UNIVERSITY OF THE WEST OF ENGLAND, BRISTOL

Design development of side road crossings for pedestrians and cyclists

Observations and Collisions Report v2.1

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Prepared for the Road Safety Trust

by

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EXECUTIVE SUMMARY

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.

The Highway Code requires drivers to Give Way to people crossing a side road, and since 29th January 2022 they should Give Way to people waiting to cross (Rules H2 170). In addition, Rule H3 states that they should not cut across cyclists going ahead when they are turning at a junction.

There are four parts to the research: observational studies, collision analysis, focus groups with road users and discussion with stakeholders about the findings. This document reports the findings from the observations and collisions analysis. The findings are taken together with the findings from the Focus Groups to into a Final Report with recommendations for practice.

Marked Priority crossings may be set-back from the kerb line of the main road by 5 metres or more (full set-back), or they may have the crossing at the kerb line (no set-back), or somewhere in between these two (partial set-back). They may have a zebra crossing for pedestrians and in this case the crossing is called a parallel crossing. The carriageway contains markings indicating that carriageway users need to Give Way to people crossing the side road, and there are no Give Way markings on the cycle track approaches to the side road. The control site did not have such Give Way markings in the carriageway, or a zebra crossing for pedestrians.

The observations. Twelve junctions with Marked Priority were selected for the five types of Marked Priority defined in Local Transport Note 1/20 Cycle Infrastructure Design. In summary there are:

- Full set-back with a parallel crossing (two sites);
- Partial set-back with a parallel crossing (one site);
- Full set-back with cycle track crossing only (four sites);
- Partial set-back with cycle track crossing only (two sites); and
- No set-back with cycle track crossing only (three sites).

LTN 1/20 does not define a layout with no set-back but with a parallel crossing. In addition, three control sites were selected for full set-back, partial set-back and no set-back which have cycle tracks but where there are no carriageway markings indicating priority for people crossing. The three main dimensions of the framing for design are therefore as follows: i) Marked Priority or not, ii) level of set-back and iii) presence of a zebra or not to create a parallel crossing. Each junction has unique characteristics, and these are relevant for interpretation of the results.

Twenty-four hours of video footage was collected at each site and all interactions between road users were noted. There were a total of 8,819 interactions, with 7,627 at the Marked Priority sites and 1,192 at the control sites. Total crossing flow in the peak hour varied from 41 to 1,093 and total flow on the side road varied from28 to 496. Six sites had much higher side road flows than crossing flows and five sites had much higher crossing flows than side road flows. The flows were more evenly balanced in the remaining four sites.

An interaction is defined as when one or other of the people crossing or the traffic turning has to yield. Interactions may result in collisions, but no collisions were recorded in the videos. Yields are defined from the point of view of the road user who is crossing the side road as follows:

- No yield by the person crossing road;
- Voluntary yield by the person crossing the road to a turning vehicle; and
- Forced yield by the person crossing as a result of driver behaviour.

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 where the person crossing yielded voluntarily 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. Of the 1,192 interactions at the three control sites, i.e. without Marked Priority, 43.3% did not require the person crossing to yield. A nearly equal number (45.8%) of people crossing yielded voluntarily, and 10.9% were forced to yield.

An alternative for providing enhanced priority for people crossing a side road is Design Priority, also called a continuous footway. For Design Priority, a previous study (Flower et al. 2021) found that the person crossing the side road took priority (i.e. did not yield) in 89.7% of those interactions. This compares with the 73.2% for Marked Priority crossings and only 43.3% of occasions for the control sites. For Design Priority, the proportion of forced yields was 8.7%, and this is lower than forced yields for Marked Priority at 23.4% and 10.9% for junctions with no enhancement of priority.

In summary, 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 a 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).

Considering together the proportions of times no yield is required and the proportion of forced yields, it appears that marked priority with a parallel crossing may be the preferred enhancement, followed by Design Priority, and finally Marked Priority without a zebra crossing (i.e. only a priority cycle track 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. 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. Cyclists create fewer forced yields than pedestrians. In the long-run, enhanced junctions may or may not improve driver behaviour at non-enhanced junctions.

Collision analysis

Data was requested for the relevant local authorities on the collision record for a five-year period before the installation of the Marked Priority crossings and for the same period after. No collisions were recorded either before or after installation of the cycle track at the control sites. Also, no collisions were reported for the two junctions with partial set-back and no zebra, and a further site was excluded from the analysis because of the lack of before data.

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.

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.

The research comprises of four parts: observational studies of interactions, collision record analysis, focus groups with road users and discussion with stakeholders about the findings. This document reports the findings from the observations and collisions analysis. The findings are taken together with the findings from the Focus Groups into a Final Report with recommendations for practice.

Side road junctions most often have priority control determined by Give Way markings and a Give Way sign. The priority is referring to the control for traffic on the carriageway, and does not specifically reference pedestrian or cycle traffic, which may be crossing the side road outside of the carriageway.

As well as cycle traffic, there are also other important wheeled-vehicle users including wheel-chair users, users of mobility scooters, and people using prams and push-chairs. It should also be noted that cycles come in many forms, including bicycles, tricycles, tandems, cargo bikes, tag-a-longs and hand cycles. Beyond these wheeled-vehicle users, a further important consideration are users of scooters, e-scooters, and other forms of emerging forms of human scale mobility. Note that the terms pedestrian and cyclist are used as shorthand in this document and should be taken as terms inclusive of all of these above types of user.

Priority junctions (or ‘yield’, or ‘Give Way’ or ‘T-junctions’) are the most ubiquitous type of junction, and two-thirds of all collisions in urban contexts occur at junctions (Department for Transport, 2017). Priority junctions therefore need to be a focus for design development. Two methods for providing enhanced priority for people crossing are Marked Priority crossings and Design Priority crossings. This report is primarily concerned with Marked Priority junctions, but comparisons are made with the evidence of Flower et al. (2021) for Design priority junctions.

Marked Priority crossings may be set-back from the kerb line of the main road by 5 metres or more (full-set-back), or they may have the crossing at the kerb line (no set-back), or somewhere in between these two (partial set-back). They may have a zebra crossing for pedestrians and in this case the crossing is called a parallel crossing (comprising of both a prioritised zebra and a prioritised cycle track). The carriageway contains markings indicating that carriageway users need to Give Way to people crossing the side road, and there are no Give Way markings on the cycle track approaches to the side road. The control sites did not have such Give Way markings in the carriageway, or a zebra crossing for pedestrians.

Figure 1 shows a typical Marked Priority crossing. The junctions has a parallel crossing comprising a two-way cycle track crossing about two car lengths from the Give Way line, and beyond that a zebra pedestrian crossing. Some Marked Priority crossings may not have a zebra crossing.

Figure 1 Typical Marked Priority crossing

The aim of the project as stated in the application to the Road Safety Trust was to provide a basis for better side road designs to reduce risk to road users. This was to be achieved by creating a typology of provision, investigating the risk reduction of different designs, understanding how road users behave in different circumstances, and why they behave in the way they do. We also set out to explore issues relating to emerging human scale mobility options. 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?

As well as objective measures on the effectiveness, we have sought perceptions from users, and these are reported in the Focus Group report. The Focus Group Report deals with research questions 2 and 3, and this report deals with the remainder of the objectives and research Question 1. The results, from this report and the Focus Group Report are drawn together in the Final Report to inform the further development of design guidance and implementation.

The Inception Report (Flower and Parkin, 2020) summarised relevant research into side road crossings. Since that review, four other relevant studies have been undertaken or are in progress. Two relate to implied zebras with one study in Manchester (Jones et al., 2021) and the other in Cardiff (Gupta et al., unpublished in draft). An 'implied' zebra crossing includes the black and white road crossings, but not zig-zag markings, amber globe (previously commonly called a 'Belisha beacon') or overhead lighting which are all currently required on public roads by legislation. Figure 2 shows such a crossing.

Figure 2 Example of a non-prescribed zebra crossing (Source: Jones et al., 2021)

The third is a project completed by the Centre for Transport and Society on behalf of Sustrans and funded by Transport Scotland (Flower et al., 2021), as mentioned above. This project focussed on design requirements for continuous footways and cycle tracks, i.e. Design Priority. The main design related issue is that the footway (and cycle track if present) are continued across the side road carriageway, with turning traffic needing to cross that footway. Hence the continuity of the carriageway is broken. The fourth study, currently in progress, is being undertaken by Living Streets Scotland and also considers continuous footways. The Final Report re-considers the relevant literature in the light of this research. Figure 3 shows an example of a Design Priority crossing.

Figure 3 Example of a Design Priority side road crossing

It should be noted that the Highway Code was re-published with updates by the Government on 29th January 2022, and took immediate effect. Note that the observational studies had already taken place at this point (in Summer 2021), but the focus groups occurred in March 2022 and fortuitously could therefore discuss the rule changes relevant to side road junctions.

There were many changes to the Highway Code, some of which are relevant to side road junctions. Firstly, an overarching 'hierarchy of users' was defined such that those in charge of vehicles that can cause the greatest harm are the ones who bear the greatest responsibility to take care and reduce the risks they pose to others. Coupled with this a new overarching Rule H1 states the following.

It is important that ALL road users are aware of The Highway Code, are considerate to other road users and understand their responsibility for the safety of others.

A Second new rule labelled H2 is defined as follows:

At a junction you should Give Way to pedestrians crossing or waiting to cross a road into which or from which you are turning. You MUST Give Way to pedestrians on a zebra crossing, and to pedestrians and cyclists on a parallel crossing

This support existing Rule 170 about side road junctions which has been amended as follows (NB only the relevant parts of this rule are quoted):

Rule 170 Take extra care at junctions. You should

- *watch out for cyclists, motorcyclists **and pedestrians** including powered wheelchairs/mobility scooters **users** as they are not always easy to see. Be aware that they may not have seen or heard you if you are approaching from behind*
- ***Give Way to** pedestrians crossing **or waiting** to cross a road into which or **from which** you are turning. If they have started to cross they have priority, so Give Way (see Rule H2)*

Emboldened words indicate the changes. Significantly, the rule suggests now, that drivers should 'watch out' for pedestrians, and this hints that the purview of drivers needs to extend from just the carriageway to the footway as well. The addition of pedestrians at this point in the Code reveals a remarkable previous omission, especially on the basis that the rule is about side road crossings. Secondly, as well as the rule about giving way to pedestrians crossing now being now written in a clearer way, the rule is extended so that drivers should Give Way to pedestrians *waiting* to cross as well as those already crossing. The rule has also been extended to say explicitly that this applies to drivers both turning in and turning out of the side road.

Of relevance also is Rule 195 about zebra and parallel crossings (i.e. zebra and cycle track crossings). The relevant parts of the new rule are quoted below.

*Rule 195 Zebra and **parallel** crossings. As you approach a zebra crossing*

- *look out for pedestrians waiting to cross and be ready to slow down or stop*
- ***you should Give Way to pedestrians waiting to cross***
- *you MUST Give Way when a pedestrian has moved onto a crossing.*

The rule has been extended to include parallel crossings and in a similar way as for side roads, priority is now afforded to people waiting to cross. Finally, overarching Rule H3 states the following:

> *You should not cut across cyclists, horse riders or horse drawn vehicles going ahead when you are turning into or out of a junction or changing direction or lane, just as you would not turn across the path of another motor vehicle. This applies whether they are using a cycle lane, a cycle track, or riding ahead on the road and you should Give Way to them.*

This new rule is deals with all turns at the junction, but is of particular relevance to the circumstance where a driver may turn left into the path of another road user when they are turning (the so-called 'left-hook' collision). It is relevant for the context in the UK in which there are more protected routes being created for cycle traffic lying adjacent to the carriageway.

The reason these rules changes are important is that they themselves may then have a relationship with what is seen as acceptable design by road users. Flower (2022) investigated the relationship between design, regulation and behaviour in the street environment with a focus particularly on marginalised users. Respondents to a Q-methodology sort readily identified the logically related interrelationship between design and regulation; for example, roads design and speed limit, and space allocation. Design and regulation in combination are relevant to side road junctions and affect the extent to which a street environment is conducive to people walking, cycling and rolling. The Highway Code rule change has made the outcomes of this research about design even more relevant to practice.

This report presents analysis of observations and collision record data for fifteen junctions and three control sites. Along with a literature review, the principles for the selection of the junctions were laid out in the Inception Report. The final method of selection is given in Section 2 of this report. Section 2 presents an analysis of the observations. Section 3 presents an analysis of the collisions and Section 4 draws conclusions.

2 OBSERVATIONAL STUDY

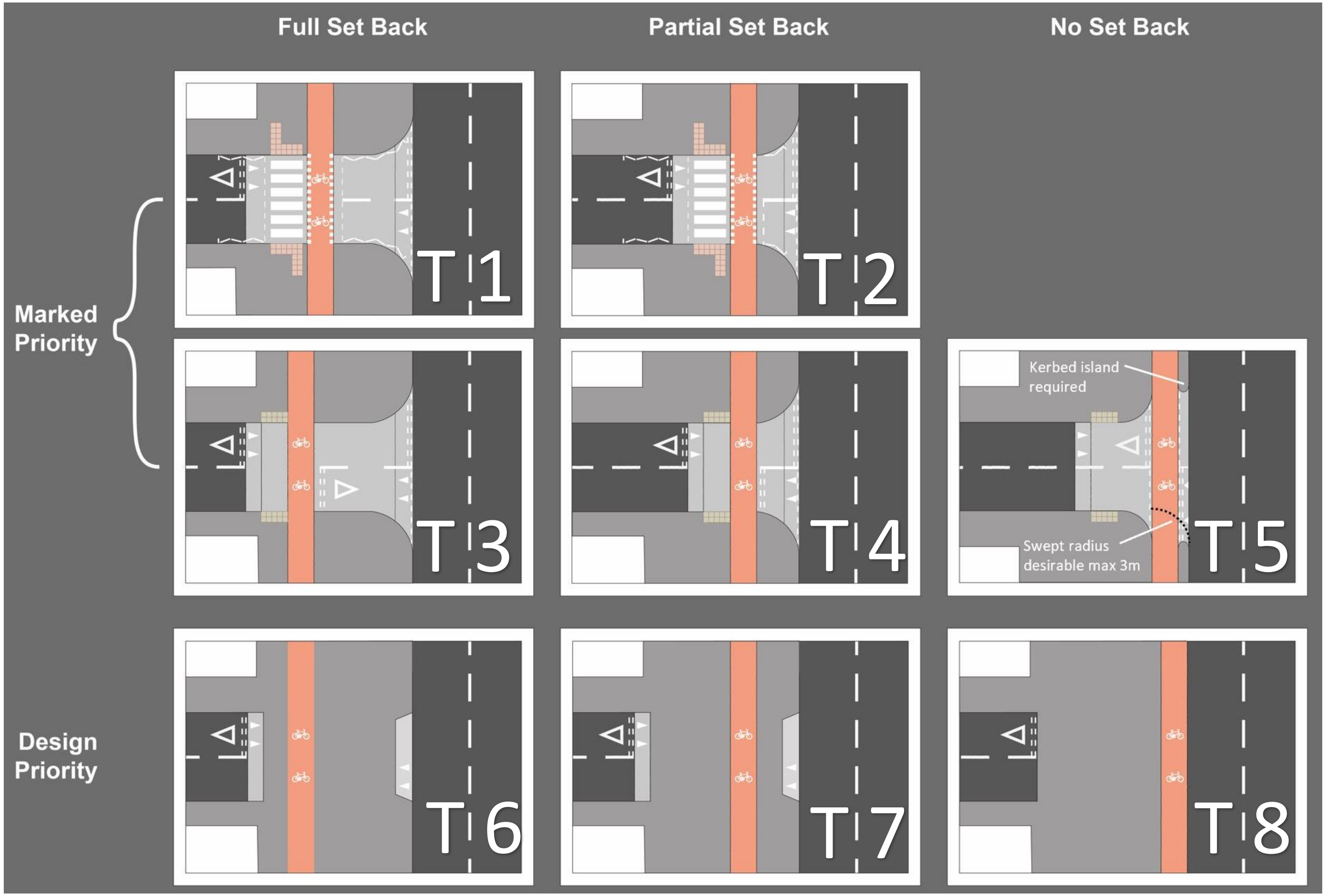
The observational study is primarily concerned with identifying the frequency and nature of interactions of all road users at side roads, both with and, as a control, without Marked Priority. This part of the research is directed at providing evidence in relation to Objective 3 and Research Question 1 about how road users behave at Marked Priority junctions. The observations will identify the nature of any yield that a pedestrian or cyclist may either offer to make, or be forced to make, to a driver, despite priority afforded to them by the Highway Code. Section 2.1 describes how the sites were selected. Section 2.2 describes the methodology for the data collection. Section 2.3 presents a descriptive analysis of the turning movement volumes. The heart of the analysis is presented in Section 2.4, which codifies and describes the nature of the interactions observed. Section 2.5 summarises the findings.

2.1 Site selection

Priority for pedestrians and cyclists at side roads can be created by using road markings and signage, and this is known as Marked Priority. The alternative is Design Priority where the physical layout of the junction provides the clues to the users about priority. There are five possible Marked Priority layouts, shown in the first to rows of Figure 4, and three possible layouts of Design Priority, as shown in the third row. The layouts are taken from Figure 10.13 of Local Transport Note 1/20 Cycle Infrastructure Design (Department for Transport, 2020).

The first row shows Marked Priority layouts with a zebra crossing for pedestrians, and these are the diagrams marked T1 and T2. The columns indicate the extent to which the crossing is set-back from the kerb line of the main road. The second row also shows Marked Priority crossings, but these do not have a zebra crossing and the priority for pedestrians is given by the positioning of the Give Way lines. These are layouts T3, T4 and T5.

Figure 4 Types of pedestrian and cycle crossing priority at side roads



Note that there is no layout with a zebra crossing with no set-back (which would have appeared in the top right hand blank area in the figure). The inclusion of the Give Way road markings on the side road in T1 and T2 are a mistake in LTN 1/20 because the zebra markings themselves are an indication that approaching vehicles should Give Way to crossing pedestrians.

Also note that the Give Way triangle in T3 and T4 is shown in a position where the traffic in the side road approaching the main road gives way to pedestrians crossing the side road. However, in T5, the Give Way triangle is show on the downstream side of the pedestrian crossing and adjacent to the cycle track. It is understood that this is an error in the figure, and this error has been corrected in an update of the same figure shown in the equivalent Figure 12.3 in the Active Travel Act Guidance (Welsh Government, 2021).

Design Priority ('continuous footways') are shown in diagrams marked T6, T7 and T8. Junctions as shown in diagrams T6 to T8 were the subject of the previous study undertaken by the Centre for Transport and Society (Flower et al., 2021).

It should be noted that the zebra lying adjacent to the cycle track crossing T1 and T2 is called a parallel crossing. For ease of reference in differentiating between T1 and T2 and the other Marked Priority crossings T3, T4 and T5, this differentiation is sometimes denoted as being either with or without a zebra.

For Marked Priority crossings, the cycle track is always nearer to the kerb than the pedestrian crossing. Similarly, for Design Priority, the cycle track crossing is on the carriageway side of the continuous footway. Set-back refers to the set-back of the cycle track from the main road carriageway kerb. If there were no cycle track with a Marked Priority design, then the set-back would refer to the distance from the kerb to the pedestrian crossing. For Design Priority, set-back without a cycle track crossing is not a relevant concept for Design Priority, because the footway would always then be adjacent to the carriageway, that is to say, with no set-back.

Twelve sites for the observational study were selected that have Marked Priority for both those using the footway and those using a cycle track across the side road. A further three sites were chosen as controls for Marked Priority and these junctions have markings that indicate that crossing cyclists and pedestrians should yield to turning vehicles.

Table 1 lists the locations of the Marked Priority junctions selected for this study. The basis of the selection is defined by a need to match to the standard layouts T1 to T5. Using the researchers' knowledge, and after using social media and the knowledge of leading designers in the field, a number of sites were identified as having the characteristics of Marked Priority crossings. There are two type T1 sites (Site numbers 1 and 6), one type T2 (7), four type T3 (2, 3, 4 and 8), two type T4 (9, 10,) and three Type T5 (12, 13 and 14).

Ten sites of the sites have priority for both those using the footway and those using a cycle track across a side road. Two sites did not provide Marked Priority for crossing pedestrians over vehicles turning out of the side road (Sites 9 and 12). All movements in and out of the side roads were permitted, except at Site 8 where it was only possible to turn in left or turn out left, and Site 14 where it was only possible to turn in. Table 2 lists the locations of the control junctions selected for this study.

Table 1 Description of the twelve Marked Priority side road junctions

Designation	Location	Comments	Image
T1: with zebra full set-back	Site 1 Birmingham Milton Street / A34. 9.5 metre set-back	• Dual-carriageway main road • Right turn in/out via central reserve • Bi-directional cycle track switches from being kerbside to non-kerbside from one side of the junction to the other • The cycle track enters shared pace just before the crossing point	
T1: with zebra full set-back	Site 6 Bradford Valley Rd / Inkersley Rd. 4.5 metre set-back (NB 0.5 metres less than the recommended 5m)	• Kerb separated bi-directional cycle track.	

T2: with zebra partial set-back	Site 7 Birmingham Olton Blvd East / Shaftmoor. Lane. 3.0 metre set-back.	• Has shared space either side of the crossing. • The crossing is in two sections across either side of the dual carriageway side road.	
T3: no zebra full set-back	Site 2 Cheltenham Hesters Way Rd / Princess Elizabeth Way. 5.0 metre set-back.	• The cycle crossing is paint separated from the footway and is highlighted in red across the junction. • There is space for two exiting vehicles (one turning out left and the other out right) to be in position at the same time.	

T3: no zebra full set-back	Site 3 Bedford Bedford Road / B531. 4.0 metres set-back (NB this is 1 metre less than recommended.)	• Paint separated bi-directional cycle track becomes shared space across the junction. • Railings corral pedestrians to cross at the designated crossing point.	
T3: no zebra full set-back	Site 4 Kingston Denmark Rd / Penrhyn Rd. 4.0 metres set-back	• Has a bi-directional kerb separated cycle track.	

T3: no zebra full set-back	Site 8 Leeds Wykebeck Valley Rd / A64. 20 metre set-back	• Uni-directional kerb separated cycle track adjacent to a busy dual carriageway. • Only turn in / turn out left movements are permitted at the junction.	
T4: no zebra partial set-back	Site 9 Ickenham High Road / Heacham Ave 2.0 metre set-back	• Verge separated bi-directional cycle track. • Give Way for traffic turning out is positioned adjacent to the cycle track and therefore offers no priority for pedestrians.	

T4: no zebra partial set-back	Site 10 Ickenham High Rd / Austin's Lane. 2.0 metre set-back	• Kerb separated bi-directional cycle track on one side of the crossing and shared space on the other. • Bollard and Give Way triangle on the shared space create ambiguity because cyclists are not required to Give Way (no similar requirements at Site 9 which is adjacent).	
T5 no zebra no set-back	Site 12 Camden Byng Place / Gordon Square.	• Kerb separated uni-directional cycle track. • Give Way for traffic turning out is positioned adjacent to the cycle track and therefore offers no priority for pedestrians.	

T5: no zebra no set-back	Site 13 Enfield Sebastopol Rd / Fore Street. 1.0 metre set-back	• Kerb separated uni-directional cycle track. • The Diagram 1055.3 (elephant's footprint) marking the cycle track crossing are not legally permitted, so there is no priority enhancement.	
T5: no zebra no set-back	Site 14 Hyde Pk West Carriage Drive.	• Kerb separated bi-directional cycle track. • An entrance to a car park and only a turn in is permitted.	

Note. The link in the title in the first column is to the Google Map image.

Table 2 Desctiption of the three control sites

Designation	Location	Comments	Image
Control for full set-back (T1 and T3)	Site 5 York Hallfield Rd / James Street. 9.0 metre set-back.	• Bi-directional paint separated cycle track • No Give Way markings on the cycle track • Raised crossing	
Control for partial set-back (T2 and T4)	Site 11 Liverpool Park Lane / Forrest Street. 1.5 metre set-back.	• Bi-directional to uni-directional kerb separated cycle track • Give Way markings on the cycle track. • Raised crossing	
Control for no set-back (T5)	Site 15 Brentford Boston Manor Rd / Boston Gardens (South).	• Bi-directional kerb separated cycle track • Give Way markings on the cycle track • Raised crossing	

Consideration was also given to detailed design and layout characteristics during the site selection process, and these may be grouped under the following headings: i) pedestrian provision, ii) cycling provision, iii) side road direction of travel, iv) carriageway markings and visibility, and v) similar adjacent treatments. Table 3 summarises individual features according to these groupings. From the point of view of the people crossing, some of the features may positively influence the nature of the junction (e.g. priority being given to crossing cyclists), while others may have a negative influence (e.g. a level change to cross the carriageway).

Table 3 Features present in each of the fifteen junctions

Zebra presence	**With zebra**			**Without zebra**									**Controls**		
Level of set-back	**Full**		**Partial**	**Full**				**Partial**		**None**			**Full**	**Partial**	**None**
Type	**T1**		**T2**	**T3**				**T4**		**T5**			**T1/3**	**T2/4**	**T5**
Site	**1**	**6**	**7**	**2**	**3**	**4**	**8**	**9**	**10**	**12**	**13**	**14**	**5**	**11**	**15**
Pedestrian provision															
Priority for crossing pedestrians	X	X	X	X	X	X	X	*	X	*	X	X			
Level change to cross carriageway	X				X		X				X				X
Deviation from desire line		X	X	X	X		X	X	X	X	X	X	X	X	X
Cycling provision															
Priority for crossing cyclist	X	X	X	X	X	X	X	X	X	X	X	X			
Level change to cross carriageway	X				X										
Continuous cycle track	X	X	***	X	X	X	X	X	X	X	X	X			
Continuous colour/material	X	X	X	X	X	X	X			X	X	X			X
Uni-directional							X			X	X			**	
Bi-directional	X	X	***	X	X	X		X	X			X	X	**	X
Side road direction															
Two-way side road	X	X	X	X	X	X	X	X	X	X	X		X	X	X
One-way turn out only															
One-way turn in only												X			
Carriageway markings & visibility															
Cycle symbol markings	X	X	X			X	X			X	X	X			X
Give away markings for turn in	X	X	X	X	X	X	X	X	X	X	++	X			
Give away markings for turn out	X			X		X	X			X	X		X		
Speed hump triangles	X					X	X				X		X	X	X
Good visibility	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Left turn in kerb radius (metres)	10	15	8	10	5	6	20	8	10	7	5	1	15	3	3
Similar adjacent treatments															
1 adjacent junction				X	X										X
2-4 adjacent junctions										X		X			
5-9 adjacent junctions			X				X	X	X		X			X	

**Only over vehicles turning into the side road; **Uni-directional on one side and bi-directional on the other; ***shared space; ++ Traffic Signs Regulations and General Directions Diagram 1055.3 marking (Elephant's footprint) used.*

Tables 1, 2 and 3 reveal that there are detailed variations of characteristics that may influence the junction's nature and use beyond the three dimensions of i) Marked Priority or not, ii) level of set-back and iii) presence or otherwise of a zebra crossing. In addition to the physical characteristics of the junction, the level of crossing and turning flows may influence the nature of interactions.

2.2 Methodology

Observational studies were carried out using video footage. This was undertaken with the survey partner, Tracsis Traffic Data Ltd, using their 'Felicity' Artificial Intelligence Software.

Video cameras were set up by Tracsis at the selected junctions as per the schedule in Table 4. Twenty-four hours of footage were collected during daylight at each location over two consecutive weekdays at each site. Filming was from 7am to 7pm on each day to cover morning peak, interpeak and evening peak traffic. Weekdays were chosen when local schools and universities were in session and after it had been verified that walking, cycling and driving activity had returned to the sites following the various Covid-19 pandemic restrictions.

Table 4 Survey times and dates by location

Location	Date
Bedford	26 & 27/5/2021
Birmingham (two sites)	16 & 17/6/2021
Cheltenham	22 & 23/6/2021
Liverpool	26 & 27/5/2021
London (seven sites)	8 & 9/6/2021 (five); 29 & 30/6/2021 (one); 30/6 & 1/7/2021 (one)
Yorkshire (Bradford, Leeds and York)	18 and 19 May 2021

One to three cameras (depending on site requirements) were used per site and positioned on adjacent lampposts. An example of a still taken from the video is shown in Figure 5.

Figure 5 Vehicle on side road yielding to crossing pedestrian, Cheltenham (Site 2)

Types of interaction were categorised as shown in Table 5. There are three types of carriageway user (drivers, cyclists and users of other wheeled vehicles such as mobility scooters), and four yielding and positioning behaviours they may adopt (based on whether they proceed or stop in one of three different positions). This makes twelve combinations. There are then nine combinations of three footway or cycle track user types (pedestrians, cyclists and users of other wheeled vehicles such as wheelchairs, mobility scooters, and prams and pushchairs) and their three yielding and positioning behaviours. Hence, there are 108 (twelve by nine) possible types of interaction. Yielding behaviours of people crossing are further defined in Section 2.4.1.

Table 5 Description of the 108 types of interaction

Carriageway users	Carriageway user yielding behaviours	Footway or cycle track users	Footway or cycle track user yielding behaviours
1 Driver	1 proceeds forward	1 Pedestrian	1 yields
2 Cyclist	2 stops behind Marked Priority	2 Cyclist	2 continues to cross in front
3 Other	3 stops on foot crossing	3 Other	3 continues to cross behind
	4 stops on cycle crossing		

Other is defined as someone who is using Time stamps were recorded by Tracsis for every interaction so that more detailed analysis could be carried out by UWE. In addition to the internal quality assurance measures employed by Tracsis, a small sample of video footage from different sites was checked by UWE to confirm the validity of the coding. The video footage was examined to determine the types of yielding behaviour and this is discussed in the next section.

2.3 Turning movement volumes by time of day

Table 6 provides data on the turning volumes at each junction for the peak hour of flow.

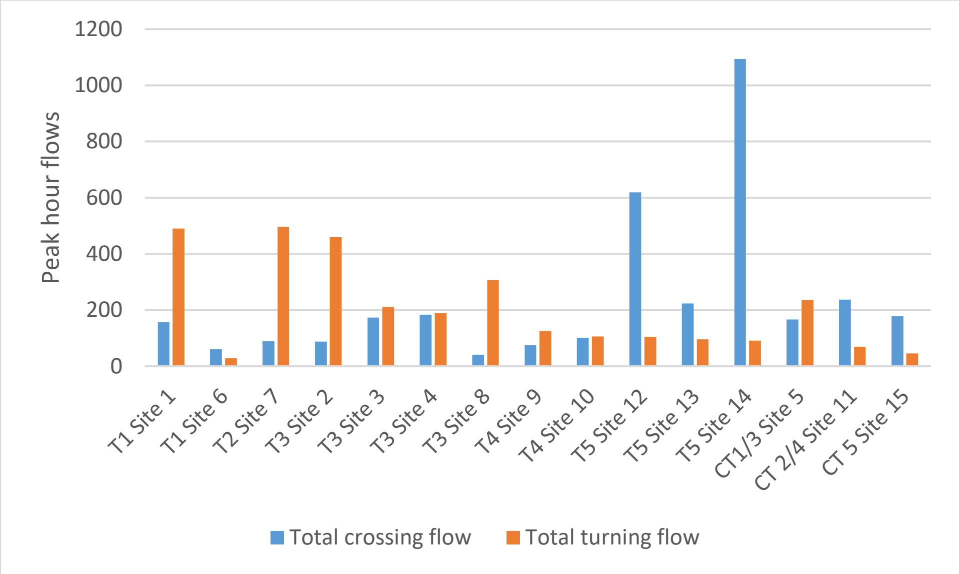
Table 6 Peak hour flows at each junction

Type, site number, city, and location	Crossing flows				Carriageway flows	
	Peds	Cycle	Other	Total	Turns in and out	two-way main road flow
T1 Site 1 Birmingham Milton street / A34	100	40	17	157	490	1,514
T1 Site 6 Bradford Valley Rd / Inkersley Rd	23	37	0	60	28	662
T2 Site 7 Birmingham Olton Blvd East / Summer Rd	86	2	1	89	496	372
T3 Site 2 Cheltenham Hesters Way Rd / Prin. Elizabeth Way	66	22	0	88	460	1,347
T3 Site 3 Bedford Bedford Road / B531	111	46	16	173	211	1,030
T3 Site 4 Kingston Denmark Rd / Penrhyn Rd	156	26	2	184	189	1,104
T3 Site 8 Leeds Wykebeck Valley Rd / A64	19	21	1	41	307	1,087
T4 Site 9 Ickenham High Road / Heacham Ave	59	14	2	75	125	2,001
T4 Site 10 Ickenham High Rd / Austin's Lane	86	7	9	102	106	2,117
T5 Site 12 Camden Byng Place / Gordon Square	360	250	9	619	105	403
T5 Site 13 Enfield Sebastopol Rd / Fore Street	195	20	8	223	96	1,048
T5 Site 14 Hyde Pk West Carriage Drive	353	728	12	1,093	91	573
CT1/3 Site 5 York Hallfield Rd / James Street	97	69	0	166	236	682
CT 2/4 Site 11 Liverpool Park Lane / Forrest St	204	16	17	237	70	520
CT 5 Site 15 Brentford Boston Manor Rd / Boston Gardens	82	93	3	178	46	858

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 (Site 14).

Six sites had more vehicles turning in and out of the side road then people crossing the side road (Sites 1, 2, 5, 7, 8 and 9, shaded grey), while five had clearly more people crossing than turning in and out (Sites 11, 12, 13, 14 and 15, shaded grey). The remainder of junctions (Sites 3, 4, 6, and 10) were more balanced in terms of the crossing versus carriageway flow. The data is also shown graphically in Figure 6.

Figure 6 Comparing crossing flows with turn volumes



Except for the Type 1 Site 6 junction, all Type 1 and Type 2 sites, that is to say sites with a zebra crossing, have higher turning flows than crossing flows. However, Site 6 has low flows both crossing and turning. For Type 3 sites (full set-back and no zebra), there is a mix of two with higher turning flows (Sites 2 and 8) and two with more balanced flows (Sites 3 and 4). For the two Type 4 sites (partial set-back and no zebra), the flows are evenly balanced.

All three Type 5 sites, with no set-back, have higher crossing flows than turning flows, as does the control site for this type, Site 15. Site 5 is the control site for Type 1 and 3 sites with full set-back and, like the Site 1, has a higher turning flow. Site 11 is the control site for Type 2 and 4 sites with partial set-back and has higher crossing flows than turning flows, which is unlike the Type 2 site which has a higher turning flow than crossing flow, and unlike the two Type 4 sites, which have fairly evenly balanced, and low crossing and turning flows.

It should be noted that in the earlier Design Priority study (Flower et al. 2021) it was suggested that continuous crossings work better in situations where more people cross the side road compared with the numbers turning in and turning out of the side road. The analysis presented in Section 2.4 discusses the impacts of flow at all types of junction (control, Marker Priority and Design Priority).

2.4 Analysis of the interactions

This section has four parts. Section 2.4.1 presents data on the types of yield for the twelve Marked Priority junctions, three control sites, and data on yields at ten junctions from the previous Design Priority study (Flower et al., 2021). Section 2.4.2 then presents the data on the following: i) the type of yield in relation to the level of set-back of the crossing from the main road kerb line; ii) variations in yielding behaviour by type of person crossing, iii) their pathway (either in front of or behind the vehicles turning); and iv) data on any visible reactions recorded from the video for the people crossing. Section 2.4.3 presents data on driver behaviour and the type of turn being made. Finally, Section 2.4.4 presents a model of the number of forced yields as explained by junction type and turning and crossing flows.

2.4.1 Type of yield for Marked Priority, control sites and Design Priority

Interactions have been defined as the intersection of the path of a vehicle turning in or turning out of the side road with the path of a person walking or cycling across the side road. Yields are defined in three ways as follows:

- No yield by the person crossing road (**No yield**);
- voluntary yield by the person crossing the road to a turning vehicle (**Voluntary yield**) and;
- a yield forced onto the person crossing by the driver the vehicle (**Forced yield**).

It is important to note 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 traffic engineering and road safety research where the viewpoint of the driver of a vehicle is typically adopted.

Tracsis, the fieldwork contractor, undertook initial analysis of the video data to identify the total number of interactions taking place at the junctions. In addition, further and much more detailed analysis of the video was undertaken by UWE of a sub-set of these interactions, which had been time stamped by Tracsis. A member of the UWE research team viewed every interaction that resulted in a person crossing yielding to a turning vehicle.

Forced yields are of primary concern because they are the ones that may lead to collisions. The time-lapsed stills in Figure 7 are taken from one of the videos at site 13 and illustrate a forced yield. A woman approaches the marked priority crossing on foot at 08:43:29 and notes to her right that a van is approaching at speed along the side road. It is still four seconds away which at 20 mph would be 36m. In the second image at 08:43:32 the van can be seen approaching and it has failed to return to the left-hand side of the road after overtaking some parked cars. In the next frame, 08:43:33 the woman seems to assess that the driver has no intention of giving way at the markings and stops short of the kerb. Note that the driver appears to maintain a central road position to maintain speed while entering the main road. In the final frame, 08:43:34 the emerging van can be seen forcing the woman to yield. The driver did not slow down to Give Way at the Give Way road markings and turned left on to the main carriageway without stopping.

Figure 7 Example of the reaction of a person crossing

The data were extracted into a spreadsheet for each interaction observed. Table 7 summarises the total number of interactions identified by Tracsis and their nature in terms of whether people walking, cycling, or using other means to cross the side road yielded to drivers turning into the side road.

Table 7 Number of yields by type by the person crossing for Marked Priority and control sites

	Number of yields by type				Percentages			
Type and site	**None**	**Voluntary**	**Forced**	**Total**	**None**	**Voluntary**	**Forced**	**Voluntary and forced**
T1 Site 1 Birmingham	743	1	155	899	82.6%	0.1%	17.2%	17.4%
T1 Site 6 Bradford	34	0	11	45	75.6%	0.0%	24.4%	24.4%
T1 Total (with zebra)	777	1	166	944	82.3%	0.1%	**17.6%**	**17.7%**
T2 Site 7 Birmingham	1,575	0	142	1,717	91.7%	0.0%	8.3%	8.3%
T2 Total (with zebra)	1,575	0	142	1,717	91.7%	0.0%	**8.3%**	**8.3%**
T3 Site 2 Cheltenham	270	0	325	595	45.4%	0.0%	54.6%	54.6%
T3 Site 3 Bedford	424	2	261	687	61.7%	0.3%	38.0%	38.3%
T3 Site 4 Kingston	827	2	158	987	83.8%	0.2%	16.0%	16.2%
T3 Site 8 Leeds	64	249	0	313	20.4%	79.6%	0.0%	79.6%
Type 3 Total (no zebra)	1,585	253	744	2,582	61.4%	9.8%	**28.8%**	**38.6%**
T4 Site 9 Ickenham	333	0	84	417	79.9%	0.0%	20.1%	20.1%
T4 Site 10 Ickenham	294	0	57	351	83.8%	0.0%	16.2%	16.2%
Type 4 Total (no zebra)	627	0	141	768	81.6%	0.0%	**18.4%**	**18.4%**
T5 Site 12 Camden	231	0	287	518	44.6%	0.0%	55.4%	55.4%
T5 Site 13 Enfield	330	1	112	443	74.5%	0.2%	25.3%	25.5%
T5 Site 14 Hyde Park	459	0	196	655	70.1%	0.0%	29.9%	29.9%
Type 5 Total (no zebra)	1,020	1	595	1,616	63.1%	0.1%	**36.8%**	**36.9%**
Marked Priority Total	5,584	255	1,788	7,627	**73.2%**	**3.3%**	**23.4%**	**26.8%**
CT1/2 Site 5 York	231	546	0	777	29.7%	70.3%	0.0%	70.3%
CT2/4 Site 11 Liverpool	178	0	91	269	66.2%	0.0%	33.8%	33.8%
CT5 Brentford	107	0	39	146	73.3%	0.0%	26.7%	26.7%
Control total	516	546	130	1,192	**43.3%**	**45.8%**	**10.9%**	**56.7%**
Total (combined)	6,100	801	1,918	8,819	69.2%	9.1%	21.7%	30.8%

Note: recall that 'Forced yield' indicates that the people walking or cycling yielded, but had no choice other than to yield, because the turning vehicle took priority

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. We discuss both measures.

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. York (5) is the only one of the three control site where there is no Give Way on the cycle track approaches. The design seems to have indicated to most people crossing that they did not have priority, and 70.3% yielded voluntarily, but there were no forced yields. By contrast, in Liverpool (11) and Brentford (15) the design treatment at the junction seems to have created ambiguity for drivers, who yielded to people crossing in most cases, and this is despite the Give Way markings on the cycle track. Subtle differences in the design and layout may have created this balance of priority.

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 zebra 8.3% to 17.6%) and with no zebra from (18.4% to 36.8%).

Site 8 is an example with no zebra at full set-back (T3, at Wykebeck Valley Rd / A64 Leeds). It is at an extreme with 79.6% of people crossing yielding voluntarily. The junction allows only the left turn-in and the left turn-out of the side road, and the kerb corner radii are large. The number of vehicles turning was many times higher than the numbers crossing. Drivers turn in at speed off the dual carriageway. This combination of design and speed seem to have created few forced yields, but many voluntary yields. People crossing perhaps do not trust they are safe to take priority.

With a zebra people crossing people yielded or had to yield for 17.7% of interactions with full set-back (T1) and for 8.3% of interactions with partial set-back (T2). This difference suggests that partial set-back may be preferable to full set-back. Without a zebra people crossing voluntarily yielded, or were forced to yield for 38.6% of interactions with full set-back (T3) and 18.4% of interactions for partial set-back (T4). Again, this suggests that partial set-back may be better than full set-back for reducing yielding by people crossing. It also indicates that the presence of a zebra as well as a cycle track priority crossing (i.e., a parallel crossing), reduces the number of yields by people crossing. With no set-back (T5) people crossing yielded in 36.9% of interactions. Hence, moving the crossing closer to the edge of carriageway than the partial set-back distance appears to offer no advantage. Set-back is discussed more fully in Section 2.4.2.

Table 8 summarises yield types in the Design Priority study.

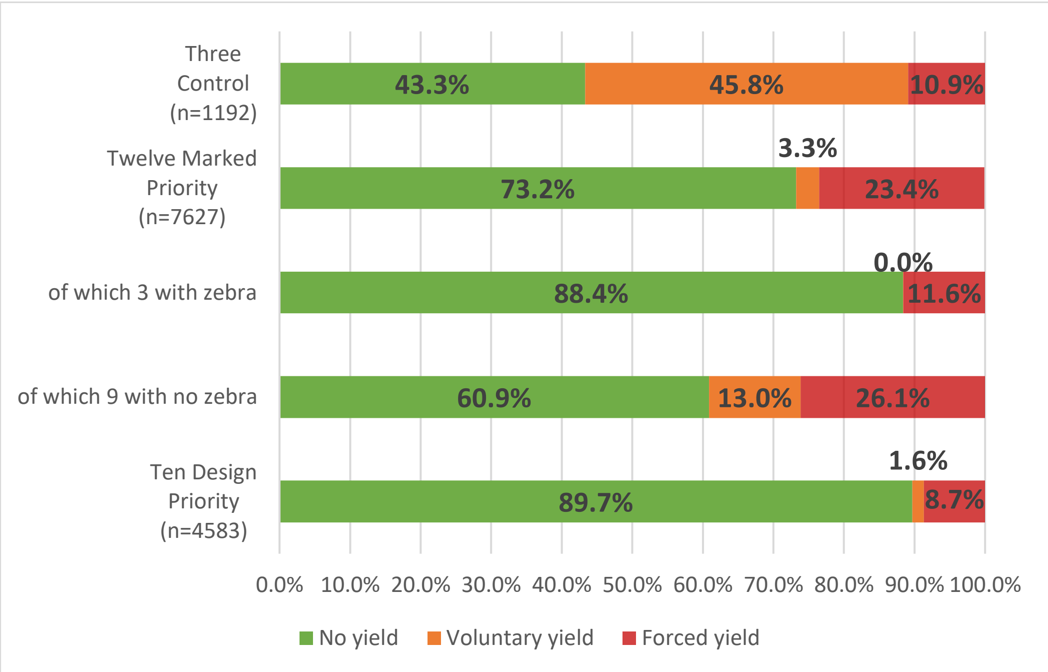
Table 8 Number of yields by type by the person crossing for Design Priority junctions

Site	Number of yields by type: None	Voluntary	Forced	Total	Percentage: None	Voluntary	Forced	Voluntary and forced
T7 Site 94 London, Stratford	194	2	10	206	94.2%	1.0%	4.9%	5.8%
T7 Site 96 Edinburgh	47	7	32	86	54.7%	8.1%	37.2%	45.3%
T7 Site 98 London, Leyton	64	6	33	103	62.1%	5.8%	32.0%	37.9%
T7 Total	305	15	75	395	77.2%	3.8%	19.0%	22.8%
T8 Site 91 Leeds	29	0	0	29	100.0%	0.0%	0.0%	0.0%
T8 Site 92 London, Oval	1,018	2	5	1,025	99.3%	0.2%	0.5%	0.7%
T8 Site 93 London, Kingston	1,254	4	14	1,272	98.6%	0.3%	1.1%	1.4%
T8 Site 95 Nottingham	28	1	1	30	93.3%	3.3%	3.3%	6.7%
T8 Site 97 Southampton*	214	34	132	380	56.3%	8.9%	34.7%	43.7%
T8 Site 99 Walthamstow*	1,121	9	131	1,261	88.9%	0.7%	10.4%	11.1%
T8 Site 910 London, Clapham*	144	8	39	191	75.4%	4.2%	20.4%	24.6%
T8 Total	3,808	58	322	4,188	90.9%	1.4%	7.7%	9.1%
Total	4,113	73	397	4,583	**89.7%**	**1.6%**	**8.7%**	10.3%

*Note: recall that 'Forced yield' indicates that the people walking or cycling yielded, but had no choice other than to yield, because the turning vehicle took priority. *Continuous footway with cycle lane across junction*

Figure 8 summarises the overall yield proportions from Tables 7 and 8 for the control sites, Marked Priority and Design Priority.

Figure 8 Summary of proportions of yield types by type of junction



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.

Care must be taken in these comparisons with the control sites because of the unusual nature of the site in York. Excluding York, the proportion of no yields at the remaining two control sites is 68.7%, and forced yields is 31.3%. There were no voluntary yields at these two sites. Accounting for this, it may still be seen that both Marked Priority with zebras and Design Priority increase the proportion of no yields.

At Design Priority sites there was a proportion of 8.7% forced yields. This compares with 10.9% at control sites and 11.6% at Marked Priority with zebras. However, at Marked Priority without zebras forced yields occur at 26.1% of interactions. Without taking account of the flows, the sample of junctions shows that Marked Priority is 3.27 times as likely (in aggregate) to have forced yields as junctions with Design Priority ($\chi^2\ (1) = 433.5, p < 0.01$). Similarly, Marked Priority is 2.51 times as likely to have forced yields as the three control sites ($\chi^2\ (1) = 95.97, p < 0.01$). It is only Design Priority Junctions that have fewer forced yields than the control sites by a factor of 0.767 ($\chi^2\ (1) = 6.157, p = 0.013$). These differences are analysed further in Section 2.4.4. That analysis accounts for the crossing and turning flows and, at Marked Priority, the presence or absence of a zebra (i.e., a parallel crossing).

2.4.2 Set-back, type of person crossing and their pathway

Table 9 summarises yield types from Tables 7 and 8 grouped by level of set-back. At Design Priority junctions, pedestrians may cross the side road on the main road side of the cycle track (even though there may be full or partial set-back of the cycle track). Hence there is in effect no set-back for pedestrians. It would be appropriate, therefore, to consider the yield characteristics of pedestrians and cyclists separately in relation to set-back. However, the cycle flows are so low that no pattern emerges. Hence, the remainder of this discussion considers pedestrian and cyclist flows combined.

Table 9 Yields by type aggregated for full, and partial and no set-back

	Number of yields by type				Percentages			
Level of set-back	No yield	Voluntary	Forced	Total	No yield	Voluntary	Forced	Voluntary and forced
Marked Priority								
Full set-back (n=6)	2362	254	910	3526	66.99%	7.2%	25.8%	33.0%
Partial set-back (n=3)	2,202	0	283	2,485	88.61%	0.0%	11.4%	11.4%
No set-back (n=3)	1,020	1	595	1,616	63.12%	0.1%	36.8%	36.9%
Design Priority								
Full set-back (n=0)								
Partial set-back (n=3)	305	15	75	395	77.2%	3.8%	19.0%	22.8%
No set-back (n=7)	3,808	58	322	4,188	90.9%	1.4%	7.7%	9.1%
Control								
Full set-back (n=1)	231	546	0	777	29.7%	70.3%	0.0%	70.3%
Partial set-back (n=1)	178	0	91	269	66.2%	0.0%	33.8%	33.8%
No set-back (n=1)	107	0	39	146	73.3%	0.0%	26.7%	26.7%

At Marked Priority junctions full set-back (Types 1 and 3), 33.0% of people crossing yielded (either voluntarily or having been forced), and this compares with 70.3% at the single control site with full set-back. Note that there are no Design Priority junctions with full set-back from the previous study.

For crossings with partial set-back at Marked Priority junctions (Types 2 and 4), a lower proportion of 11.4% of yields were made, and this compares with 33.8% at the single control site and 22.8% at the three Design Priority sites. With no set-back, the proportion of yields at Marked Priority junctions was 36.9%, but lower at the control site (26.7%) and lower again at the seven Design Priority sites (9.1%). Note that the partial set-back junctions for Design Priority included Edinburgh which was one-way with only turns into the side road and had a bus lane which creates a more sweeping turn for traffic turning left into the side road. Both of these features may contribute to higher yields by people crossing. The junction at Leyton also had a bus lane. Finally, the third junction was at Stratford which had a low number of yields by people crossing. It can be seen then, that the aggregate proportions of yields for Design Priority are masking site related issues.

For sites with no set-back, Design Priority has the lowest proportion of yields at 9.1%, with the control site at 26.7% and Marked Priority with the greatest proportion of yields at 36.9%. The site at Camden follows the design of an LTN 1/20 type T5 layout with the Give Way line on exit from the side road being positioned adjacent to the cycle track hence offering no enhanced priority for people crossing. Camden has the highest proportion of forced and voluntary yields at 55.4%, and this is increasing the mean value for this type of crossing.

Set-back is further considered in the modelling in Section 2.4.4.

Table 10 shows the types of yield made by pedestrians, cyclists and other users. Note that most people crossing were pedestrians: 75% for Marked Priority crossings, 68% at the control sites and 72% at the Design Priority junctions.

Table 10 Number of yields for pedestrians, cyclists and others

Junction and yield type	Pedestrian	Cyclist	Others	Total
Marked Priority				
Voluntary yield	224	32	1	257
Forced Yield	1,499	262	33	1794
Total	**1,743**	**294**	**34**	**2,051**
Percentage	**85%**	**14.5%**	**1.5%**	
Control				
Voluntary yield	294	250	1	545
Forced Yield	105	19	6	130
Total	**399**	**269**	**7**	**675**
Percentage	**59%**	**40%**	**1%**	
Design Priority				
Voluntary yield	70	4	1	75
Forced Yield	373	17	9	399
Total	**443**	**21**	**10**	**474**
Percentage	**93.5%**	**4.5%**	**2.0%**	

85% of voluntary and forced yields at Marked Priority are with pedestrians, but 75% of interactions were with pedestrians, and hence pedestrians are over-represented compared with cyclists and other users. Similarly, at Design Priority 93.5% of voluntary and forced yields were with pedestrians compared with 72% of interactions being with pedestrians. Again pedestrians are over-represented. For the control sites, however, the proportion of the pedestrian interactions is 68% and the proportion of the voluntary and forced yields is 59%, suggesting that voluntary and forced yields are over-represented for cyclists.

Table 11 presents data on the pathway taken by people crossing the side road, which can either be in front of, or behind the vehicle in the side road waiting to cross. These data are for the occasions when the pedestrian or cyclist is not yielding to the turning traffic.

Table 11 Pathway of pedestrian or cyclist relative to the yielding vehicle

Junction type	Pathway	Pedestrian	Cyclist	Other	Total
Marked Priority	In front	2,776	933	97	3,806
(n=12)	Behind	1,429	354	34	1,817
	Total	**4,205**	**1,287**	**131**	**5,623**
Control sites	In front	168	74	4	246
(n=3)	Behind	182	83	5	270
	Total	**350**	**157**	**9**	**516**
Design Priority	In front	1146	1108	-	2254
(n=10)	Behind	1820	35	-	1855
	Total	**2970**	**1143**	**-**	**4109**

The patterns of movement that emerge by junction type and mode are heterogeneous, as follows:

- At Marked Priority junctions about twice as many pedestrians cross in front of the vehicle giving way as those crossing behind, and for cyclists it is nearly three times.
- For the control sites there is little difference between the numbers crossing in front and those crossing behind.
- For Design Priority junctions more pedestrians cross behind the vehicle giving way than those that cross in front, but almost all cyclists cross in front.

There is a different pattern of behaviour at each junction type. Marked Priority is regularising the pathway in front of the vehicle giving way. For Design Priority and control sites there is more crossing behind than in front by pedestrians. However, Design Priority appears to regularise the pathway of cyclists to almost always be in front of the vehicle giving way, suggesting that Design Priority cycle crossings are used as intended by cyclists.

Table 12 provides more detail on the pathway in relation to the direction of the turning traffic. The data for Design Priority are based on the smaller sample of more detailed analysis undertaken by UWE, and hence the total of 1,549 (the number at the bottom right of the table) is lower than the total of 4,109 in Table 11.

Table 12 Numbers crossing in front and behind the vehicle turning at Marked Priority junctions

Junction type	Crossing point	Pedestrian or cyclist	In left	In right	Out left	Out right	Total
Marked Priority (n=12)	In front	Pedestrian	283	493	808	957	2,541
		Cyclist	315	207	209	193	924
	Behind	Pedestrian	70	56	459	822	1,407
		Cyclist	28	36	95	146	305
	Total		**696**	**792**	**1571**	**2118**	**5177**
	Percentage pedestrians behind		19.8%	10.2%	36.2%	46.2%	35.6%
	Percentage cyclists behind		8.2%	14.8%	31.3%	43.1%	24.8%
Control sites (n=3)	In front	Pedestrian	17	21	90	40	168
		Cyclist	3	1	36	34	74
	Behind	Pedestrian	5	19	103	55	182
		Cyclist	4	8	25	22	59
	Total		**29**	**49**	**254**	**151**	**483**
	Percentage pedestrians behind		22.7%	47.5%	53.4%	57.9%	52.0%
	Percentage cyclists behind		57.1%	88.9%	41.0%	39.3%	44.4%
Design Priority (n=10)	In front	Pedestrian	69	47	232	29	377
		Cyclist	19	30	841	18	908
	Behind	Pedestrian	10	11	189	45	255
		Cyclist	0	1	8	0	9
	Total		**98**	**89**	**1270**	**92**	**1549**
	Percentage pedestrians behind		12.7%	19.0%	44.9%	60.8%	40.3%
	Percentage cyclists behind		0.0%	3.2%	0.9%	0.0%	1.0%

The table indicates the percentages of pathways that were behind the vehicle. The percentages that pass behind for flows turning out of the side road range 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 for both Marked Priority and Design Priority. This is because vehicles turning out of the side road may be blocking the pathway.

The pattern is slightly different for the control sites. The percentage of pedestrians passing behind vehicles turning out is relatively high compared with enhanced junctions. In contrast to enhanced sites, cyclists more often passed behind the vehicle when it had turned into the side road, rather than when it was turning out.

Table 13 presents data on the reaction that was determinable from the video for 1,892 of the cases that the pedestrian or cyclist had when engaging in an interaction.

Table 13 Reaction of person crossing by yield type for Marked Priority and controls

	No yield	Voluntary yield	Forced yield	Total
Adjusts route and proceeds behind vehicles	4	8	1,645	**1,657**
Recoils / steps back	0	0	56	**56**
Acknowledges yield and proceeds	0	0	53	**53**
Stops short of kerb line	0	0	52	**52**
Turns head to vehicle	0	0	21	**21**
Adjusts route and proceeds in front of vehicle	2	0	16	**18**
Uses pre-existing dropped kerb	0	0	16	**16**
Adjusts route proceeds in front and acknowledges	0	0	9	**9**
Walks on the spot	0	0	7	**7**
Acknowledges yield but waves vehicle on	0	0	3	**3**
Crosses when others do	0	0	0	**0**
	6	8	1,878	**1,892**

By far the most common reaction after being forced to yield is for the person crossing to adjust their route and proceed behind the turning vehicle. The other main types of reaction are: 'recoils / steps back'; 'acknowledges yield and proceeds' (presumably usually in response to an acknowledgement by the driver, not seen on the video); and 'stops short of the kerb line'.

2.4.3 Influence of driver turn behaviour on yield type

Table 14 summarises the type of yield made by the person crossing for different driver turn behaviours. Note that this was categorised for 655 cases.

Table 14 Yield type by person crossing for for Marked Priority and control combined

Driver turn behaviour	Voluntary yield	Forced yield	Total
Illegal manoeuvre		3	**3**
Multiple stops at cycle track and footway		85	**85**
Changes from making right to left turn after delay		11	**11**
Right turn in, waiting for gap in traffic	3	551	**554**
Turns from carriageway into cycle track/lane		2	**2**
Total	3	652	**655**

The most common behaviour creating a forced yield is linked to the right turn into the side road when the driver may be waiting for gap in the on-coming traffic stream. The second most common behaviour relates to multi-stage movements when the turning driver takes the turn in stages and straddles either the pedestrian or cyclist crossing point while waiting for a gap in traffic to turn. Types of illegal manoeuvre included going the wrong way up a one-way street and making a banned turn. It should be noted that these illegal manoeuvres are not linked directly with the fact that a Marked Priority junction was present.

The person crossing the side road may be travelling in the same direction as the main road flow in the lane nearest the side road, or they may be travelling in the opposite direction to this main road flow. Table 15 shows the number of yields by the people crossing by both the nature of turn being made by the driver and the direction of travel of the person crossing relative to the main road near-side lane flow. These data are for both the twelve Marked Priority junctions and the three control sites.

Table 15 Number of yields by type by direction of crossing flow and turn flow direction

Vehicle turn	**No yield**		**Voluntary yield**		**Forced yields by crossing direction (relative to main road flow)**		**Total forced yields**		**Number of interactions**
Marked Priority					**With flow**	**Against flow**			
Left In	714	47.5%	179	11.9%	322	288	610	40.6%	1503
Right In	820	59.0%	3	0.2%	285	281	566	40.7%	1389
Left Out	1611	79.8%	72	3.6%	161	174	335	16.6%	2018
Right Out	2161	90.0%	3	0.1%	108	129	237	9.9%	2401
U-turn	270	85.4%	0	0	23	23	46	14.6%	316
Total	5576		257		899	895	1794		7627
Control sites									
Left In	29	17.4%	103	61.7%	15	20	35	21.0%	167
Right In	50	18.7%	163	60.8%	27	28	55	20.5%	268
Left Out	280	57.1%	185	37.8%	9	16	25	5.1%	490
Right Out	157	59.0%	94	35.3%	10	5	15	5.6%	266
Total	516		545		61	69	130		1191

At control sites, for the left turn in and the left turn out, most yields are voluntary yields (left turn in 61.7% and right turn in 60.8%). Over a third of interactions are voluntary yields for the turn out movements (37.8% left turn out and 35.3% for the right turn out). This suggests people crossing at control sites are negotiating their way with drivers and cyclists on the carriageway. Around a fifth of left turns in (21.0%) and right turns in (20.5%) are forced yields, but this is much lower for the left turn out (5.1%) and the right turn out (5.6%).

By contrast with control sites, Marked Priority junctions have many fewer voluntary yields (ranging from virtually none up to 11.9% for the left turn in). However, there are many more forced yields at Marked Priority junctions than control sites, especially for the left turn in (40.6%) and right turn in (40.7%). The left turn out and right turn out proportions of forced yields are lower (16.6% and 14.6%), but still higher than for the control sites.

There may be more forced yields with more generous turning radii. It is the left turn in and the left turn out that are the relevant movements, because drivers turning right will generate their own pathway, which is less related to the kerb line. There is not statistically significant correlation, however, between the proportion of forced yields and the corner radii for the left turns (see Table 3 for the kerb radii).

Table 16 shows the same data as Table 15 but for Design Priority.

Table 16 Number of yields by type and nature of the turn at Design Priority junctions

Vehicle turn	No yield		Voluntary yield		Forced yields by crossing direction (relative to main road flow)		Total forced yields		Number of interactions
Design					**With flow**	**Against flow**			
Left In	101	44.1%	12	5.2%	75	40	116	50.7%	229
Right In	92	33.0%	27	9.7%	82	78	160	57.3%	279
Left Out	1272	91.6%	29	2.1%	46	41	88	6.3%	1389
Right Out	92	73.6%	5	4.0%	15	13	28	22.4%	125
Total	1557		73		218	172	392		2022

As with to Marked Priority junctions, Design Priority junctions demonstrate lower proportions of voluntary yields than the control sites. Again, there are slightly higher proportions of voluntary yields for the left turn in (5.2%) and the right turn in (9.7%) than for the left turn out (2.1%) and the right turn out (4.0%). The pattern of forced yields is different between Marked Priority junctions and Design Priority junctions. Half of all interactions at Design Priority junctions are forced yields for the turns in (left in 50.7% and right in 57.3%), which is a greater proportion than the 40.6% and 40.7%

for Marked Priority. For the turns out, the left turn out is lower (6.3%) than for Marked Priority (16.6%) and the right turn out is higher (22.4%) than for Marked Priority (14.6%).

The direction of flow of people crossing does not appear to affect the types of yield, except for left turns in, which have more forced yields by people crossing with the main road traffic flow than against the main road traffic flow (75 with as opposed to 40 against the flow). This is logical because a driver turning in left would see people on the footway or cycle track that were approaching from ahead, but by contrast they may fail to properly turn to their left to look to check for people crossing in their direction of travel. A resulting collision from such an interaction would be called a 'left hook' collision.

The direction of flow of people crossing also affects the type of yield at Marked Priority, control sites and Design Priority junctions. For Marked Priority the significant difference by flow direction (χ^2 $(2) = 35.83,\ p < 0.001$) results from more forced yields compared to voluntary yields for the contraflow direction of travel. For the control sites, there are significantly more voluntary yields as compared with no yields (χ^2 $(2) = 7.258,\ p = 0.027$). For Design Priority, the picture is more mixed, with fewer yields and forced yields than would be expected in the contraflow direction, and more voluntary yields than would be expected (χ^2 $(2) = 6.67,\ p = 0.036$).

The impact of turning flows on the number of yields is now explored more fully in Section 2.4.4.

2.4.4 Model of the number of forced yields explained by junction type and flows

A range of modelling has been undertaken summarised in Table 17. The dependent variable is the number of forced yields, or the number of forced and voluntary yields, in a 15-minute period. The flows relate to the 15-minute period. The distribution of the number of yields will follow a negative binomial regression model with log link.

Table 17 Summary of modelling of undertaken

No.	1 Yield	2 Junction type	3 Crossing flows	4 Turn flows	5 Set-back	7 Zebra	8 Flow product	6 Site	9 Ratio of flows	10 Interactions
1	F	Y	D	Y						
2	F	Y	D	Y	Y					
14	F	Y	D	Y		Y				
15	F	Y	D	Y	Y	Y				
5	F	Y	D	Y			Y			
6	F	Y	D	Y						2x3+2x4
16	F	Y	D	Y		Y				2x3+2x4
7	FV	Y	D	Y						
9	FV	Y	A	Y						
8	F	Y	A	Y						
13	F	Y	A	Y					Y	
10	F	Y	A	Y						2x3+2x4
11	F	Y	A	Y						3x4
12	F		A	Y						2x3+2x4
3	F		D	Y	Y					
4	F		D	Y				Y		

Notes for each column

1 F= Number of forced yields, FV = number of forced and voluntary yields

2 variable for Marked and Design Priority with the based being the control junction

3 D = Disaggregated into pedestrian, cyclist and other, for with flow and contra-flow, A = aggregated for with flow and contra-flow

4 Aggregated turn flows for the four turning directions

5 Categorical variable for level of set-back with the based being no set-back

6 Each of the twenty-five sites represented as a categorical variable

7 Categorical variable for the presence of a zebra (i.e. a parallel crossing) at Marked Priority

8 Total crossing flow multiplied by total turning flow divided by 100

9 Ratios of both aggregate with and contra-flows to aggregate turning flow (two variables)

10 Indicates which columns have interaction terms in the model

The six models after Model 1 are iterations on Model 1 (2, 14, 15, 5, 6 and 16). They contain a categorical variable for junction type, crossing flows disaggregated by type of person crossing, and turning flows. They test for set-back, presence of a zebra, the product of the aggregate flows, and interactions of the junction type with flows.

Models 7 and 9 use the total of forced and voluntary yields as the dependent variable, with Model 9 considering the crossing flows aggregated by direction. The next five models (8, 13, 10, 11 and 12) use crossing flows aggregated by direction, with the final model excluding a categorical variable for the junction type. The final two models similarly exclude the junction type and instead use set-back and a categorical variable for the specific site.

All the models had similar explanatory power, but many models had many non-significant terms, especially the models with interactions terms. Individual non-significant interaction terms were eliminated, but these models were rejected when a main effect was turned non-significant. The flows with crossing flows disaggregated by type of person crossing provide a better insight than the models with the crossing flow aggregated. This is partly because there is evidence from the descriptive analysis that there are differences by type of person crossing, and partly because designers are interested in the different effects for different users.

The models that aggregated voluntary and forced yields as the dependent variable (7 and 9) did not offer additional insight as compared with their equivalent that used forced yields (1 and 8). The two models that did not have a categorical variable for the junction type (3 and 4) had many non-significant variables. In the case of the model that used only set-back (3), one of the categorical variables was not significant, and both categorical variables were not significant for set-back for Models 2 and 15. The flow product in Model 5 was a significant variable but does not add additional insight.

As a result of the considerations above, Model 14 has emerged as the most instructive, and its results are shown in Table 18. It was expected that one of the models with (at least some) interaction terms between junction type and flow may have provided deeper insight. As noted above, there were no suitable models with interactions terms. Hence, the resulting model shows only a main effect of the junction type and presence of zebra, with no interplay between the nature of the junction type and flows.

Table 18 Number of forced yields regressed again the junction type and turning and crossing flows

Variables	Coefficient (β)	Wald Chi-Square	P value	Mean value	Elasticity
Dependent: number forced yields				1.56	
Intercept	-2.927	151.235	<.001		
Base: control site					
Marked Priority	1.249	77.212	0		3.487
Design Priority	0.353	3.779	0.052		1.423
Base: no zebra					
With zebra	-1.165	51.654	<.001		0.312
Pedestrian with flow	0.017	26.569	<.001	14.08	0.239
Cycle with flow	-0.001	0.182	0.669	10.86	-0.011
Other users with flow	0.164	15.622	<.001	0.56	0.092
Pedestrian contra flow	0.022	35.636	<.001	13.22	0.291
Cycle contra flow	0.009	6.816	0.009	4.50	0.041
Other users contra-flow	0.023	0.269	0.604	0.46	0.011
Left turn out flow	-0.001	0.142	0.706	13.79	-0.014
Right turn out flow	-0.001	0.044	0.833	9.28	-0.009
Left turn in flow	-0.009	3.83	0.05	12.18	-0.110
Right turn in flow	0.048	109.865	<.001	12.76	0.612
Log likelihood	-2143				
Akaike's Information Criterion	4380				
Negative binomial	1.25				

Marked Priority and Design Priority are categorical variables representing the presence of that type of junction relative to the control sites. The flows are divided into pedestrian and cyclist flows, and the flows of other types of people crossing. With flow indicates that the person crossing was proceeding in the direction of the flow of motor traffic on the main road on the nearside to the side road. Direction of travel on the footway relative to the main road flow may be important, and hence these flows are split into with (main road near-side) flow and contra-flow.

The aim of the modelling is to explore the data further and hence non-significant variables have been left in the model. The elasticities have been estimated for the mean value of the variables[i]. The model confirms that relative to control sites, marked priority and design priority created more forced yields, with more than 3.487 times as many forced yields for Marked Priority as for the

[i] The elasticity for a categorical predictor will change the fitted mean multiplicatively relative the excluded category by $\exp(\beta)$. Changing from a k^{th} (non-excluded) category to a j^{th} category will change the mean multiplicatively by $\exp(\beta_j - \beta_k)$. The elasticity for a numerical predictor at its mean value, x_j, is $\beta_j . x_j$. See here for further information.

control site. Design Priority demonstrates 1.423 times as many forced yields as for a control site. The effect of a switch from Design Priority to Marked Priority is to increase the number of forced yields by a factor of 2.450 (estimated as the $\text{Exp}\,(1.249 - 0.353)$). The p value for the Design Priority coefficient is marginally greater than the normal (arbitrary) cut-off of 0.05. It should be recalled that the quantum of data for the Design Priority study is less than for the Marked Priority study.

The presence of a zebra at a Marked Priority has a marked effect and reduces the number of forced yields by a factor of 0.312. Hence, combining the Marked Priority and zebra factor indicates that a parallel crossing increases the number of forced yields compared to the control junctions by a factor of 1.087. This suggests that all Marked Priority crossings ought to have parallel crossings, i.e. with a zebra.

A positive elasticity, for example 0.017 for pedestrians with flow, indicates that for every additional pedestrian who crosses, there are 0.017 additional forced yields occurring. In other words, it would take an additional pedestrian crossing flow of a 100 in a 15-minute period to generate just under two (1.7) additional forced yields.

Firstly, it is worth noting the non-significant variables as follows: i) the cycle flow in the direction of main road traffic on the nearside to the side road, ii) other users in the contra flow direction and iii) the both the left turn out and right turn out flows. Some of these parameter values are 'wrong sign' because it may be expected that any additional flow would increase the number of forced yields.

Considering now the significant turning flow coefficients, the right turn in (0.612) elasticity indicates that for every additional 10 vehicles turning in in a 15-minute period there would be just over 6 additional forced yields. This is a large effect size. The left turn in flow appears to be of wrong sign (-0.110), implying that an increase in the flow of traffic turning in left in has the effect of reducing the number of forced yields. As noted, it has been difficult to determine a convincing pattern if interactions, but it could be that the left turn in flow has a moderating effect on the propensity of the right turn in flow to increase forced yields.

A flow of pedestrians crossing in the contra-flow direction to the main road nearside flow of traffic create the greatest increases in the number of forced yields (0.291) which is marginally greater than for pedestrians in the with flow direction. It appears, however, that there is no need for additional concern about cycle traffic moving in the contra-flow direction, because the elasticity is lower than for the contra-flow pedestrian flow (0.041).

In sum, the model confirms that Marked Priority with only cycle track crossings and no zebra crossing generates 3.487 more forced yields than the control junctions, and a marked Priority with a parallel crossing generates 1.087 more forced yields. A Design Priority junction generates 1.423 more forced yields than the control junctions.

2.5 Summary of findings

People crossing side roads may not yield (as they need not) to turning traffic, or they may voluntarily yield. Drivers may also force people to yield. The following summarises the main findings from the observational study.

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 COLLISION INVESTIGATION

This section describes the collision analysis undertaken at the fifteen side road junctions for which observations have been made, as described in Table 1 (site with Marked Priority) and Table 2 (control sites). This chapter therefore provides evidence relating to the second objective of the research: to investigate the safety performance of different types of crossing using the collision record. The installation of Marked Priority crossings has been undertaken principally to enhance the priority for people crossing side roads, and not principally to reduce collisions risk. On this basis, the analysis has focused on the relation between the types of yield observed and the numbers of collisions, rather than a comparison of the collision record at these junctions with other junctions, as would be carried out for a collision reduction strategy.

Section 3.1 describes the methodological approach and Section 3.2 presents the results. Section 3.3 provide an interpretation of those results and Section 3.4 a summary.

3.1 Methodological approach

Collisions and injuries occurring on the public highway are reportable to the police. These data will underestimate the number of collisions and injuries because of under-reporting. This is a known general problem that is particularly pronounced in relation to cycling, and this results partly from the number of injuries that results from falls, which require medical treatment, but because they involve no other vehicle are less likely to be considered by the injured party as being reportable (e.g. Lyons et al., 2008).

The statistics relate only to personal injury collisions because damage only collisions are not reportable. The reporting can occur either because a participant in the collision reports the collision after the event, or, if the collision is more serious, it may be that the police attend the scene. The data recorded is often lacking in accuracy in some way. For those collisions reported after the event, the police record can only be as good as the historical recall of the participant and their ability to explain the collision. When the police attend, they only see the aftermath of the collision and they will still need to develop an understanding of the event from accounts provided to them.

These police collected data are shared with local authorities and are known as STATS19 data. All the local authorities (or in London, Transport for London) were approached for their STATS19 data. We could have derived the data from the STAT19 archive, however that would have required a significant task in extracting data from the dataset for the specific junctions of interest: bespoke software is used by local authorities to perform this task. Requests were made for the data for all personal injury road collisions for each junction for the five years prior to the implementation of the Marked Priority crossing or, for the control sites, prior to the implementation of the cycle track with Give Ways for cyclists. Similar requests were made for the 100m radius along each arm of the junction.

Table 19 shows the approximate installation date and the data that was provided by the local authorities. In some cases, it was clear there was some uncertainty as to exactly when the installation took place, with Site 3 in Bedford having been installed sometime between 1979 and 1985.

Table 19 Installation date and periods of data obtained from the collision record

		Before period		After period	
Site	Approximate date of the change	From	To	From	To
T1 Birmingham, Newtown (1)	December 2018	01/14	12/18	01/19	05/21
T1 Bradford (6)	May 2019	04/14	05/19	06/19	08/20
T2 Birmingham, Acocks Green (7)	December 2018	01/14	12/18	01/19	05/21
T3 Cheltenham (2)	December 2005	01/01	12/05	01/06	05/21
T3 Bedford (3)	1979 to 1985	None	None	21/7/08	20/7/21
T3 Kingston, Denmark Rd (4)	April 2020	06/16	03/20	04/20	05/21
T3 Leeds, York Rd (8)	July 2016	07/11	06/16	07/16	06/21
T4 Ickenham, Heacham Rd (9)	August 2007	07/03	08/07	09/07	08/08
T4 Ickenham Austin's Ln (10)	August 2007	07/03	08/07	09/07	08/08
T5 London, Camden (12)	December 2015	08/10	11/15	12/15	05/21
T5 London, Enfield (13)	April 2019	05/14	03/19	04/19	05/21
T5 London, Hyde Park (14)	December 2015	11/10	11/15	12/15	05/21
CT1/3 York (5)	March 2008	03/04	02/08	03/09	12/20
CT2/4 Liverpool (11)	June 2018	07/13	06/18	06/18	07/21
CT5 London, Brentford (15)	August 2018	06/16	05/18	06/18	05/21

3.2 Results

Table 20 shows the number of injury numbers that occurred at ten of the junctions for the before and after periods. Data for the before period for Site 3 was not collected because the change was effected at this site at some point somewhere between 1979 and 1985, and so it was difficult to determine when the before period ended. There were no collisions at either Sites 9 and 10 in Ickenham, which are the two Type 4 sites (partial set-back without a zebra crossing). There were also no collisions in the three control sites in either the before or after period (Sites 5, 11 and 15). The table shows the total number of injuries, and the number of injuries involving a cyclist or a pedestrian.

Table 20 Injury numbers at Marked Priority junctions

		Serious			Slight					
		All	Of which cyclists	Of which pedestrians	All	Of which cyclists	Pedestrians	Total	Years	Mean number per year
T1 S1 Birmingham	Before	4	0	1	7	1	1	11	5	2.2
	After	0	0	0	2	0	0	2	2.42	0.4
T1 S6 Bradford	Before	0	0	0	1	0	0	1	5	0.2
	After	0	0	0	0	0	0	0	1.17	0
T2 S7 Birmingham	Before	1	0	1	3	0	1	4	5	0.8
	After	1	0	1	0	0	0	1	2.42	0.2
T3 S2 Cheltenham	Before	1	0	0	2	0	0	3	5	0.6
	After	1	1	0	4	0	0	5	15.4	1
T3 S3 Bedford	Before									
	After	0	0	0	4	0	0	4	13	0.8
T3 S4 Kingston	Before	0	0	0	5	3	0	5	3.83	1
	After	0	0	0	0	0	0	0	1.17	0
T3 S8 Leeds	Before	0	0	0	2	2	0	2	5	0.4
	After	0	0	0	1	0	0	1	5	0.2
T5 S12 Camden	Before	2	1	0	6	6	0	8	5.33	1.6
	After	0	0	0	0	0	0	0	5.5	0
T5 S13 Enfield	Before	1	0	1	8	0	0	9	4.92	1.8
	After	2	1	0	4	1	0	6	2.12	1.2
T5 S14 Hyde Park	Before	0	0	0	1	1	0	1	5.08	0.2
	After	0	0	0	1	0	0	1	5.5	0.2
Total for ten sites	Before							44	52.16	8.8
	After							16	42.7	3.2

The number of injuries at these ten junctions are low and this reinforces the point that the sites have been re-design to enhance priority and not to solve a collision problem. 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 situation it is only Site 2 in Cheltenham which has a higher mean rate in the after period.

There is no significant difference between the before and after period injury numbers (after taking account of the different periods of the before and the after period) for any site, apart from Site 12 in Camden, where there were eight injuries in the before period to none in the after period ($\chi^2(1) = 6.35, p = 0.01$). When Site 12 is aggregated with the other T5 sites, the difference is not statistically significant. Neither is it significant for the other junctions types when aggregated (i.e. types T1, T3 and T5, note that there is only one site for type T2, and there are no collisions in either the before period or the after period for T4).

It is inappropriate to draw conclusions from this analysis and this is because the numbers of injuries are at such a low that random effects dominate. In the absence of any evidence of change at the control sites, it may have been appropriate to extend this simple analysis to include all other priority junctions in the district (i.e. to use comparator sites). However, the low numbers indicate that such an analysis would not reveal anything of significance.

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 after enhancement 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.

The number of injuries is driven by the number of interactions taking place and there will have been some variability in both motor traffic flows and traffic crossing flows across the periods in question. Some of these differences between the before and after periods could have been partly because of the changed nature of the junction, with, for example, the possibility of increased crossing flows because of the Marked Priority. The impact of such changes in flows (both turning and crossing), had they been available, would have a provided a further mechanism for analysis and interpretation. However, the potential for a greater level of interpretation would be limited on the basis of the low numbers of injuries observed.

The focus of the research has been on the nature of interactions, and in particular when an interaction occurs the nature of the yield that is taking place. The yield of most concern is where the person crossing is forced to yield. Table 21 compares the number of forced yields taken from Table 7 and the injury rate per year taken from Table 20. Unsurprisingly because of the low injury rate, no pattern emerges, and the correlation s not significant.

Table 21 Comparison of the number of forced yields and the number of injuries in the after period

Type and site	Number of Forced Yields	Injury rate per year
T1 Site 1 Birmingham	155	0.4
T1 Site 6 Bradford	11	0.0
T2 Site 7 Birmingham	142	0.2
T3 Site 2 Cheltenham	325	1.0
T3 Site 3 Bedford	261	0.8
T3 Site 4 Kingston	158	0.0
T3 Site 8 Leeds	0	0.2
T4 Site 9 Ickenham	84	0.0
T4 Site 10 Ickenham	57	0.0
T5 Site 12 Camden	287	0.0
T5 Site 13 Enfield	112	1.2
T5 Site 14 Hyde Park	196	0.2

3.3 Summary

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 enhancements and 16 in the 40.7 years after enhancement. There are hence fewer injury collisions after enhancement 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 after enhancement and the number of forced yields observed.

4 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 a 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).

Considering together the proportions of times no yield is required and forced yields, it appears that marked priority with a parallel crossing may be the preferred enhancement, followed by Design Priority, and finally Marked Priority without a zebra crossing (i.e. only a priority cycle track 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. 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. Cyclists create fewer forced yields than pedestrians. 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.

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