UNIVERSITY OF THE WEST OF ENGLAND, BRISTOL

Design development of side road crossings for pedestrians and cyclists

Final Report v2.1

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by

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Contents

EXECUTIVE SUMMARY

Why does side road design need to be developed?

The Road Safety Trust awarded the Centre for Transport and Society at the University of the West of England, Bristol a grant to undertake research relating to the provision of Marked Priority for people walking and cycling across the side road at give way junctions.

Side road design defined in four ways: i) a conventional layout with a break in the footway; ii) 'side road entry treatment' which raises the pathway that people use to cross; iii) Design Priority, also called a continuous footway where priority is reinforced by the layout and surface materials; iv) Marked Priority where road markings prioritise a cycle track, sometimes with a zebra crossing.

Recent design development has resulted in an increasing number of junctions are being enhanced either with Marked Priority or Design Priority. This Marked Priority study complements a previous Design Priority study (Flower et al., 2021).

Behaviour is determined by design and road rules. A Highway Code change came into effect from 29th January 2022. Drivers turning in or out of a side road should now give way not only to pedestrians and cyclists crossing, but also to waiting pedestrians and approaching cyclists.

Data collected included observations of interactions to determine the yielding behaviour, an analysis of the collision record, and focus groups to understand attitudes and behaviours of road users.

What was found from the research undertaken?

The **observational study** collected data from twelve Marked Priority junctions, some with cycle track and zebra crossings (called parallel crossings) and some with only cycle track crossings and three control sites. Data were pooled with the ten sites from the complementary Design Priority study.

The analysis was based on three types of yield: **No Yield** by the person crossing; **Voluntary Yield** to a turning driver by the person crossing and; a **Forced Yield** where the driver compelled the person crossing to yield. When considering risk, the primary concern is the proportion of forced yields. However, when considering priority, the measure of interest is the combination of forced and voluntary yields.

The table summarises the aggregate proportion of yields by type at each of the junction types.

Junction type	No yield	Voluntary yield	Forced yield	Number of interactions
3 conventional sites	43.3%	45.8%	10.9%	1192
12 Marked Priority	73.2%	3.3%	23.4%	7627
of which 3 with zebra	88.4%	0.0%	11.6%	2661
of which 9 with no zebra	60.9%	13.0%	26.1%	4966
10 Design Priority	89.7%	1.6%	8.7%	4583

Modelling explained the variation in the number of forced yields in a 15-minute period relative to flows and junction type. This demonstrated that, relative to the control sites, there are:

- 1.088 times more forced yields at Marked Priority junctions with a parallel crossing;
- 1.423 times more forced yields at Design Priority junctions; and
- 3.487 times more forced yields at Marked Priority junctions without a parallel crossing.

Marked priority with a parallel crossing appears to be the preferred enhancement from a priority enhancing and risk reduction point of view, followed by Design Priority and Marked Priority without a parallel crossing.

The level of set-back of the crossing from the main road kerb line has no effect. The flow with greatest impact on forced yields is the right turn in with an elasticity of 0.612 (i.e., an increase in flow of 10 would increase the number of forced yields by an average of 6.12). Pedestrians crossing in the contra-flow direction to the near-side main road flow experience 20% more forced yields than with flow. Cyclists have fewer forced yields than pedestrians.

There are statistically significantly fewer injury **collisions** after Marked Priority enhancement. Hesitancy is needed in suggesting that this indicates a real injury reduction effect. No correlation was revealed between the mean number of injuries per year and the number of forced yields observed.

Twenty-seven women and twenty men took part in the **focus groups**, and fifteen participants were disabled people. Respondents thought that zebra crossings are recognised and respected, hence perceptions of junctions with zebras tended to be more positive.

Road markings indicating priority for crossing cyclists were positively perceived, especially when reinforced by other design elements. Set-back crossings raised criticisms. Deviations from the desire line need to be clearly and unambiguously indicated for pedestrians who are blind or partially sighted. They were also perceived as moving the cycle route and pedestrians into close proximity resulting in cyclists' status as 'traffic' being reduced.

Participants were more concerned with vehicles turning into the side road than with those turning out of the side road. This concern is justified by the modelling. Contextual factors were important to respondents, including speed limit, corner kerb radii, crossing length, vehicle volume, separation of the footway and cycle track, and continuity of treatment along a main road.

Blind and partially sighted people expressed preference for unambiguous designs. Wheelchair and mobility scooter users welcomed the absence of slopes and cambers, dropped kerbs and raised crossings. Overall, respondents recommended more consistency in the use of road markings, and types of treatment and street furniture across the country to minimise ambiguity and confusion.

How should side road priority enhancement be implemented?

1. From a consideration of the yielding behaviour, Marked Priority crossings with a zebra crossing (i.e. a parallel crossing) would be the preferred enhancement, followed by Design Priority crossings (also known as continuous footways), and finally Marked Priority crossings without a zebra crossing (i.e. only a priority cycle track crossing). There may be contexts where Design Priority is preferable to Marked Priority, and/or where parallel crossings are not possible.
2. By default, the crossing should be adjacent to the main road kerb line because set-back introduces disadvantage for people crossing, including deviation from the desire line, and has no effect on forced yields. For parallel crossings, this would require the use of implied zebras (i.e. zebras without zig zag markings or yellow globes). Such a development would depend on confirmation of the outcomes of the on-going implied zebra trials.
3. Consideration should be given to incorporating implied zebras in Design Priority crossings and this is because zebras are well recognised and regarded.
4. Bi-directional cycle tracks can be used because drivers create fewer forced yields for cyclists than for pedestrians, and contra-flow movements do not create more forced yields.
5. It is important that Marked Priority and Design Priority enhancements are implemented consistently across the country to minimise ambiguity and confusion for road users.
6. Further research should be undertaken to understand whether enhanced junctions may encourage or discourage drivers to obey the Highway Code rules at conventional junctions, and whether there are developments needed in the positioning of road markings at conventional junctions.

1 INTRODUCTION

The Road Safety Trust awarded the Centre for Transport and Society at the University of the West of England, Bristol a grant to undertake research relating to the provision of Marked Priority crossings for people crossing the side road at give way junctions. Marked Priority crossings provide enhanced priority for people walking and people cycling.

Behaviour is determined partly by design and partly by the rules of the road. When turning into a main road from a side road, drivers, motorcyclists, and cyclists give way to motor traffic on the main road. Similarly, when they are turning right into the side road, they give way to on-coming motor traffic on the main road. Highway Code Rule 170 states that drivers should give way to pedestrians crossing a side road that they are turning into or out of. In a revision that came into effect from 29th January 2022, they should also give way to pedestrians waiting to cross. In addition, Rule 180 instructs right turning drivers to 'watch out for cyclists, motorcyclists, pedestrians and other road users'. Similarly, Rule 183 states that, when turning left, drivers should give way to any vehicles using a bus lane, cycle lane or cycle track from either direction. New Rule H3 adds that drivers turning into or out of a junction should not cut across cyclists.

Side road design may broadly be of four types as follows:

1. A **conventional layout** with the side road carriageway creating a break in the footway. The kerb line where pedestrians cross may be dropped to the level of the carriageway to avoid a step. Cycle tracks would typically not have priority over the side road.
2. **Side road entry treatment** that raises the carriageway to footway level to provide a warning to drivers that they are entering a network of quieter streets.
3. **Design Priority** where the priority of pedestrians across the side road is reinforced by a continuous footway to its full width across the carriageway. The kerb lines and kerb radii at the junction are removed, and there is a ramp up from carriageway level to footway level on each side of the footway. Such a design may also include a continuous cycle track.
4. **Marked Priority for cycle track crossings at side roads** where there are 'give way' lines on the carriageway both sides of the cycle track, and sometimes pedestrians are given additional priority by a zebra crossing, and this is known as a parallel crossing.

Figure 1.1 shows an image of a Marked Priority crossing (left hand side) and a Design Priority crossing.

Figure 1.1 Marked Priority junction (left hand side) and Design Priority junction

A previous study undertaken by UWE Bristol for Sustrans and Transport Scotland considered continuous footway designs (Flower et al., 2021). The research reported here considers Marked Priority crossings, and then makes recommendations about the nature and use of Marked Priority and Design Priority.

Cycle traffic, especially on main roads, may be accommodated by a cycle track separated both from the carriageway and from the footway. There are many layouts where there may be either no provision for cyclists, a painted advisory or mandatory cycle lane in the carriageway, or provision where cyclists and pedestrians are required to share the footway.

As well as cycle traffic, there are other important wheeled-vehicle users including wheelchair users, users of mobility scooters, and people using prams and pushchairs. If e-scooters are provided with a legal basis by the government after the e-scooter trials that began in Autumn 2020, then they will become a vehicle type that will use the same infrastructure as cycle traffic.

Side road junctions are points where the paths of street users going in different directions intersect, and this creates risk. In the years 2017 to 2020, 31% to 34% of collisions in built-up areas occurred at side road junctions or staggered junctions (i.e. two offset side road junctions, one on each side of the main road). These crossing points may also create delay for pedestrians and cyclists.

Much recent design development has occurred relating to side road junctions. It is therefore appropriate to investigate the interactions, attitudes and behaviours of road users at side road junctions. The aim of the project is to provide a basis for better side road designs to reduce risk to road users. This has been achieved by investigating the risk reduction of different designs, and understanding how road users behave in different circumstances, and why they behave in those ways. The objectives are expressed as follows:

1 To develop a typology of different side road crossing provision for pedestrians and cyclists, and validated by highway authority designers.

2 To investigate the safety performance of different types of crossing using the collision record.

3 To understand behaviour within different side road designs.

Objective 3 is supported by the following research questions:

1. How do road users behave in situations where side roads have been enhanced relative to standard designs?
2. Why do they behave in that way?
3. What do road users think of human scale mobility and its implications for side road crossings?

Chapter 2 describes what is known already about side road junction design and road user behaviour. Chapter 3 presents the methodology and the findings from this research, and this includes observations, collision analysis and outcomes from focus groups. Chapter 3 deals with Objective 2 about safety performance and Objective 3 about behaviour.

Chapter 4 presents recommendations for further development of side road junction design. The development of these recommendations was assisted by a workshop in September 2022 that took place to present the research and recommendations to designers. In addition to the study team, nine people attended and were drawn from: the Department for Transport, Active Travel England, Edinburgh City Council and five consultancies specialising in street design. Further development in thinking took place at a meeting of the Department for Transport Cycling and Walking Infrastructure Group in March 2023. Chapter 4 therefore satisfies Objective 1.

2 DESIGN GUIDANCE AND PREVIOUS RESEARCH

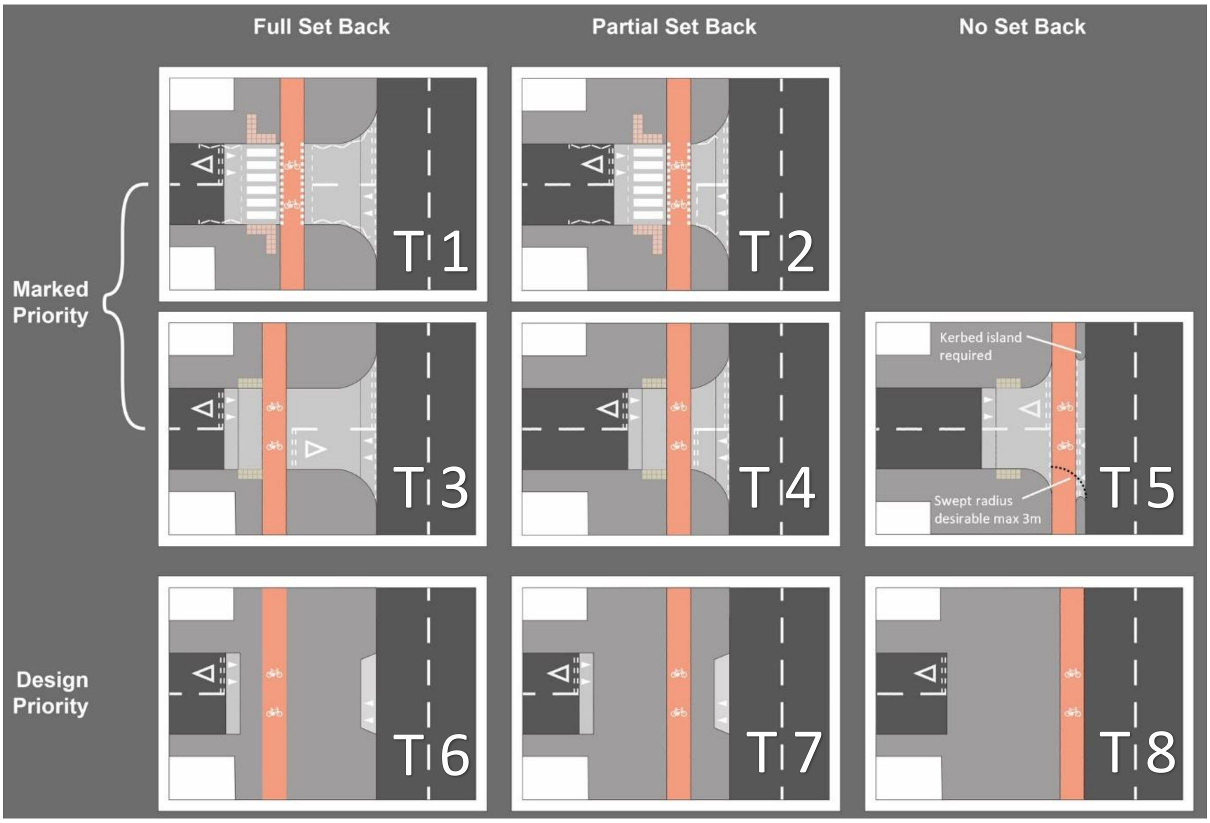
This chapter summarises current English, Scottish and Welsh design guidance for side road junctions, and research on side road entry treatments and Design Priority crossings.

2.1 Current design guidance

2.1.1 Local Transport Note 1/20 Cycle Infrastructure Design

Local Transport Note 1/20 Cycle Infrastructure Design (Department for Transport, 2020) provides a summary of the types of side road priority for pedestrians and cyclists. Figure 10.13 of LTN 1/20, replicated as Figure 2.1 below, shows priority can be of two types: either Marked Priority, or Design Priority. Marked Priority may include Marked Priority just for cycle traffic, or may also include zebra markings for pedestrians. Set-back is measured from the main road kerb line to the cycle track, with full set-back being at least a car length (5m) from the kerb line, partial set-back being less than a car length from the kerb line, and no set-back having the cycle track adjacent to the kerb line.

Figure 2.1 Priority crossings of cycle tracks at side roads



Pedestrian priority with a zebra is not shown as an option with no set-back. Paragraph 10.5.12 suggests that ‘it is preferable in safety terms that cycle tracks crossing side roads are one-way in the direction of traffic on the main carriageway’.

Full set-back with Marked Priority (T1 and T3 in Figure 2.1) is regarded as ‘a crossroads junction of the minor arm with priority given to the cyclist using standard give way markings’ (para. 10.5.13). LTN 1/20 suggests that the arrangement is suitable where traffic flows on the minor arm are up to around 2,000 passenger car units (PCUs) per day. Assuming a factor of ten reduction to the peak hour, and an equal split of traffic in each direction implies 100 PCUs per direction per hour, or 25 per 15-minute period. Paragraph 10.5.15 suggests that ‘the crossing should preferably be raised and paved in a material which contrasts with the carriageway and which is the same as the cycle track on either side’. LTN 1/20 specifies that small corner radii should be used, preferably no more than 4.0m, and 6.0m at most. A give way triangle road marking to Traffic Signs Regulations and General Directions Diagram 1023A ‘may be used to reinforce the requirement for drivers to give way’ (para. 10.5.16). A parallel crossing is suitable for crossing a ‘busier minor arm’ (para. 10.5.18).

Partial set-back with Marked Priority (T2 and T4) ‘should be used with caution and only where traffic volumes and speeds are low’ (para. 10.5.21). This is because vehicles waiting to turn out of the junction tend to block the cycle crossing. To minimise this possibility side road flows should be low (typically less than 2,000 PCU/day), and there should be frequent gaps in the streams of traffic on the major.

No set-back with Marked Priority (T5) junctions can have the give way markings, according to LTN 1/20, applied ‘close to the edge of the carriageway’ and to ‘indicate that cyclists passing the junction have legal priority over traffic turning in and out of the side road’ (para. 10.5.28). Active Travel Act Guidance (Welsh Government, 2022) however, shows the equivalent figure (as Figure 12.3) and the give way line in a position in advance of the pedestrian crossing path so drivers give way to pedestrians. It also does not show the kerbed island between the cycle track and the carriageway and suggests that the cycle track should be flush with the carriageway.

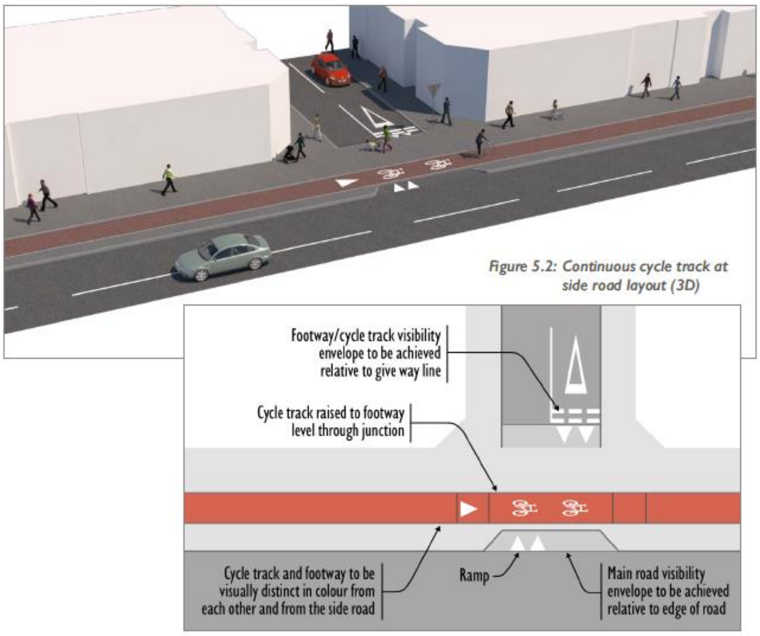
For **Design Priority** crossings (T6, T7 and T8), LTN 1/20 suggests that effective priority is achieved through design, where ‘changes in surfacing and minimal (if any) road markings are used’ (para. 10.5.11). LTN 1/20 suggests that the choice between design and Marked Priority depends on ‘factors such as the context and the available budget’. Paragraph 10.5.26 notes that full and partial set-back Design Priority junctions have ‘not yet been widely applied in the UK’. For Design Priority junctions with no set-back, paragraph 10.5.24 suggests that the approach is suitable for one-way cycle tracks along the main road (i.e., travelling in the same direction as the adjacent traffic lane). It also suggests that 'drivers must give way to cyclists when leaving the side road, but there is no priority for cyclists over traffic turning in', and this statement contradicts Highway Code Rule 183, noted above, which states that, when turning left, drivers should give way to any vehicles using, inter alia, a cycle track, and where that traffic is coming from either direction.

Tactile paving, i.e. paving with 5mm high, 25mm diameter flat-topped blisters (upstands) set 64-67mm apart, may be provided in the footway typically at the kerb line to indicate to visually impaired people that carrying straight on would involve crossing a carriageway. Note that this would typically be provided at the kerb line at conventional priority junctions. It appears in the Marked Priority layouts, but not the Design Priority layouts.

2.1.2 Cycling by Design and Active Travel Act Guidance on Design Priority crossings

Cycling by Design (Transport Scotland, 2021) provides more detail on how designers should create continuous cycle tracks and footways, as shown in Figure 2.2 (which replicates Figures 5.2 and 5.3 in Cycling by Design, CbD).

Figure 2.2 Cycling by Design Continuous footway



CbD suggests that continuous cycle track and footway layouts should convey a strong visual indication of priority over approaching and turning motor traffic. It is suggested they are suited to low motor traffic volumes and speeds. They are recommended because they will improve the continuity of cycling infrastructure. CbD notes that the 'visual continuity, ramp and the tight [i.*e., small*] corner radii are intended to encourage lower speeds of approaching and turning motor traffic'.

Clear visibility of the cycle track and footway is described essential to allow time to react and wait before commencing a turn. Parking and loading should not be allowed to reduce visibility. The cycle track and footway materials used on the approach to the junction should be maintained across the side road, and should contrast with the carriageway.

CbD is equivocal about the use of tactile paving by stating that designers should consider the need for tactile paving or other information to convey a warning to visually impaired people that they are entering a space also used by motor vehicles. Tactile paving would detract from the message that the space is continuous for pedestrians and that pedestrians have priority.

2.1.3 Active Travel Act Guidance and side road entry treatment

In addition to the differences to LTN 1/20 pointed out above in relation to no set-back and Marked Priority, the Active Travel Act Guidance (Welsh Government, 2021) provides designs for both side road entry treatment (Figure DE604) and Design Priority (which it calls 'blended side road entry treatment') as shown in Figure 2.3 and 2.4.

Figure 2.3 Active Travel Act Guidance side road entry treatment

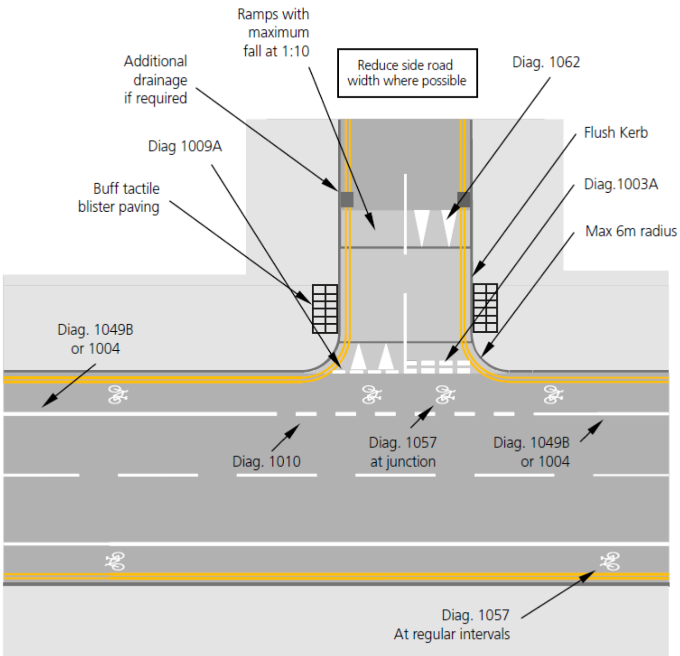
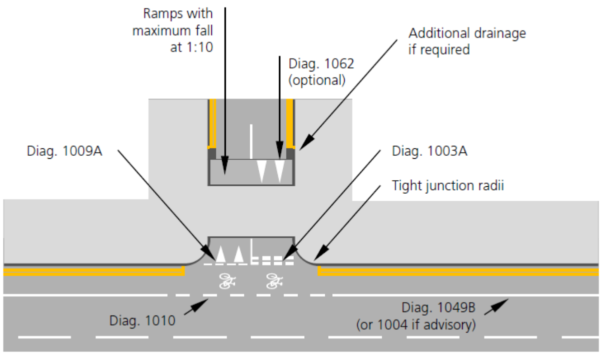
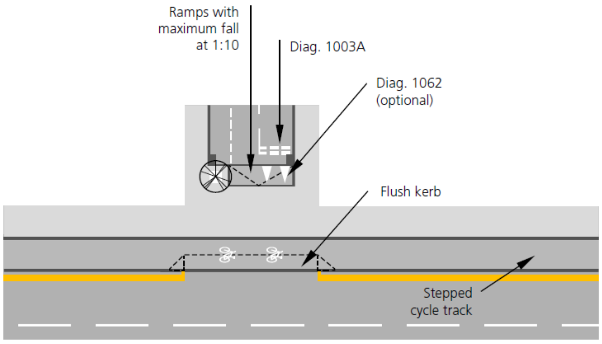


Figure 2.4 Active Travel Act Guidance blended side road entry treatment



Layout 1



Layout 2

Cycle by Design eliminates all kerbs from its continuous footway layout, including kerb radii at the junction, and creates a sharp upstand for turning traffic. By contrast, the Active Travel Act Guidance is equivocal about radii for Design Priority crossings (blended crossings), and offers options both with and without kerb turning radii.

2.2 Research on side road design

2.2.1 Side road entry treatment

Wood et al. (2006) undertook observational studies at eight side entry treatment sites in London and used three control sites. Out of 633 interactions at junctions with various forms of side road treatment, they found that drivers yielded in 56% of cases. At the control sites, there were 263 interactions and 59% of drivers yielded priority. At the control sites, the movement with the lowest proportion of drivers giving way (28%) was the right turn into the side road, but these were all concentrated at one of the three control sites. For the other three drivers' turning movements, the proportion who yielded varied from 61% to 74%. Their analysis also considered interactions where ‘pedestrians appeared to force drivers to give way’ (the opposite of the definition of forced yield used in this study, where the pedestrian is deemed to be forced to yield by the driver). They found this proportion of driver yields was 5%.

2.2.2 Design Priority crossings

Steer Davies Gleave (2018) undertook research for Transport for London on Design Priority crossings at seven sites. They report that in 3,537 interactions with pedestrians, drivers yielded priority in some form or another on 77.5% of occasions, and for the 260 interactions with cyclists, drivers gave way on 95.3% of occasions. Pooling the pedestrian and cycle data gives a proportion of 78.7% of drivers giving way out of a total of 3,797 interactions.

Flower et al. (2021) studied ten Design Priority crossings across the UK. Rather than the perspective of the driver, as with this study, the perspective of the pedestrian and cyclist was adopted. Out of 4,583 observed interactions, 399, or 8.7% were forced yields (i.e. despite having priority, a driver’s actions forced the pedestrian or cyclists to yield). The two other types of yield were ‘No yield’, defined as when people walking or cycling did not yield to the driver or turning cyclist (89.7%) and ‘voluntary yield’ when the crossing pedestrian or cyclists yielded voluntarily (1.6%). These results suggest a higher proportion of yielding by drivers (89.7%) than the Steer Davies Gleave (2018) study (78.7%). Flower et al. (2021) conclude that there is no evidence that Design Priority crossings should not be used above a certain level of turning flow. On the contrary they suggest that, regardless of whether the number of turns is high, design factors should be used to limit the number of forced yields.

Focus groups were conducted with twenty-six cyclists, pedestrians, parents with young children, and other road users including drivers. Participants suggested the following: distinctive paving material should be used for the footway; turning vehicles should be slowed by raising the level of the footway crossing; obstructions and gradients on the footway should be avoided; separated cycle tracks should be used; road markings should be unambiguous and well-maintained. Participants suggested that tactile paving would be counter-intuitive and should not therefore be used, but that explaining to local visually impaired people the nature of Design Priority crossings would be appropriate.

Key informant interviews confirmed junction design features that enhance the design of continuous crossings for pedestrians and cyclists including the following: continuity along the main road of the kerb line, road markings and crossing level and materials and colours; absence of corner kerb radii; vertical upstands to slow turning vehicles; good visibility for all users; features that constrain drivers to their pathway; as wide a footway as possible; and self-evident priority for pedestrians and cyclists.

Additionally, the key informants identified a range of other wider features that improve the pedestrian and cyclist experience as follows: low number of turning vehicles; one-way on side road preferably towards the main road; area wide traffic management to reduce turning vehicle flow; low main road traffic flow; high numbers of pedestrians and cyclists crossing; more non-motorised users crossing than vehicles turning; Design Priority crossings as gateway points to the side road network; and uni-directional cycle tracks.

Remaining design challenges identified by the informants were as follows: a lack of more detailed guidance; apparent obligation to use tactile paving at flush crossing points; over-complication of designs; poor visibility; bi-directional cycle tracks; raised tables implying space to be shared by pedestrians and cyclists; ineffectiveness of narrow continuous footways; set-back often difficult to achieve; a need to avoid ambiguous or misleading road markings; and material choice.

2.2.3 Zebra crossings

Jones et al. (2021) evaluated a trial at two sites in Manchester side roads with a zebra crossing without yellow globes, zig-zag markings or additional lighting, which are requirements for standard zebra crossings. They showed that the propensity of vehicles to give way to crossing pedestrians at the implied zebra ranged from 26-43% ‘without’ to 57-71% ‘with’ the zebra. Further similar trials are taking place in Wales with data yet to be published. Their widespread use would require a change to traffic regulation.

2.3 Summary

Much design development has been undertaken and appears in recent design guidance in England, Scotland and Wales. There are some important differences in nomenclature and design detail. Drivers yield priority at Design Priority junctions on between 79% to 90% of occasions. Drivers yield priority at zebra markings at side roads on between 57% to 71% of occasions. Drivers yield priority at control junctions on between 26% to 59% of occasions. Design Priority enhances driver yielding. There is a gap in the literature relating to the behaviour of users at Marked Priority junctions.

3 THE FINDINGS FROM THIS RESEARCH

This chapter summarises the observational studies, collision analysis and focus groups undertaken as part of this research.

3.1 Observational studies

The observational studies deal with user behaviour and therefore answer Research Question 1 linked with Objective 3. The observational study was primarily concerned with identifying the frequency and nature of interactions of all road users at side roads, both with Marked Priority, and, as a control, without Marked Priority. A full discussion of the observational study is provided in Flower et al. (2023). Table 3.1 summarises the locations and types of crossing at the twelve sites and three control sites.

Table 3.1 Location and type of crossings

Type of crossing	Location and city	Site Number
T1 with zebra full set-back	Milton street / A34 Birmingham	1
	Valley Rd / Inkersley Rd Bradford	6
T2 with zebra partial set-back	Olton Blvd East / Summer Rd Birmingham	7
T3 no zebra full set-back	Hesters Way Rd / Princess Elizabeth Way Cheltenham	2
	Bedford Road / B531 Bedford	3
	Denmark Rd / Penrhyn Rd Kingston	4
	Wykebeck Valley Rd / A64 Leeds	8
T4 no zebra partial set-back	High Road / Heacham Av. Ickenham	9
	High Rd / Austin's Ln Ickenham	10
T5 no zebra no set-back	Byng Place / Gordon Sq Camden	12
	Sebastopol Rd / Fore St Enfield	13
	West Carriage Drive Hyde Pk	14
Control for T1/3	Hallfield Rd / James St York	5
Control for T2/4	Park Ln / Forrest St Liverpool	11
Control for T5	Boston Manor Rd / Boston Gardens Brentford	15

Note that the designations in the first column (T1 to T5) relate to Figure 2.1.

Each site had characteristics that differed from the standard layout in various ways. Observational studies were carried out using video footage. Two consecutive weekdays were filmed from 7am to 7pm at each site. There were 108 interaction types based on three carriageway user types (driver, cyclist, other) and three footway / cycle track user types (pedestrian, cyclist, other), four carriageway user behaviours (proceeds forward, stops behind Marked Priority, stops on foot crossing, stops on cycle crossing) and three footway / cycle track user behaviours (yields, continues to cross in front, continues to cross behind).

The volume of crossing pedestrians varied from 19 to 360 pedestrians in the peak hour. That is a significant variation and ranges from 1 every 3 minutes to 1 every 10 seconds. Similarly, there was a large variation in cycle flow from 2 to 728 at the busiest cycle junction). Six sites had more vehicles turning in and out of the side road than people crossing the side road (Sites 1, 2, 5, 7, 8 and 9), while five had more people crossing than turning in and out (11, 12, 13, 14 and 15). The remainder of sites (3, 4, 6, and 10) were more nearly balanced in terms of the crossing versus carriageway flow.

Yields were defined in three ways as follows: No Yield by the person crossing road; a Voluntary Yield by the person crossing the road to a turning vehicle and; a Forced Yield where the driver compelled the person crossing to yield. **It is worth repeating that yielding is defined for the purposes of this research from the point of view of the pedestrian or cyclist crossing the road**. It is important to take this viewpoint because it is the people who are crossing the side road which are of interest to the research. It should be noted that this is different from the viewpoint taken in previous studies.

Overall proportions of yield types

Table 3.2 summarises the data from this study for crossing types T1 to T5 and also data from the Flower et al. (2021) study on Design Priority crossings, i.e. crossing types T7 and T8 (NB No Type 6 junctions could be found for this previous study). Of the 7,627 interactions at the twelve sites with Marked Priority, the majority (5584, 73.2%) did not require the person crossing to yield. There were some instances where the person crossing yielded voluntarily to the driver turning into or out of the side road (255, 3.3%). The person crossing was forced to yield on 1788 occasions (23.4%).

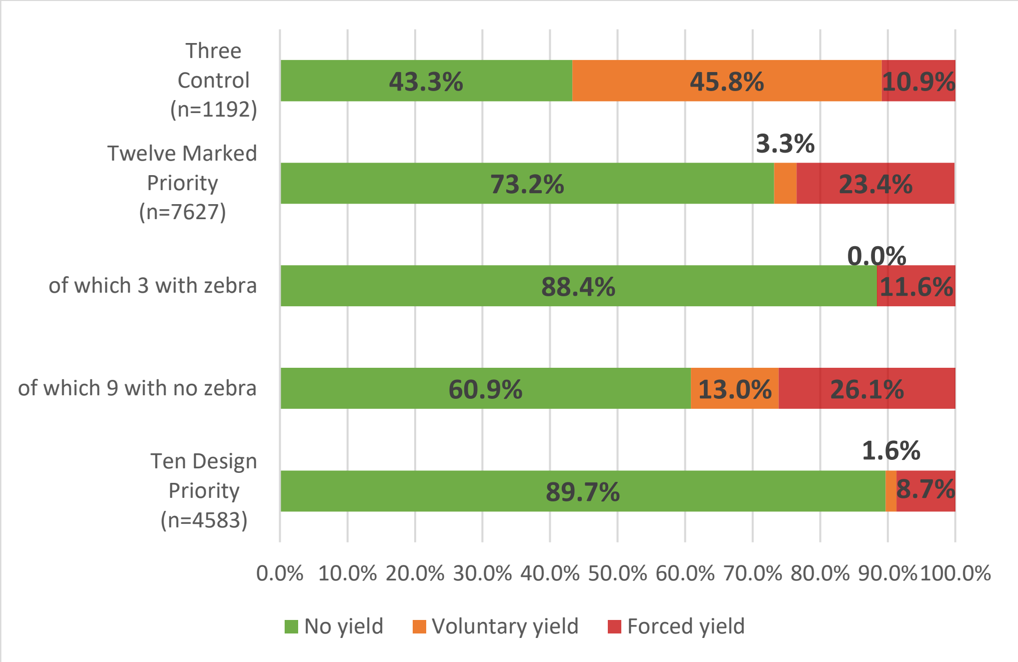
Table 3.2 Summary of yields by people crossing the side road by crossing type

Site	No yield	Voluntary yield	Forced yield	Percentage voluntary and forced yields	Total
T1 Birmingham, Newtown (1)	743	1	155	17.3%	899
T1 Bradford (6)	34	0	11	24.4%	45
T1 sub-total	**777**	**1**	**166**	**17.7%**	**944**
T2 Birmingham, Acocks Green (7)	1575	0	142	8.3%	1717
T2 sub-total	**1575**	**0**	**142**	**8.3%**	**1717**
T3 Cheltenham (2)	270	0	325	54.6%	595
T3 Bedford (3)	424	2	261	38.3%	687
T3 Kingston, Denmark Rd (4)	827	2	158	16.2%	987
T3 Leeds, York Rd (8)	64	249	0	79.5%	313
T3 sub-total	**1585**	**253**	**744**	**38.6%**	**2582**
T4 Ickenham, Heacham Rd (9)	333	0	84	20.1%	417
T4 Ickenham Austin’s Ln (10)	294	0	57	16.2%	351
T4 sub-total	**627**	**0**	**141**	**18.4%**	**768**
T5 London, Camden (12)	231	0	287	55.4%	518
T5 London, Enfield (13)	330	1	112	25.5%	443
T5 London, Hyde Park (14)	459	0	196	29.9%	655
T5 sub-total	**1198**	**1**	**686**	**36.4%**	**1885**
Marked Priority total	**5584**	**255**	**1788**	**26.8%**	**7627**
CT3 York (5)	231	546	0	70.3%	777
CT4 Liverpool (11)	178	0	91	33.8%	269
CT5 London, Brentford (15)	107	0	39	26.7%	146
Control sub-total	**516**	**546**	**130**	**56.7%**	**1192**
T6 Full SB Design Priority	Note that no examples of T6 were found; no data available				
T7 London, Stratford (94)	194	2	10	5.8%	206
T7 Edinburgh (96)	47	7	32	45.3%	86
T7 London, Leyton (98)	64	6	33	37.9%	103
T7 Partial SB Design Priority	**305**	**15**	**75**	**22.8%**	**395****
T8 Leeds, Kirkstall Rd (91)	29	0	0	0.0%	29
T8 London, Oval (92)	1018	2	5	0.7%	1025
T8 Kingston, Grove Cres. (93)	1254	4	14	1.4%	1272
T8 Nottingham (95)	28	1	1	6.7%	30
T8* Southampton (97)	214	34	132	43.7%	380
T8* London, Walthamstow (99)	1121	9	131	11.1%	1261
T8* London, Clapham (910)	144	8	39	24.6%	191
T8 No SB Design Priority	**3808**	**58**	**322**	**9.1%**	**4188**
Design total	**4113**	**73**	**397**	**10.3%**	**4583**

*Continuous footway with cycle lane across junction **Note T7 totals data was based on a very small sample size compared with the other junction types.

Figure 3.1 summarises the proportions of yield types by type of junction.

Figure 3.1 Summary of proportions of yield types by type of junction



When considering risk, the primary concern is the proportion of forced yields. However, when considering priority, the measure of more interest is the combination of forced and voluntary yields. Both measures are considered.

Of the 1,192 interactions at the three control sites, 43.3% on average did not require the person crossing to yield and a nearly equal proportion (45.8%) yielded voluntarily. 10.9% were forced to yield.

Of the 7,627 interactions at the twelve sites with Marked Priority, the majority (73.2%) did not require the person crossing to yield. There were some instances of voluntary yields to the driver turning into or out of the side road (3.3%). The person crossing was forced to yield on 23.4% of occasions by the car driver. However, this does vary by whether a zebra is present or not. With a zebra, the proportion of no yields is higher and the proportion of forced yields is lower than the aggregate, with the absence of a zebra creating forced yields in 26.1% of occasions.

At Design Priority sites, pedestrians and cyclists took priority (i.e. did not yield) in 89.7% of interactions. This compares with 88.4% for Marked Priority with zebras, 60.9% without zebras and 43.3% at the control sites.

Descriptive analysis and modelling

Sixteen negative binomial models with log link were estimated to explain the number of forced yields in 15-minute periods. The independent variables tested are the 15-minute vehicle turning flows, the crossing flows of pedestrians, cyclists and other users, the level of set-back of the junction, and, for Marked Priority, the presence of a parallel crossing. Interactions between categorical variables and flow were estimated in some models.

The model that provided the most insight included categorical variables for junction type, the presence of a parallel crossing, and turning and crossing flows. Interaction terms did not assist in explaining variation. The following points summarise the findings from a descriptive analysis of the data and the modelling.

Design treatment at control site may have created ambiguity. From a descriptive analysis of the control sites it can be seen that even with a Give Way marked on the cycle track, the design treatment at the two junctions observed seems to have created ambiguity for drivers, who yielded to people crossing in most cases. This suggests that subtle differences in design appear to tip the balance of driver behaviour towards giving way.

Many fewer voluntary yields at enhanced junctions. Compared with control junctions, there are many fewer voluntary yields at junctions enhanced by either Marked Priority or Design Priority. Hence, such enhancement may be interpreted as confirming to road users the nature of the priorities that exist at side roads for people crossing. This finding needs to be treated with caution because the very different nature of the yields at the three control sites.

Comparison of no yield and forced yield proportions. The modelling indicates that, compared with control sites, there are 3.487 times more forced yields at Marked Priority without a parallel crossing, 1.088 times more forced yields with a parallel crossing, and 1.423 times more forced yields at Design Priority. This should be considered recognising the comments above about the two control sites and the possible effect of the design features at two of the control junctions.

No effect of set-back. Descriptive analysis suggests that full set-back creates more yields than partial set-back, and, except for Marked Priority, partial set-back creates more yields than no set-back. However, the modelling has not found that set-back is significant.

Right turns into the side road generate most forced yields. The descriptive analysis noted that the most common reason for a forced yield is linked to the right turn into the side road. This is confirmed by the modelling which found a large effect size with an elasticity of 0.612.

Contra-flow pedestrians have a modestly higher number of forced yields. The descriptive analysis found some significant differences in yields by direction of the people crossing. This is reflected in the modelling reflected in the difference in elasticity for pedestrians with and contra-flow (0.239 and 0.291 respectively). This difference in elasticity indicates just over 20% more forced yields per pedestrian crossing in the contra-flow direction.

Cyclists create fewer forced yields than pedestrians. From the descriptive analysis, Design Priority and Marked Priority appear to provide better priority for cyclists than pedestrians. The modelling confirms this in so far as, for the one cycling coefficient that is significant (for the contra-flow direction), the elasticity for cycling is lower than for pedestrians (0.041 compared with 0.291, i.e., a factor of seven smaller).

The pathway of people crossing. The percentages of people crossing who pass behind a vehicle turning out of a side road ranges from 31%-46% for Marked Priority and from virtually nothing to 61% for Design Priority. The percentages for pedestrians passing behind is greater than for cyclists passing behind in every case. Passing behind the vehicle is more likely to occur for turning movements out of the side road than turning in to the side road. This is because vehicles turning out of the side road may be blocking the pathway.

Kerb radii. No statistically significant correlation was found between the proportion of forced yields and the corner radii for the left turns.

Effect of enhanced junctions on behaviour at non-enhanced junctions. There remains the question about the consequences of providing some side roads with Marked Priority or Design Priority, while not enhancing others. Driver behaviour at non-enhanced junctions may become worse relative to enhanced junctions. On the other hand, better behaviour at enhanced junctions may positively influence behaviour non-enhanced junctions. The January 2022 revision to the Highway Code may have the effect of leading behaviour towards better behaviour overall. Further research would be required to understand whether this happens.

3.2 Collision analysis

The collision analysis deals with Objective 2. Collisions and injuries occurring on the public highway are reportable to the police. The statistics relate only to personal injury collisions because damage only collisions are not reportable. These data are shared and with local authorities and are known as STATS19 data. Data on collisions was obtained at all 15 junctions for the five-year period before treatment and for a variable period after treatment (depending on how long ago the change to the junction was made).

The number of collisions indicates low collisions rates. As a comparator, The Welsh Government defines a collision cluster site as a site with four injury collisions or more in a three-year period. This equates to a mean of 1.33 collision per year. This suggests that, according to this criterion, Sites 1, 12 and 13 in the before situation may have become junctions of some concern in relation to the collision record. In the after period, it is only Site 2 in Cheltenham which has a higher mean rate.

Indicatively, it is instructive to consider all sites in aggregate. This have been done for nine of the sites, excluding the two sites for which there are no before or after injuries recorded (Sites 9 and 10), and excluding Site 3 for which there is no before data. There were a total of 44 injury collisions at the sites in the 44.16 years before enhancement and 16 in the 40.7 years after enhancement. There are hence fewer injury collisions in the after period than would be expected, and this is statistically significant ($\chi^2(1) = 10.1, p = 0.01$). It should be stressed that the aggregate analysis has grouped across all types of Marked Priority crossing, with different levels of set back and with the presence and absence of a zebra crossing for pedestrians. Hesitancy is needed in suggesting that this points in the direction of an injury reducing effect of the Marked Priority crossings. No correlation was revealed between the mean number of injuries per year in the after period and the number of forced yields observed.

3.3 Focus groups

The focus groups provide evidence to answer Research questions 2 and 3 linked with Objective 3. This section describes the findings of the qualitative research undertaken to explore how clearly and effectively different road users think priority is indicated in different types of side road crossings. Focus groups were used to explore the perceptions, behaviours and attitudes of pedestrians, cyclists, drivers. As a result of the Covid-19 pandemic and the national restrictions in place to limit the spread of infection, the group discussions were undertaken on-line. A full discussion of the focus groups is provided in Ricci and Parkin (2023).

Twenty-seven women and twenty men took part in the groups. Fifteen participants were disabled and reported having physical and sensory impairments affecting their day-to-day mobility: four had a mobility impairment (two used a wheelchair) and eleven were blind or partially sighted. Of these, four were guide dog users. One participant reported having been injured in a collision with a vehicle while cycling.

Junctions for discussion were selected from those for which observations had been made and based on the geographical distribution of the group's members. Eleven of the fifteen junctions were discussed. NVivo software was used to identify themes that emerged. The following main points emerged from the focus groups discussions, and these are grouped under the headings of concerns, design features and regulation.

- **Concerns**
    - **Shared concerns.** Disabled and non-disabled people shared many concerns, however there are specific issues that affect how disabled people cross a side road junction. Wheelchair and mobility scooter users favoured the absence of slopes and cambers, the use of dropped kerbs at both sides of a crossing, and raised crossings.
    - **Blind and partially sighted people** expressed a preference for clear and unambiguous crossing designs such as signalised crossings. They expressed strong concerns about crossing designs where users need to rely on visual cues and adopt behaviours clashing with current guide dog training instructions, and where cycle tracks and footways are not physically separated.
    - **Traffic turning off the main road creates most concern**. People were generally more concerned with vehicles turning into the side road than with those exiting the side road. Drivers turning into the side road (from the left and the right-hand side) could potentially do so at speed, and without gaining a full picture of all the road users crossing, or waiting to cross, the side road.
    - **Consistency**. Overall, people recommended more consistency in the use of road markings, and types of treatment and street furniture across the country to minimise ambiguity and confusion. People identified positive and negative features in all the ten junctions under

consideration (nine Marked Priority and one control), and this implies that design need to be improved

- **Design features**
    - **Zebras**. Zebra road markings were perceived to be generally well recognised and respected, hence perceptions of junctions which featured this type of pedestrian crossing tended to be more positive. Marked priority junctions that did not feature a zebra crossing were perceived as creating ambiguity, hence potential risk, for pedestrians.
    - **Surface design**. Road markings indicating priority for crossing cyclists were positively perceived, especially when reinforced by other design elements such as cycle symbols, using the same colour and material across the cycle crossing as on the approaches and differentiated from the colour of the carriageway, and having a raised crossing at the same level as the cycle track.
    - **Set-back**. The position of the pedestrian and cycle crossings (no set-back, partial or full set-back from the edge of the main road carriageway) influenced perceptions of convenience and safety in different ways. Deviations from the desire line need to be clearly and unambiguously indicated for pedestrians who are blind or partially sighted. Some cyclists may decide to ride on the main road carriageway rather than the cycle track to avoid the inconvenience of deviating from their desire line because of the set-back. Set-back crossings were perceived as moving the cycle route and pedestrians into close proximity, and changing the cyclists status away from being 'traffic'.
    - **Wider factors.** Contextual factors are important in shaping people's perceptions. These include the speed limit on the main road and the side road, the radii of the kerb between the main and side road, the length of the crossing, the volume, direction and type of vehicles that could travel through the junction, whether the footway and the cycle track were physically separated, and whether any other nearby junctions had similar or different treatments.
- **Regulation**
    - **Highway Code.** The main relevant Highway Code change of 29th January 2022 requires turning drivers to Give Way not only to people already crossing the side road, but also to people waiting to cross. There was no indication that people felt more comfortable and safer crossing a side road after the changes in the Highway Code.

- **Change is possible**. Respondents suggested that it is possible for road users to change their behaviour, for example because of regulatory changes, but they suggested such changes take time and need further support, such as enforcement and education.

- **Human scale mobility**, such as electric scooters, are supported in principle, but several significant shortcomings were noted, such as obstruction of the footway.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

The observational data has shown that people crossing did not have to yield at Marked Priority junctions on 73.2% of occasions, and 89.7% of occasions at Design Priority junctions. At control sites the proportion was 43.3%. This indicates that priority is being enhanced by both Marked Priority and Design Priority. Modelling of the number of yields forced on people crossing by drivers in a 15-minute period as explained by flows and junction type has shown that, compared with the control sites, there are:

- 1.088 times more forced yields at Marked Priority junctions with a parallel crossing (i.e. with both a cycle track and zebra crossing);
- 1.423 times more forced yields at Design Priority junctions; and
- 3.487 times more forced yields at Marked Priority junctions without a parallel crossing (i.e. with a cycle track crossing but no zebra crossing).

The level of set-back appears to have no effect. The flow that has the greatest impact on the number of forced yields is the right turn in flow of vehicles with an elasticity of 0.612 (an increase in flow of ten increases the number of forced yields by 6.12). Pedestrians crossing in the contra-flow direction to the near-side main road flow may experience around 20% more forced yields than pedestrians walking with the near-side main road flow (elasticities of 0.239 and 0.291 respectively). Cyclists create fewer forced yields than pedestrians (elasticity of 0.041 compared with 0.291). In the long-run, enhanced junctions may or may not improve driver behaviour at non-enhanced junctions.

The number of injuries was generally low at all the junctions, and in some cases there were no collisions recorded. For the junctions and the periods for which data is available, there were a total of 44 injury collisions at the sites in the 44.16 years before period and 16 in the after period of 40.7 years. This difference is statistically significant. No correlation was revealed between the mean number of injuries per year in the after period and the number of forced yields observed.

Participants in the Focus Groups showed that some concerns were shared between disabled people and non-disabled people. Blind and partially sighted people expressed strong concerns about crossing designs where users need to rely on visual cues and adopt behaviours clashing with current guide dog training instructions, and where cycle tracks and footways are not physically separated.

Traffic turning off the main road creates most concern for people crossing, and this is borne out by the rate of forced yields created by vehicles turning right into a side road. Participants recognised that designs are not consistent and this needs to be improved.

Marked Priority with zebra crossings, i.e. parallel crossings, were preferred. Again, the evidence from the observational study suggests performance is better than at Marked Priority junctions without parallel crossings. Road markings are perceived positively, especially when reinforced with other design elements.

Set-back from the kerb line of the main road was criticised because of the deviation it entails and the perception that it brings pedestrians and cyclists closer together than they otherwise would be. Other contextual factors are important such as speed limit, kerb corner radii size, and length of crossing.

Participants thought that it is possible to change road user behaviour in relation to the revised Highway Code. They also supported in principle human scale mobility, such as electric scooters, but a significant shortcoming is obstruction of the footway.

4.2 Recommendations

The following recommendations are drawn.

1. From a consideration of the yielding behaviour, Marked Priority crossings with a zebra crossing (i.e. a parallel crossing) would be the preferred enhancement, followed by Design Priority crossings (also known as continuous footways), and finally Marked Priority crossings without a zebra crossing (i.e. only a priority cycle track crossing). There may be contexts where Design Priority is preferable to Marked Priority, and/or where parallel crossings are not possible.
2. By default, the crossing should be adjacent to the main road kerb line because set-back introduces disadvantage for people crossing, including deviation from the desire line, and has no effect on forced yields. For parallel crossings, this would require the use of implied zebras (i.e. zebras without zig zag markings or yellow globes). Such a development would depend on confirmation of the outcomes of the on-going implied zebra trials.
3. Consideration should be given to incorporating implied zebras in Design Priority crossings and this is because zebras are well recognised and regarded.

4. Bi-directional cycle tracks can be used because drivers create fewer forced yields for cyclists than for pedestrians, and contra-flow movements do not create more forced yields.
5. It is important that Marked Priority and Design Priority enhancements are implemented consistently across the country to minimise ambiguity and confusion for road users.
6. Further research should be undertaken to understand whether enhanced junctions may encourage or discourage drivers to obey the Highway Code rules at conventional junctions, and whether there are developments needed in the positioning of road markings at conventional junctions.

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