasks safely.

A consistent limitation of the research reviewed is that none of the principal pedestrian safety studies normalised crash rates for pedestrian or vehicle exposure, meaning treatments installed in high-pedestrian environments may appear less safe than they are. Notwithstanding this limitation, the evidence consistently indicates that pedestrian safety is influenced more by slip-lane geometry and crossing design than by the presence of a slip lane itself. O'Brien *et al*. (2010) found lower pedestrian injury crash rates at slip lanes than at conventional signalised turns in Melbourne whereas Sharobim (2016) found broadly comparable outcomes for the two categories in Auckland. O'Brien (2019) also using Auckland sites showed that high-entry-angle (HEA) slip lanes substantially outperformed both conventional signalised turns and low-entry-angle (LEA) slip lanes. The available evidence therefore suggests that pedestrian crossings can operate safely at slip lanes when combined with HEA geometry, low vehicle speeds, adequate setbacks, and good sight lines. LEA slip lanes remain associated with poor pedestrian safety outcomes and should thus be avoided.

The available evidence regarding cyclist safety is more limited. However, both the literature and established design guidance indicate that cyclists generally benefit when left turn conflicts are resolved prior to the intersection in a simpler environment with lower driver workload. This supports the use of either exclusive left turn lanes or carefully designed slip lanes rather than layouts where people cycling and turning drivers interact at the limit line of a signalised intersection. For slip lanes specifically, lower vehicle speeds and improved visibility at both the entry and exit points are expected to improve cyclist safety outcomes.

Overall, the evidence indicates that active-user safety depends less on whether a left turn is signalised or accommodated by a slip lane, and more on whether the treatment supports low turning speeds, good visibility, manageable driver workload, and focused driver attention. Of the treatments reviewed, HEA slip lanes generally perform well against these criteria and appear capable of achieving very good pedestrian and cyclist safety outcomes. LEA slip lanes perform poorly because their geometry encourages higher speeds, more difficult gap-assessment tasks, and reduced visibility of potential conflicts. Where slip lanes are retained or introduced, emphasis should therefore be placed on achieving HEA geometry and incorporating complementary measures that reduce operating speeds and help drivers recognise and respond to pedestrians and cyclists.

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