



## **PUBLISHED PROJECT REPORT PPR730**

### **Off-street trials of a Bus Stop Bypass**

An assessment of user perceptions, safety, capacity and accessibility

**York I and Tong S**

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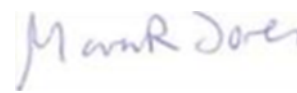
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## Executive Summary

TRL has conducted a trial to evaluate the concept of a Bus Stop Bypass (BSB), and assess pedestrian crossing options with varying pedestrians and cycle flows.

A Bus Stop Bypass involves taking an on-carriageway cycle lane via a cycle track behind a bus stop. The purpose of this is to remove the need for cyclists to overtake a stationary bus thereby improving cyclist comfort and safety by reducing the collision risk for cyclists. A consequence of applying this concept is that pedestrians need to cross the cycle track to reach the bus stop for which a crossing point is provided. Four variations of crossing points were assessed. These were with, and without, a Zebra crossing; and with the crossing point being either dropped to the level of the cycle track, or at footway level on a flat top table with an entry and exit ramp<sup>1</sup>. These are referred to as:

- **No Ramp/No Zebra:** (at the level of the cycle track<sup>2</sup>, uncontrolled crossing) the pedestrians cross the cycle track via a dropped kerb, and no pedestrian crossing was marked.
- **No Ramp/Zebra:** (at the level of the cycle track, controlled crossing) the pedestrians crossed the cycle track via a dropped kerb, and a Zebra pedestrian crossing was marked.
- **Ramp/No Zebra:** (at footway level, uncontrolled crossing) the pedestrians crossed the cycle track via a ramp at footway height, and no pedestrian crossing was marked.
- **Ramp/Zebra:** (at footway level, controlled<sup>3</sup> crossing) the pedestrians crossed the cycle track via a ramp at footway height, and a pedestrian crossing was marked.

It should be borne in mind that these were the only design variations tested. For other aspects of the design of Bus Stop Bypasses the trial considered the overall concept and not individual design variations in detail. As a consequence the effect of different angles of entry, and exit, to the bus stop bypass, and the effect of different widths of the bus stop island are not considered.

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<sup>1</sup> This flat top table is referred to as a ramp, and is synonymous with the term hump.

<sup>2</sup> This could also be referred to as 'at-grade', as it is the same level as the cycle track.

<sup>3</sup> A controlled crossing means a crossing with a method of control conferring priority. In this report controlled crossings were zebra crossings, and an uncontrolled crossing has no markings except for the dropped kerbs and tactile paving.



**No Ramp/No Zebra**



**No Ramp/Zebra**



**Ramp/No Zebra**



**Ramp/Zebra**

A Bus Stop Bypass was built on TRL's test track and three types of trial were conducted. The first trial involved (able bodied) participant cyclists and pedestrians using the Bus Stop Bypass at the same time, under different flow conditions. Their behaviour was recorded by video cameras; cyclist speeds were measured with Automatic Tube Counters; a sample of pedestrians and cyclists were asked direct feedback questions on their experiences whilst taking part in the trial; all participants completed a questionnaire after the trial; and some took part in focus groups.

The second trial was conducted with people who had a range of disabilities (including sight, hearing and mobility issues). They completed a questionnaire after completing the trial and then gave further feedback in a focus group.

The data obtained from both cyclists and pedestrians in these trials was analysed to investigate how the four types of bus stop bypass affected the following:

1. Understanding and participants' opinions.
2. Use of the designated crossing point.
3. Cyclists' journey time.
4. Interactions between cyclists and pedestrians.
5. Accessibility issues.

The third trial investigated the capacity of the Bus Stop Island. This involved 97 pedestrians being allocated to two start points: one upstream, and one downstream, of the bus stop. They were then released in groups of varying sizes and asked to wait at the bus stop. After all had been released, they returned back to the start points and the process was repeated. This trial took direct measurement of how pedestrians queued at the bus stop, their distribution at the bus stop, and the maximum number that were willing to queue on the Bus Stop Island.

All three trials were designed to achieve four research aims. These aims and the conclusions reached in the studies are shown below.

**Aim 1: Identify the pedestrian capacity of the Bus Stop Island: defined as the number of people who can be accommodated on the island**

The trials have developed a formula that estimates the maximum capacity, and effective capacity of the Bus Stop Island trialled. Although, the formula is based upon one specific island design, it can provide an initial estimate for the capacity of other Bus Stop Islands.

- **The maximum capacity** of bus stop island can be estimated using the formula  $\text{Area A}/2.4 + \text{Area B}/1.0 + \text{Area C}/0.6 + \text{Area D}/0.6 + \text{Area E}/1.6$ , where the Areas A to E are defined in Section 3.3.
- **The effective capacity** of a bus stop island (when people choose not to wait on the island) can be estimated as approximately 85% of the maximum capacity.



## **Aim 2: Determine the levels / thresholds of occupancy that queuing seemed to break down.**

Analysis of the development of bus passenger queues during the trials identified two types of queuing depending on the direction in which the queue formed. However, there was a consistent range in which the formalised queue<sup>4</sup> broke down and pedestrians started to walk to the nearest available gap.

- **Formalised queuing** ceased after 33 to 47 pedestrians were waiting on the bus stop island.

## **Aim 3: Identify how the interaction between pedestrians and cyclists can be safely managed**

The Bus Stop Bypass introduces a situation of potential direct conflict between pedestrians and cyclists, with pedestrians crossing in front of cyclists to reach the Bus Stop Island. Safety of the four designs tested can be based upon direct observations of interaction rates between cyclists and pedestrians, and understanding (and agreement) of priorities. These have resulted in the following conclusions based upon the behaviours observed in the trials:

- **A Zebra crossing** reduced the probability of interactions between cyclists and pedestrians. It had the greatest agreement amongst participants regarding priorities both at the crossing and elsewhere. It had the highest scoring for perceived safety. Furthermore, participants with impaired sight found it easier to locate.
- **Dropped kerbs** were generally preferred at the Zebra crossing except at high the pedestrian flows. Pedestrians and cyclists felt safer with a dropped kerb. Generally a ramp increased interaction rates, although slightly decreased the number of serious interactions (i.e. involving two participants having a near, or very near, miss). The conflicting evidence on all interactions, and serious, interactions mean that no conclusion can be reached on the effect on overall safety. However, if the pedestrian flow was high (greater than  $0.4 \times [\text{cycle flow}] + 12$  pedestrians per minute) then a ramp decreased the number of interactions occurring. A ramp reduced cycle journey times provided the pedestrian flow was relative large ( $3 \times [\text{cycle flow}] + 3$  pedestrians per minute). People with impaired mobility, including wheelchair users, preferred the Ramp/Zebra crossing, while others in the accessibility trial expressed a slight preference for No Ramp.

## **Aim 4: Identify the features of the bus stop island layout that are attractive to cyclists and that encourage them to use the bypass cycle track**

- **The Bus Stop Bypass appeared to be attractive to participant cyclists.** Between 45% and 50% of the cyclists stated that they would be more likely to cycle in town with Bus Stop Bypasses being available. It should be noted that this is only a statement of potential intention, and may not translate into a real increase.
- **The Bus Stop Bypass appeared to have advantages for participant cyclists' perceived safety,** compared with using the main carriageway. Between 50% and 60% stated they would use the Bus Stop Bypass under low traffic flows, and more

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<sup>4</sup> Formalised queue is where there is a clear progression from first to last arrival in a line.

under high traffic flows. However, the actual use would depend on whether a bus was waiting at the bus stop and the relative conditions on the Bus Stop Bypass and the main carriageway.

- **An at cycle track level designated crossing point was** perceived to be safer by cyclists.
- **A Zebra crossing had advantages and disadvantages for cyclists.** Cyclist journey times were generally lower without a Zebra crossing, particularly under high cyclist flows. This was likely to have been a result of greater ambiguity over priorities and cyclists claiming greater ownership of the cycle bypass track under high cycle flows (i.e. cyclists not giving way as often thus maintaining a higher average speed). However, a Zebra crossing was easy to identify and clarified priorities for all users and reduced the number of interactions between cyclists and pedestrians.

It is important to recognise that any off-street trial inevitably has its limitations and it cannot be assumed that the behaviours reported here would be replicated in a real street environment. The findings of this trial should not therefore be regarded as design guidance: further experience from on-street trials will therefore be needed, and other design considerations taken into account, before more definitive design recommendations can be made.

## 1 Introduction

TRL has investigated the implications of implementing Bus Stop Bypass (BSB) infrastructure on behalf of TfL. A Bus Stop Bypass involves a cycle lane being taken away from the carriageway and behind a bus stop (at which point this lane is described as a 'track' rather than a 'lane', because it is segregated from other traffic). The aim is to improve the comfort and reduce the collision risk for cyclists from overtaking buses at a bus stop. To help pedestrians reach the Bus Stop Island a crossing point is provided.

The layout of Bus Stop Bypass (BSB) assessed was based on one that has started to appear in the UK, for example, in Brighton. TfL have introduced similar facilities along the cycle superhighway CS2 extension from Stratford to Bow with 6 bus stop bypasses implemented. A picture of the trial BSB is shown in Figure 1.



**Figure 1: The trial Bus Stop Bypass (BSB) with an at cycle- track level uncontrolled (No Ramp/No Zebra) pedestrian crossing**

The BSB can be understood as consisting of four main features, as shown in Figure 2.

- A **Bypass Cycle Track** - this is behind the bus stop and separates the bus stop island from the pedestrian footway.
- A **Bus Stop Island** (BSI) – which is the location where buses pull up and will normally have a bus stop sign and bus stop shelter.
- The **Main Footway** - this is the pedestrian footway used by all pedestrians.
- A **Designated crossing point** – the location provided for pedestrians to cross between the main footway and the bus stop island and usually indicated with tactile paving.



**Figure 2 Highlighted layout of a Bus Stop Bypass (BSB) with an at-grade uncontrolled (No ramp, No Zebra) pedestrian crossing**

Four different types were layout to help pedestrians cross to and from the Bus Stop Island were trialled:

- **No Ramp/No Zebra:** (at cycle-track level uncontrolled crossing) the pedestrians crossed the cycle track via a dropped kerb, and no pedestrian crossing was marked in the cycle track.
- **No Ramp/Zebra:** (at cycle track level controlled crossing) the pedestrians crossed the cycle track via a dropped kerb, and a pedestrian crossing was marked in the cycle track.
- **Ramp/No Zebra:** (at footway level uncontrolled crossing) the pedestrians crossed the cycle track via a flat table at footway height, and no pedestrian crossing was marked in the cycle track.
- **Ramp/Zebra:** (at footway level controlled crossing) the pedestrians crossed the cycle track via a flat table at footway height, and a pedestrian crossing was marked in the cycle track.

These were the only variations tested as the focus of the trial was on the crossing. It is possible that the effect of a Bus Stop Bypass could also vary with different angles of entry (and exit) to the bus stop bypass. Also, different widths of the bus stop island could influence how pedestrians cross to the island and use it. However, these design variants were not tested in the trial. The uncontrolled crossing points had only appropriate tactile pavement areas to mark them on the footway and the bus stop island, whilst the controlled crossing points had Zebra crossing points which were marked to meet current road traffic regulations, see Figure 3.



**No Ramp/No Zebra**



**No Ramp/Zebra**



**Ramp/No Zebra**



**Ramp/Zebra**

**Figure 3: The Four Types of Crossing Point**



## 2 Key areas of investigation

The layout of the BSB requires pedestrians to cross a cycle track in order to pass between a bus stop and the footway. This creates a potential for cycle and pedestrian interactions, which in turn may require one of the users to give way to another.

Therefore a lack of understanding of how to act within the area, or agreement over who has priority if an interaction occurs, could lead to safety concerns. It was also important to ascertain how pedestrians and cyclists used the Bus Stop Bypass, and what the consequences were for cyclist journey times and interactions between the users.

The purpose of this study was to analyse observations and feedback from participant cyclists, participant pedestrians and pedestrians with a range of disabilities. Five core themes were investigated for each type of designated crossing point:

1. **Evaluate capacity** – estimate the number of people willing to wait on the Bus Stop Island before they decide to either queue in the cycle track, or the main footway.
2. **Participants' perceptions** – the users' perception of how to use the design. Also, their perceptions on ease of use, safety and whether they would use it.
3. **Use of the crossing** – the extent to which pedestrians followed their desire line to the bus stop or would use the designated crossing point.
4. **Journey Time** – any time penalty encountered by cyclists using the Bus Stop Bypass compared to the time for travelling around the bus.
5. **Interactions** – the frequency and type of interactions occurring between cyclists and pedestrians.
6. **Accessibility** – the issues faced by those with mobility issues, including wheelchair users as well as people with sight, and hearing impediments.

### AIMS

- 1 Identify the pedestrian capacity of the Bus Stop Island: defined as the number of people who can be accommodated on the island.
- 2 Determine the levels / thresholds of occupancy that queuing seemed to break down.
- 3 Identify how the interaction between pedestrians and cyclists can be safely managed.
- 4 Identify the features of the bus stop island layout that are attractive to cyclists and that encourage them to use the bypass cycle track.

### 3 Approach

Three distinct trials were required to evaluate the key areas of investigation. The main trial consisted of members of the public either cycling through the Bypass Cycle track, or walking to and from the Bus Stop Island. Each type of participant was given instructions when to start and where to cycle or walk to, but no other information on how to use the facility. The second trial was for people with a range of disabilities to experience the Bus Stop Bypass under controlled conditions. The third trial investigated the capacity of the Bus Stop Island by asking participants to walk to the bus stop and wait for a bus, whilst observing where they chose to stand.

Details of the trials are summarised in the following sections and greater detail is provided in Appendices A, B and C. In addition, the sample compositions of participants taking part in these trials are summarised in Appendix D.

#### 3.1 Main trial design

The main trials were based upon a full factorial design<sup>5</sup>, distributed to minimise the effects of inter-group variations whilst avoiding fatigue, and included repeated observations across different groups (repeats) to examine inter-group variability.

The design considered understanding, use of the crossing, cyclist journey time and interactions with four types of pedestrian crossing (see Chapter 1), four levels of cycle flow and three levels of pedestrian flow, see Table 1.

**Table 1: Pedestrian crossings and flows tested**

Variable	Detail
Designated Crossing Point	No Ramp/No Zebra, OR No Ramp/Zebra, OR Ramp/No Zebra OR Ramp/Zebra.
Pedestrian Flow	Zero, 'Low', 'Medium', and 'High'. The actual flows were randomised, to represent more realistic pedestrian flows, but were based on averages of 0, 180, 300 and 450 per hour both to, and from, the bus stop.
Cyclist Flow	Zero, 'Low', 'Medium', and 'High'. The actual flows were randomised, but were based on averages of 0, 150, 300 and 600 per hour past the bus stop.

The trials took place between 5th August and 10th October 2013. Each of the designated crossing types were trialled for three days during this time period. Further details of the flows used are in Appendix A, together with information on participant recruitment, and how the sessions were organised.

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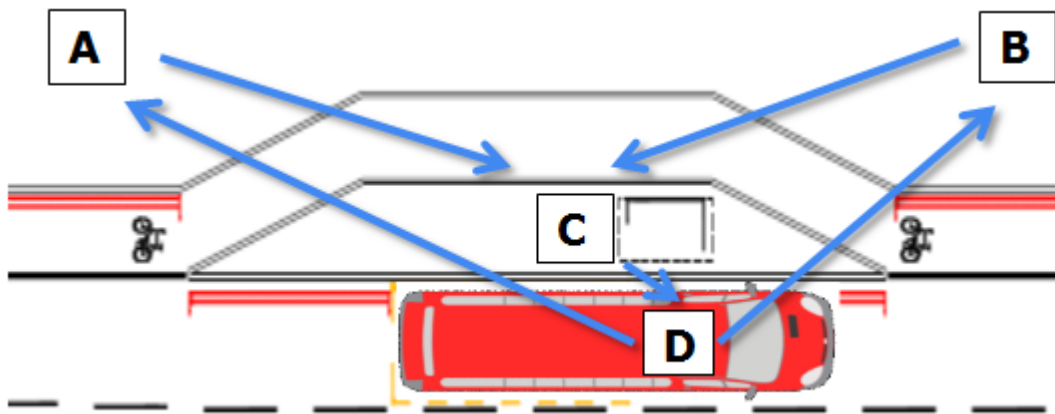
<sup>5</sup> A full factorial design is a statistical design in which all the individual effects of a defined set of independent variables can be isolated, together with how they interact. In reality this means that all combinations of variable values are represented in the design.

### 3.1.1 Pedestrian routes

Pedestrian participants started at one of the four locations marked in Figure 4: A and B were origin/destination points for a pedestrian journey located on the footway and upstream/downstream of the bus stop respectively, C was on the bus stop island (to wait for a bus) and D was on board a bus waiting at the bus stop.

Any given pedestrian was set a randomised route from the route sections shown below whereby the end point of a route section becomes the next route section start point. A session then consisted of different numbers of participants being asked to move within "1 minute time segments" either from:

- A to C (walking to and waiting at bus stop)
- B to C (walking to and waiting at bus stop)
- C to D (boarding bus)
- D to A (alighting bus and walking away left)
- D to B (alighting bus and walking away right)



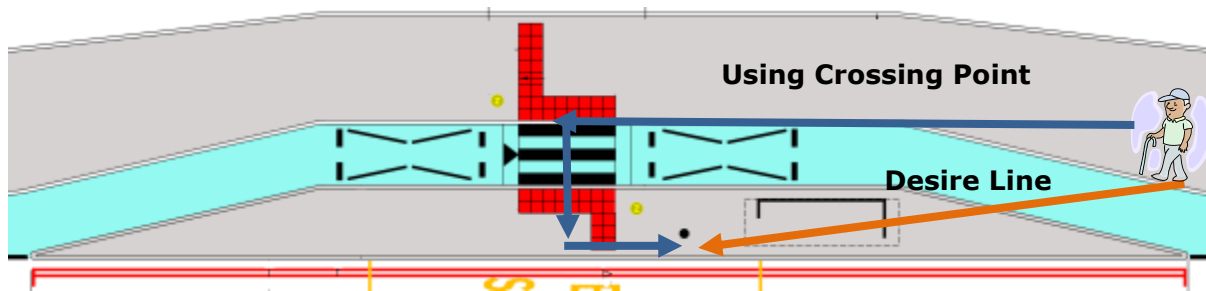
**Figure 4 Diagram of bus stop bypass showing starting points A and B**

### 3.1.2 Desire lines

Most pedestrians will naturally use desire lines, i.e. the shortest distance between two points, unless there is a reason for walking further. The designated pedestrian crossing point used within this trial was positioned in line with a waiting bus's back doors. The crossing point was therefore approximately half way along the length of the Bus Stop Island.

Bus users (pedestrians) arriving at the bus stop from either direction along the footway are faced with a decision of using their direct desire line or walking further to the designated pedestrian crossing point, see Figure 5. It is possible that repeated movements encouraged a 'learning effect' among participants that may have influenced the results.

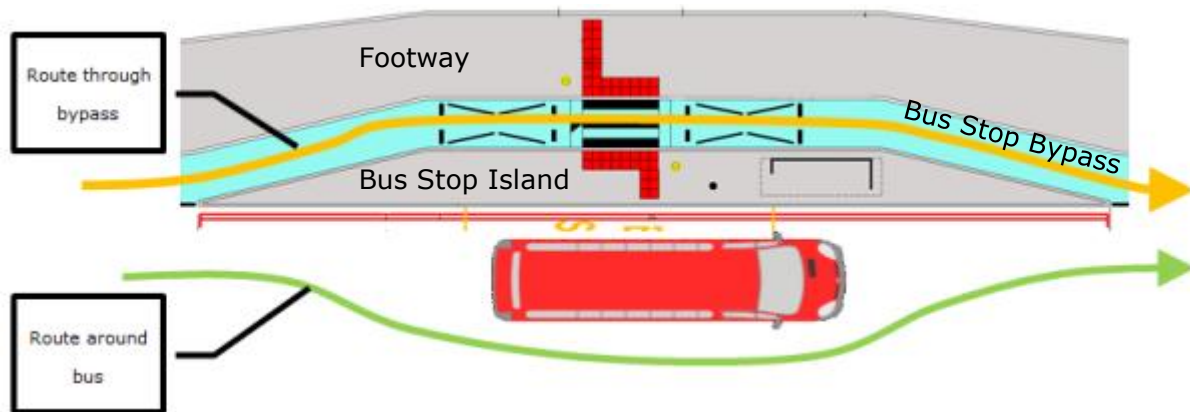




**Figure 5: Pedestrian Route Choice**

### 3.1.3 Cyclist only sessions

For some sessions only cyclists took part (sessions 1, 4 and 7 see Appendix A). Cyclists approaching a Bus Stop Bypass will usually have a choice of either cycling on the carriageway, potentially around a stopped bus, or passing along the bus stop bypass whilst negotiating pedestrians and crossing points, see Figure 6.



**Figure 6 Routes available to cyclists**

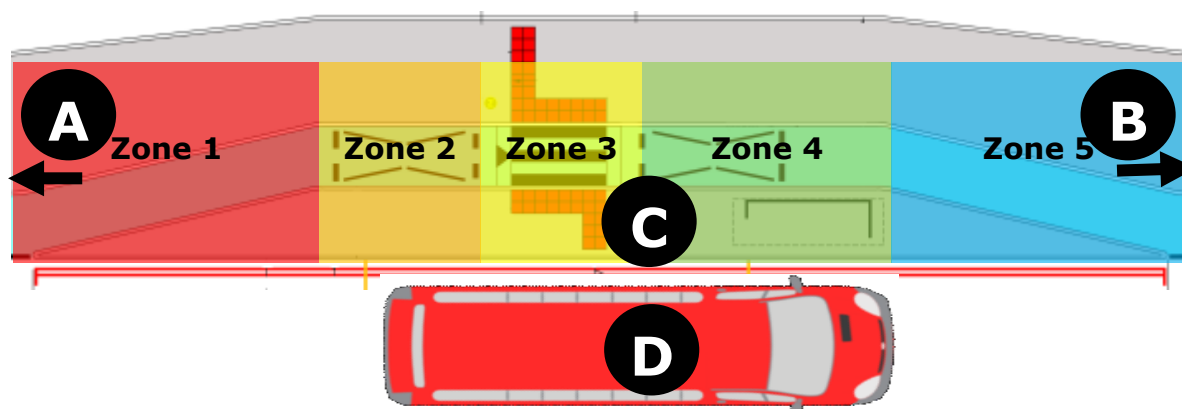
Cyclists were asked to cycle three times past the bus stop on a looped circuit from an upstream start point via the bus stop to a turning point downstream of the bus stop and then back to the start point on the opposite side of the road. This provided a measure of all cyclists' journey times on the main carriageway going around a stationary bus, and using an empty Bus Stop Bypass.

In one run cyclists were asked to use the Bus Stop Bypass and released individually. In another they were asked to use the Bus Stop Bypass and a number of cyclists (2, 3, 5 or 10) were released at the same time. They were released individually in another run and asked to overtake the bus on the road. Further details of the cyclist only sessions can be found in Appendix A.

### 3.1.4 Definition of crossing zones

The zones where pedestrians could cross to, and from, the Bus Stop Island were defined using the areas indicated in Figure 7. Zone 3 was the area of any designated crossing point including 1 metre either side of any marked area: it was defined by the start of the dropped kerbs, or the width of the ramp, as appropriate. Zones 2 and 4 were the areas either side of this to the point where the island tapered. Zones 1 and 5 were the areas furthest from the centre. Points A and B were the starting (arrival) points for

pedestrians. These simulate walking along a footway to a bus stop at Point C. Participants also travelled from C onto a stationary bus (Point D) and then returned back to one of the points A and B.



**Figure 7: Crossing Zones**

### **3.1.5 Questionnaire and Focus Group data collected**

A sample of the cyclist, and pedestrian, participants were asked at the completion of each pedestrian movement how they found the journey they had just made (in terms of safety, ease of use and, for cyclists, their preferred route – either using the bypass track or overtaking the bus).

After the trial, participants were asked to complete an off-track questionnaire on their overall opinions of the situations they had experienced, including:

- Ease of use
- Overall rating of the infrastructure
- Perceived safety
- Perceived priority

Also, some participants were invited to take part in a focus group (one for each trial layout), to examine opinions in more depth.

### **3.1.6 Video data collected**

Video cameras were located to cover the whole of the bus stop island and the crossing point from several angles. The cameras were on poles at least double head height so the view would not be obscured by the movement of large numbers of pedestrians.

Six cameras were used to identify locations where pedestrians chose to cross, either by a direct route from their starting point or at or near the designated crossing point. The results of analysing this data are contained in the Use Of Designated Crossing Point Chapter.

In addition, information was collected on the interactive behaviour of cyclists using the bypass cycle track and pedestrians crossing onto the bus stop island. Each cyclist was observed throughout their journey through the bus stop bypass track. An interaction was defined as either the cyclist, or at least one pedestrian, either:

- Slowing down;
- Stopping; or
- Deviating from their initial path (swerving).

For each interaction information was collected on:

- the number of pedestrians involved;
- the action taken by cyclist and pedestrian;
- the severity of the interaction (five levels from precautionary, through near miss and up to collision); and
- who gave way.

Cyclists were asked to cycle as if they were approaching a bus stop island on a street in London. However, it was necessary to advise them to avoid a collision with pedestrians crossing the bypass cycle track. This advice may have influenced the behaviour of participants in the trial.

### **3.1.7 Automatic Traffic Counter data collected**

Two Automated Traffic Counters (ATCs) were used to record to a high accuracy (within 1/1000 of a second) the times at which cyclists crossed tubes placed just before the entry to, and just after the exit from, the Bus Stop Bypass track. Cyclists' timings at the first timing point were also recorded, to a lower level of accuracy, from the video cameras. The video timings were used to match individual cyclists with the ATC tube records so that their journey times between the two could be calculated. However, this made it necessary to ask cyclists not to overtake each other – a situation that might not be replicated in real life.

The same ATC tubes were used whether the cyclists used the Bus Stop Bypass or the main carriageway. The distance between them was 75.8m using the route through the Bus Stop Bypass. The route around the bus would have been of a similar distance, although with greater variability as the cyclists would have had greater choice over their position in the lane.

## **3.2 Second (Accessibility) trial design**

The second (accessibility) trial involved a mixed design with data treated as an independent sample. Participants were a combination of people who trialled more than one crossing type at the bus stop bypass facility and people who only trialled one type of crossing.

Four different groups of people with disabilities were involved in the one day trials on each of the four types (see Chapter 1) of Bus Stop Bypass: Wheelchair users, People with visual impairments (including people with guide dogs, sticks and also a helper), people with hearing impairments (including people with hearing dogs) and a general group, including the aged (i.e. over 75 years old), those with learning difficulties and people using a stick.

Each participant walked to, and from, the Bus Stop Island three times. They began from the same start points (A and B) as in the main trial. After their experience they took

answered a questionnaire and took part in a focus group. Further details of the trial procedures are contained in Appendix B.

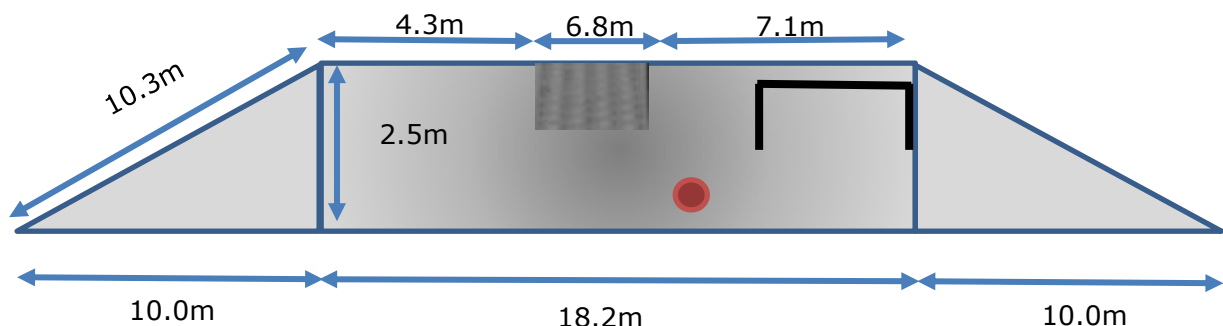
### 3.3 Third (Capacity) trial design

The third trial was a repeated measures design conducted on the 29<sup>th</sup> July 2013. It used randomised flow profiles at three different levels of pedestrian flow: low, medium and high. The number of repeats was chosen to obtain statistical validity. The order of the pedestrian flow rates was such that it minimised the effects of fatigue (and learning) during the day. A summary of the details are in this section, with further details of the design and procedures contained in Appendix C.

#### 3.3.1 Island tested

The design considered understanding, use of the crossing, cyclist journey time and interactions with four types of pedestrian crossing (see Chapter 1), four levels of cycle flow and three levels of pedestrian flow.

The capacity of an implemented Bus Stop Island (see Figure 8) would be expected to be a function of by its main usable area; i.e. the area where pedestrians would choose to stand. The island trialled was 38.2m in total length, but the expected main usable area was 18.2m in length: i.e. the rectangular area that included the bus shelter and the boarding/alighting zone and had a width of 2.45m.



**Figure 8 Bus Stop Bypass island dimensions**

For the trial layout an uncontrolled pedestrian crossing point was located towards the centre of the bus stop island, see Figure 3. It should be noted that capacity was estimated for one design of Bus Stop Island. In reality, the on-street design will vary depending on the space available, and could affect capacity.

#### 3.3.2 Trial procedure

A total of 97 pedestrians were allocated to two stop points, A and B as in the main trial, see Figure 4. They were then released in pre-determined groups<sup>6</sup> from each starting point and asked to behave as if they were approaching a bus stop to catching a bus in London. After all pedestrians were released, they were again re-allocated back to the

<sup>6</sup> Pedestrians were released in groups whose sizes that were randomly selected from a Poisson distribution, a statistical distribution observed in such situations. Three Poisson distributions were used to simulate three pedestrian flow rates low, medium, high: 200, 360 and 450 pedestrians per hour arriving at the bus stop.

two start points and the process was repeated. No pedestrians had any impairment that could prevent them walking to and from the bus stop repeatedly.

### 3.3.3 Cyclist flow

Fifteen cyclists created a flow through the bus stop bypass. Cyclists were set off at 20 second intervals during the trial, and this interval was the same for all of the sessions.

### 3.3.4 Fruin Index

The Fruin Index measures the Level of Service for pedestrians using different infrastructure. For waiting pedestrians the scale ranges from A, which is highly comfortable with plenty of space for all pedestrians, through to F which is highly crowded and uncomfortable, see Table 2.

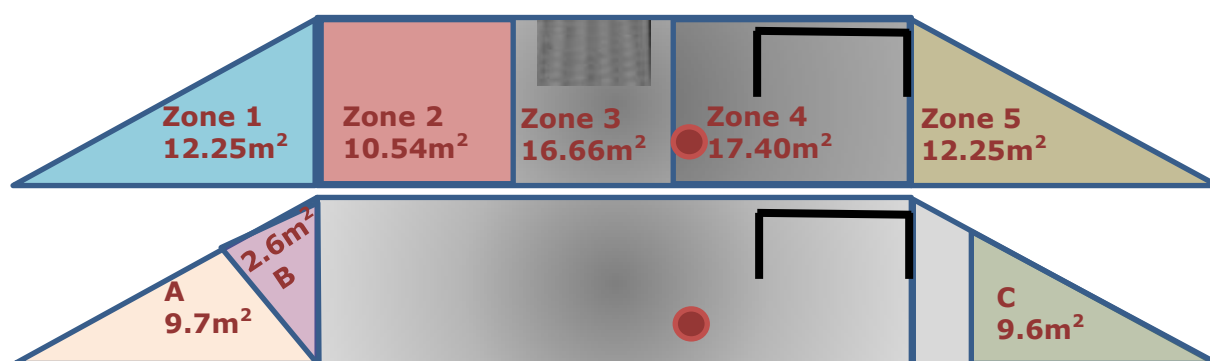
This Index can be used to provide a scale on which acceptable, and maximum, levels of crowding are established.

**Table 2: Fruin Index Standards**

Fruin Index Level of Service	Average area per passenger (Sq. metre)	Description
<b>A</b>	$\geq 1.3 \text{ m}^2$	Space for standing and free circulation
<b>B</b>	$0.93\text{-}1.2 \text{ m}^2$	Space for standing and restricted circulation through the queue without disturbance of others
<b>C</b>	$0.65\text{-}0.93 \text{ m}^2$	Space for standing and restricted circulation through the queue with disturbance of others
<b>D</b>	$0.28\text{-}0.65 \text{ m}^2$	Space for standing without personal contact, severely restricted circulation, and movement forward only as a group
<b>E</b>	$0.19\text{-}0.28 \text{ m}^2$	Space for standing with personal contact, circulation not possible.
<b>F</b>	$\leq 0.19 \text{ m}^2$	Space for standing only with close personal contact, and no movement is possible.

### 3.3.5 Definition and areas of waiting zones

The zones where pedestrians could wait on the Bus Stop Island were defined as the parts of the crossing zones (see Figure 7) that were on the Bus Stop Island. These, together with sub-zones (A, B and C) are shown in Figure 9.



**Figure 9: Diagram of BSI showing taped off areas and different sections**

### **3.3.6 Questionnaire data collected**

A sample of the pedestrian participants was asked to complete a short questionnaire in the trial. This asked for information on how crowded they felt the Bus Stop Island was when they approached it, how comfortable they felt and how safe they felt.

After the trial participants were asked to complete an off-track questionnaire on their overall opinions of the situations they had experienced, including:

- Ease of use
- Overall rating of the infrastructure
- Perceived safety
- Perceived priority

### **3.3.7 Video data collected**

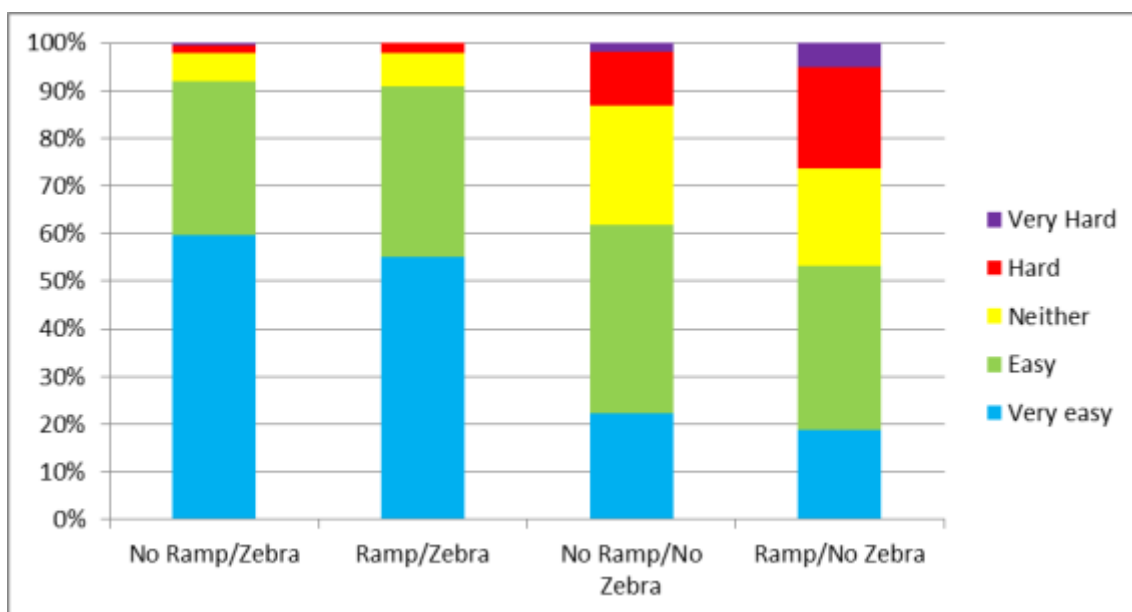
Video cameras were located to cover the whole of the Bus Stop Island and the crossing point from several angles. The cameras were on poles at least double head height so the view would not be obscured by the movement of large numbers of pedestrians. Six cameras were used to identify locations where pedestrians waited for the bus.

## 4 User Opinions

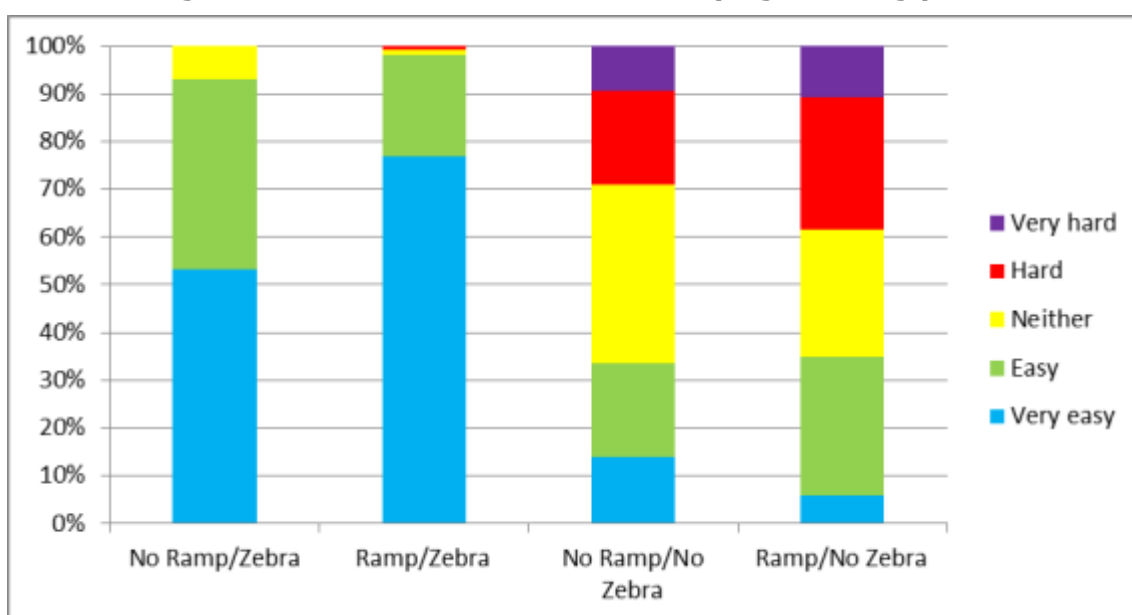
The following subsections present the participants' understanding and opinions of the Bus Stop Bypass. Comparisons are made between the four different designated crossing designs for varying pedestrian and cyclist flows. Findings are based on on-track questionnaires, final questionnaire responses, and focus group discussions.

### 4.1 Ease of identification of the crossing point

Participant pedestrians and cyclists were asked to rate how easily they identified the designated crossing point. The different levels of cycle and pedestrian flows were experienced by the same numbers of participants in each of the trials, and therefore they would (on average) not be expected to influence the overall assessments. The participant answers are summarised in Figure 10 and Figure 11.



**Figure 10 Pedestrians' ease of identifying crossing point**



**Figure 11 Cyclists' ease of identifying crossing point**

More than 50% of the pedestrian participants found all the crossings easy to identify. However, this increased to over 90% if a Zebra crossing was present. The identification of the pedestrian crossing by cyclists was even more strongly dependent on the Zebra crossing. It increased the percentage of cyclists stating it was easy to see from approximately 35% to more than 90%.

The (open question) feedback on the pedestrian crossing was in agreement. Seven (3%) pedestrians experiencing an uncontrolled at cycle-track level (No Ramp/No Zebra) crossing failed to even realise there was a designated crossing point for the pedestrians. Also, a further twenty-one (9%) stated it was difficult to see, or should be more clearly marked. The equivalent numbers with an uncontrolled, but at footway level raised (Ramp/No Zebra) crossing were 3 (1%) and 24 (9%) respectively. Such comments were not made if a Zebra crossing was provided.

This was even more of an issue with cyclists. Cyclists were asked for similar feedback on the pedestrian crossing: 20% had not noticed the uncontrolled, and at cycle track level, (No Ramp/No Zebra) crossing. This reduced to 11% when it was an uncontrolled, and at footway level, (Ramp/No Zebra) crossing. A further 15%, and 7%, respectively stated that the crossing was not clear. Such comments were not received in the feedback from those experiencing a Zebra crossing. This subject also arose in the cyclists' general (unprompted open question) feedback, with 18 to 21% mentioning a need for greater visibility and clarity of an element of the bus stop bypass without a Zebra crossing, compared to 5 to 7% with a Zebra crossing.

The same opinions were also expressed within the focus groups. For example, a cyclist commenting on the uncontrolled crossing with dropped kerb:

*"...didn't realise there was a crossing until after the trial when I was doing the questionnaire".*

Also, in the pedestrian focus group for a footway level uncontrolled crossing (Ramp/No Zebra) it was observed that the majority of the participants did not realise there was a designated crossing.

In contrast, the focus groups with cyclists experiencing a Zebra crossing did not raise such issues, and the pedestrians experiencing the at cycle track level Zebra crossing (i.e. with a dropped kerb) concluded that the bus stop island was easy to understand and the majority entered using the Zebra crossing markings.

## 4.2 Rating the crossing

The participants were asked to score different aspects of the pedestrian crossing. Their answers are summarised in Figure 12 and Figure 13.



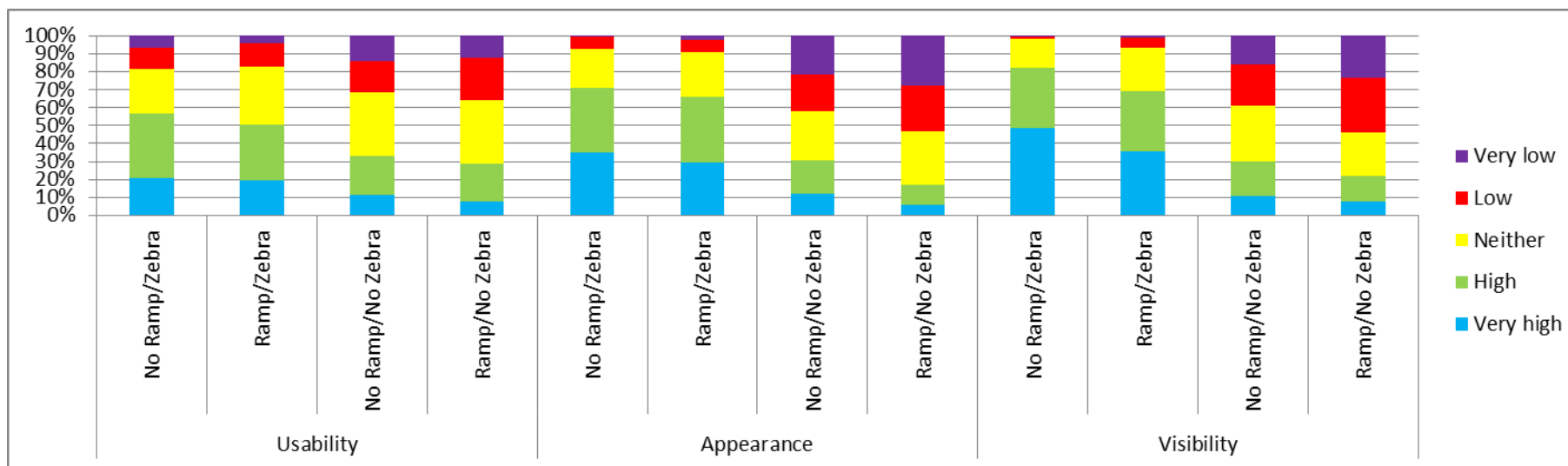


Figure 12 Pedestrians' rating of the crossing

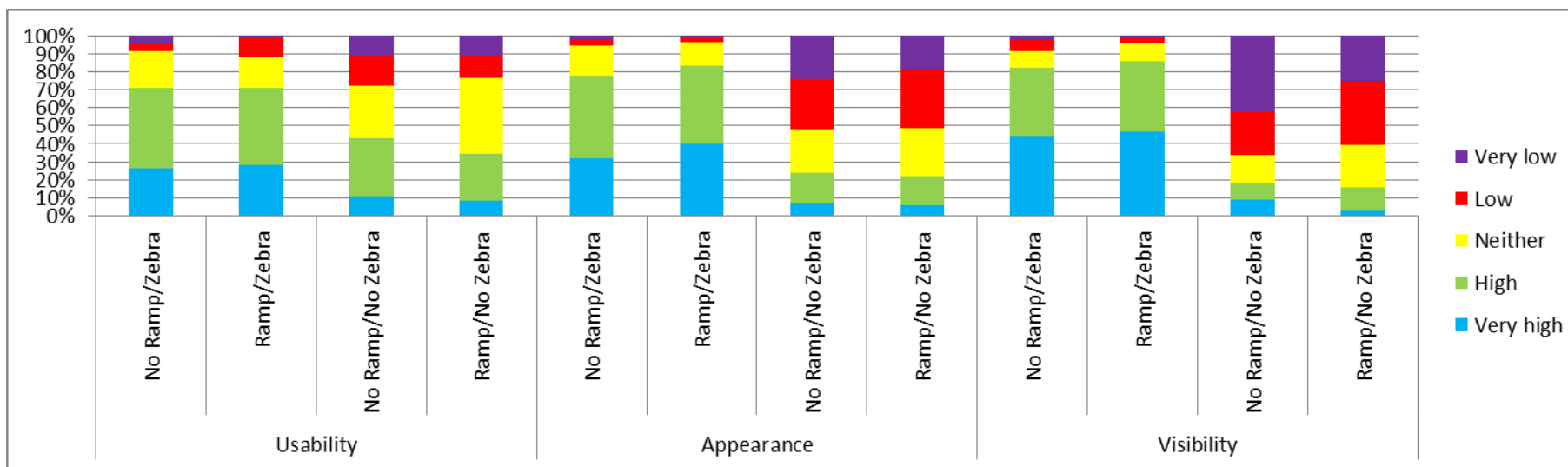


Figure 13 Cyclists' rating of the crossing

The scores given by cyclists and pedestrians were in agreement. All users considered that appearance, visibility and usability of the crossing were not as good without a Zebra crossing. With a Zebra crossing, less than 10% scored the appearance and visibility low, but 39 to 66% scored them low without a Zebra crossing.

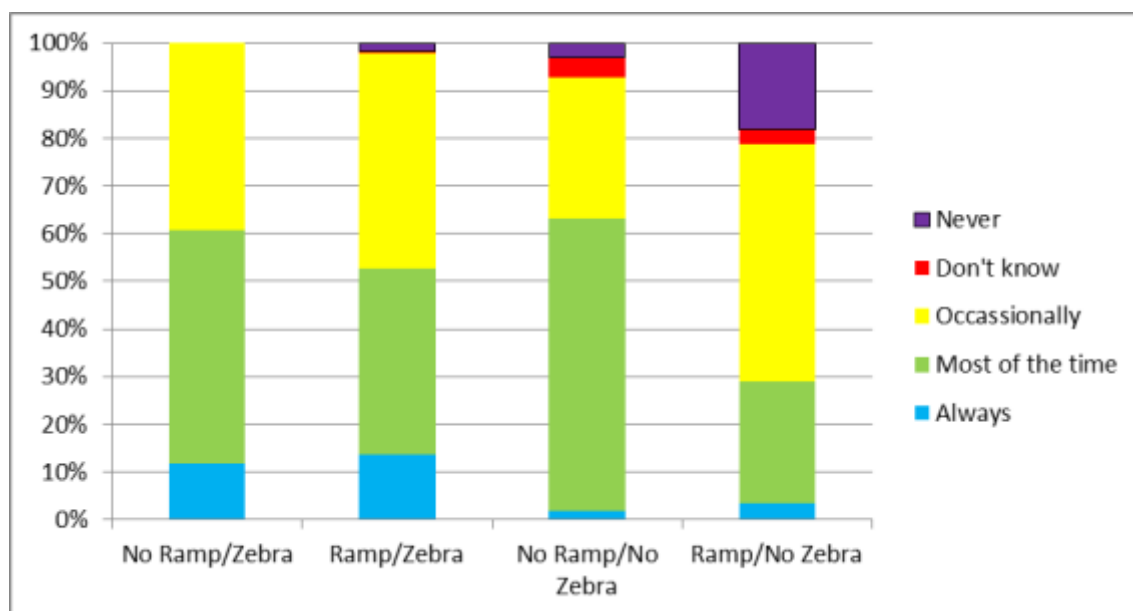
This scoring is in agreement with the feedback from the focus groups. Pedestrians who had experienced the at cycle track level (dropped kerb) crossing without Zebra markings were concerned about more vulnerable bus users (children or pushchairs), particularly during busy periods. There was also a general consensus that the bus stop lacked necessary signage and road markings. With an at footway level crossing without Zebra markings (Ramp/No Zebra) they suggested they did not understand how to navigate the layout, and agreed the layout was inadequately signposted.

However, the feedback from those that had experienced a Zebra crossing was more positive, with comments more in agreement that they found the layout easy to understand and navigate, and that the road markings were clear.

One concern expressed by pedestrian participants in some of the focus groups was exiting the bus stop. They felt that bus users exiting the bus may be unaware of the cycle path due to the lack of signage warning pedestrians of the upcoming cycle path.

### 4.3 Using the crossing

Participant bus passengers/pedestrians were asked to state how often they used the crossing (rather than remaining on their direct desire lines). The same numbers of participants experienced each of the different levels of cycle and pedestrian flows in each of the trials, and therefore they would (on average) not be expected to influence the overall assessments. The participant answers are summarised in Figure 14.



**Figure 14 Use of the crossing**

The chart shows that pedestrians were more likely to use the designated crossing point if a Zebra crossing was provided, particularly if it was also at footway level (on a ramp), when just over half stated they used it most of the time.

#### 4.4 Ease of seeing other users

The pedestrian participants were asked to comment on how easy it was to see the cyclists and judge their distance and speed. Similarly, cyclist participants were asked to comment on how easy it was to see the pedestrians and judge their paths. Their answers are summarised in Figure 15 and Figure 16.

Most pedestrians found it easy to see (over 60%) and assess the speed and distance (over 50%) of the cyclists, which is in agreement with the high percentage who considered that the bus stop was easy to use. However, they considered it to be easier if there was a Zebra crossing provided. It is unclear whether this variation is a result of the implied higher pedestrian priority with a Zebra crossing, and possibly lower cycle speeds as a result, or if it is related to pedestrians being more likely to use the designated crossing point.

Most cyclists (over 80%) found it easy to see the pedestrians, but (as expected) less easy (less than 50% of cyclists) to judge where they were walking to. The only trend was that there was a higher probability (an increase of 14%) of cyclists finding it very easy to see pedestrians with a Zebra crossing.

Cyclists were also asked to rate their agreement with statements on the relative ease of seeing and negotiating pedestrians both with, and without, a bus stop bypass. They generally felt that the bus stop bypass made it easier to see pedestrians (between 55% to 76% stated it improved across the trials), but the bypass resulted in a smaller improvement in their ability to negotiate pedestrians (between 42% to 60% stated it improved it across the trials).

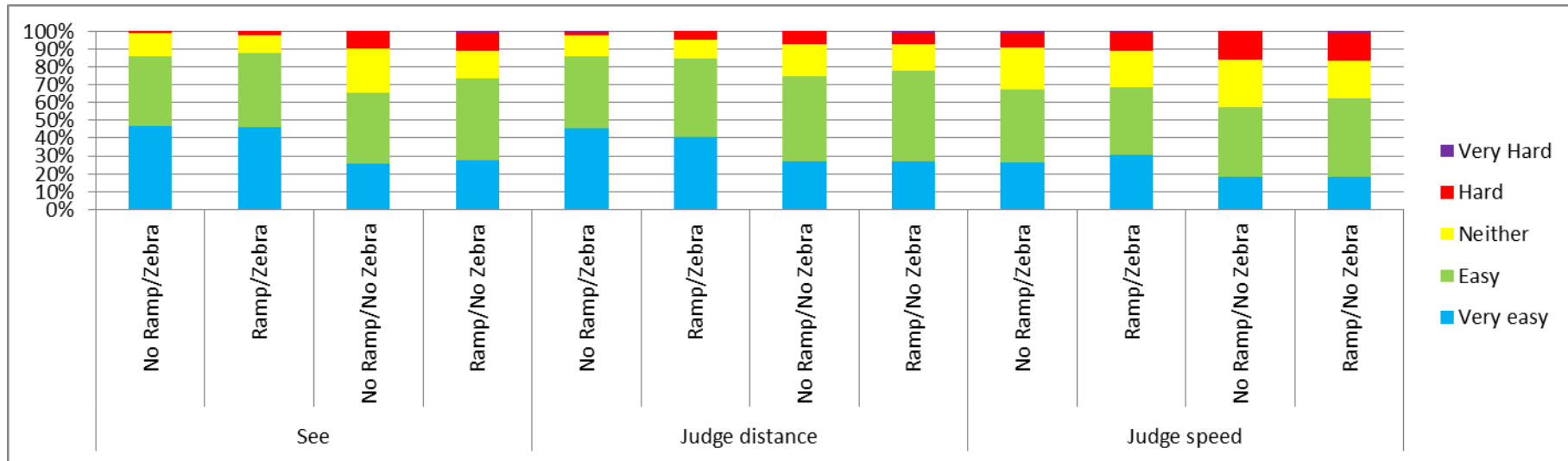


Figure 15 Pedestrians' ease of seeing and assessing other users

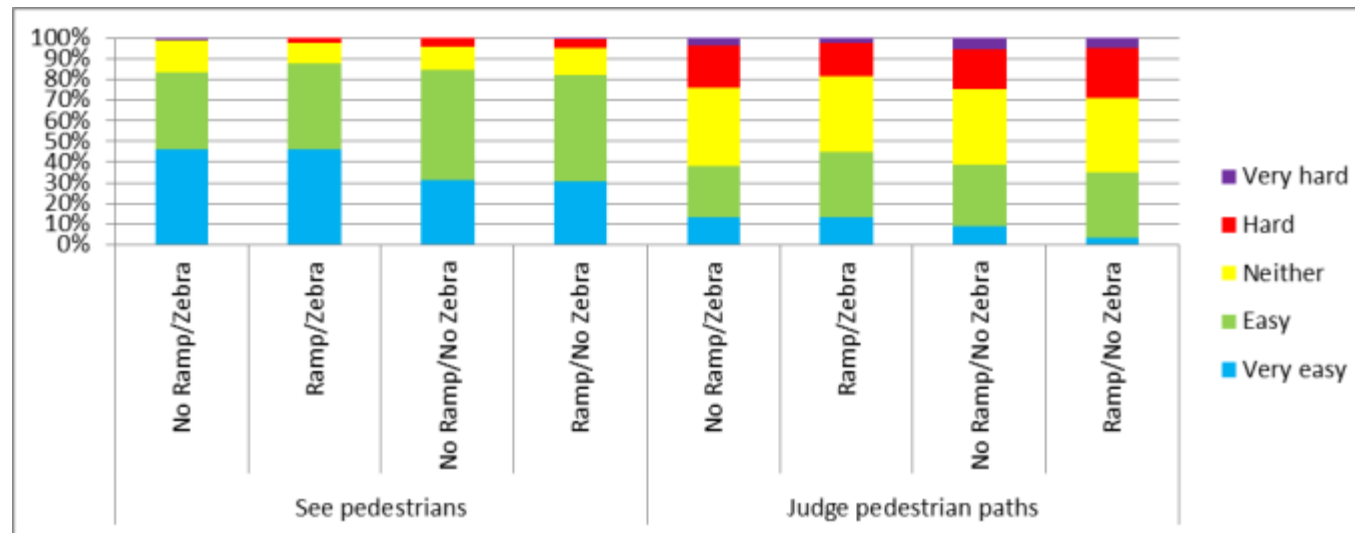
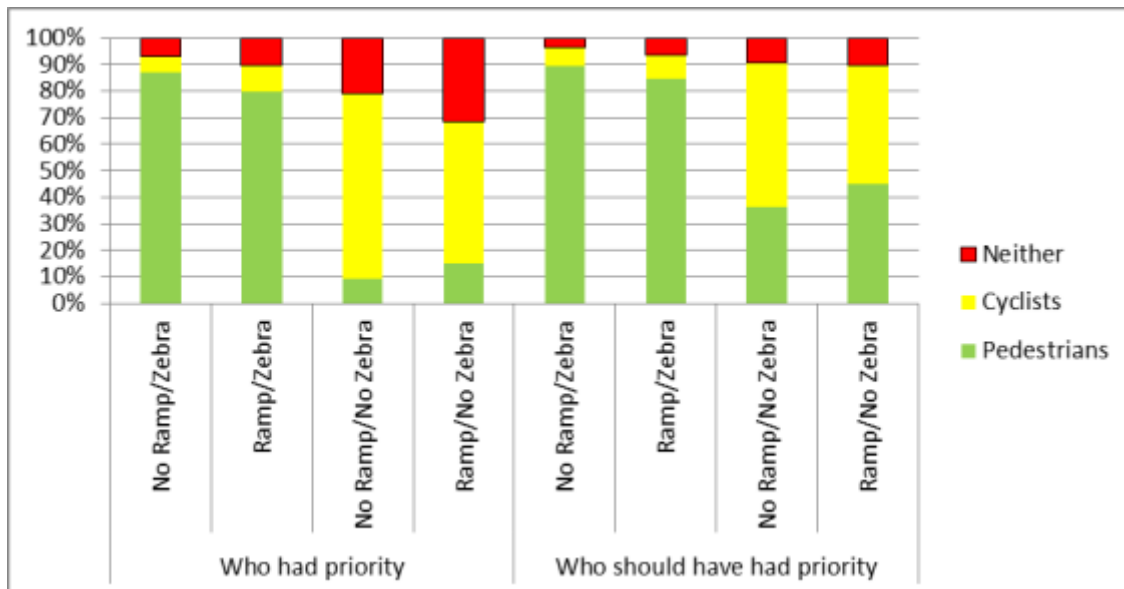


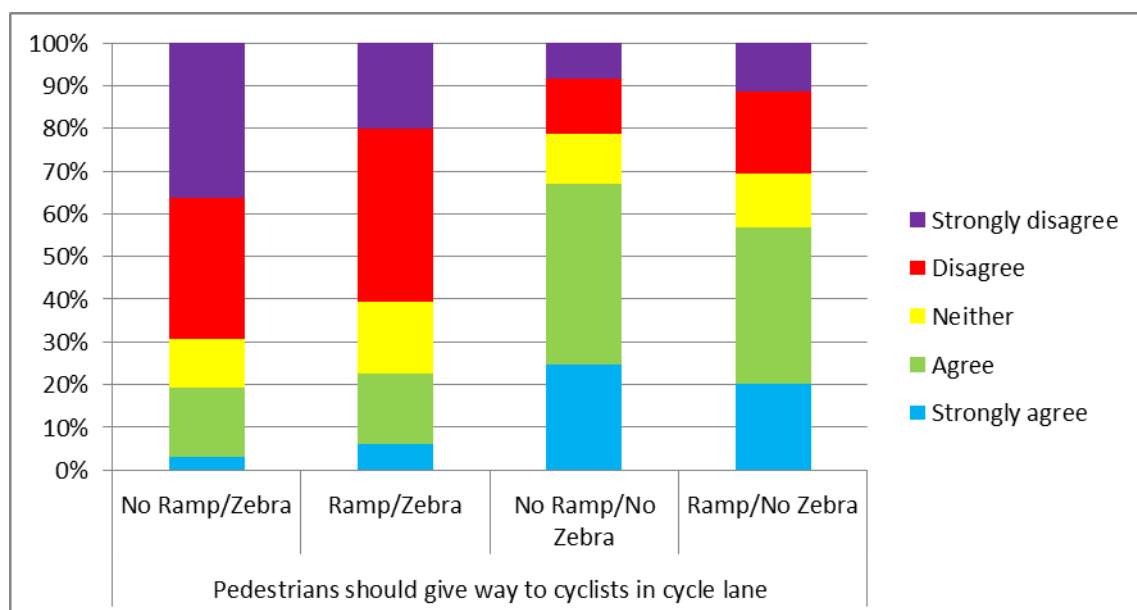
Figure 16 Cyclists' ease of seeing and assessing other users

#### 4.5 Perceived priority

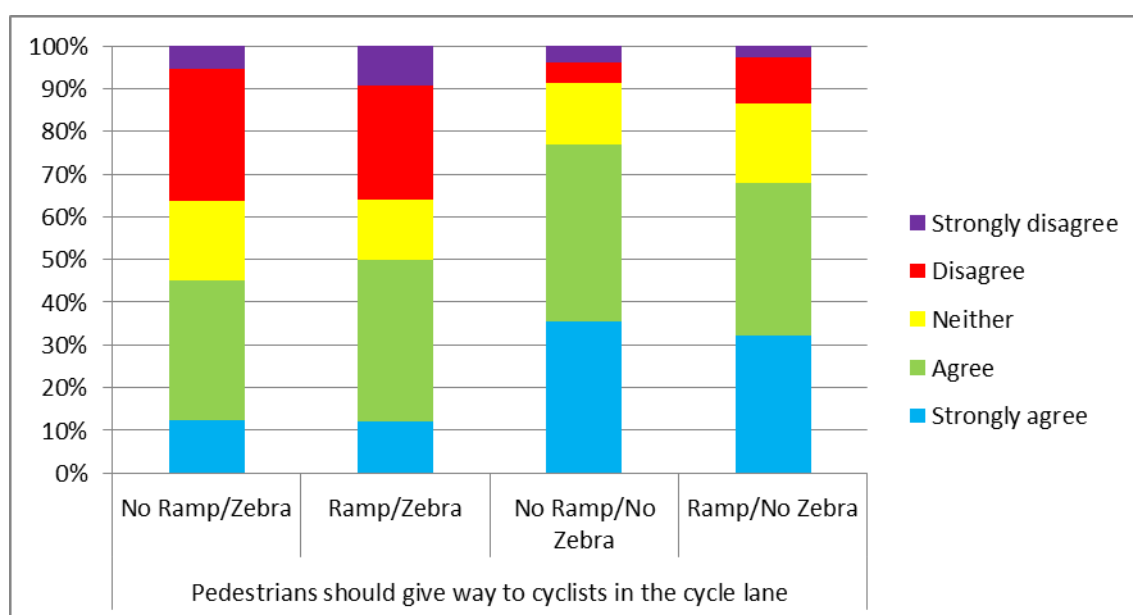
Pedestrians and cyclists were asked slightly different questions about priority at the crossing: this stemmed from the questionnaires being tailored to the elements of the bus stop bypass being used by the participants. Pedestrians were asked who, in their opinion had received priority during the trial at the dedicated crossing point and who should have had priority. Both pedestrians and cyclists were directly asked if pedestrians should have given way to cyclists in the cycle track, and was therefore based upon their whole journey through the bus stop bypass. Their answers are summarised in Figure 17 to Figure 19.



**Figure 17 Pedestrians' feedback on who had priority**



**Figure 18 Pedestrians' extent of agreement that pedestrians should give way to cyclists in the cycle track (i.e. that cyclists had priority in the cycle track)**



**Figure 19 Cyclists' extent of agreement that pedestrians should give way to cyclists in the cycle track (i.e. that cyclists had priority in the cycle track)**

A Zebra crossing was a clear indicator to pedestrians that they had priority **at the crossing point**, with at least 80% stating both that they had, and should have had, it. This expectation was particularly strong at the Zebra crossing with a dropped kerb (No Ramp/Zebra). Without a Zebra crossing most (at least 54%) considered cyclists had priority, and less than 15% thought pedestrians had priority. However, at least 36% felt that pedestrians should have had priority. Also, with a Zebra crossing, higher percentages thought that the markings on the crossing should give them – the pedestrians – priority (84% to 89% compared to 36% to 45%).

This opinion was also present when pedestrians were asked to rate their agreement with statements on priority **in the cycle track**. With a Zebra crossing, higher percentages of the participants considered they should **not** give way to cyclists in the cycle track (61% to 69% compared to 21% to 31%).

There was a stronger feeling amongst cyclists, compared to pedestrians, that they should have priority when **in the cycle bypass track** (i.e. away from the crossing): 36% considering that pedestrians should not give way to them in the track if a Zebra crossing was present, compared to at least 60% of pedestrians. This percentage was less than 13% without a Zebra crossing for cyclists compared to 20 to 30% for pedestrians.

Overall, this does imply a lack of agreement between the users over priority. Although the majority of both pedestrians and cyclists agreed that pedestrians had priority if a Zebra crossing was present, almost twice as many pedestrians as cyclists consider that they had priority in the cycle track.

Feedback from the pedestrian focus groups also highlighted that pedestrians felt they had priority if a Zebra crossing was present, but many considered cyclists had priority if no Zebra crossing was present, although they felt pedestrians should have priority if there was an uncontrolled at footway level crossing.

Similarly, feedback from the cyclists' focus groups was that pedestrians had priority at a Zebra crossing, but the majority suggested pedestrians should give cyclists priority on the remainder of the cycle path.

*"Cyclists have priority until you come to the Zebra crossing"*

However, without a Zebra crossing the majority of cyclists expressed they felt priority was ambiguous.

*"...no clear priority"*

## **4.6 Safety (and ease) of use**

### **4.6.1 Overall**

Participants were asked how easy it was for them to use the bus stop bypass during the trial they experienced. This involved pedestrians crossing the cycle bypass either to get to, or from, the bus stop island. Cyclists had to enter the cycle track, ride across the pedestrian crossing and then exit the cycle track back onto the main carriageway. The range of pedestrian and cyclist flows experienced were the same for all types of designated crossing point, therefore any overall reported differences should be attributable to the type of crossing provided. Their answers are summarised in Figure 20 and Figure 21.

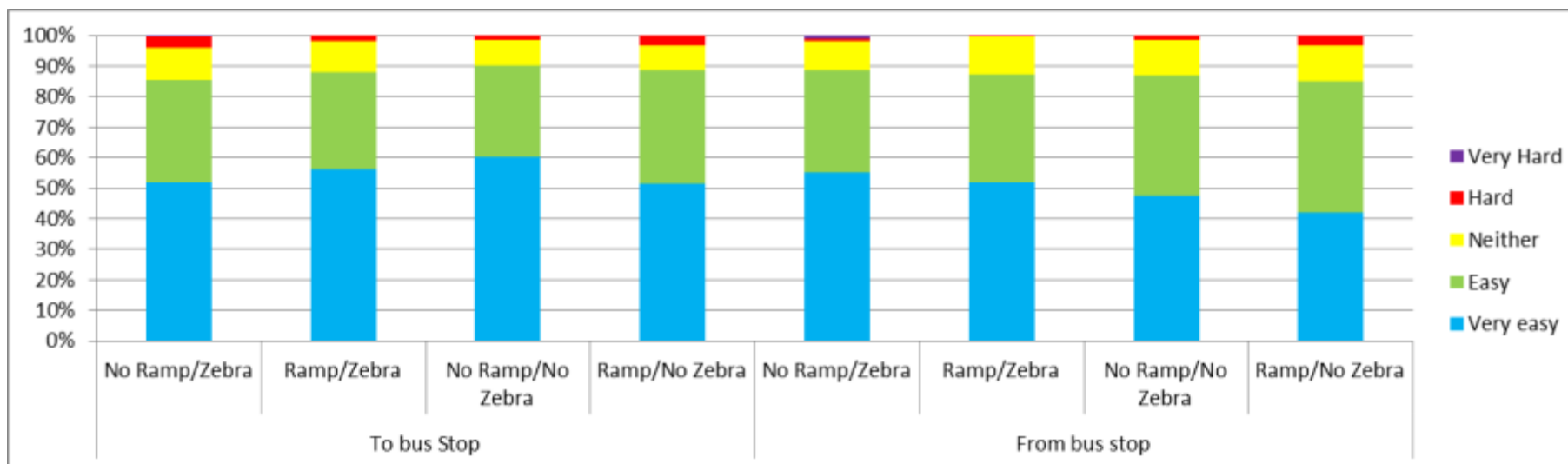


Figure 20 Pedestrians' ease of use

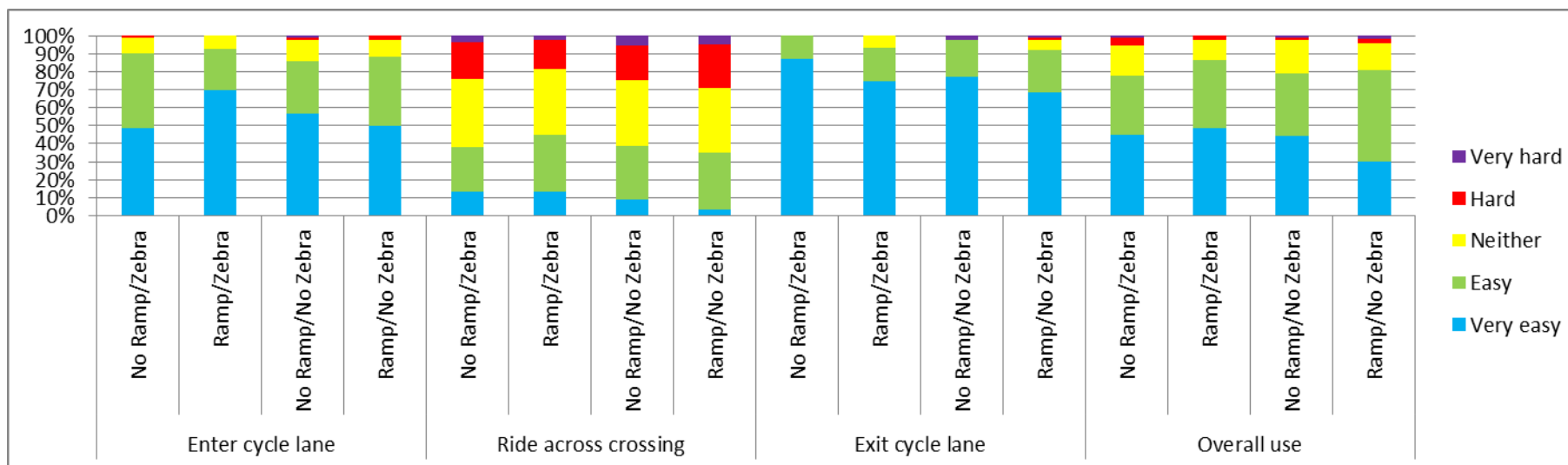


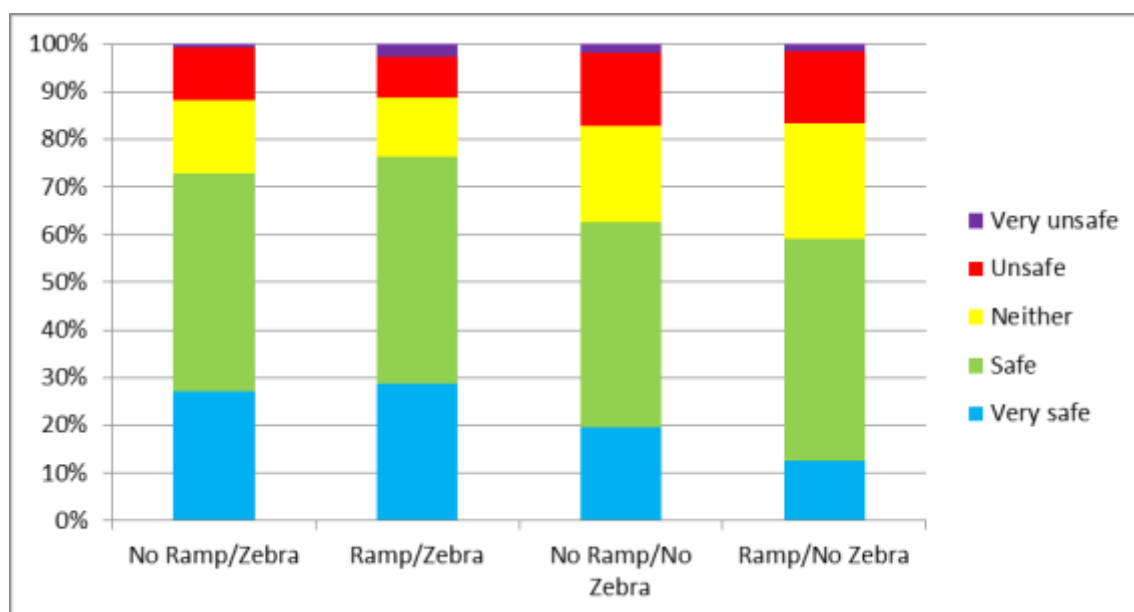
Figure 21 Cyclists' ease of use



Pedestrian participants did not encounter any difficulties in using the bus stop, with at least 85% considering it easy with any type of pedestrian crossing. Similarly, the cyclists found the bus stop bypass easy to use, with at least 78% scoring as easy to use.

In detail, cyclists found getting into the bus stop bypass more difficult than re-joining the main carriageway, which was probably owing to a tighter turn being required for cyclists to get into the bus stop bypass in the trial layout. However, the hardest action was riding across the designated pedestrian crossing: less than 45% of the cyclists found it easy. This was almost certainly only a result of the higher density of pedestrians at this location, as difficulty did not greatly vary with the type of pedestrian crossing.

Pedestrians also generally felt safe crossing to the bus stop (at least 59%). However, 10% to 15% felt more safe if there was a Zebra crossing, and this difference was significant<sup>7</sup>, see Figure 22.

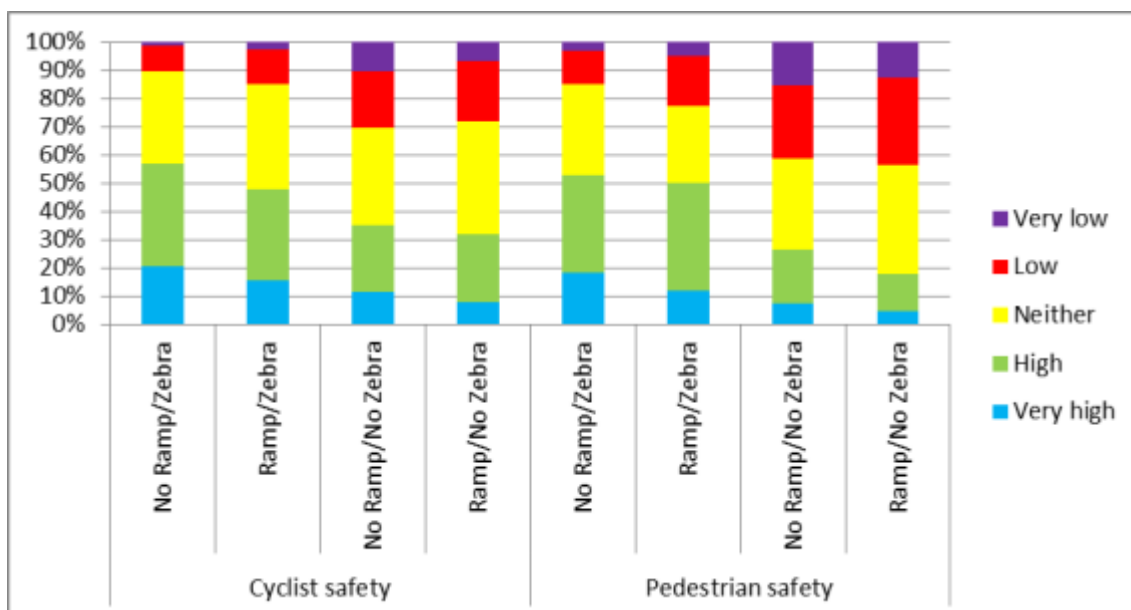


**Figure 22 Safety of crossing to the island**

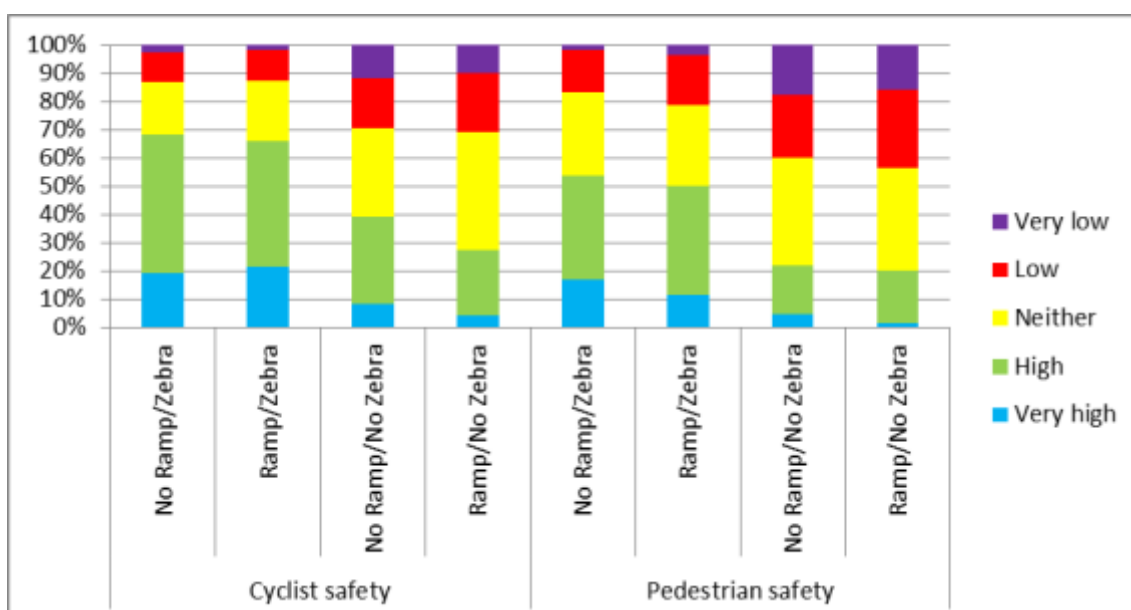
The same difference was found when pedestrians were asked to rate their agreement with statements on safety. With a Zebra crossing, lower percentages considered the cycle track was dangerous for pedestrians (33% to 34% compared to 52% to 54%).

Both the pedestrians and cyclists were asked to rate the safety of the designated pedestrian crossing from both their perspective and that of the other participants taking part in the trial, see Figure 23 and Figure 24.

<sup>7</sup> In this report significant refers to the result being statistically significant at the 95% confidence level. Also weakly significant refers to the result being statistically significant at the 90% confidence level.



**Figure 23 Pedestrians' assessed safety of the designated crossing**



**Figure 24 Cyclists' assessed safety of the designated crossing**

The scores from both the pedestrians and the cyclists were remarkably similar. Both considered the Zebra crossing to be significantly safer for all users: at most 40% scored safety high without a Zebra crossing, and 48 to 68% scored safety high with a Zebra crossing.

The participants also rated their own safety slightly lower with an at footway level, than with a at cycle track level crossing if no Zebra crossing was provided (/No Zebra compared to No /No Zebra): approximately 10% fewer scored safety high and this was weakly statistically significant.

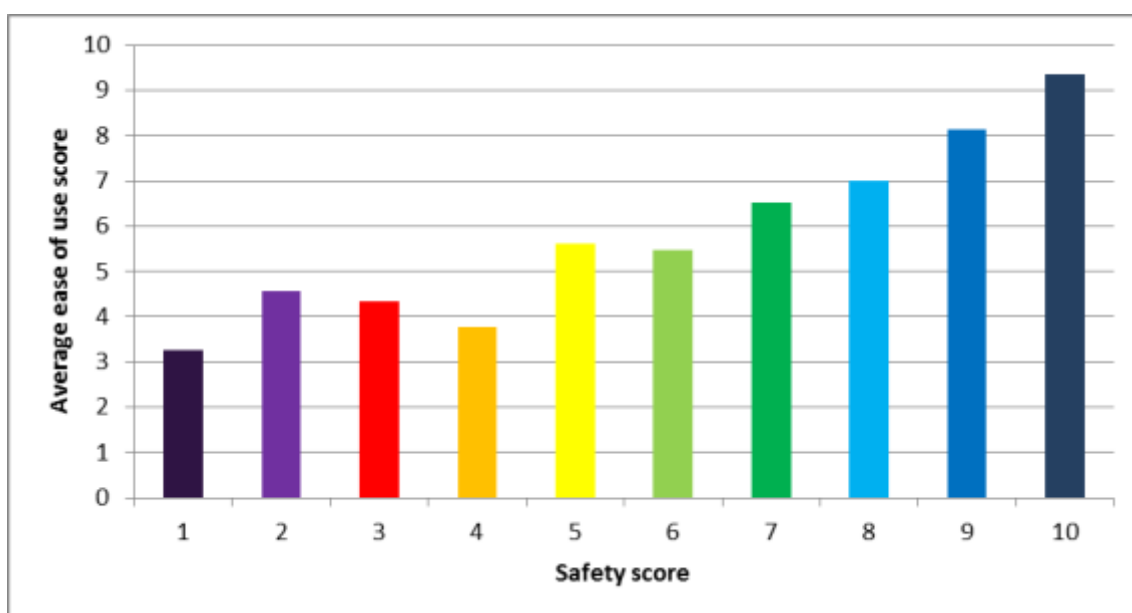
However, the feedback from the pedestrian focus groups was a general consensus that the cycle track would improve cycle safety, but it would be less safe for bus users. This was also the feedback from the cyclist focus group, with particular concern raised for bus users exiting the bus as they may be unaware of the cycle path. However, there was a suggestion that it might encourage less confident cyclists as it removed the need to overtake buses.

#### 4.6.2 On track assessment

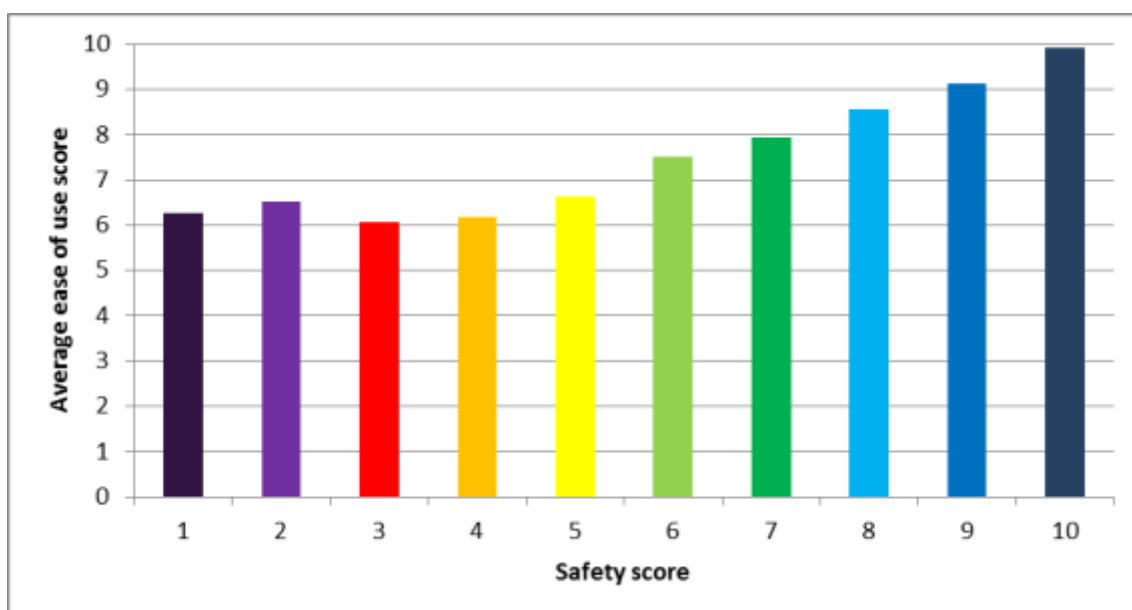
A sample of pedestrians was asked to rate the safety, and ease, of crossing to and from the bus stop island after each group had been released from the start points. Similarly, a sample of cyclists were asked to rate the safety and ease of using the bus stop bypass after they had used it and returned back to their start point.

This analysis considered how the different types of pedestrian crossing and conditions at the bus stop bypass influenced participants' rating scores and decisions.

The average ease of use scores associated with each of the safety scores are summarised for the pedestrians and cyclists in Figure 25 and Figure 26. A higher score (i.e. 10) means that the facility was easier or safer to use.



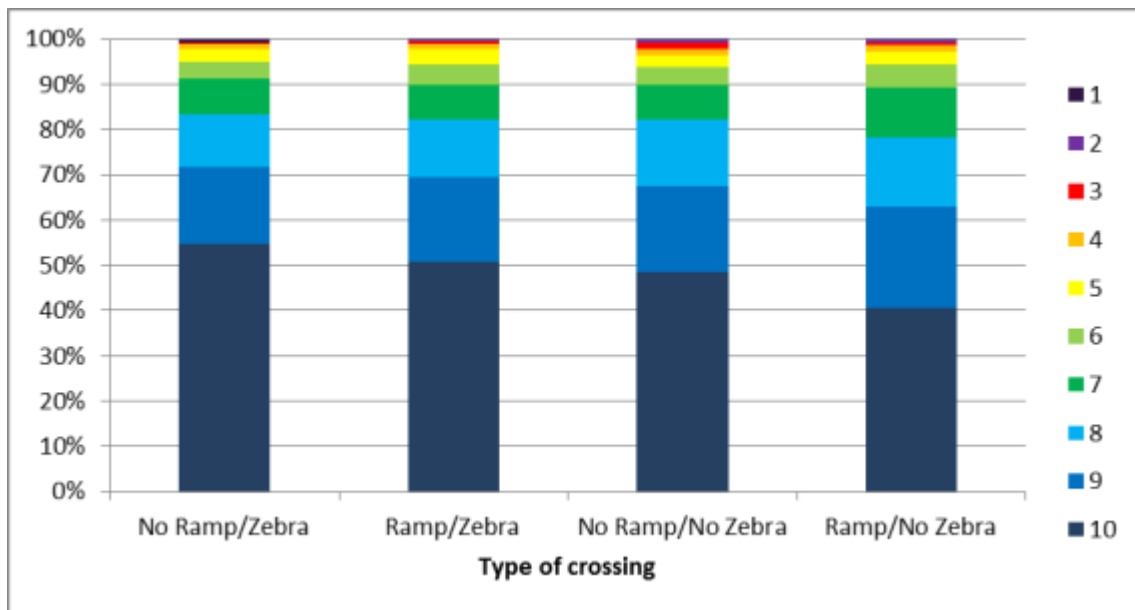
**Figure 25 Pedestrians' relationship between safety and ease of use**



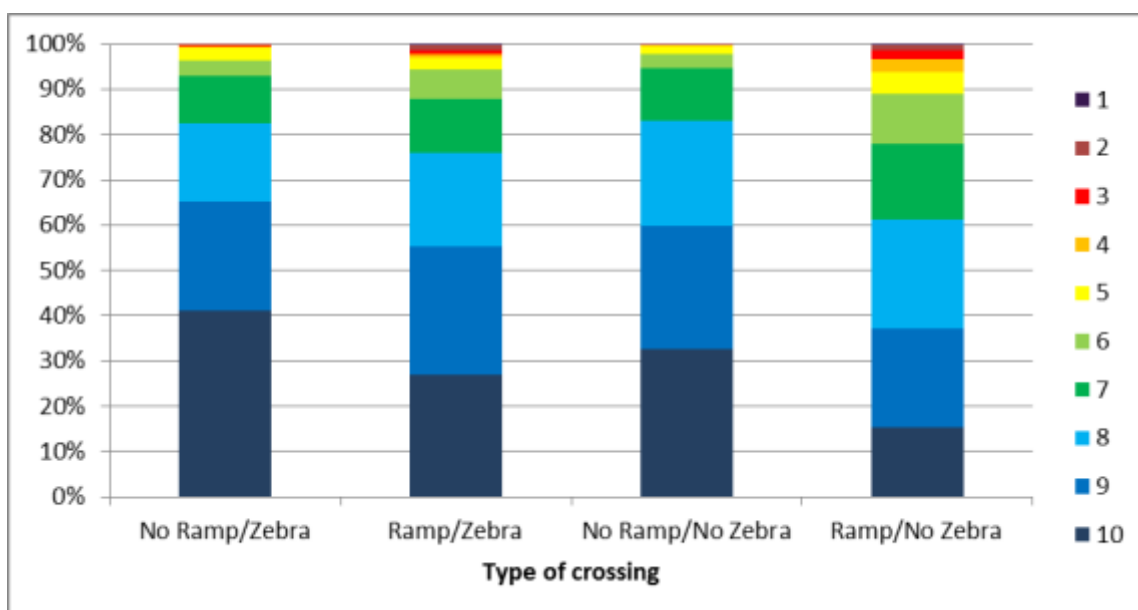
**Figure 26 Cyclists' relationship between safety and ease of use**

Cyclists rated the relative ease of use against safety higher than pedestrians, but there was a clear (linear) underlying relationship between the measures for safety scores above three. The remainder of the section therefore only examines the participants' safety scores in relation to the conditions they experienced on the bus stop bypass, and similar results would be expected for the ease of use scores. The effect of individual factors (i.e. type of crossing and flows) were considered separately, and then a statistical model developed to isolate the independent variations.

The safety scores given by pedestrians and cyclists during each of the trials with different types of pedestrian crossing are summarised in Figure 27 and Figure 28.



**Figure 27 Pedestrians' safety scores for all uses of the different crossings**



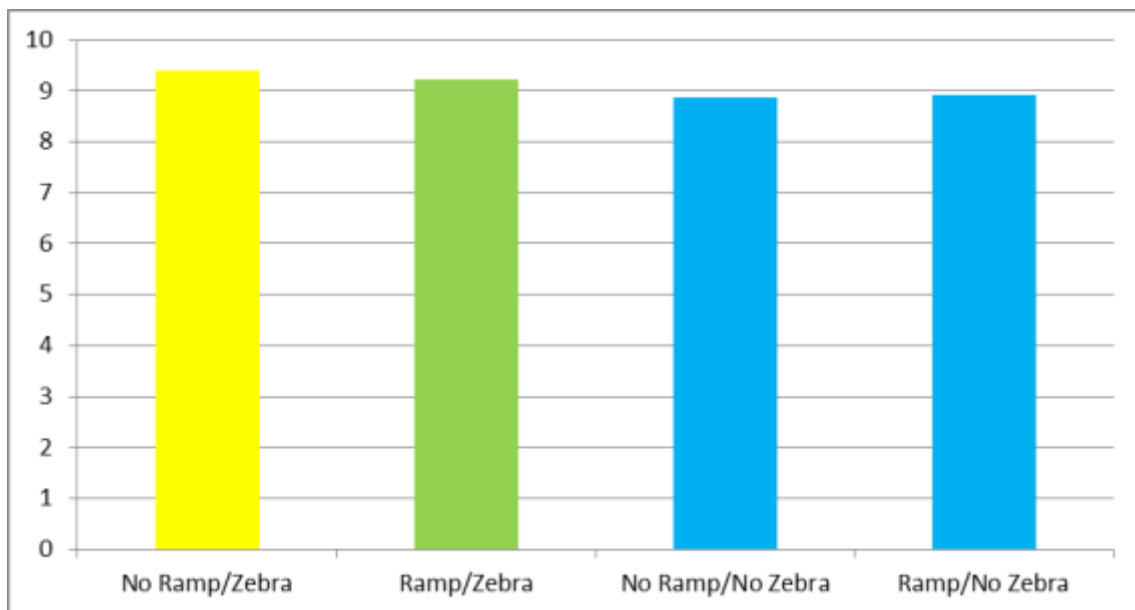
**Figure 28 Cyclists' safety scores for all uses of the different crossings**

Pedestrians gave higher safety ratings than cyclists for all the bus stop bypasses: 63 to 72% of pedestrians considered the facilities scored 9 or above for safety compared to 37

to 65% of cyclists. Overall, both the pedestrians and the cyclists scored the safety of a crossing with a at cycle track level controlled (No /Zebra) crossing to be greatest. Both sets of participants also rated the at-footway level uncontrolled (/No Zebra) as the least safe.

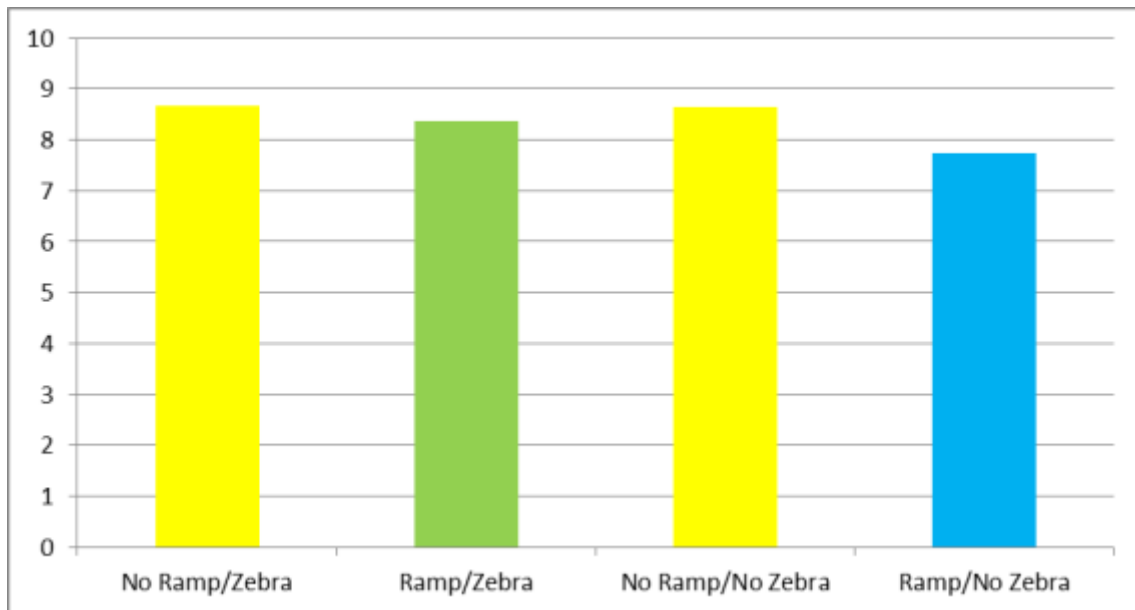
The safety scores given by pedestrians and cyclists during each of the trials with different cycle flows, and pedestrian flows implied cyclist and pedestrian flows had little effect on cyclists' perception of safety, but a stronger negative effect on pedestrians' perception of safety.

An ANOVA model<sup>8</sup> was developed that investigated the effect of the variables in combination and the results of this modelling are summarised in Figure 29 to Figure 32 **Figure 30**: any bar that is a different colour has a value that is statistically different from the other bars, and those bars of the same colour were not statistically different from each other.

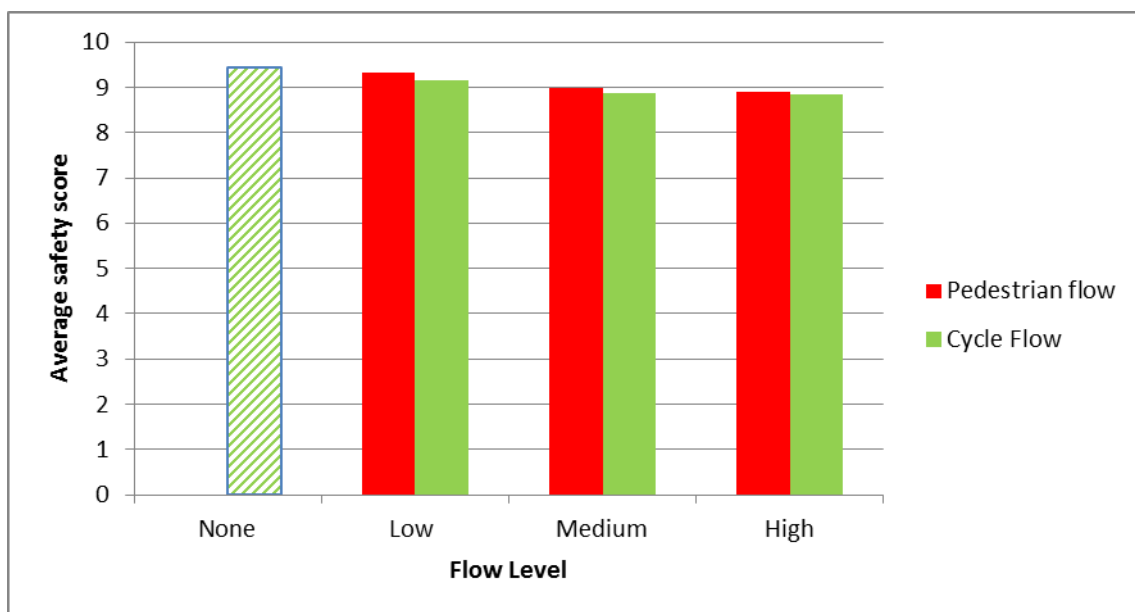


**Figure 29 Pedestrians' estimated marginal mean safety scores with different types of crossing (Different colours show which are statistically different from each other)**

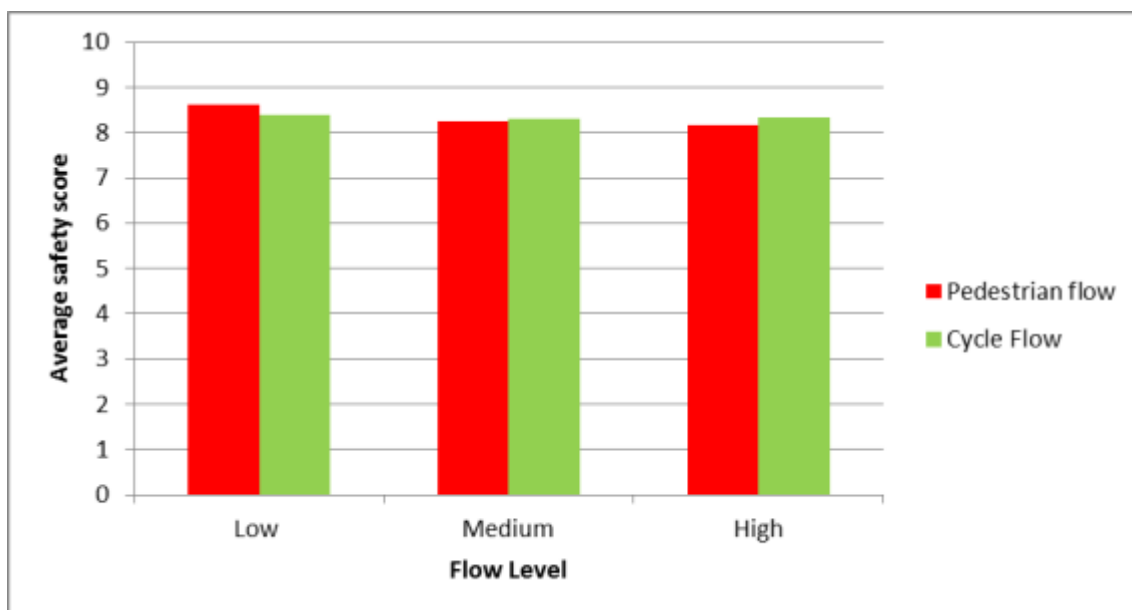
<sup>8</sup> Analysis of variance (ANOVA) is a collection of statistical models used to analyse the differences between group means and their associated procedures (such as "variation" among and between groups)



**Figure 30 Cyclists' estimated marginal mean safety scores with different types of crossing (Different colours show which are statistically different from each other)**



**Figure 31 Pedestrians' estimated marginal mean safety scores with different flows**



**Figure 32 Cyclists' estimated marginal mean safety scores with different flows**

Overall, this analysis shows that all types of pedestrian crossings and conditions experienced on these crossings were considered to be generally safe. Pedestrians found the safer crossings to be with a zebra crossing, particularly if at cycle track level. However, cyclists considered the safest crossings to be at cycle track level.

Pedestrians considered it less safe to use the bus stop bypass as pedestrian flows increased (all changes statistically significant), and less safe as cycle flows increased (only the change from medium to high flows was not statistically significant)

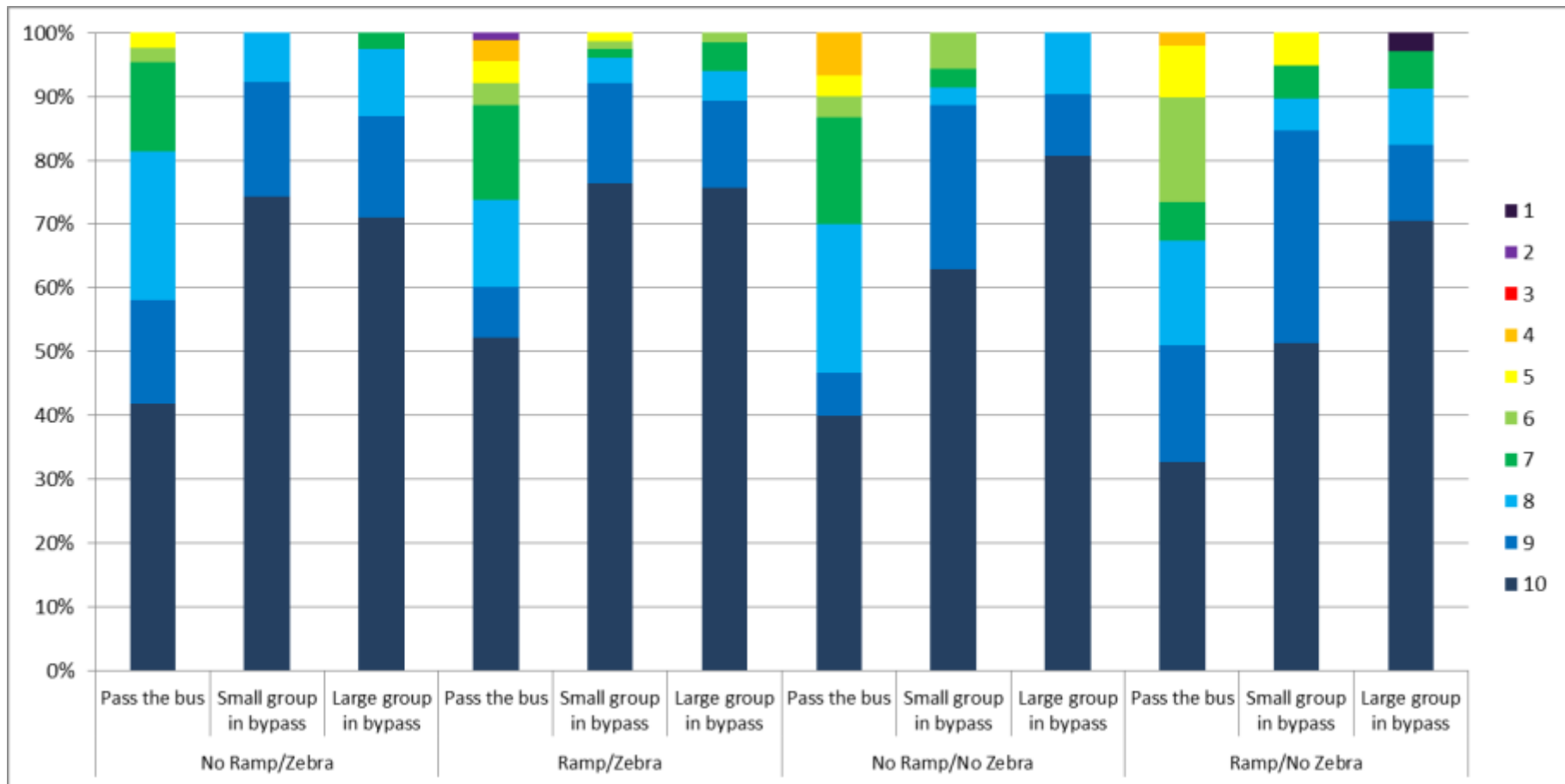
Cyclists did not feel that any changes to cycle flows affected their safety, and only the change from low to medium pedestrian flow reduced safety.

#### **4.6.3 Cyclist's safest routes**

Cyclists took part in an initial session where they performed three runs without any pedestrians present on track. These were:

- Passed the bus: Cycling passed the bus on the main carriageway and not using the bypass
- Small group bypass: Cycling along the bypass in a small groups of cyclists (between 1 and 5 depending on the number of cyclists available)
- Large group bypass: Cycling along the bypass in a larger groups of cyclists (between 2 and 10 depending on the number of cyclists available, and approximately double the size of the smaller group experienced)

Their safety scores for each of these runs are summarised in Figure 33.



**Figure 33 Safety scores for different cycle routes: cyclists**



Cyclists felt safer using the bus stop bypass, rather than remaining on the carriageway: their average safety score increasing by at least 0.9. Also, there was evidence they felt safer in a larger group, unless a ramp was present in the bypass.

This is in agreement with the cyclists' rating of statements on ease and safety. Between 66% and 72% considered the bus stop bypass safer than remaining on the highway, and 68% to 74% considered it was easier (and safer) to overtake buses at a bus stop with a bus stop bypass.

However, less than 35% considered it was easier to use under all circumstances than remaining on the highway. The percentage range of cyclists stating they would use it under specific circumstances is as follows: 28% to 37% stated that they would use it whether a bus was there or not, and 20% to 44% stated they would only use the bypass if a bus was at the stop. In addition, 38% to 56% considered they would stay on the road if many pedestrians were near the bus stop.

#### **4.7 Use in reality**

The pedestrian participants were asked if they would expect to use the designated crossing point if they encountered such a bus stop in London under different flow conditions, their answers are summarised in Figure 34.

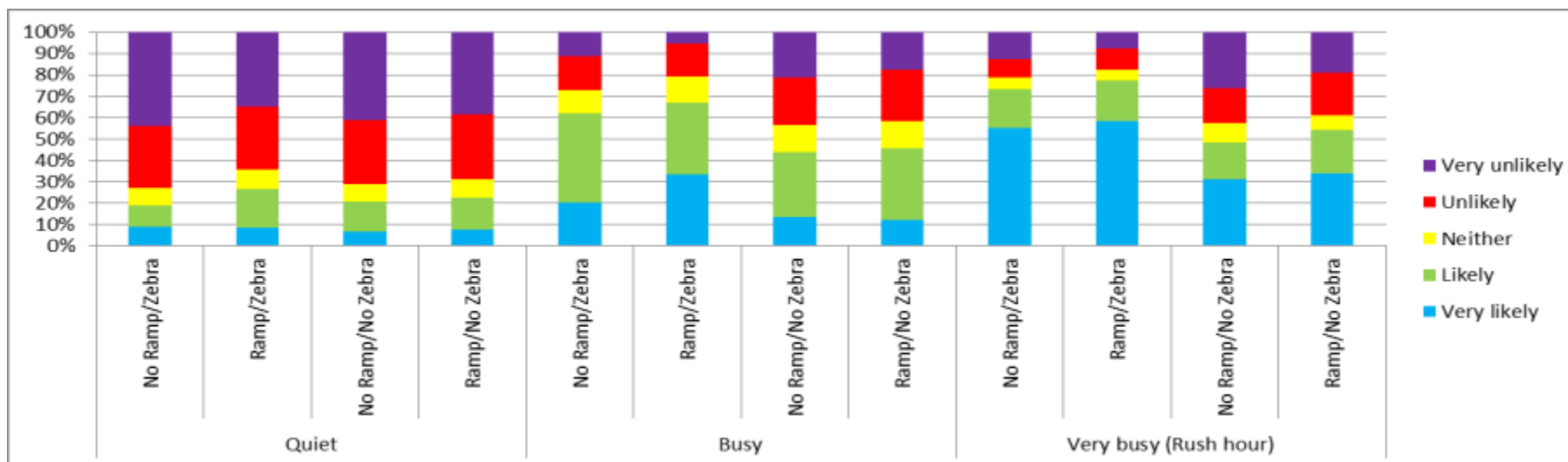


Figure 34 Pedestrians' expected probability of using the designated crossing point

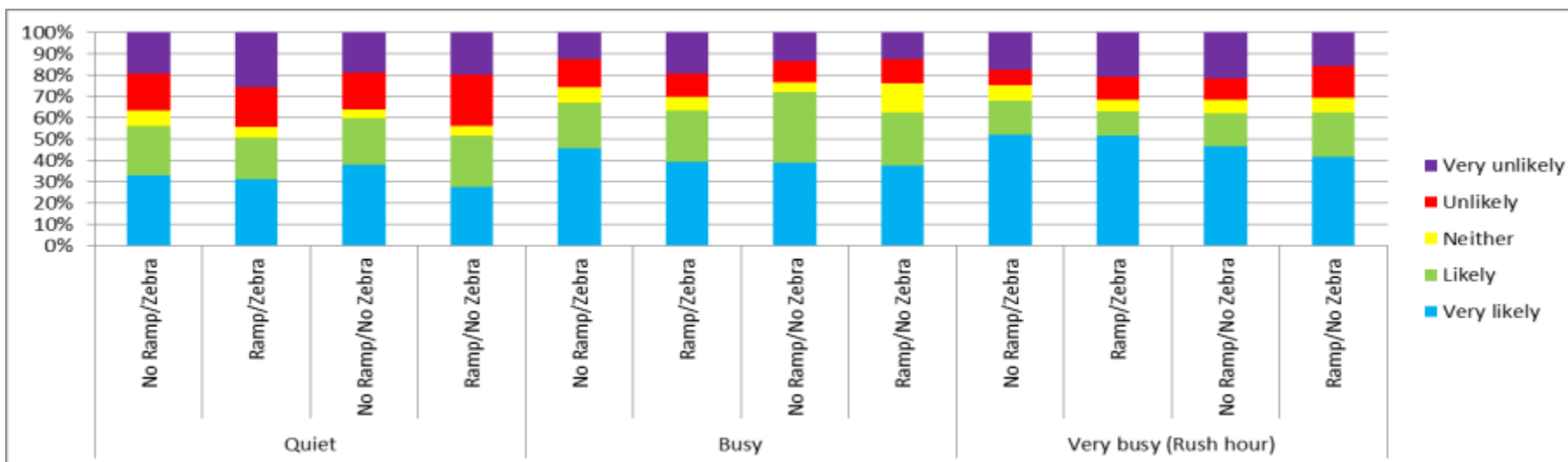


Figure 35 Cyclists' expected probability of using the bus stop bypass

As expected the percentages increased under higher flow conditions. However, whilst at least 50% extra would expect to use the designated crossing point if a Zebra crossing was present, the increase was only 28 to 32% without a Zebra crossing. In addition, for all types of crossing, between 28 and 35% of pedestrian participants stated that they would be put off using the buses under high cycle flow conditions.

In a similar vein, the cyclist participants were asked if they would expect to use the bus stop bypass if they encountered such a bus stop in London under different general flow (i.e. traffic and pedestrian) conditions, their answers are summarised in Figure 34.

50 to 60% of the cyclists stated they would use the bypass under low flow traffic conditions, with the higher percentages occurring if traffic levels were raised. This tended to increase slightly up to approximately 70% in higher general flow conditions, irrespective of the type of pedestrian crossing.

Less than 20% of cyclists thought they should not be segregated from the main carriageway at the bus stop, and although 25% to 43% of cyclists considered it took longer to use the bypass, only up to 21% thought it would delay their journey.

Overall, balancing the pro and cons, between 45 and 50% of the cyclists stated that they would be more likely to cycle in town if such cycle tracks were installed. It should be noted that this is only a statement of potential intention, and may not translate into a real increase.

The feedback from the cyclists' focus groups also indicated that conditions at the bus stop and type of cyclist would affect whether they used the bus stop bypass. There was some agreement that the choice to use the bypass would be dependent on the number of pedestrians at the bus stop.

*"I would use the bypass when there were no pedestrians;  
however, if there were pedestrians I wouldn't use it..."*

In one focus group the majority of participants suggested they felt it was unlikely that cyclists would use the bypass if no bus was present. The experience of the cyclists also affected their willingness to use the bus stop bypass, with a limited number of participants in one focus group who described themselves as confident cyclists suggesting they were frequently delayed by the cyclist in front, which could affect their decision over whether to use the cycle path or continue on the carriageway. In contrast, participants in a different focus group who described themselves as less confident cyclists agreed they would be encouraged to cycle more if they were segregated from the traffic.

*"Makes it easier for less confident cyclists but will not make any  
difference to confident cyclists as they won't use it"*

## 4.8 Other points of interest

Some other consistent facts were also present in the feedback from the pedestrians and cyclists, these included:

- In all the trials approximately a quarter of the cyclists stated (in an open question) that the cycle track was easy to use.

- Some cyclists would like barriers to separate them from pedestrians and prevent pedestrians crossing without using the designated crossing point: 13 to 26% of the cyclists raised this across the trials in an open question.
- Pedestrians felt that the bus stop bypass would be beneficial to cyclists, but a dis-benefit for pedestrians (focus group). Similar, feedback was received from cyclists with a consensus within one group that the layout would benefit less confident cyclists, but it was suggested in another focus group that the layout created a new risk between cyclists and pedestrians.

*"Less likely to get hit by a car, but more likely to have an accident with a pedestrian"*

*"Creates more problems than it solves"*

- Cyclists had some concerns over exiting the bus stop bypass, with concerns about the line of sight if the bus stop island was crowded, and felt it needed signage to warn of re-entering a carriageway (focus group).

## 4.9 Summary of user opinions findings

This section summarises the significant findings from the main trial questionnaire involving pedestrian and cyclist understanding of the bus stop bypass.

### 4.9.1 Overview of a bus stop bypass

Subject	Pedestrians	Cyclists	Conclusion
<b>Seeing the designated crossing point</b>	At least 50% found all easy to identify, and less than 30% found them difficult to identify	At least 35% found all crossing types easy to identify, and less than 40% found them difficult to identify	Crossing point was reasonably obvious to participants
<b>See other users</b>	Most (over 50%) found it easy to see cyclists	Most (over 80%) found it easy to see pedestrians	Visibility was good for all bus stop bypasses
<b>Judge speeds and paths of other users</b>	Most (over 60%) found it easy to judge the speed and distance of cyclists	Fewer (less than 50%) found it easy to judge pedestrian movements	It was relatively easy to judge cyclists in the cycle track, but more difficult to judge pedestrian movements.
<b>Ease of use</b>	No difficulties in using with at least 85% considering all of them easy	No difficulties in overall use with at least 78% considering all of them easy	Bus stop bypasses were easy to use
<b>Overall safety</b>	All types of pedestrian crossings and conditions experienced were considered to be generally safe (on-track scores). A general consensus from focus groups was that the bus stop bypass would improve cycle safety, but it would be less safe for bus users. Some concern was raised in particular for bus users exiting the bus as they may be unaware of the cycle path.		The bus stop bypass was considered to be generally safe. However, it was also considered a safety improvement for cyclists, but worse for pedestrians.
<b>Safety of crossing to bus stop</b>	Generally considered safe, by at least 59%		Generally safe to cross at the bus stop
<b>Safety of cyclists</b>		Cyclists felt safer using the bus stop bypass, rather than remaining on the road: their average safety score increasing by at least 0.9.	Cyclists felt safer on the bypass than on the main carriageway
<b>Cycle use</b>		45 and 50% of the cyclists stated that they would be more likely to cycle in town if such cycle tracks were installed. There was a suggestion it might encourage less confident cyclists.	It could increase some cycling.

#### 4.9.2 Safely managing interactions

Subject	Pedestrians	Cyclists	Conclusion
Seeing the designated crossing point	Less than 2% found it hard to identify with Zebra crossing. A ramp had no effect.	Less than 1% found it hard to identify with Zebra crossing. A ramp had no effect.	Zebra crossing makes the designated pedestrian crossing point easier to see and looked better.
	3% experiencing No Ramp/No Zebra crossing failed to notice it.	20% experiencing No Ramp/No Zebra crossing failed to notice it.	
Rating the crossing	Less than 10% scored appearance/visibility low with a Zebra crossing, but 39 to 66% did so without one. Concern over vulnerable users without one.		
See other users	Easier if there was a Zebra crossing provided.	Easier if there was a Zebra crossing provided	Zebra crossing assists seeing others
Priority at the crossing	80% felt they had priority with a Zebra crossing, but less than 15% without one and 20% to 30% considered no one had priority	Generally felt pedestrians had priority at a Zebra crossing, but without one the priority was unclear.	Pedestrians have priority at a Zebra crossing, but there was a lack of clarity and agreement as to who had priority at a crossing point without a Zebra crossing, or in the cycle track.
Priority elsewhere in the bus stop bypass	61 to 69% felt they should not give way to cyclists with a Zebra crossing, but only 21 to 31% without one.	36% felt pedestrians should not give way to cyclists with a Zebra crossing, and less than 13% without one.	
Safety of crossing to the bus stop island	10 to 15% considered it safer with a Zebra crossing. On-track responses agreed and showed the at cycle track level crossing to be safest.		Pedestrians' perceived safety in crossing to the bus stop increased with a Zebra crossing, particularly at cycle track level.
Safety of crossing to the bus stop island across the cycle track	At least 18% more considered it dangerous without a Zebra crossing.		
Safety of using the cycle track		Cyclists (on track) considered the safest crossings to be at cycle track level.	Cyclists' perceived safety was greater if it was at cycle track level.
Safety of using the designated	Significantly safer for all users with a Zebra crossing. They rated their own safety slightly lower (by 10%)		The Zebra crossing especially if at cycle

<b>crossing point</b>	with an at footway level crossing.	<b>track level</b> was considered to make the designated crossing point safer.
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#### 4.9.3 Features attractive to cyclists

Subject	Cyclists	Conclusion
<b>Use of the bypass</b>	50 to 60% of the cyclists stated they would use the bypass under low flow traffic conditions, with the lowest percentages occurring if it was at footway level. This increased slightly with flow. However, the number would decrease with the number of pedestrians at the bus stop. They also stated they would be unlikely to use it if a bus was not at the stop.	Use of the bypass would be dependent on the relative conditions on the bypass and the main road.
	Less than 35% considered it was easier to use under all circumstances than remaining on the highway: 28% to 37% stated that they would use it whether a bus was there or not, and 20% to 44% stated they would only use the bypass if a bus was at the stop. In addition, 38% to 56% considered they would stay on the road if many pedestrians were near the bus stop.	
<b>Flows and safety</b>	Changes to cycle flows did not affect their perceived safety, and only the change from low to medium pedestrian flow reduced perceived safety.	Flows at a bus stop bypass did not affect perceived safety.

#### 4.9.4 Features attractive to pedestrians

Subject	Pedestrians	Conclusion
<b>Using the crossing point</b>	More likely to use the designated crossing point with a Zebra crossing, especially if at footway level (i.e. Ramp/Zebra crossing).	<b>Zebra crossing</b> encourages greater use of designated crossing point. So does higher flows, but more so with a <b>Zebra crossing</b> .
	Under higher flow conditions at least 50% more would expect to use it with a Zebra crossing, but the increase was 28 to 32% without a Zebra crossing.	
<b>Flows and safety</b>	Increases to cycle, or pedestrian flows adversely affected their perceived safety.	Increased flows reduced perceived safety.
<b>Use of bus services</b>	For all types of crossing, between 28 and 35% of pedestrian participants stated that they would be put off using the buses under high flow conditions.	High flows could affect willingness to use bus services.

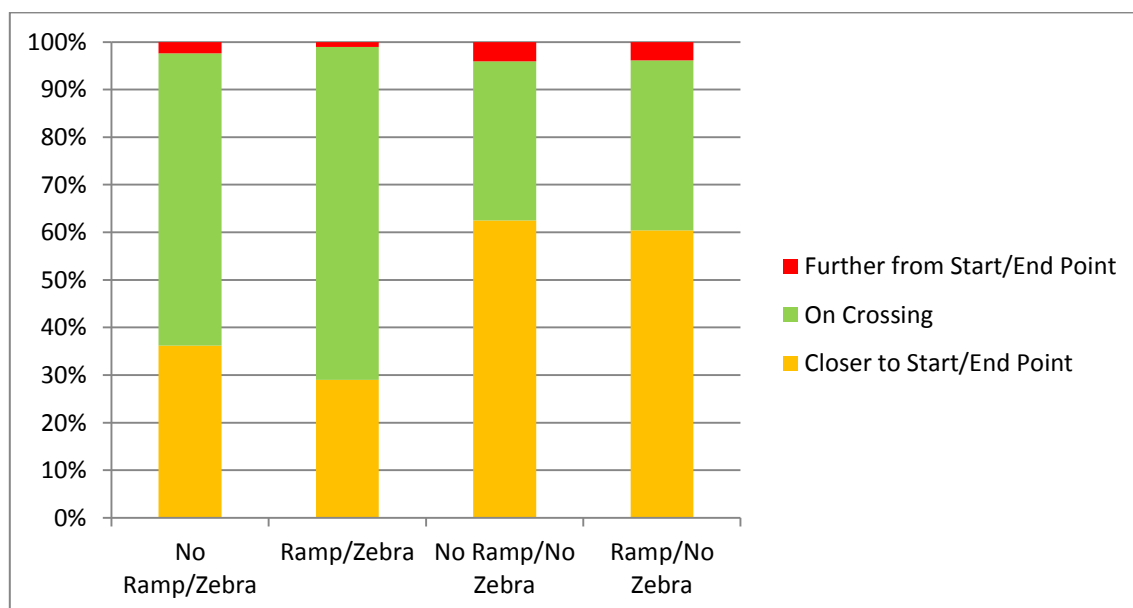
## 5 Use of the designated crossing point

This chapter examines how pedestrians crossed the cycle bypass track under a variety of different situations: different types of pedestrian designated crossing point, the level of cycle flow in the cycle track, and pedestrian flow.

### 5.1 The effect of type of designated crossing point

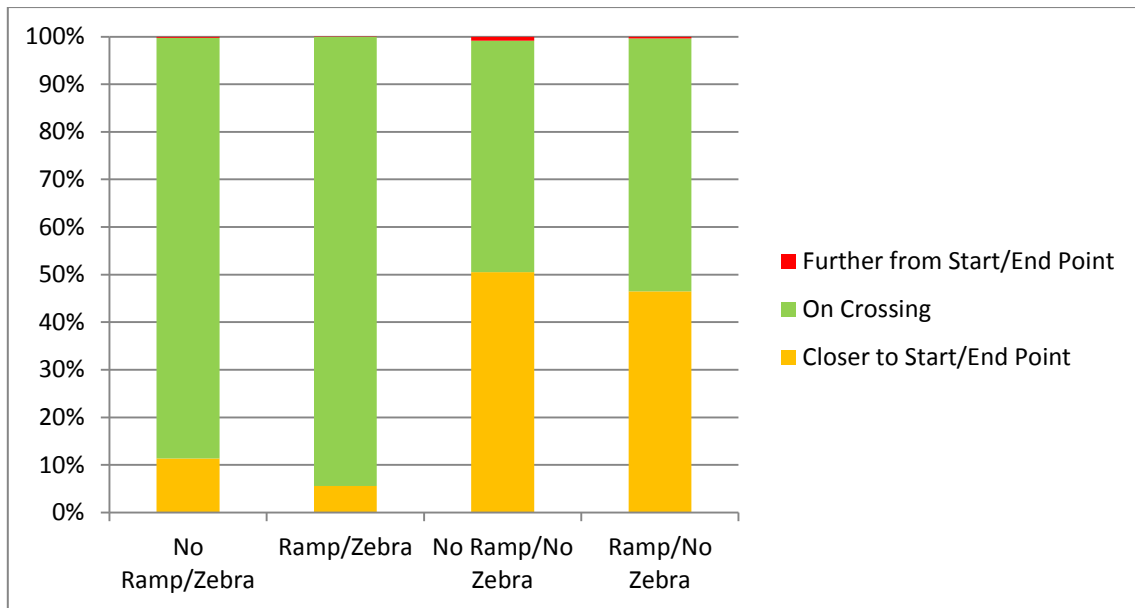
Four different types of designated crossing point were tested. The same pedestrian and cyclist flows were tested on all types of designated crossing points over the three survey days. The observations were consequently balanced with respect to any flow effects, with the exception of any missing observations. It is possible to gain an insight into the use of the crossing with respect to the type of designated crossing point by taking overall averages. These are shown for all pedestrians crossing the cycle track in Figure 36, pedestrians walking to A and B from the Bus Stop Island in Figure 37, pedestrians walking to the Bus Stop Island from A and B combined in Figure 38, and for A and B separately in Figure 39.

Note that the terms used in the graphs are relative to the start point (A or B), therefore from Point A, 'Close to Start/End Point' is Zones 1 and 2, 'On Crossing' is Zone 3, and 'Further from Start/End Point' is Zones 4 and 5. References from Point B follow a similar pattern: for example, 'Close to Start/End Point' is Zones 4 and 5. This convention has been implemented owing to pedestrians using their desire lines will result in them using the zones 'Close to Start/End Point'.

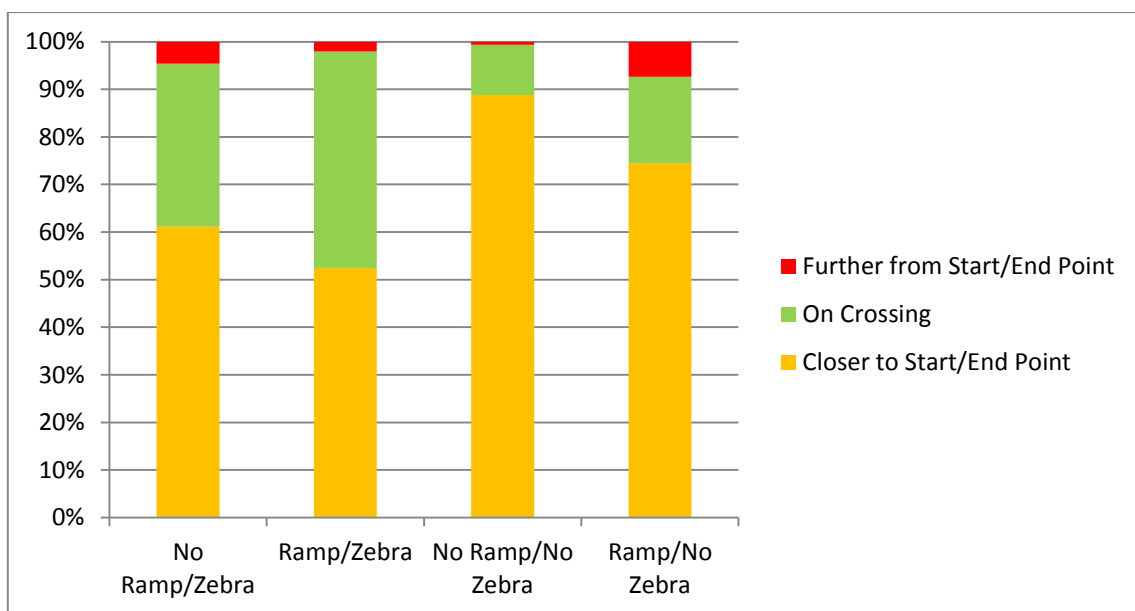


**Figure 36: All crossing movements**

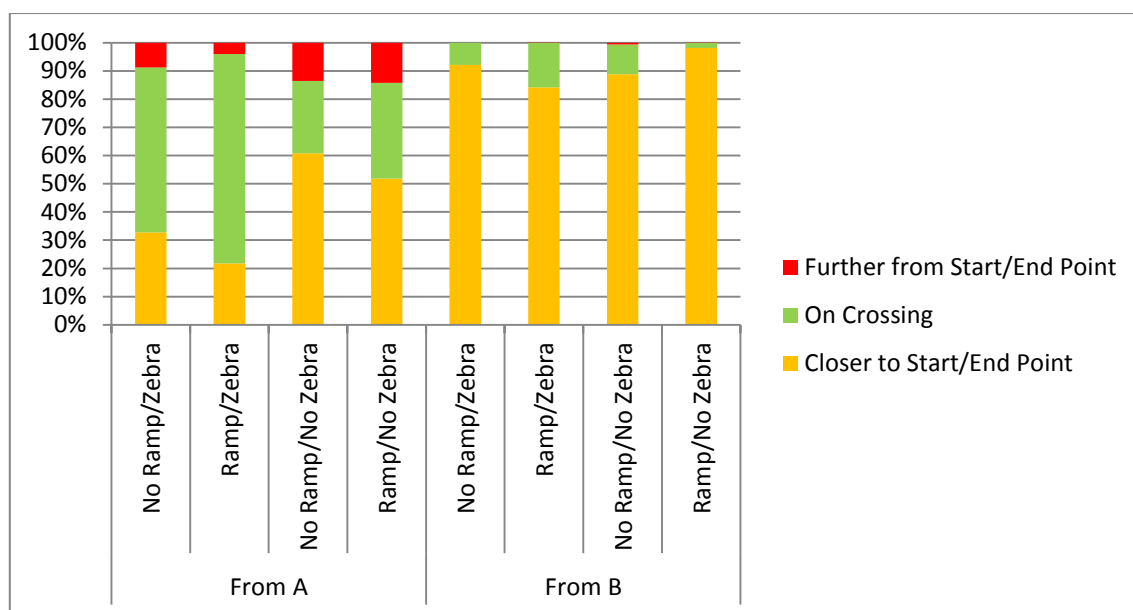




**Figure 37: From The Bus Stop Island**



**Figure 38: To The Bus Stop Island**



**Figure 39: To The Bus Stop Island from A and B**

The presence of a Zebra crossing was the main reason for pedestrians using the designated crossing point, with the Ramp/Zebra crossing being slightly (but still statistically significant) more attractive than the No Ramp/Zebra crossing. Overall, 33 to 36% used the designated crossing point with an uncontrolled (No Zebra) crossing, whilst 61 to 70% used it if there was a Zebra crossing.

The highest percentage of pedestrians who used the crossing walked from the Bus Stop Island to Points A and B: 49 to 53% without a Zebra crossing, and 88 to 94% with a Zebra crossing. This is not surprising as they alighted from the bus opposite the designated crossing point and thus the path deviation required was small and the path was less likely to require passing through the pedestrians waiting at the bus stop.

The same behaviour variation was evident for those pedestrians crossing to the Bus Stop Island, although lower percentages used the designated crossing point: only 11 to 18% of pedestrians used the designated crossing point without a Zebra crossing, but 34% did if there was a Zebra crossing and 45% if it also had a ramp.

There was a distinct and significant difference in the percentage of pedestrians using the designated crossing point from the two Start Points A and B. Less than 16% of pedestrians used the designated crossing point from B with any of the types of crossing. This was probably the result of two influencing factors. Firstly, the cyclists were travelling towards them, so making decisions on gap acceptance in the cycle flow easier as they walked towards the bus stop. Secondly, using the crossing had the highest walking distance "penalty", as they had to walk back on themselves to get to the bus stop (see Figure 5).

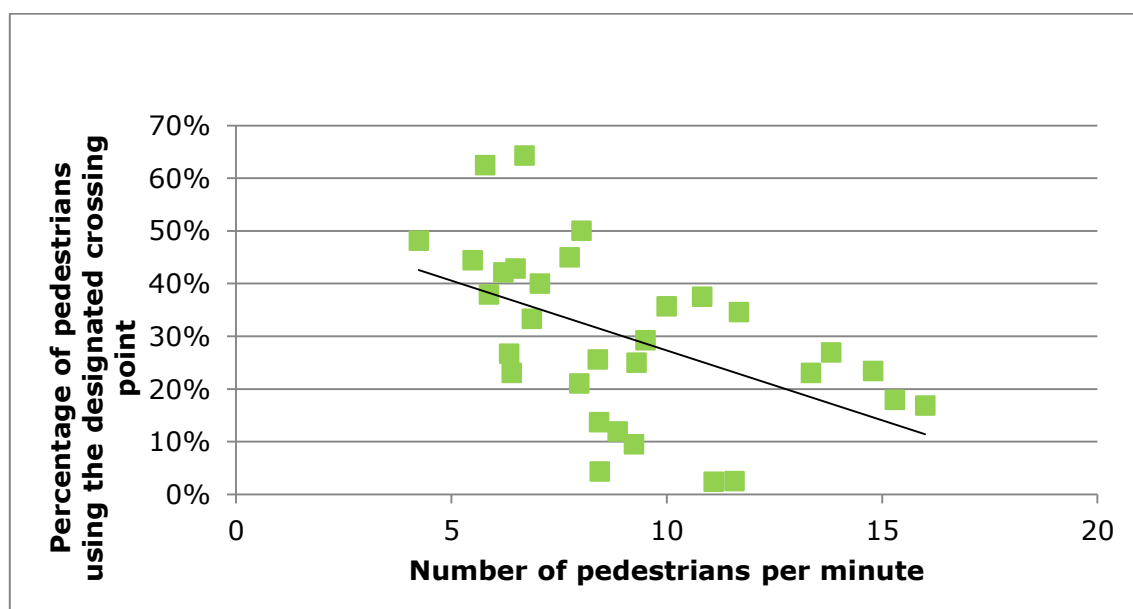
However, the cyclists approached them from behind when walking from A and the path deviation required to use the crossing was smaller. This resulted in higher percentages of pedestrians using the designated crossing point, particularly if a Zebra crossing was present: 26 to 34% used the designated crossing point without a Zebra crossing, which increased to 58% with a Zebra crossing and 74% with a ramped, Zebra crossing.

## 5.2 The effect of pedestrian and cycle flow

### 5.2.1 Crossing to the Bus Stop Island

It might be assumed that pedestrians will use the crossing (Zone 3) only if they consider walking the extra distance to the crossing to be advantageous for some reason (such as safety) over walking directly to the bus stop along their desire line.

The use of the crossing will therefore depend on a number of factors including its visibility, the extent of priority afforded by the crossing, the extent of ownership they feel over the cycle track and opportunities to cross between cyclists. Relative priorities and opportunities to cross would be expected to vary according to the relative flows of cyclists and pedestrians. Higher flows of cyclists would be expected to result in fewer opportunities to cross between them, whilst higher flows of pedestrians could provide a greater feeling of ownership, by numbers, of the cycle track. An example of the trend between use of the designated crossing point and the flow of pedestrians is shown in Figure 40.



**Figure 40: Example of how pedestrian flow affected use of the designated crossing point from start point A – No Ramp/No Zebra**

A clear trend is evident with very few pedestrians using the designated crossing point when it was in No Ramp/No Zebra configuration and pedestrian flows were high.

Regression analysis<sup>9</sup> has been used to investigate how the flows of pedestrians and cyclists affect use of the each of the types of crossing. These have been summarised in Table 3 and Table 4, using the following information:

<sup>9</sup> Regression analysis is a statistical process for estimating the relationships among variables. In this report the extent to which a linear relationship exists between two variables is investigated.

1. The average predicted percentage that would use the designated crossing if no cycles were on the cycle track and there was a low pedestrian flow (i.e. the regression constant).
2. The average percentage point changes that would be expected to occur with high cyclist and pedestrian flows. A high flow was defined as 10 cyclists, or 15 pedestrians, per minute. Also, the value is only provided if it is weakly significant from zero. The following colour coding is used:
  - a. BLACK – No (statistically significant) effect found
  - b. GREY – Average value that is weakly significant from zero
  - c. WHITE – Average value that is significant from zero

The use of linear regression modelling provides a prediction of the average percentage of pedestrians that would use the dedicated crossing point with different cycle and pedestrian flows. However, such modelling has limits of (direct) applicability. For example, extrapolating the line in Figure 40 would imply that with pedestrian flows above 20 per minute, less than 0% of pedestrians would use the crossing. In reality, at high pedestrian flows, clearly fewer than zero pedestrians cannot use the crossing; the model should be interpreted as predicting that 0% of pedestrians use the crossing. The same principle should be applied if the model predicts that more than 100% of pedestrians use the crossing.

**Table 3: Effect of flows on designated crossing point use: from A**

Designated Crossing Type	Predicted percentage using designated crossing: no cycles and a low pedestrian flow	Percentage change in crossing use	
		Effect of an increase of 10 pedestrians per minute	Effect of an increase of 10 cyclists per minute
No Ramp/ Zebra	48%	Not significant	Not significant
Ramp/ Zebra	62%	Not significant	+24%
No Ramp/ No Zebra	54%	-34%	+21%
Ramp/No Zebra	32%	Not significant	+14%

**Table 4: Effect of flows on designated crossing point use: from B**

Designated Crossing Type	Predicted percentage using designated crossing: no cycles and a low pedestrian flow	Percentage change in crossing use	
		Effect of an increase of 10 pedestrians per minute	Effect of an increase of 10 cyclists per minute
No Ramp/ Zebra	14%	Not significant	Not significant
Ramp/ Zebra	24%	Not significant	Not significant
No Ramp/ No Zebra	9%	-8%	Not significant
Ramp/No Zebra	9%	Not significant	Not significant

Few pedestrians (less than 24%) who walked to the bus stop from Point B (with the cyclists coming towards them) were likely to use the designated crossing point under any circumstances. Even fewer (less than 10% of the pedestrians) used the designated crossing point with no Zebra crossing. Flows only affected this percentage at the No Ramp/No Zebra crossing: it was highly unlikely to be used by pedestrians starting from Point B when there were high pedestrian flows.

The situation was found to be different for pedestrians walking to the bus stop from Point A (with the cyclists coming from behind them). A higher percentage used the designated crossing point compared to pedestrians walking from Point B. Also, this percentage was dependent on the relative flows of pedestrians and cyclists. However, as with those starting from Point B, the percentage who used the designated crossing point was generally higher with a Zebra crossing.

If there was a Ramp/Zebra crossing then 62% of those from Point A used it with low cycle flows and up to 86% with high cycle flows. This compares to 32% under low cycle flows with a Ramp/No Zebra crossing which increased to 46% under high cycle flows. At the No Ramp/Zebra crossing, 48% used it under all flow conditions. This compares to

54% under low cycle and pedestrian flows at a No Ramp/No Zebra crossing which decreased by 51% points under high pedestrian flows and/or increased by 21% points under high cycle flows.

### 5.2.2 Crossing from the Bus Stop Island

Pedestrians left a stationary bus and started directly in line with the designated crossing point. So, the probability of using the crossing point would be expected to be fairly high. The same analysis as for pedestrians crossing to the island was conducted for all those crossing from the island. The results are summarised in Table 5.

**Table 5: Effect of flows on designated crossing point use: from Bus Stop Island**

Designated Crossing Type	Predicted percentage using designated crossing: no cycles and a low pedestrian flow	Percentage change in crossing use	
		Effect of an increase of 10 pedestrians per minute	Effect of an increase of 10 cyclists per minute
No Ramp/ Zebra	84%	Not significant	20% <sup>10</sup>
Ramp/ Zebra	88%	Not significant	9%
No Ramp/ No Zebra	57%	Not significant	Not significant
Ramp/No Zebra	49%	Not significant	14%

The percentage of pedestrians who started from the Bus Stop Island and used the designated crossing point was highest when a Zebra crossing was present: over 84% used the Zebra crossing when there were low cyclist flows. Also, this percentage was consistently higher than the equivalent percentages for pedestrians crossing from Point B, and from Point A, when a Zebra crossing was present.

Without a Zebra crossing, 49% to 57% used the designated crossing point when starting from the Bus Stop Island under low cyclist flows.

For three of the designated crossing point types (excluding the No Ramp/No Zebra crossing) high cycle flows increased the percentage using the dedicated crossing point to cross from the Bus Stop Island to 63% without a Zebra crossing and over 97% with one.

<sup>10</sup> Note that the values in the tables are predicted percentages for pedestrians using the crossing, using linear regression modelling. Therefore, any predictions exceeding 100% have reached the (absolute) predictive limits of the model and should be interpreted as 100% of pedestrians using the crossing.

### 5.3 Summary of use of the designated crossing point findings

This section summarises the significant findings from the observed use of the designated crossing point

#### 5.3.1 Overview of use

Subject	Pedestrians	Conclusion
<b>Direction of approach</b>	Use varied with direction of approach. The highest percentage was from the Bus Stop Island, 20 to 30% more than from Point A, which was at least 15% more than from Point B. From Point B (downstream of the bus stop) less than 16% used it.	Route choice varied according to proximity of the designated crossing point and ease of seeing cyclists.

#### 5.3.2 Type of crossing

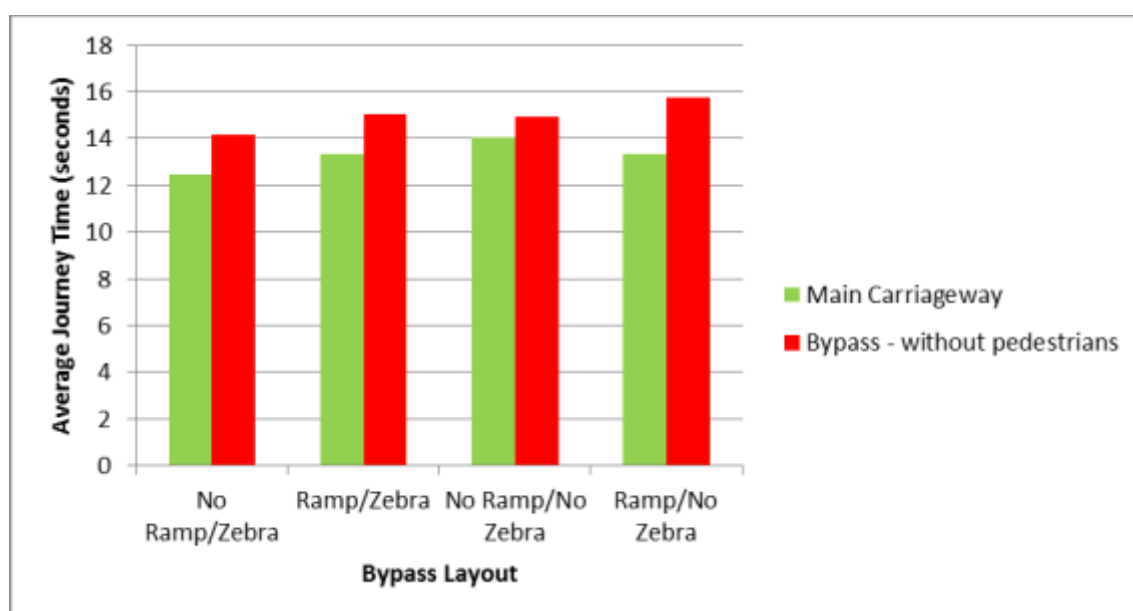
Subject	Pedestrians	Conclusion
<b>Direction of approach</b>	More pedestrians used the designated crossing point if a Zebra crossing was present: changing from below 36% to over 61%. The main increases were approximately 40% from the Bus Stop Island, and 34 to 40% from Point A. It had little effect on those crossing from Point B.	<b>Zebra crossing</b> encouraged greater use of designated crossing point.
<b>Increased flows for crossing from B (from downstream, cycles coming towards them)</b>	Use of crossing was unaffected by flows with a Zebra crossing, with less than 24% using it. Maximum of 10% used it without a Zebra crossing, and this was further reduced with high pedestrian flows.	Flows had little effect on crossing use. Tended to remain on desire lines
<b>Increased flows for crossing from A (from upstream, cycles coming behind them)</b>	Use of crossing was dependent on flows: Ramp/Zebra: increase of 24% points under high cycle flows. No Ramp/No Zebra: increase of 21% points under high cycle flows, but reduction by up to 51% point in high pedestrian flows. Ramp/No Zebra: increase of 14% points under high cycle flows.	Except for with a No Ramp/ Zebra, more pedestrians used the designated crossing point under high cycle flows, but at the No Ramp/No Zebra use decreased under high pedestrian flows.
<b>Increased flows for crossing from Bus Stop Island</b>	Use of the crossing increased by 9 to 20% under high cycle flows: except at the No Ramp/No Zebra crossing.	Except for with a No Ramp/ No Zebra, more pedestrians used the designated crossing point under high cycle flows (600 cycles per hour)

## 6 Effect on Cyclist Journey Times

Three sessions were undertaken as part of each daily trial with just the cyclists and no pedestrians, these investigated the effect of the Bus Stop Bypass infrastructure on cyclists' journey times. In the other sessions, the flows of pedestrians and cyclists varied and these ascertained any effect of these flows on the cyclists' journey time through the Bus Bypass Track.

### 6.1 Effect of the infrastructure

For all four designated crossing points, the average speeds used by cyclists on the Bus Stop Bypass were between 10.8mph (4.83 m/s)<sup>11</sup> and 12.0mph (5.26 m/s). The average journey times for cyclists using the bypass, and for remaining on the carriageway and going around a stopped bus, are summarised in Figure 41. Also, the associated sample sizes and standard deviations are in Table 6.



**Figure 41: Average cyclist journey time**

<sup>11</sup> m/s is the speed in metres per second



**Table 6: Average cyclist journey times**

	Around bus			Through bypass		
	Mean (seconds)	Standard deviation	Sample size	Mean (seconds)	Standard deviation	Sample size
<b>No Ramp/ Zebra</b>	12.4	1.9	219	14.2	2.1	429
<b>Ramp/ Zebra</b>	13.3	1.7	198	15.0	2.0	391
<b>No Ramp/ No Zebra</b>	14.1	2.0	173	14.9	2.7	350
<b>Ramp/ No Zebra</b>	14.0	2.0	213	15.8	2.4	433

The delay associated with using the cycle bypass was between 0.9 and 1.7 seconds, and these were statistically significant delays. The only variation between the types of designated crossing points was with the No Ramp/No Zebra designated crossing point, which caused a slightly smaller average delay (0.8 seconds) than the others (1.7 seconds).

## 6.2 Effect of flow conditions

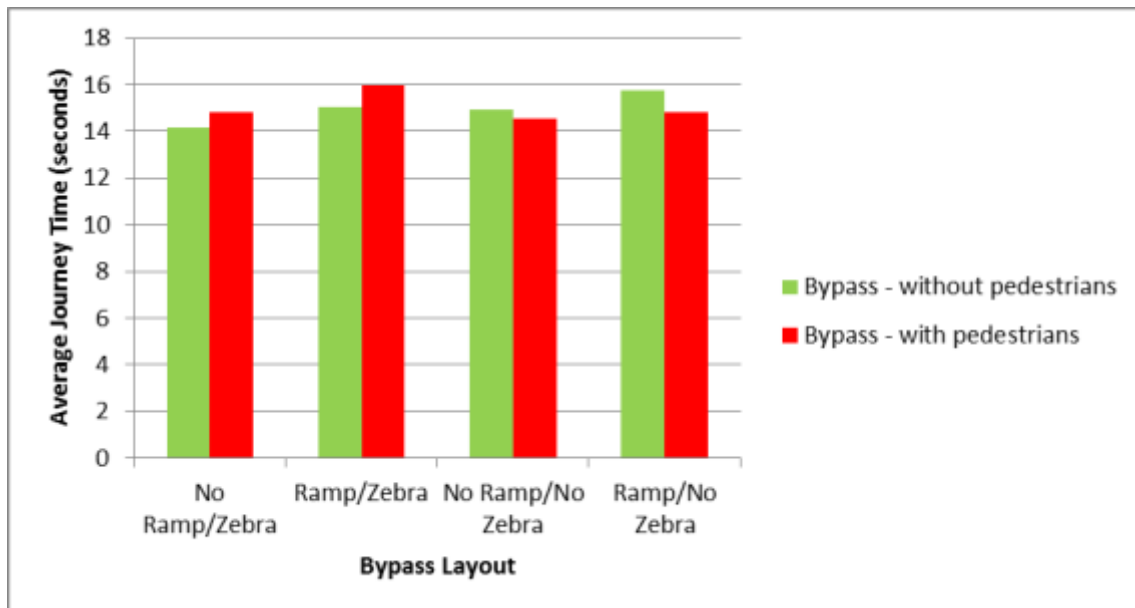
The effect of pedestrian, and cyclist, flows on cyclist journey times is now examined. The same levels of cyclist and pedestrian flows were experienced by cyclists with each of the four types of pedestrian crossing: excluding missing data. The combinations used within the trial are summarised in Table 7, which uses the following nomenclature:

- LP = Low Pedestrian Flow (Average 180 per hour in both directions)
- MP = Medium Pedestrian Flow (Average 300 per hour in both directions)
- HP = High Pedestrian Flow (Average 450 per hour in both directions)
- ZC = No cyclist flow
- LC = Low Cyclist Flow (Average 150 per hour)
- MC = Medium Cyclist Flow (Average 300 per hour)
- HC = High Cyclist Flow (Average 600 per hour)

**Table 7: Pedestrian and cyclists flows in each session**

Day	Cycle Group 1		Cycle Group 1 & 2		Cycle Group 2	
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
<b>1</b>	LP/ZC	LP/LC	MP/MC	MP/HC	LP/ZC	LP/LC
<b>2</b>	MP/ZC	MP/LC	HP/MC	HP/HC	LP/MC	LP/HC
<b>3</b>	LP/MC	LP/HC	HP/ZC	HP/LC	MP/LC	MP/MC

The overall average cyclist journey times across all sessions with one of the four designated crossing points are summarised in Figure 42.



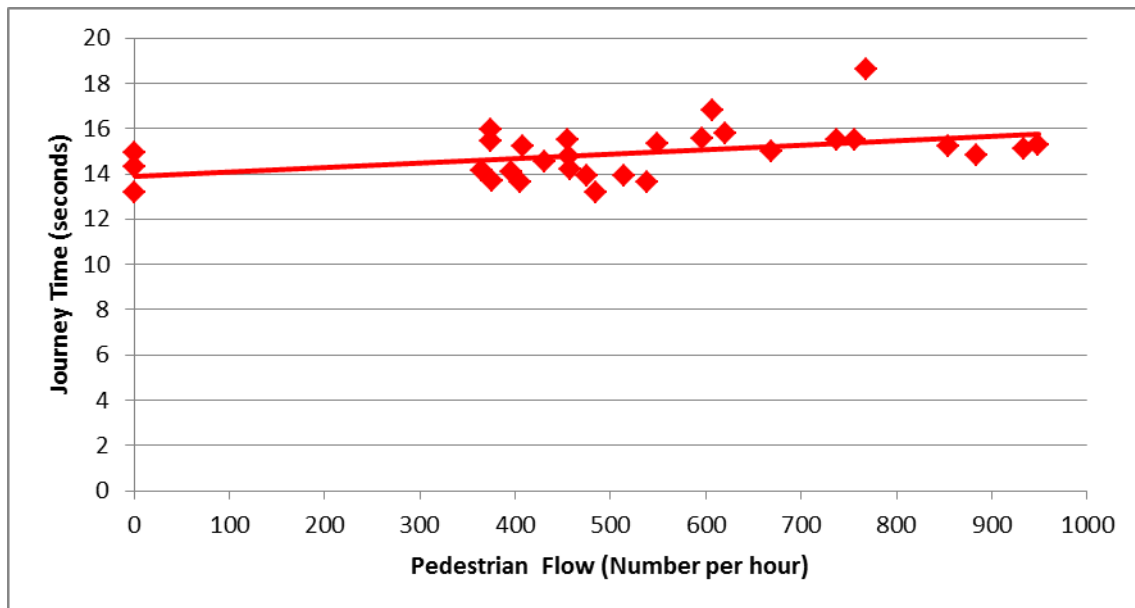
**Figure 42: Average cyclist journey time using the Bus Stop Bypass**

The overall effect of pedestrians on cyclist's journey times was on average fairly small: at most 1 second, or 0.7mph (0.31 m/s), which was a change of 6% in average speed. However, these changes were statistically significant; except with the No Ramp/No Zebra designated crossing point.

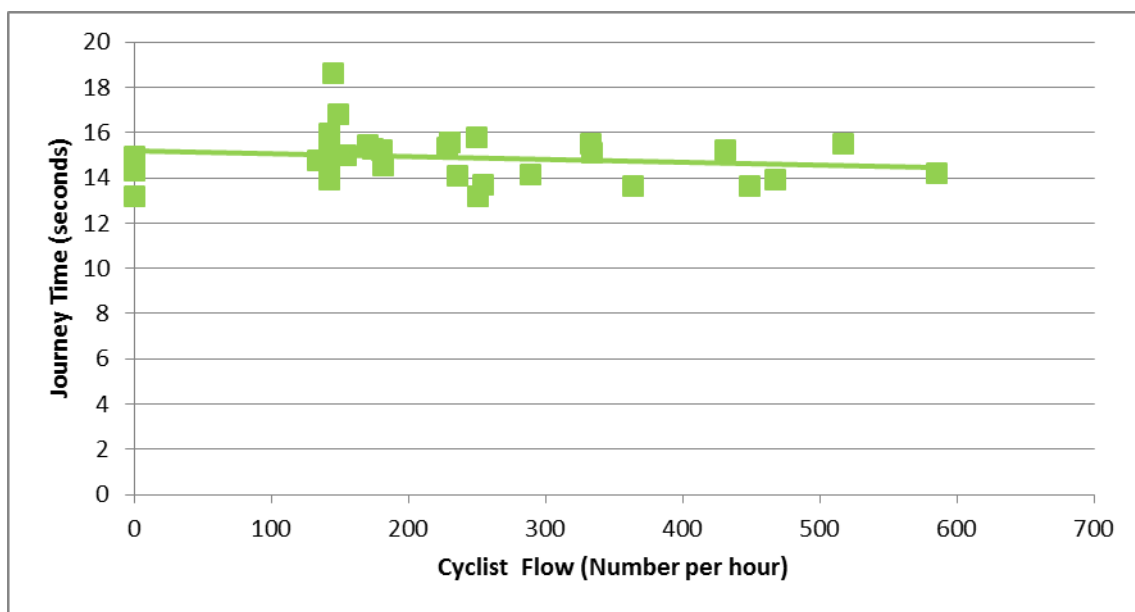
Cyclists were delayed by pedestrians when a Zebra crossing was present. The reason for the delay with a Zebra crossing was probably owing to cyclists giving way to pedestrians: most pedestrians used such a designated crossing point, and cyclists considered pedestrians had priority at a Zebra crossing.

This was the expected behaviour, as it would be thought that cyclists would always travel more slowly in the presence of pedestrians. However, Figure 42 shows that the opposite held where there was no Zebra crossing. In fact, cyclists actually travelled slightly quicker in the presence of pedestrians with such designated pedestrian crossing points, and the difference was statistically significant if a ramp was present. This was possibly a result of claiming their perceived priority. Pedestrians tended not to use such a designated crossing point, so were more distributed along the length of the Bus Stop Bypass. Also, cyclists considered priority was unclear at the designated crossing point if there was no Zebra crossing, and they generally considered that they had priority elsewhere in the Bus Stop Bypass.

Some incremental effects of varying pedestrian and cyclist flows with the four designated crossing points were evident in the data. Examples of how increasing pedestrian, and cyclist, flows affected average journey times are shown in Figure 43 and Figure 44, for the No Ramp, with a Zebra, designated pedestrian crossing point.



**Figure 43: Example of how pedestrian flow affects cyclist journey times**



**Figure 44: Example of how cycle flow affects cyclist journey times**

Regression analysis was performed to ascertain any significant effects of increasing pedestrian, and cyclist, flows on average cyclist journey times. The results of this analysis are summarised in Table 8.

**Table 8: Predicted cyclist journey times (seconds) in the Bus Stop Bypass  
(Regression Analysis)**

Designated Crossing Type	Measured average with no pedestrian flow (seconds)	Regression Analysis		
		Predicted journey time with no other cycles and no pedestrian flow (Regression Constant) (seconds)	Effect of an increase of 10 pedestrians per minute (seconds)	Effect of an increase of 10 cyclists per minute (seconds)
<b>No Ramp/Zebra</b>	<b>12.4</b>	14.4	1.6	-2.0
<b>Ramp/Zebra</b>	<b>13.3</b>	14.9	Not significant	2.8
<b>No Ramp/No Zebra</b>	<b>14.1</b>	13.5	1.1	Not significant
<b>Ramp/No Zebra</b>	<b>14.0</b>	13.5	1.4	Not significant

The overall effect of the type of designated crossing point can be seen in the Regression Constants, which concur with the overall average journey times: delays with a Zebra crossing and higher speeds without one.

If the designated crossing point had a ramp and a Zebra crossing, the presence of pedestrian flows increased cyclist journey times, but increasing pedestrian flows had no observable further effect on cyclist journey times. This was possibly as result of high percentages (and therefore reasonable numbers) of pedestrians using the designated crossing points under all conditions. Higher cyclist flows encouraged more pedestrians to use the designated crossing point, and this in turn appears to have increased cyclist delays by up to 2.8 seconds: a reduction in average speed from 11.3 to 9.7mph (5.1 to 4.3 m/s).

If the designated crossing point was a No Ramp/Zebra designated crossing point, the presence of pedestrian flows increased cyclist journey times, and increasing pedestrian flows further increased cyclist journey times by up to an additional 2.4 seconds: a reduction in average speed from 11.8 to 10.1mph (5.3 to 4.5 m/s). It is difficult to fully explain this trend. A high percentage of pedestrians used such a designated crossing point under all flow conditions, and this did not change with pedestrian flows. However, it may be a result of pedestrians making greater claim to the bypass track when they were more of them. This varying strength of claim for the Bus Stop Bypass could also account for cyclists' journey times decreasing if their flows increased, even though more pedestrians used the designated crossing point from the Bus Stop Island. The reduction with high cyclist flows was 2.0 seconds: an increase in average speed from 11.8 to 13.6mph (5.3 to 6.1 m/s).

If the designated crossing point did not have a Zebra crossing, the presence of small pedestrian flows decreased cyclist journey times, but increasing pedestrian flows counteracted this by increasing average cyclist journey times by between 1.7 to 2.1 seconds with high pedestrian flows: a maximum reduction in average speed from 12.6 to 11.4mph (5.6 to 5.1 m/s). Lower percentages of pedestrians used such a designated crossing point under all flow conditions, and high pedestrian flows decreased this

percentage further at a cycle track level designated crossing point. Again, this may be a result of pedestrians making greater claim to the Bus Stop Bypass when there were more of them. In contrast, higher cyclist flows encouraged more pedestrians to use the designated crossing point, whilst also permitting cyclists to have greater claim to the Bus Stop Bypass. Overall, the various changes in interactions resulted in no observable effect on cyclists' journey times.

### 6.3 Summary of cyclists journey time findings

This section summarises the significant findings from the observed cyclist journey times.

#### 6.3.1 Overview of journey time

Subject	Cyclists	Conclusion
<b>Delay from infrastructure</b>	With no other traffic, or pedestrians, present, cyclists took between 0.9 and 1.7 seconds longer to use the bypass track than to remain on the main carriageway and pass a stationary bus. The delay was smallest with the No Ramp/No Zebra, designated crossing point.	Using the Bus Stop Bypass only had a small effect on journey times, and type of designated crossing point had little effect.
<b>Delay from pedestrians</b>	The predicted maximum additional average delay under the highest pedestrian flows tested was 4.4 seconds: at a No Ramp/Zebra crossing. At all other tested designated pedestrian crossing points the delay was less than 2 seconds.	

### 6.3.2 Type of crossing

Subject	Pedestrians	Conclusion
<b>Average effect of pedestrian flows</b>	On average, pedestrians only delayed cyclists by 1 second in the Bus Stop Bypass if a Zebra crossing was present. In contrast, their journey time reduced by up to 1 second without a Zebra Crossing.	Average delay to cyclists was small with a Zebra crossing, and cyclists tended to have less delay without a Zebra crossing, possibly as a result of psychologically claiming their perceived priority.
<b>Effect of high pedestrian flows (900 per hour)</b>	<p>With a Ramp/Zebra crossing: increased pedestrian flows had no effect</p> <p>With No Ramp/Zebra crossing: increased pedestrian flows increased cyclist journey times by up to 2.4 seconds.</p> <p>With No Zebra crossing: increased pedestrian flows increased cyclist journey times by between 1.7 to 2.1 seconds.</p>	<p>Ramp/Zebra crossing: existence of pedestrian flows increased cyclist journey times, but higher flows had no further effect. Increased cyclist flows increased average cycle journey times, possibly owing to more pedestrians choosing to use the designated crossing point.</p> <p>No Ramp/Zebra crossing: existence of pedestrian flows increased cyclist journey times, and increasing pedestrian flows further increased them, but increased cyclist flows decreased average cycle journey times by up to 2.0 seconds. Possibly this was a result of a greater claim to the Bus Stop Bypass being made by the dominant flow.</p>
<b>Effect of high cyclist flows (600 per hour)</b>	<p>With a Ramp/Zebra crossing: increased cyclist flows increased average cycle journey times by up to 2.8 seconds.</p> <p>With No Ramp/Zebra crossing: increased cyclist flows decreased average cycle journey times by up to 2.0 seconds.</p>	<p>With No Zebra crossing: the presence of pedestrian flows decreased cyclist journey times. Increasing pedestrian flows counteracted this. Possibly as pedestrians made greater claim to the Bus Stop Bypass when they were more of them.</p>

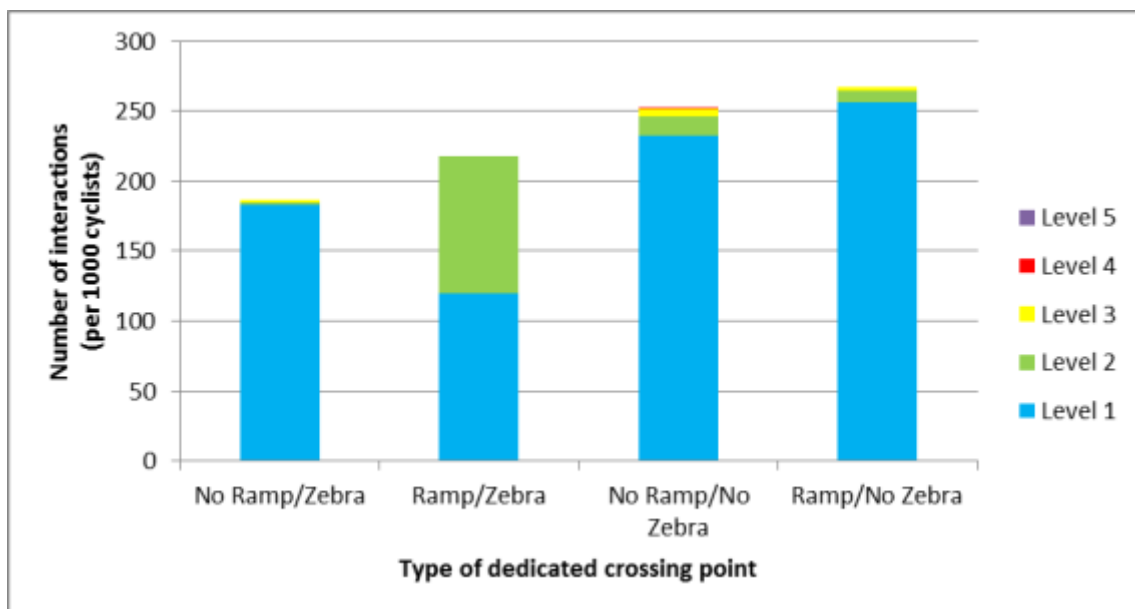
## 7 Interactions between pedestrians and cyclists

### 7.1 Number and severity of interactions

A first measure of safety at the bus stop bypass is the number of interactions that occurred. Owing to the different number of cyclists that travelled through the bus stop bypass track in each trial day, the results for interactions are presented as numbers per 1000 cyclists. Interactions were also classified according to the maximum severity of the reaction of the pedestrian and cyclist involved in the interaction:

- Level 1: Precaution – For example, a pedestrian, or cyclist, markedly slowing down in carriageway in response to another user requiring the same space.
- Level 2: Controlled Action - Pedestrian, or cyclist, deviating from route.
- Level 3: Near Miss - Pedestrian, or cyclist, rapidly slowing down, stopping or changing direction to avoid collision.
- Level 4: Very Near Miss - Pedestrian, or cyclist, using emergency braking or violent swerve.
- Level 5: Collision – Contact between a cyclists and a pedestrian.

An interaction is defined as “an observable situation in which two or more road users approach each other in space and time to such as extent that a collision is imminent if their movements remain unchanged”. This excludes advanced give way behaviour where a participant slows down in advance of a developing situation, but includes where they markedly slow down and give way when in proximity of another participant who would otherwise collide with them. The resulting relative number of interactions that occurred are summarised in Figure 45.



**Figure 45 Relative numbers of interactions**

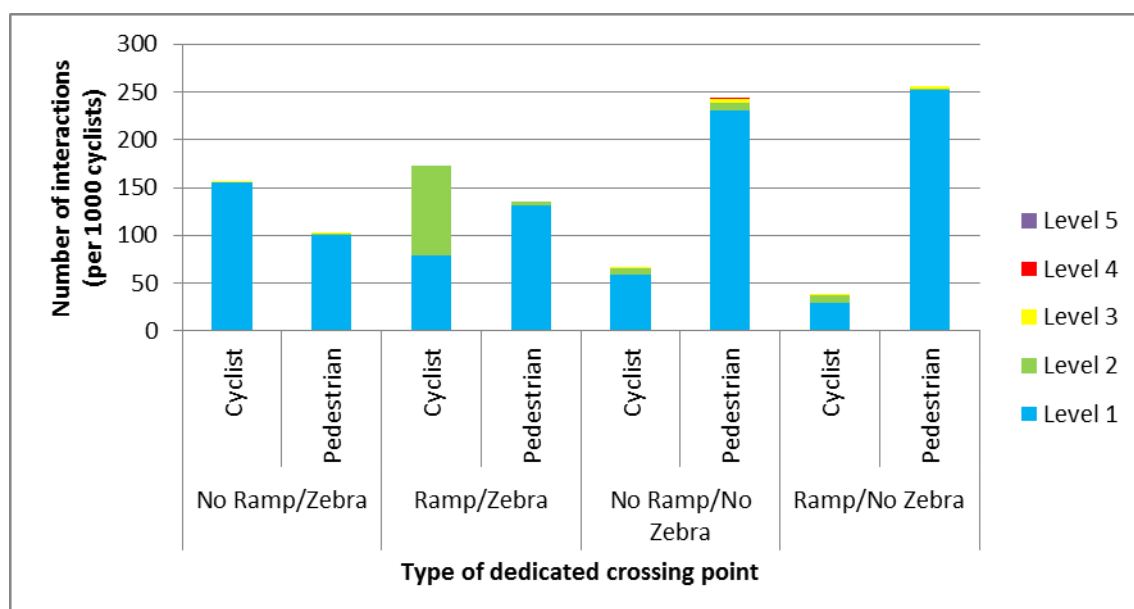
Nearly all (98%) of interactions were minor (precautionary or controlled actions); which was expected owing to the cautionary nature of participants under trial conditions. There is a clear trend in the total number of interactions occurring according to type of

dedicated crossing point at the bus stop bypass. The lowest interaction rates were with a Zebra crossing. Interaction rates increased if there was no Zebra crossing, and also increased to a lesser degree if there was a ramp. The interaction rates varied from an average of 19% of all cyclists at a at cycle track level Zebra crossing to 27% at an at footway level dedicated crossing without a Zebra. The increase without a Zebra crossing was statistically significant, whilst that associated with a ramp was not statistically significant.

The other notable variation in interactions was the greater number of “controlled action”, compared to “precautionary”, interactions with the at footway level Zebra crossing. This was not a large difference in the severity of the interaction, but was a distinct variation in the strength of behavioural response. Further investigation of these Level 2 interactions showed that in 96% of cases it was the cyclist who had reacted more strongly, also that 80% of these interactions occurred in Zone 3 (at the Zebra crossing) and a further 15% in Zone 2 (just ahead of the Zebra crossing). (see Figure 7 for a map of the zones.) In addition, in 73% of these interactions the cyclist stopped. The variation in behavioural response could have been a result of the large percentage of pedestrians who used this type of designated crossing point, combined with the fact that cyclists’ journey times were unaffected by pedestrian flows at this type of designated crossing point. That is, cyclists were able to maintain their speed in the bypass cycle track, but then may have needed to brake slightly harder for pedestrians at the at footway level Zebra crossing.

### 7.1.1 Type of participant most affected in the interactions

The individual level of the cyclists and pedestrians involved in interactions are summarised in Figure 46.



**Figure 46: Relative numbers of interactions by participant type**

There was a clear difference between whether action was taken by the pedestrian, or cyclist, in an interaction at dedicated crossing points with, and without, a Zebra crossing. With a Zebra crossing the actions were more evenly split between cyclists and

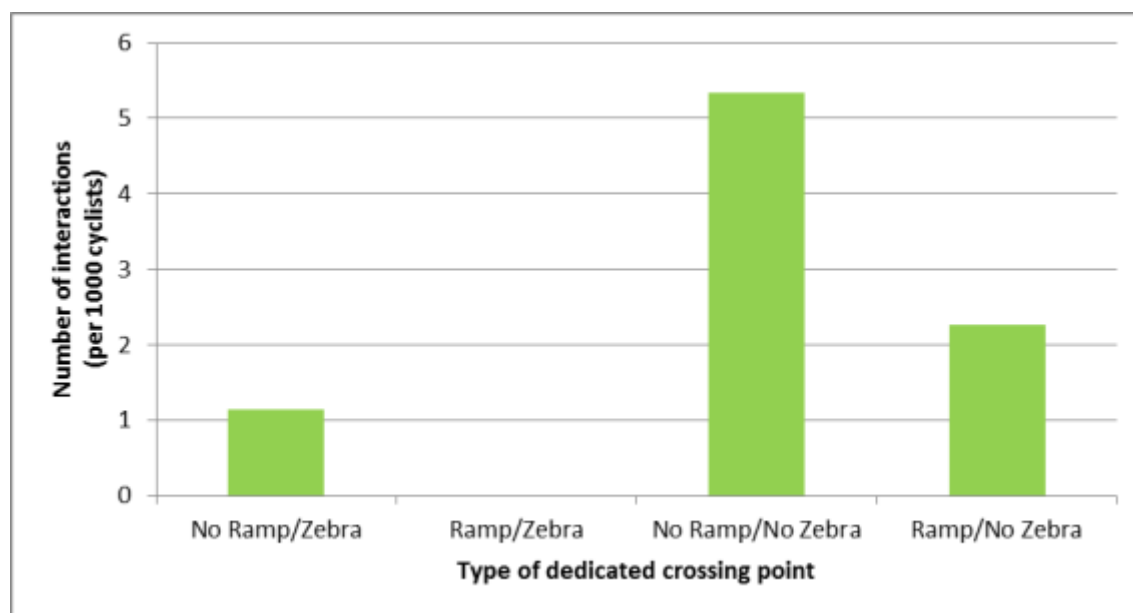


pedestrians: 40 to 44% of interactions were from pedestrians. However, without a Zebra crossing this increased to 79 to 87%.

In addition, it would appear that the presence of a ramp also slightly increased the number of actions taken by pedestrians: by 4% with a Zebra crossing and 8% without one.

### 7.1.2 Serious interactions

The rate of occurrence of serious interactions (Level 3 and above) are summarised in Figure 47.



**Figure 47: Occurrence rates for most serious interactions (Level 3 or more)**

Most (86%<sup>12</sup>) of all serious interactions occurred when there was no Zebra crossing. Also, slightly over half all serious interactions (55%) did not occur in Zone 3. Unlike the Level 2 interactions at the at footway level Zebra crossing, most of these involved serious pedestrian actions, rather than cyclist actions: 82% involved a serious pedestrian action and 32% a serious cyclist action. Also, in 67% of cases the pedestrian gave way to the cyclist in the serious interactions. Thus serious interactions tended to occur with pedestrians not using the dedicated crossing point, and required an action on behalf of the pedestrian to give way to the cyclist.

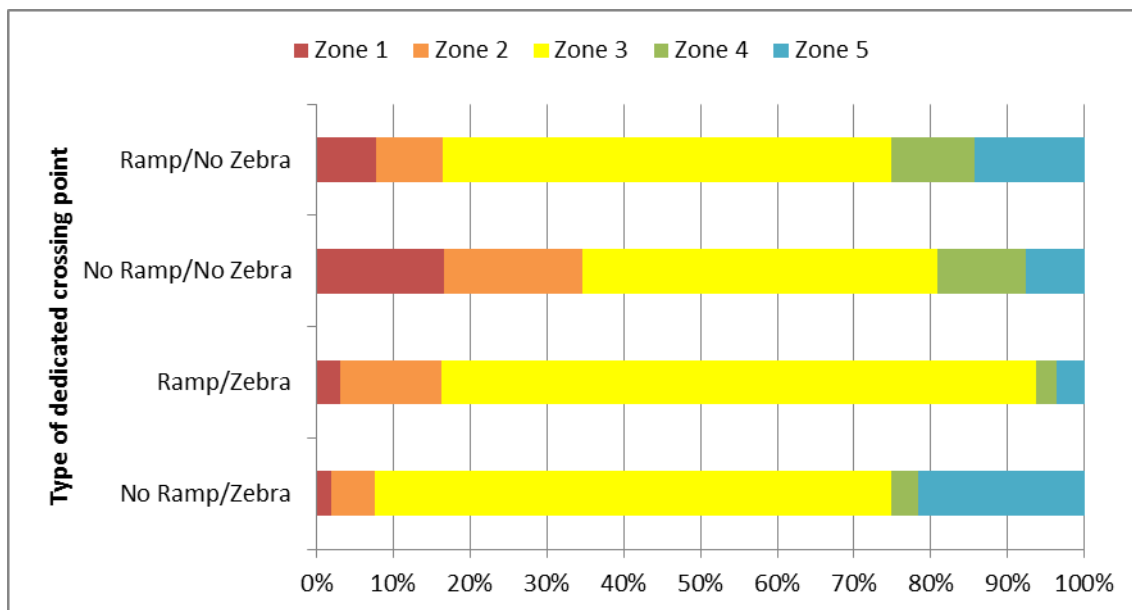
Also, raising the crossing point slightly decreased the probability of serious interactions.

## 7.2 Location of interactions

Pedestrians were able to cross from the footway to the bus stop island, and make the return journey, using one of five crossing zones. Zone 3 contained the dedicated

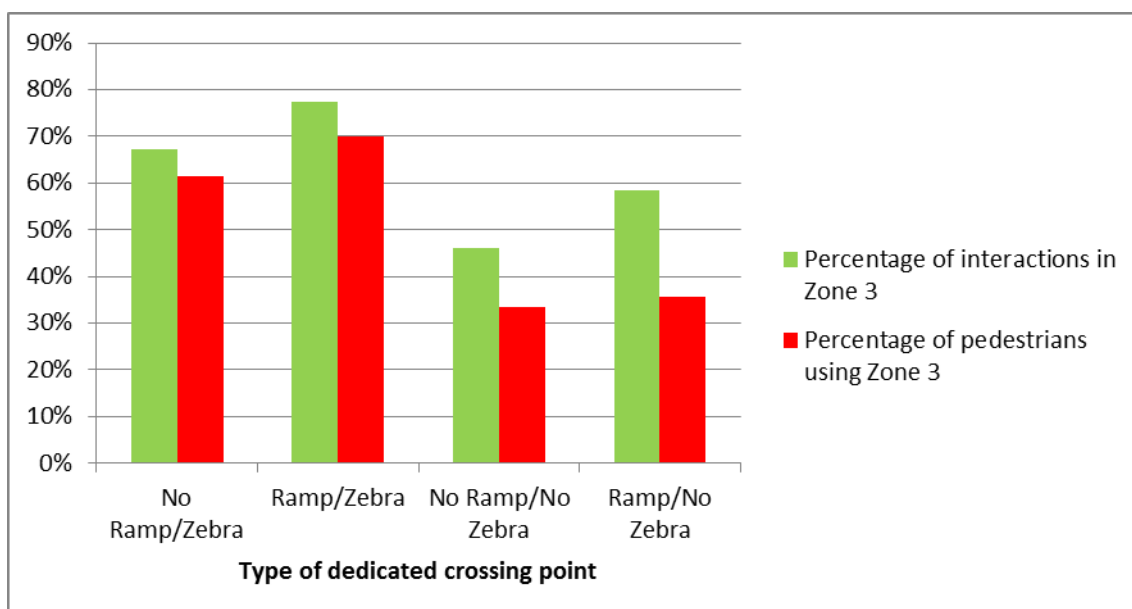
<sup>12</sup> 86% was significantly greater, at the 95% confidence level, than 50%. So, even allowing for random variations in the sample, we can state that most serious interactions would be expected to occur with no zebra crossing, even though the sample is small.

crossing point, zones 2 and 4 were adjacent to this crossing point, whilst zones 1 and 5 were furthest from the crossing point and were where the bus stop island narrowed. The percentage of all the interactions that occurred in each zone are summarised in Figure 48.



**Figure 48: Zones for all interactions**

Interactions at the dedicated crossing point accounted for 46 to 74% of all interactions. The highest percentage was at an at footway level Zebra crossing, and overall, the trend followed the percentage of pedestrians using the crossing, see Figure 49.



**Figure 49: Comparison of location of pedestrians and interactions**

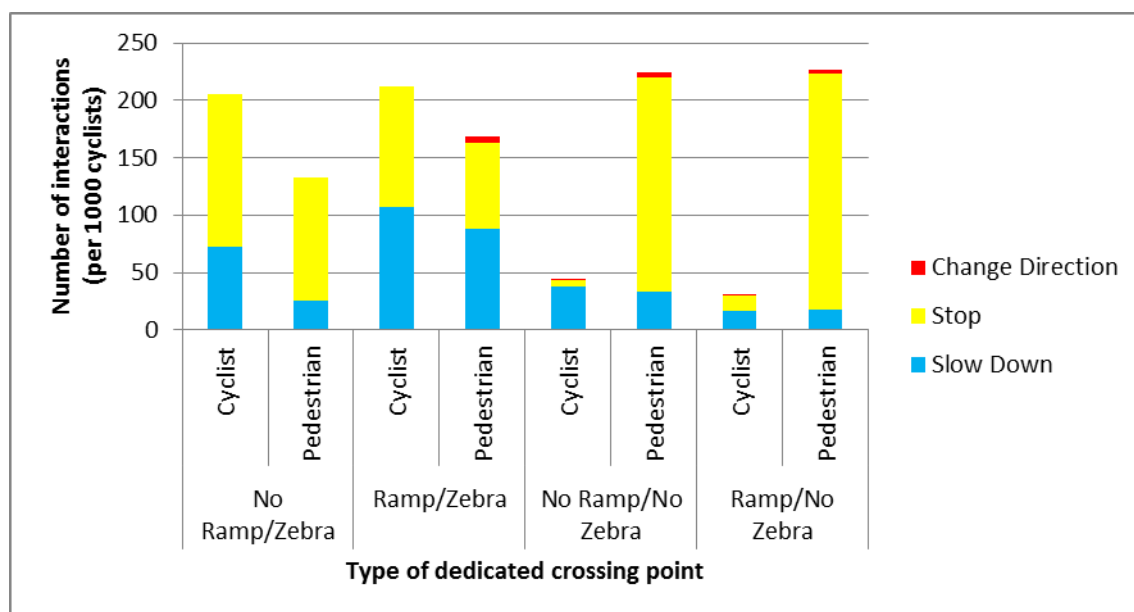
The percentage of interactions at the dedicated crossing point always exceeded the overall percentage of pedestrians using it, implying that the dedicated crossing point was the focus of the highest interaction rates, particularly if there was not a Zebra crossing.

However, the difference was within 7 percentage points when a Zebra crossing was present; that is the locations of the interactions were primarily dependent on the location of the pedestrians.

However, this relationship was less evident at dedicated crossing points without a Zebra crossing, where the percentage of interactions was 13% more than the percentage of pedestrians without a ramp, but 23% more with a ramp. This increase in interaction rates without a Zebra crossing conforms to the lack of agreement between cyclists and pedestrians over priority at such a crossing point (see Chapter 4 User Opinions); i.e. greater concentrations of interactions occur where there was a divergence in opinion over priority.

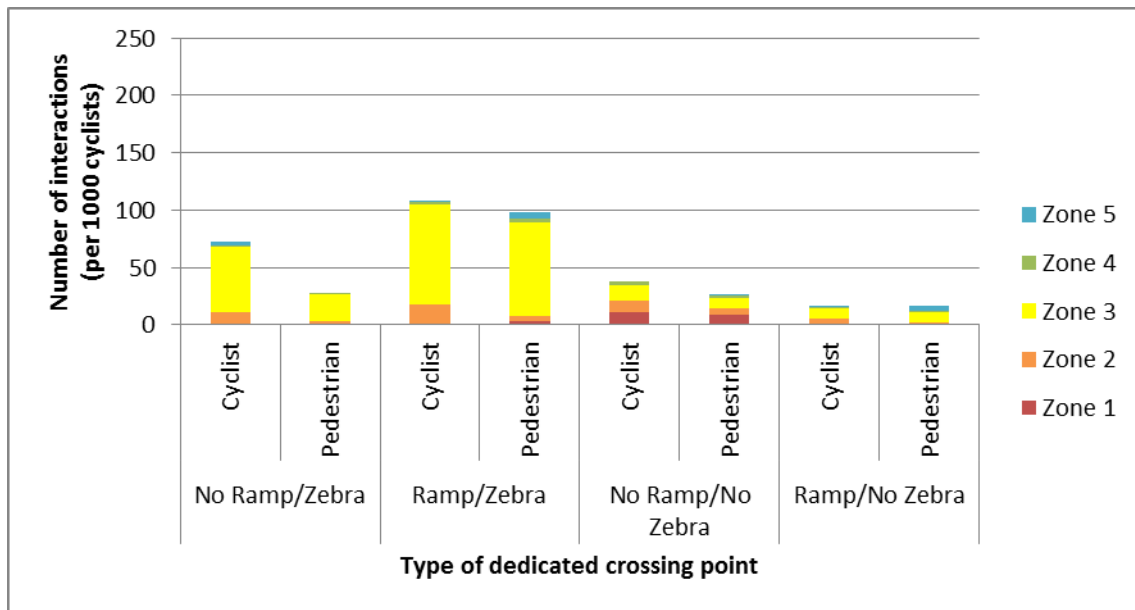
### 7.3 Actions taken by participants in an interaction

An occurrence of an interaction was determined by the resulting action taken by the participant(s). Both the pedestrians and cyclists have the options of slowing down, stopping, or changing direction to avoid a collision in an interaction. The number of actions by type performed by cyclists and pedestrians in interactions are summarised in Figure 50. Also, the zones of the actions for when the participants slowed down are in Figure 51 and Figure 52 for when they stopped or changed direction.

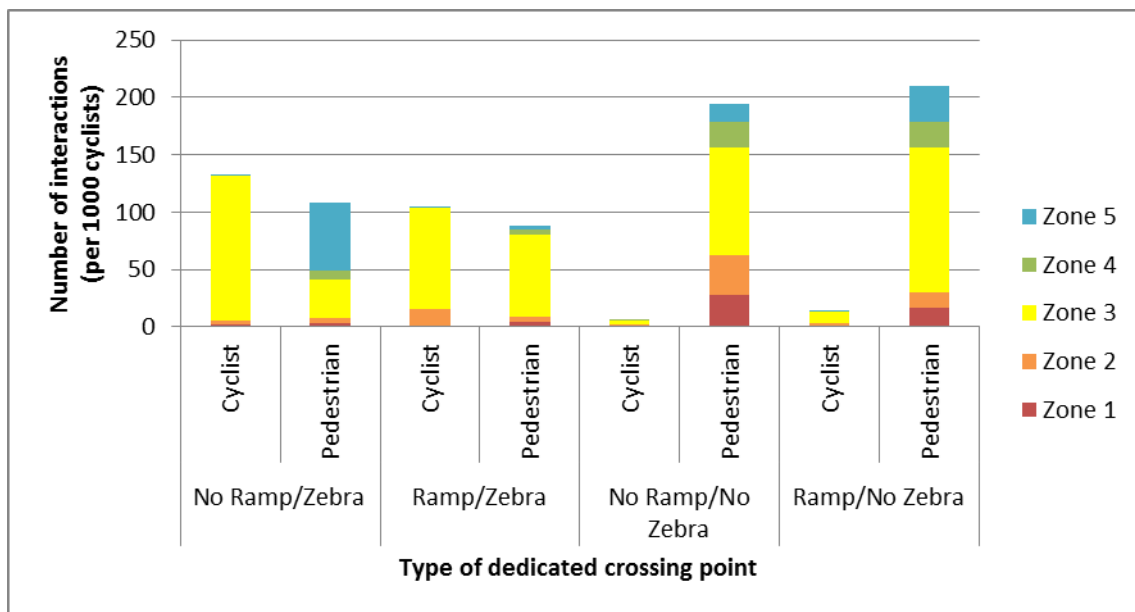


**Figure 50: Actions taken in interactions**

Only 1% of actions involved a participant changing direction. Also, the type of participant that took an action varied according to whether the dedicated crossing point had a Zebra crossing. Without a Zebra crossing most of the actions were taken by pedestrians who, in at least 83% of cases, stopped. The actions with a Zebra crossing were more evenly distributed between cyclists and pedestrians; with between 56 and 61% of actions taken by cyclists. This difference was probably a result of a higher percentage of both cyclists and pedestrians considering cyclists had priority if there was no Zebra crossing.



**Figure 51: Slow down actions taken in interactions**

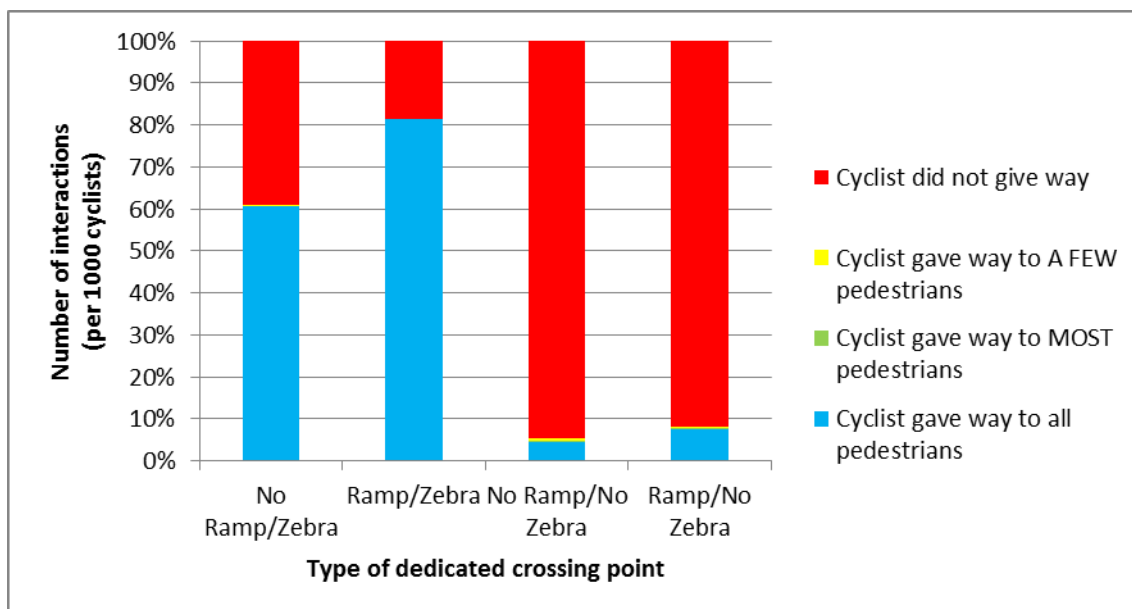


**Figure 52: Stop and change direction actions taken in interactions**

The main differences tended to follow the overall locations of the interactions, see Section 7.2, with most occurring in Zone 3 (at the dedicated crossing point). Outside of Zone 3, 66% of all avoidance actions were taken by pedestrians if there was a Zebra crossing, 77% were taken by pedestrians if there was no Zebra crossing; this again conforms with pedestrian and cyclist understanding of who had priority in the bus stop cycle track.

## 7.4 Who gave way in interactions

An analysis has been performed of the actions taken by cyclists and pedestrians involved in interactions. Their actions imply who gave way, however, the type of participants who gave way were separately recorded to confirm who took priority in interactions, see Figure 53.

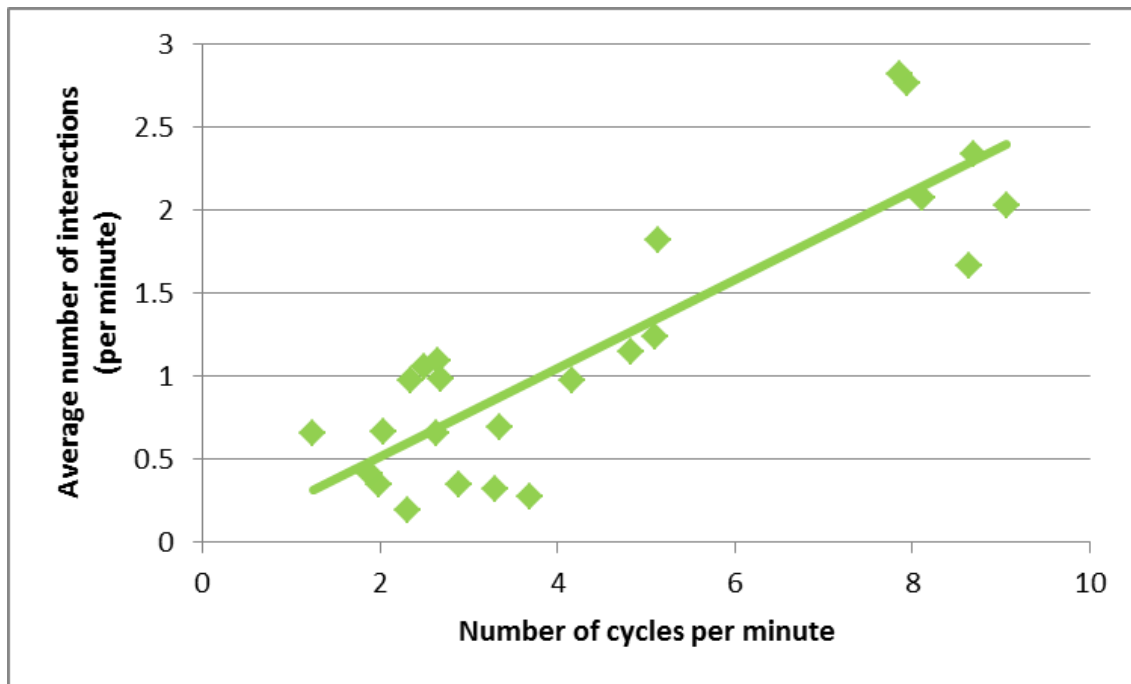


**Figure 53: Who gave way in interactions**

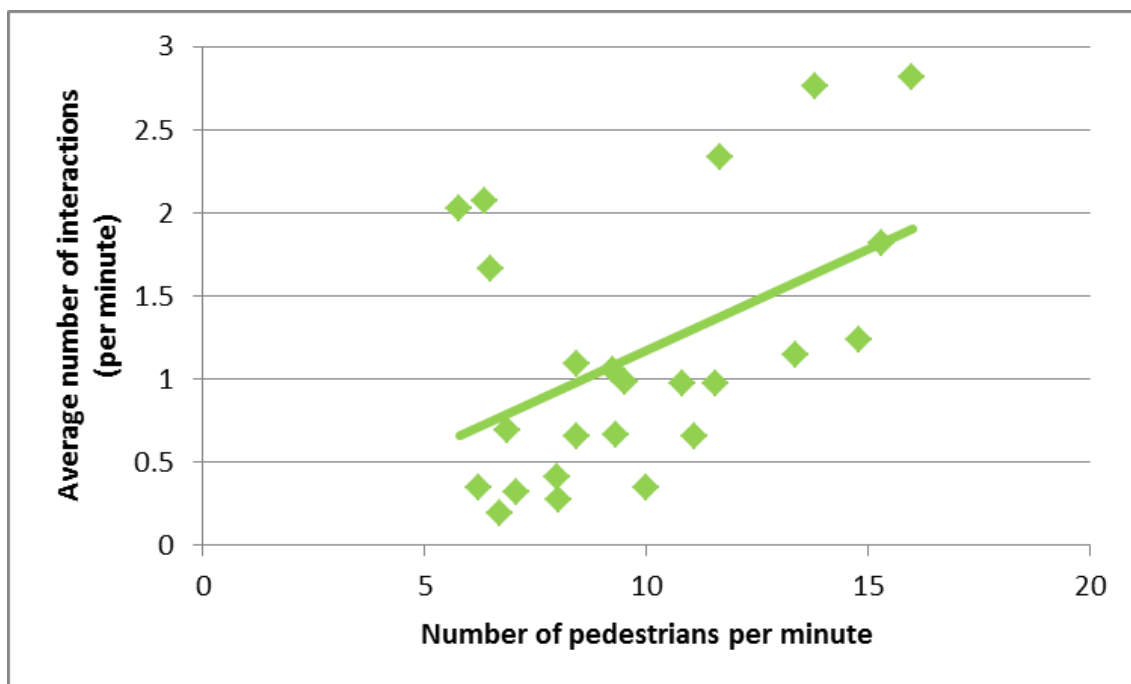
As expected, cyclists tended to give way if there was a Zebra crossing, but less than 10% did so without one.

## 7.5 Effect of pedestrian and cyclist flows

Interactions would be expected to increase with the flows of pedestrians and cyclists, as the opportunity for the two meeting should increase. Examples of such relationships are shown in Figure 54 and Figure 55 for a at cycle track level dedicated crossing point without a Zebra crossing.



**Figure 54: Effect of increasing cycle flows**



**Figure 55: Effect of increasing pedestrian flows**

Regression analysis was performed to identify these trends for each type of dedicated crossing point, the results of which are summarised in Table 9.

**Table 9: Effect of flows on cycle and pedestrian interactions**  
(Coefficients are significant at the 95% confidence level except for \* which was significant at the 90% confidence level)

Designated Crossing Type	Increase in number of interactions per minute	
	Effect of an increase of 10 pedestrians per minute	Effect of an increase of 10 cyclists per minute
No Ramp/Zebra	1.03	1.14
Ramp/Zebra	0.54*	1.32
No Ramp/No Zebra	1.01	2.16
Ramp/No Zebra	0.69	3.28

Two different effects are evident from the regression models. Firstly, higher flows of pedestrians only have a relatively small effect if the dedicated crossing point was at footway level (i.e. a ramp). Secondly, higher cycle flows have a greater effect on the number of interactions if there is not a Zebra crossing available for pedestrians, and even more so if the dedicated crossing point was at footway level, and is in agreement with cyclists' on-track feedback on perceived safety (see Chapter 4 User Opinions), although the ramp reduced the number of serious interactions.

In addition, pedestrian flows had a more limited effect on the number of interactions than cycle flows.

The effect of increasing cycle flows is probably owing to cyclists expecting priority in the bus stop bypass track, whilst the small effect of a ramp with higher pedestrian flows could be a result of reduced cycle speeds at the dedicated crossing point.

## 7.6 Summary of interaction findings

The findings from the interaction analysis at a bus stop bypass are shown in **Table 10** and **Table 11** below. These imply that the least number of interactions (which is a proxy for safety) occurred at a dedicated crossing point with a Zebra. It also implies it is best to have the crossing below footway at cycle track level at grade unless there are high flows of pedestrians.

**Table 10: Overall effect of a Bus Stop Bypass**

Subject	Overall effect of bus stop bypass
<b>Interaction strength</b>	Nearly all (98%) of interactions were minor.
<b>Location of interactions</b>	The dedicated crossing point accounted for 46 to 74% of all interactions, and the rates were highest in this area. That is, more interactions per pedestrian occurred at the dedicated crossing point than elsewhere.
<b>Type of action</b>	Only 1% of all actions involved a participant changing direction, in the remainder they slowed down or stopped in response to another road user.

**Table 11: Effect of the type of dedicated crossing point**

Subject	Zebra	Ramp
<b>Interaction rates</b>	Reduced rate by 5 to 6% points.	Increased rate by 2 to 3% points.
<b>Serious Interactions</b>	Reduced, only 14% occurred with a Zebra crossing.	Slightly reduced.
<b>Avoidance actions</b>	Fewer pedestrians took avoidance actions (40 to 44%) compared to 79 to 87%.	
<b>Safety of crossing point</b>	Lowered the rate of interactions for pedestrians using the crossing point.	
<b>Who took action</b>	More cyclists took action.	
<b>Who took action: not on crossing</b>	Fewer pedestrians take the actions (66 compared to 77%).	
<b>Giving way</b>	Cyclists more likely to have given way.	
<b>Increasing pedestrian flows</b>		Reduced effect of increasing pedestrian flows: from 2 to 1 interactions for every 20 pedestrians per minute.
<b>Increasing cyclist flows</b>	Reduced effect of increasing cyclist flows from 5 to 2, interactions for every 20 pedestrians per minute.	



## 8 Accessibility findings

The accessibility trials consisted of four groups of people with different disabilities experiencing each of the four Bus Stop Bypasses under controlled conditions with low cycle flows. The four disability groups were people who were wheelchair users, blind and partially sighted, deaf and hard of hearing or those with other age or cognitive-related mobility impairments.

All participants experienced crossing to and from the Bus Stop Island at least twice and then provided feedback on their experience including ease of use, ability to distinguish the crossing point, perceived safety, use of the designated crossing point and willingness to use such a facility in reality. Full analysis of the feedback is contained in Appendix E.

In many cases, the results only distinguished differences in opinions between the different groups of participants and not which Bus Stop Bypass facility was preferred. Generally, and in line with expectations, blind and partially sighted people reported the most difficulty when using the facility, and felt less safe. Blind and partially sighted participants were more likely to use the designated crossing point, as were wheelchair users because level access was not provided elsewhere due to the kerbs. Several respondents reported difficulties related to the unexpected feature of a cycle track dividing a footway, and a lack of experience of having to negotiate such a feature to access a bus stop.

There was a general feeling of being wary of using the bus stop bypass facility. Also, the majority of blind and partially sighted participants stated that they would be deterred from using buses on routes where there were bus stops with a cycle bypass track.

About half of all the participants with a disability used the designated crossing point every time they crossed the cycle bypass track. Those with hearing loss or mobility impairments were less likely to use the crossing point and were more likely to follow their desire line across the bypass track. However, participants with sight loss, or wheelchair users, almost always used the designated crossing point. The type of designated crossing point did not affect the rate of use of the crossing point, unlike with participants without a disability who were more likely to use the designated crossing point if a Zebra crossing was present.

The remainder of this section summarises the most relevant findings with regard to the type of designated crossing point, and compares them to the opinions of participants in the main trial (people without disabilities).

The main differences were owing to the presence of a Zebra crossing. Overall a Zebra crossing made the designated crossing point easier for people with disabilities to locate (particularly for those participants with sight loss), and was overall more appealing in appearance. The improved ease of locating the designated crossing point with a Zebra crossing was also found amongst participants without a disability.

Participants with a disability perceived that pedestrian safety was significantly greater at a No Ramp/Zebra crossing than at either of the no Zebra crossing designs. This is similar to participants without disabilities who felt safer if the designated crossing point had a Zebra crossing, although these participants generally felt safe at all crossings.

At least three-quarters of participants with a disability recognised that pedestrians had right of way with a Zebra crossing, and this compares well to the over 80% of pedestrians without a disability who also recognised they had priority. Participants with a

disability tended to agree that pedestrians should give way to cyclists using the bypass track at a No Ramp/No Zebra crossing.

Without a Zebra crossing there was some confusion about priorities amongst the participants with disabilities: approximately 40% considered cyclists had priority but approximately 20 to 30% considered they had priority as pedestrians. This is in contrast with participants without a disability: 50 to 70% considered cyclists had priority, and less than 15% considered they had priority as pedestrians.

The preferred crossing type was the Ramp/Zebra for people with mobility impairments (including wheelchair users). However, half of the blind and partially sighted participants stated that they preferred the No Ramp/Zebra crossing because the dropped kerb gave extra confirmation of the position of the designated crossing point. Participants without a disability rated the crossings with a Zebra higher than those without one. However, they did not tend to differentiate greatly between whether the Zebra crossing was at footway level or not, with only a slight preference for the No Ramp/Zebra crossing.

Subject	Pedestrians	Conclusion
<b>Overall ease of use</b>	General wariness of the bus stop bypass facility.	Concerns over concept, although could in part be a result of unfamiliarity.
<b>Ease of locating designated crossing point</b>	Easier to locate with a Zebra crossing.	<b>Zebra crossing</b> creates a high contrast to highlight dedicated crossing point
<b>Safety</b>	Significantly greater at a No Ramp/Zebra crossing than without a Zebra crossing.	<b>Zebra crossing</b> improves perception of safety <b>Ramp</b> preferred by mobility impaired including wheelchair users.
<b>Right of way</b>	Generally clear with a Zebra crossing, however not so without one where approximately 20 to 30% considered they had priority, and approximately 40% considered cyclists had priority.	<b>Zebra crossing</b> improves understanding of right of way.

## 9 Capacity of the Bus Stop Island

### 9.1 Observations

The trial facilitators provided feedback from their observations of the day's trial. These are given in detail in. However, the following main observations were made:

1. Some pedestrians waited on the cycle bypass track and footway, suggesting that the trial was successful in creating conditions when capacity was exceeded.
2. Many pedestrians followed their desire lines, particularly when cycles were riding towards them.
3. Pedestrians generally gave way to cyclists.
4. Cyclists altered their position in the cycle track to maximise distance from waiting pedestrians, and some used cycle bells as a warning.

### 9.2 Participant opinions

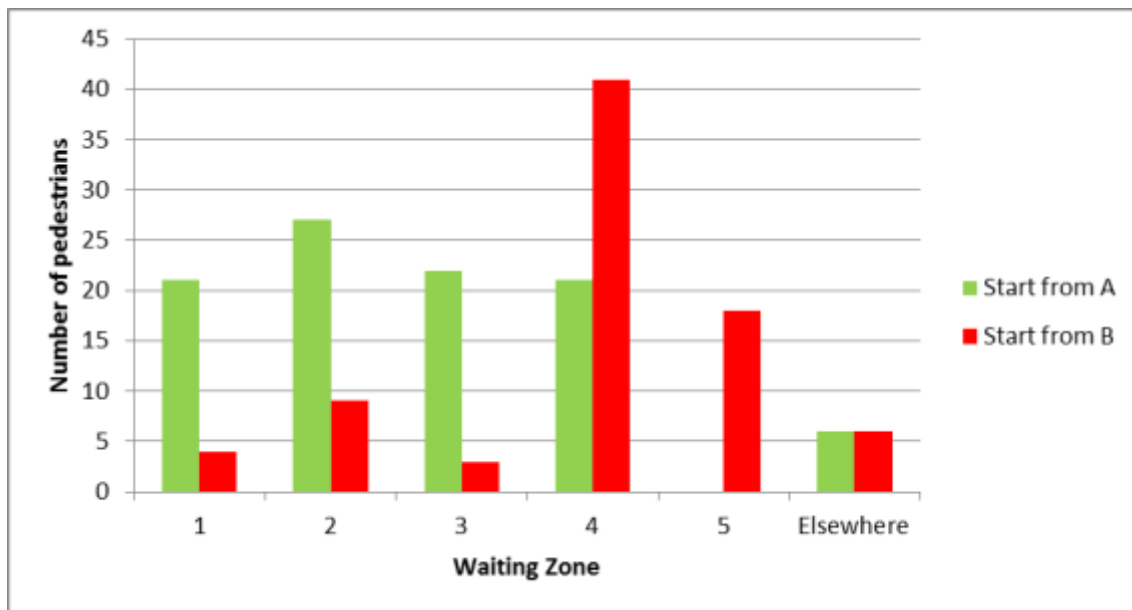
After the trial all participants were asked to complete an off-track questionnaire on their overall opinions of the situations they had experienced. This information was collected for comparison with the main trial, but generally did not add to the understanding of which type of Bus Stop Bypass performed best, as the capacity trial was only performed with a No Zebra/No Ramp designated crossing point. For this reason the full results are in Appendix F, and a summary of how the findings compare to those in the main trial are discussed here:

1. 92% to 93% found it easy to walk to and from the bus stop, approximately the same as in the main trial (87% to 90%)
2. 58% of participants found it easy to identify the crossing point, approximately the same as in the main trial (62%)
3. 65% participants considered that the bus stop was safe, approximately the same as in the main trial (63%)
4. 81% of the participant understood that the cyclists had right of way, compared with 70% in the main trial
5. 40% of the participants thought they should have had priority, approximately the same as in the main trial (36%)
6. Only 8 to 16% of the participants considered any aspect of interacting with the cyclists was difficult, approximately the same as in the main trial (7% to 16%)
7. 73% stated they used the crossing most of the time, which was similar to the main trial (63%)

### 9.3 Participant choice of waiting location

A sample of participants was asked to complete a short on-track questionnaire. This included information on which zones they passed through, where they chose to walk to, and their assessment of safety and comfort.

Information on the route used by the participant pedestrians (bus passengers) was collected including the zone they waited in for a bus according to the point they started from on the footway, see Figure 56.



**Figure 56: Zone waited in according to start point**

Most of those starting from B, which was closest to the bus stop shelter, walked to the shelter or to the tapering part of the island nearest to their start point. Those starting from A often walked further and were more evenly distributed in the four areas nearest to their start point. This overview includes both situations with few pedestrians on the Bus Stop Island, and when the Island was crowded. In reality, whilst those from B always tended to walk to near the bus shelter, those from A walked to end of the queue when the Bus Stop Island was not crowded, but distributed themselves into available spaces when it was more crowded.

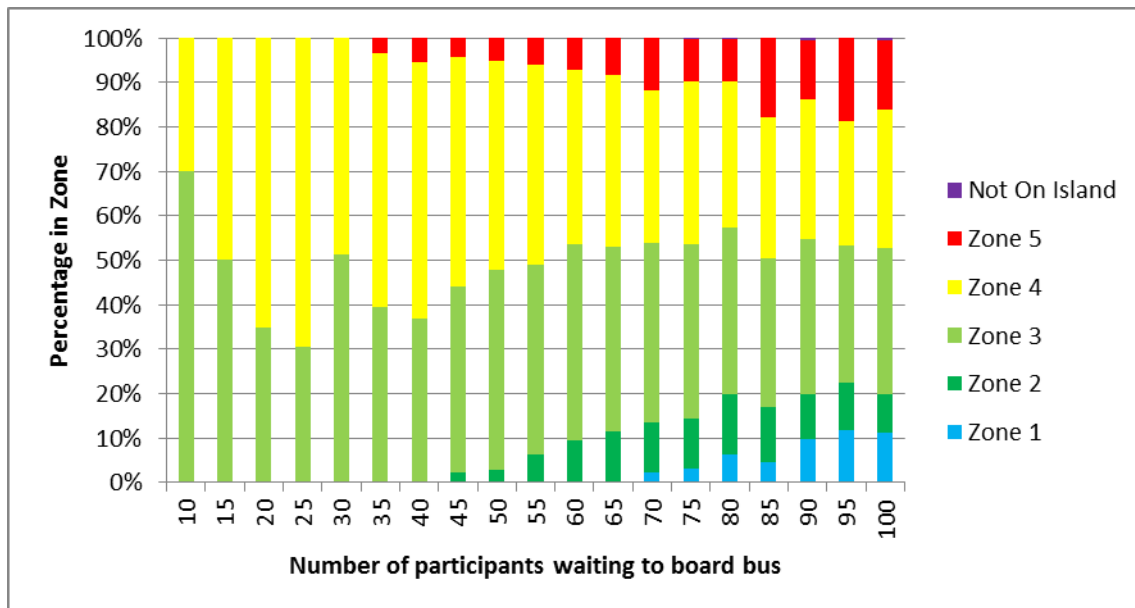
The resulting even distribution of pedestrians when filling in gaps after the queue had broken down resulted in minimised the effect of crowding on their perceived feeling of comfort and safety, see Appendix F for further details.

## 9.4 Queuing Locations

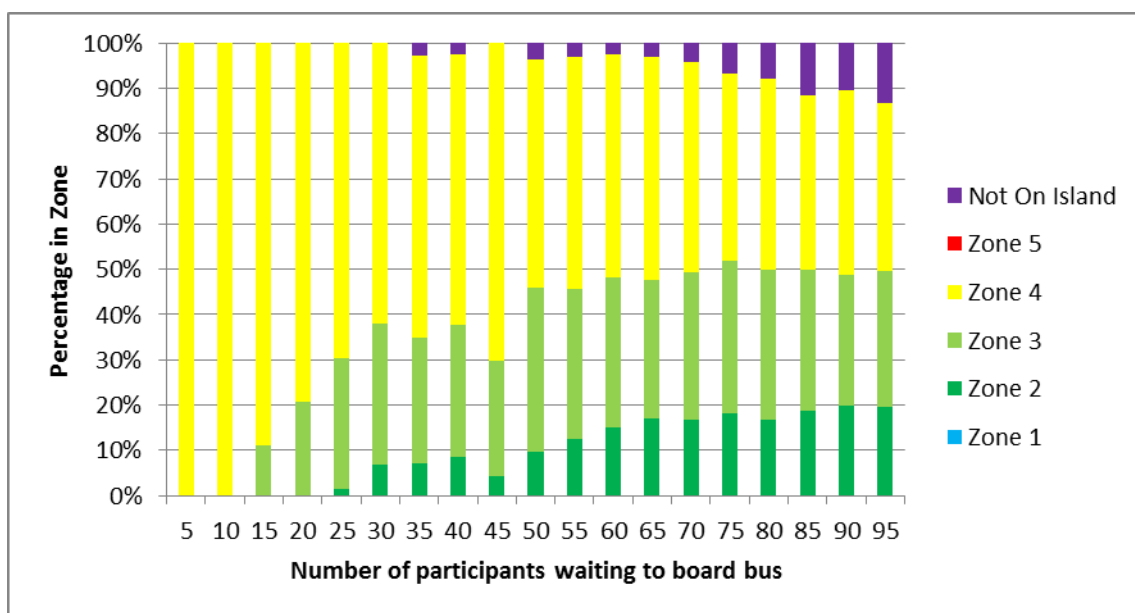
Pedestrians were released from the two start points (A and B) in groups, and the pedestrians in the group were permitted to reach their chosen destination before the next ones were released. Counts were made of which zone(s) pedestrians in each group moved to and stood within whilst waiting for a bus.

This approach permitted incremental observations of how queuing on the bus stop island developed over time, when the bus queues broke down (i.e. no formalised queue could be seen) and when the capacity of the bus stop island was reached.

The choice of zone) made by pedestrians, for differing numbers of pedestrians waiting on the bus stop island are displayed in Figure 57, when all areas on the island were available to the pedestrians, and in Figure 58 for when the two tapers (Areas A, B and C) were cordoned off (see Section 3.3).



**Figure 57: Percentage of pedestrians in each zone: All areas available**



**Figure 58: Percentage of pedestrians in each zone: Areas A, B and C not available**

If the whole of the bus stop island was available to pedestrians they started by congregating near the bus stop flag (Zones 3 and 4). As more pedestrians arrived (up to approximately 25 pedestrians) they tended to queue inside the bus stop shelter (Zone 4). The percentage of pedestrians in Zone 3 then increased up to 35 pedestrians. With between 35 and 45 pedestrians on the bus stop island they started to also use Zone 5. Then, with up to 75 pedestrians the percentages in both Zones 2 and 5 increased. Beyond 75 pedestrians on the bus stop island they also started to use Zone 1.

Space on the bus stop island was limited by cordoning off areas A, B and C (which removed Zones 1 and 5) in one session. The same pattern of pedestrian distribution was observed. However, with more than 45 pedestrians on the island, there was a consistent

increase in the percentage of pedestrians who chose to wait either on the footway, or in the cycle track.

### 9.5 Threshold for formalised queuing

Pedestrians arriving at the Bus Stop Island will tend to form an orderly queue whilst waiting for the bus. The previous section shows that (as expected) the queue starts to form near the bus stop pole and the bus shelter. The queue can then develop in one of two directions. This was observed to generally continue until reaching the island's boundary, or could loop back on itself when the closed end of the bus stop shelter was reached, see Figure 59.



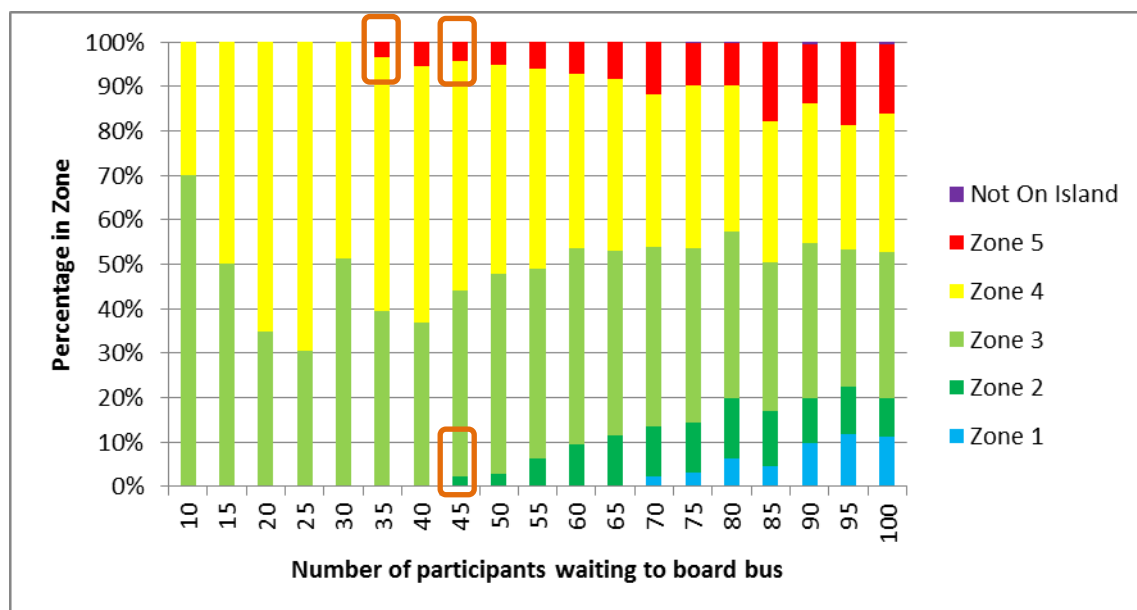
**Figure 59: Pedestrians form an orderly queue turning back on itself  
(20 pedestrians)**

A time was reached where the end of the queue could extend no further, or it was unclear to arriving pedestrians where the queue terminated. At this time the queue "broke down". That is, pedestrians waited on the island in more an ad hoc manner, choosing their location by where there was space on the island, see Figure 60.



**Figure 60: Pedestrians after queue “broken down”  
(50 pedestrians)**

The time when an orderly queue started to fragment was variable depending on both how the initial queue formed and individual behaviours. However, on average, Figure 61 indicates that the queue fragmented at between 33 and 47 pedestrians waiting on the island (i.e. between 35 and 45 on the x axis). Above 33 pedestrians they start to queue in Zone 5, which can be indicative of not joining a queue. However when between 43 and 47 pedestrians are on the island, they start to wait in both Zones 2 and 5; so it is certain that no orderly queuing is taking place, Figure 61. (The boxes indicate where queuing starts to break down).



**Figure 61: Queuing according to where people stand**

A maximum queue length of between 33 and 47 pedestrians also appears logical from calculating possible queue lengths starting at the bus stop pole and either extending in

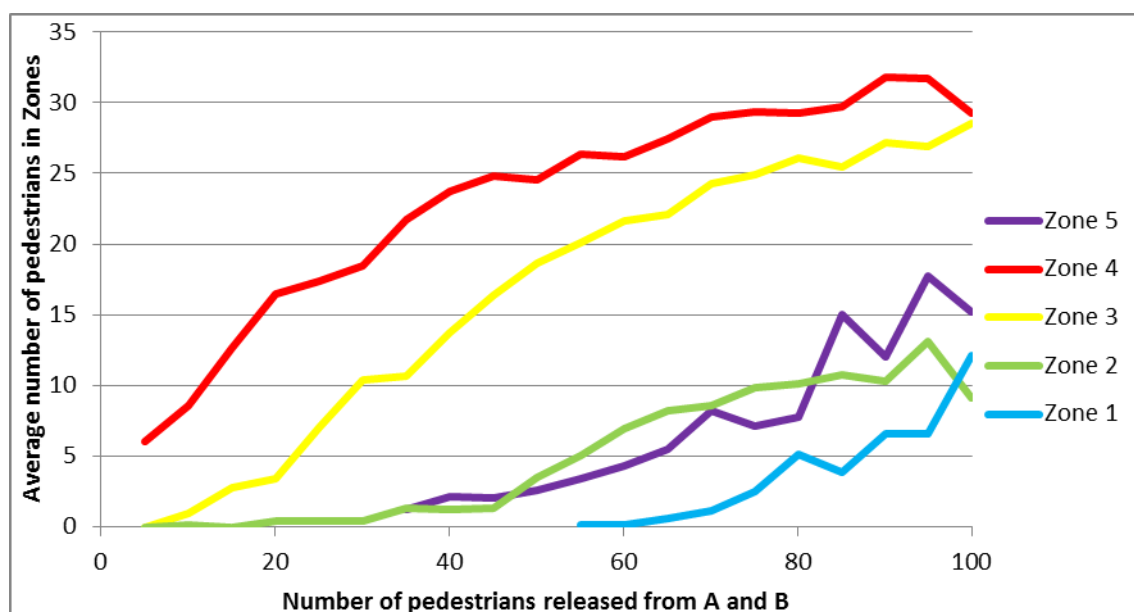


one direction until it reaches one end of the island, or reaches the closed end of the bus shelter and loop back until they reach the bus stop pole again. Using these distances and assuming that pedestrians occupy a distance of 0.45m<sup>13</sup> in the queue, it is predicted that the queue will naturally terminate at a length of between 33 and 47 pedestrians.

## 9.6 Capacity of the Bus Stop Island

The capacity of the Bus Stop Island is the maximum number of pedestrians that are willing to stand on it. Above the island's capacity, (most) additional pedestrians arriving at the bus stop will either wait on the footway, or in the cycle way.

A comparison of these observations would suggest that the Bus Stop Island's capacity lies somewhere between 75 and 97 pedestrians, see an example in Appendix F. The relationship between arriving pedestrians and where they stand is summarised in Figure 62.



**Figure 62: Average number of pedestrians in each zone, according to number waiting at the bus stop**

The use of each zone can be split into four stages as the number of pedestrians arriving increases, see **Table 12**.

<sup>13</sup> <http://www.tfl.gov.uk/assets/downloads/businessandpartners/pedestrian-comfort-guidance-technical-guide.pdf>



**Table 12: Zone use stages**

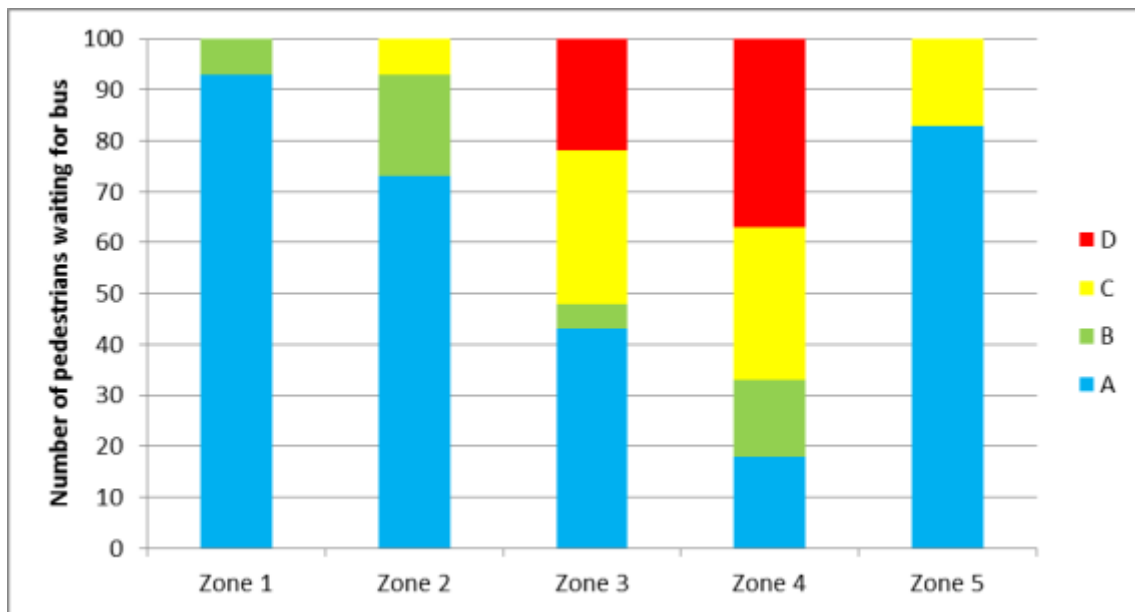
Stage	Usage Type	Reference Colour
1	Not used	<b>COLOUR</b>
2	In Use - Steady filling up	<b>COLOUR</b>
3	Occasional use – Slow filling up	<b>COLOUR</b>
4	Prefer not to use – Very few join the others in the zone	<b>COLOUR</b>

These stages correspond to different rates of increase of pedestrians in the zone: i.e. at higher stages the zone is more crowded and a lower percentage of arriving pedestrians choose to use it. Trend (regression) lines have been fitted to each rate of increase of pedestrians in each zone in each stage. These are summarised, together with the location of the usage stages in Table 13. It should be noted that the trend lines, and associated percentage of arriving pedestrians using a zone, are only a guide and will therefore not sum to 100%.

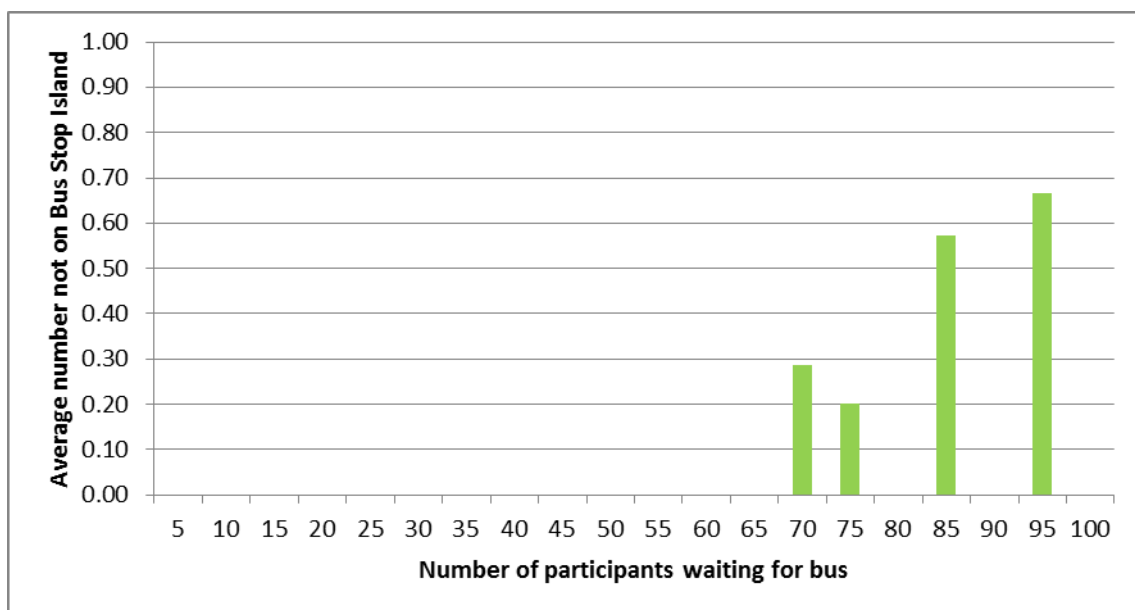
**Table 13: Location of zone use stages (Associated percentages of arriving pedestrians queuing in each zone)**

Pedestrians Released ( $\pm 2.5$ )	Zone				
	1	2	3	4	5
5			(40%)	(67%)	
10					
15					
20				(20%)	
25					
30	(19%)	(25%)	(20%)	(8 to 17%)	(16%)
35					
40					
45					
50					
55	(19%)	(4%)	(11%)	(8 to 17%)	(6%)
60					
65					
70					
75					
80	(19%)	(4%)	(11%)	(8 to 17%)	(6%)
85					
90					

It would be expected that the usage of an area by pedestrians would be related to their resulting comfort level, and therefore the Fruin Index. The average Fruin Indices for each zone with differing numbers of pedestrians waiting for a bus are summarised in Figure 63: with the higher index assumed for all numbers of pedestrians after it has initially been reached. In addition, the average number of pedestrians not waiting at the Bus Stop Island (i.e. on the footway, or in the cycle way) are summarised in Figure 64.



**Figure 63: Average Fruin Index according to number waiting at the bus stop**



**Figure 64: Average number of pedestrians not waiting on Bus Stop Island according to number waiting at the bus stop**

There appeared to be a strong correlation between the Level of Service in an area (Fruin Level of Service) and the stage of use of an area. In fact the following mapping relationship was generally found, see Table 14.

**Table 14: Relationship between usage stages and Fruin Level of Service**

Stage	Usage Type	Fruin Level of Service
1	Not used	<b>N/A</b>
2	In Use - Steady filling up	<b>A</b>
3	Occasional use – Slow filling up	<b>B</b>
		<b>C</b>
4	Prefer not to use – Very few join the others in the zone	<b>C</b>
		<b>D</b>

The results in Table 15 are for the average Levels of Service when different numbers of pedestrians were waiting for a bus.

When between 68 and 77 pedestrians were waiting at the bus stop a few were observed to be waiting on the cycle track. This is marked with the **ORANGE** Line. However, with more than 83 pedestrians waiting at the bus stop, some remained on the footway rather than crossing the cycle track: this point is marked with a **RED** Line. From these observations it can be concluded that the maximum capacity occurs in the range 68 to 83 pedestrians.

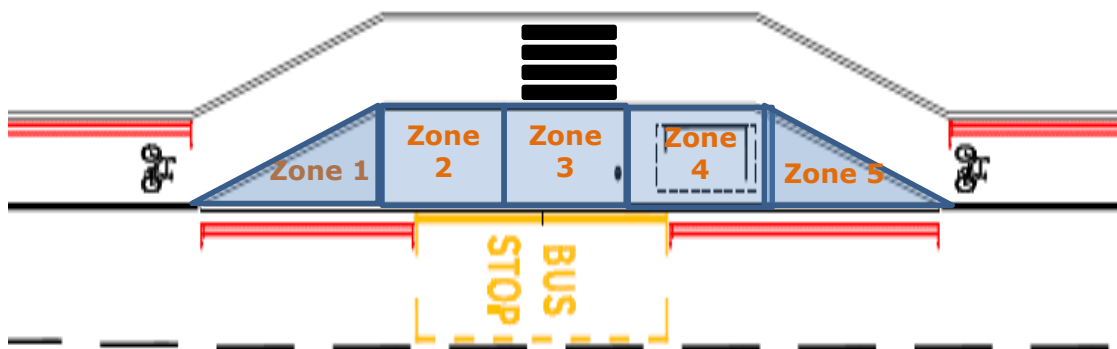
**Table 15: Fruin Levels of Service in each zone with different numbers of pedestrians queuing for a bus**

Pedestrians Released ( $\pm 2.5$ )	Zone				
	1	2	3	4	5
<b>5</b>			<b>A</b>	<b>A</b>	
<b>10</b>					
<b>15</b>					
<b>20</b>				<b>B</b>	
<b>25</b>					
<b>30</b>					
<b>35</b>	<b>A</b>	<b>A</b>	<b>C</b>	<b>C</b>	<b>A</b>
<b>40</b>					
<b>45</b>					
<b>50</b>					
<b>55</b>					
<b>60</b>					
<b>65</b>				<b>D</b>	
<b>70</b>					
<b>75</b>		<b>B</b>			
<b>80</b>			<b>D</b>		
<b>85</b>					<b>C</b>
<b>90</b>					
<b>95</b>		<b>C</b>			

This analysis shows that different parts of the Bus Stop Island (Zones) have different acceptable Levels of Service. In the remaining analysis it is assumed that the absolute capacity of the Bus Stop Island is at the red line, and the amber line shows when capacity has almost been reached, and crowding is unacceptable for some pedestrians.

Pedestrians accepted a low level of service (D) in the bus shelter area (Zone 4), and just accepted the same level of service in the area near to the pedestrian crossing point (Zone 3).

The acceptable level of service decreased with distance from these “main” queuing areas. They just accepted a C level of service on the tapering part of the island, nearest bus stop (Zone 5), but only a level B on the non-tapered area further from the bus stop shelter than the pedestrian crossing (Zone 2), and only a level A, on the tapering part of the island, furthest from the bus stop (Zone 1), see Figure 65.



**Figure 65: Bus Stop Island Zone Locations for Capacity Calculation**

It is not possible to accurately predict the capacity of any Bus Stop Island on the basis of observations from a single example. However, an initial hypothesis has been developed based upon these observations. A model for predicting the capacity of a bus stop island is presented in Table 16. Zone 4 is defined as containing the bus stop shelter and flag, and no infrastructure is present in the other zones. The calculated areas do not exclude the relatively small areas excluded by the infrastructure. A worked example of the model, using the dimensions of the trial bus stop, is given in Appendix F.

It is hypothesised that some pedestrians will start to encroach into the cycle track at approximately 85% of capacity (i.e. 68 pedestrians on the studied bus stop island).

It is also possible to consider the capacity of the island when pedestrians were prevented from using the island's tapers. The equation predicts that the capacity would be 66 to 69<sup>14</sup> pedestrians, and that pedestrians would start to stand in the cycle track when 56 to 59 pedestrians were waiting for the bus, which appears to be a reasonable guide from Figure 60. A few pedestrians did wait on the footway below these bus stop island loadings. However, it is probable that the introduced barriers prevented the island occasionally reaching capacity owing to blocking certain pedestrian routes to gaps on the island.

<sup>14</sup> The ranges were derived using sensitivity testing of the potential effect of the barriers on the effectively available space.

**Table 16: Modelled capacity of a bus stop island**

Zone	Definition	Area Size (m <sup>2</sup> )	Max. pedestrian density	Capacity
1	Tapered area in the opposite direction to the bus stop from the pedestrian crossing	$\alpha$	2.4	$\alpha/2.4$
2	Area between Zones 1 and 3	$\beta$	1.0	$B/1.0$
3	1 metre each side of the dropped kerb at the pedestrian crossing point	$\gamma$	0.6	$\gamma/0.6$
4	Area between Zones 3 and 5 (containing bus stop)	$\delta$	0.6	$\delta/0.6$
5	Tapered area in the same direction as the bus stop from the pedestrian crossing	$\epsilon$	1.6	$\epsilon/1.6$
<b>TOTAL CAPACITY</b>		$\alpha/2.4 + B/1.0 + \gamma/0.6 + \delta/0.6 + \epsilon/1.6$		

## 9.7 Summary of capacity findings

This section summarises the significant findings from the capacity trial.

Subject	Cyclists	Conclusion
<b>Where people wait for the bus</b>	Five different phases of pedestrian queuing were found Up to 10 – stand near to bus stop Up to 25 – stand in bus shelter Up to 35 – queue near shelter Up to 45 – start queuing on taper nearest shelter Up to 75 – start queuing on both of tapers	Five distinct phases of queuing were observed
<b>Formalised queue limits</b>	Formalised queuing ceased after 33 to 47 pedestrians were waiting on the bus stop island.	The number of people on the Bus Stop Island when queuing breaks down lies between 33 and 47.
<b>Effective capacity</b>	A few pedestrians encroach into the cycle track above 85% of capacity	Effective capacity of the island is approximately 85% of the calculated capacity.

The capacity of the bus stop island can be estimated by splitting it into 5 zones. The capacity of each zone is calculated by measuring its area (m<sup>2</sup>) and dividing by the number shown below.

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Tapered area	Between Zones 1 & 3	Dropped kerb + 1m	Between Zones 3 & 5	Tapered area



## 10 Overall conclusions

The summaries from each chapter are now combined to form an overall impression on the suitability of the design concept and which types of designated crossing point were found to be preferable under different trial conditions. The conclusions have mainly been based upon the main study, with key points from the accessibility study included. This approach was to ensure that the conclusions were balanced, although more detailed information on the accessibility study findings is in the appendices.

The findings have been collated into those on the Bus Stop Bypass in general, the effect of having a Zebra crossing, the effect of a ramp, and those specific to a specific type of designated crossing point. These findings have then informed the recommendations which meet the aims of this project.

Both the pedestrian, and cyclist, flows contained in the design were chosen to be representative of the range encountered in London. Also, the average speeds used by cyclists on the Bus Stop Bypass were between 10.8mph (4.83 m/s), and 12.0mph (5.26 m/s), and were therefore of the same order as expected in London.

However, it is possible that other physical characteristics (for example the angles of entry to the bus stop bypass and the width of the bus stop island) could influence behaviours. The conclusions should therefore be considered to apply to the tested design, as a proof of concept and cannot be applied as detailed design guidance.

### 10.1 Bus Stop Bypass Design Concept

Assessment Area	Reason	Good/Bad
User Opinions	Designated crossing point reasonably obvious	Green
	Good visibility	Green
	Cyclist movements easy to judge	Green
	Easy to use	Green
	Generally safe	Green
	Benefit to cyclists' perceived safety/ Cyclists felt safer than on main carriageway	Green
	Disbenefit to pedestrians' perceived safety	Red
	Could increase some use of cycles	Green
	May encourage cycling	Green
	Use of bypass dependent on relative conditions in bypass and on the road (50%/60% with low traffic flow conditions)	Grey
	May discourage bus passengers under high cycle flows	Red
Observed Effects	Designated crossing point use increased with cycle flows	Grey
	Infrastructure had little effect on cyclist journey times. It increased by 1 to 2 seconds (over a 14 to 16 second journey) compared with using the main carriageway. The average maximum delay was 4.4 seconds under high	Green

	pedestrian flows compared to using the carriageway	
	Nearly all interactions were minor, and generally occurred at the designated crossing point	
	All types did not affect ease of movement	

## 10.2 Bus Stop Bypass Including A Ramp

The conclusions in this sections hold for all pedestrian crossings that included a ramp: i.e. both the Ramp/Zebra and Ramp/No Zebra crossings.

Assessment Area	Reason	Good/ Bad
Opinions	Reduced perceived cyclist, and pedestrian, safety at the designated crossing point	
Interactions	Increased interaction rate, but reduced rate of serious interactions. Overall, unclear as to the effect on safety.	
	Reduced rate of increase of interactions with high pedestrian flows	
Accessibility	Mobility impaired and wheelchair users preferred ramp, however those with visual impairments showed slight preference for no-ramp.	

## 10.3 Bus Stop Bypass including A Zebra Crossing

The conclusions in this sections hold for all pedestrian crossings that included a Zebra crossing: i.e. both the Ramp/Zebra and No Ramp/Zebra crossings.

Assessment Area	Reason	Good/ Bad
Opinions	Easier to see, and better rated for looks	
	Clarity and agreement between cyclists and pedestrians over priority at the crossing	
	Improved pedestrians' perceived safety	
	Improved cyclists' perceived safety at the designated crossing point	
Crossing Use	More pedestrians used the designated crossing point	
	Reduced the percentage of pedestrians following their desire lines under high pedestrian flow conditions.	
Interactions	Slightly reduced interaction rates	

	Reduced the frequency of serious interactions	
	Reduced the effect of cycle flows on interactions	
Accessibility	Participants preferred the increased visual contrast and ease of locating (especially for those with sight or hearing loss). Participants in all groups appreciated the priority over cyclists at the crossing point.	

#### 10.4 Bus Stop Bypass Crossing Specific Feedback

Assessment Area	Reason	Good/Bad
Journey Time	<b>No Ramp/ Zebra</b> increased average cycle delay by 2.4 seconds under high pedestrian flows compared with using the main carriageway	
Accessibility	<b>Ramp/No Zebra:</b> participants with sight loss had difficulties locating crossing	
	<b>No Ramp/ Zebra</b> easier to locate for participants with sight loss by using dropped kerbs	
	<b>No Ramp/ Zebra</b> felt safer	

#### 10.5 Bus Stop Bypass Capacity

Assessment Area	Reason
Formalised queue limits	Formalised queuing ceased after 33 to 47 pedestrians were waiting on the bus stop island.
Capacity	Capacity can be estimated using the formula: $\text{Area A}/2.4 + \text{Area B}/1.0 + \text{Area C}/0.6 + \text{Area D}/0.6 + \text{Area E}/1.6$ Where the Areas A to E are defined in Section 3.3. A few waiting passengers encroach into the cycle track above 85% of capacity

#### 10.6 Bus Stop Bypass Conclusions

**Aim 1: Identify the pedestrian capacity of the Bus Stop Island: defined as the number of people who can be accommodated on the island**

The trials have developed a formula that estimates the maximum capacity, and effective capacity of the Bus Stop Island trialled. Although, the formula is based upon one specific island design, it can provide an initial estimate for the capacity of other Bus Stop Islands.

- **The maximum capacity** of bus stop island can be estimated using the formula  $\text{Area A}/2.4 + \text{Area B}/1.0 + \text{Area C}/0.6 + \text{Area D}/0.6 + \text{Area E}/1.6$ , where the Areas A to E are defined in Section 3.3.



- **The effective capacity** of a bus stop island (when people choose not to wait on the island) can be estimated as approximately 85% of the maximum capacity.

**Aim 2: Determine the levels / thresholds of occupancy that queuing seemed to break down.**

Analysis of the development of bus passenger queues during the trials identified two types of queuing depending on the direction in which the queue formed. However, there was a consistent range in which the formalised queue broke down and pedestrians started to walk to the nearest available gap.

- **Formalised queuing** ceased after 33 to 47 pedestrians were waiting on the bus stop island.

**Aim 3: Identify how the interaction between pedestrians and cyclists can be safely managed**

The Bus Stop Bypass introduces a situation of potential direct conflict between pedestrians and cyclists, with pedestrians crossing in front of cyclists to reach the Bus Stop Island. Safety of the four designs tested can be based upon direct observations of interaction rates between cyclists and pedestrians, and understanding (and agreement) of priorities. These have resulted in the following conclusions based on the behaviours observed in the trials.

- **A Zebra crossing** reduced the probability of interactions between cyclists and pedestrians. As an interaction is defined as a pre-cursor of a collision, and identifies avoidance action a reduction in interactions can be considered as a safety improvement. It had the greatest agreement amongst participants regarding priorities both at the crossing and elsewhere. It had the highest scoring for perceived safety. In addition it had the highest pedestrian use of the designated crossing point. Furthermore, participants with sight and hearing loss found it easier to locate.
- **Dropped kerbs (no ramp)** were generally preferred at the Zebra crossing unless the pedestrian flow was high (greater than triple the cycle flow + 3 pedestrians). Pedestrians and cyclists felt safer with a dropped kerb. In general a ramp increased interaction rates, which is likely to have influenced the perceived safety scores, although it slightly decreased the number of serious interactions (i.e. involving two participants having a near, or very near, miss). The conflicting evidence on all interactions, and serious, interactions meant that no conclusion can be reached on the effect on overall safety. However, when the pedestrian flow was high (greater than  $0.4 \times [\text{cycle flow}] + 12$  pedestrians per minute) then a ramp decreased the number of interactions occurring. A ramp also reduced cycle journey times when the pedestrian flow was relative large ( $3 \times [\text{cycle flow}] + 3$  pedestrians per minute). It was also found that pedestrian use of the designated crossing point was greater with a ramp, especially at high cycle flows. People with impaired mobility, including wheelchair users, preferred the Ramp/Zebra crossing, while other participants in the accessibility trial expressed a slight preference for No Ramp.

**Aim 4: Identify the features of the bus stop island layout that are attractive to cyclists and that encourage them to use the bypass cycle track**

- **The Bus Stop Bypass appeared to be attractive to cyclists.** Between 45% and 50% of the cyclists stated that they would be more likely to cycle in town with Bus Stop Bypasses being available. It should be noted that this is only a statement of potential intention, and may not translate into a real increase.

- **The Bus Stop Bypass appeared to have advantages for cyclists' perceived safety**, compared with using the main carriageway, whilst not unduly affecting their journey times or pedestrian safety. Between 50% and 60% stated they would use the Bus Stop Bypass under low traffic flows, and more under high traffic flows. However, the actual use would depend on whether a bus was waiting at the bus stop and the relative conditions on the Bus Stop Bypass and the main carriageway.
- **An at cycle track level designated crossing point was preferred.** Such a crossing point was perceived as safer by cyclists.
- **A Zebra crossing had advantages and disadvantages for cyclists.** Cyclist journey times were generally lower without a Zebra crossing, particularly under high cyclist flows. This was a result of pedestrians having a lesser ownership of the shared area, and cyclists claiming greater ownership of the Cycle Bypass Track, particularly under high cycle flows. However, a Zebra crossing was easy to identify and clarified priorities for all users and thus reduced the number of interactions between cyclists and pedestrians.

It is important to recognise that any off-street trial inevitably has its limitations and it cannot be assumed that the behaviours reported here would be replicated in a real street environment. The findings of this trial should not therefore be regarded as design guidance: further experience from on-street trials will therefore be needed, and other design considerations taken into account, before more definitive design recommendations can be made.