Appendix B Trials Findings Reports

This appendix contains the findings reports for the individual roundabout trials. The trials reported on are shown in the table below:

Trial code	Description	Objectives	Appendix
M5	Individual user trials, Dutch markings	Understanding how car drivers, cyclists, motorcyclists and lorry drivers react to and use the roundabout individually	B1
M6a	Cyclists interacting with drivers, Dutch markings	Understanding how cyclists react when encountering cars driven by controlled drivers	B2
M6b	Drivers interacting with cyclists, Dutch markings	Understanding how drivers react when encountering cycles ridden by controlled riders	B3
M21	Cyclists interacting with drivers, UK markings	Understanding how cyclists react when encountering cars driven by controlled drivers	B4
M22	Drivers interacting with cyclists, UK markings	Understanding how drivers react when encountering cycles ridden by controlled riders	B5
M25	Pedestrians and cyclists interacting, UK markings	Understanding how cyclists and pedestrians interact when encountering each other on the roundabout and zebra crossings	B6
M26	Cyclists and cyclists interacting, UK markings	Understanding how cyclists using the cycle lane interact with other cyclists using the car lane on the roundabout	B7
M27	Cyclists, pedestrians and drivers interacting, UK markings	Understanding the interactions between cyclists, pedestrians and car drivers when all three are using the roundabout/zebra crossings	B8
M28c	Capacity trials, UK markings, long vehicle effects	Understand the capacity implications of this type of roundabout design. A separate report is being produced on capacity, but this trial also provided input to the safety implications.	B9

In addition to the trials report, this appendix also contains a technical note on road markings for cycle priority at roundabouts (Appendix B10), and a review of literature relating to collision between cyclist and large vehicles at roundabouts with circulatory cycle tracks (Appendix B11)

B.1 M5 Individual Users Reaction trials

Off street trials of Dutch-style roundabout

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. These were placed directly alongside the cycle path where it crosses the car lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBa.M5). The layout is shown in Figure 1.

The different designs of entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

An important aspect of this initial build of the roundabout is that it used standard Dutch-style road markings including 'sharks teeth' (white triangles) to show where drivers should give way and 'elephants feet' (white squares) to highlight the orbital cycle lane as it crossed the entry and exit arms. This design has been used to establish a baseline of participant behaviour against a design which is used in the Netherlands. It was used for

the first two series of trials (this trial methodology M5, and subsequently M6 which investigated the interactions between cyclists and drivers). After these initial trials, the roundabout was changed to use UK style markings for subsequent trials.

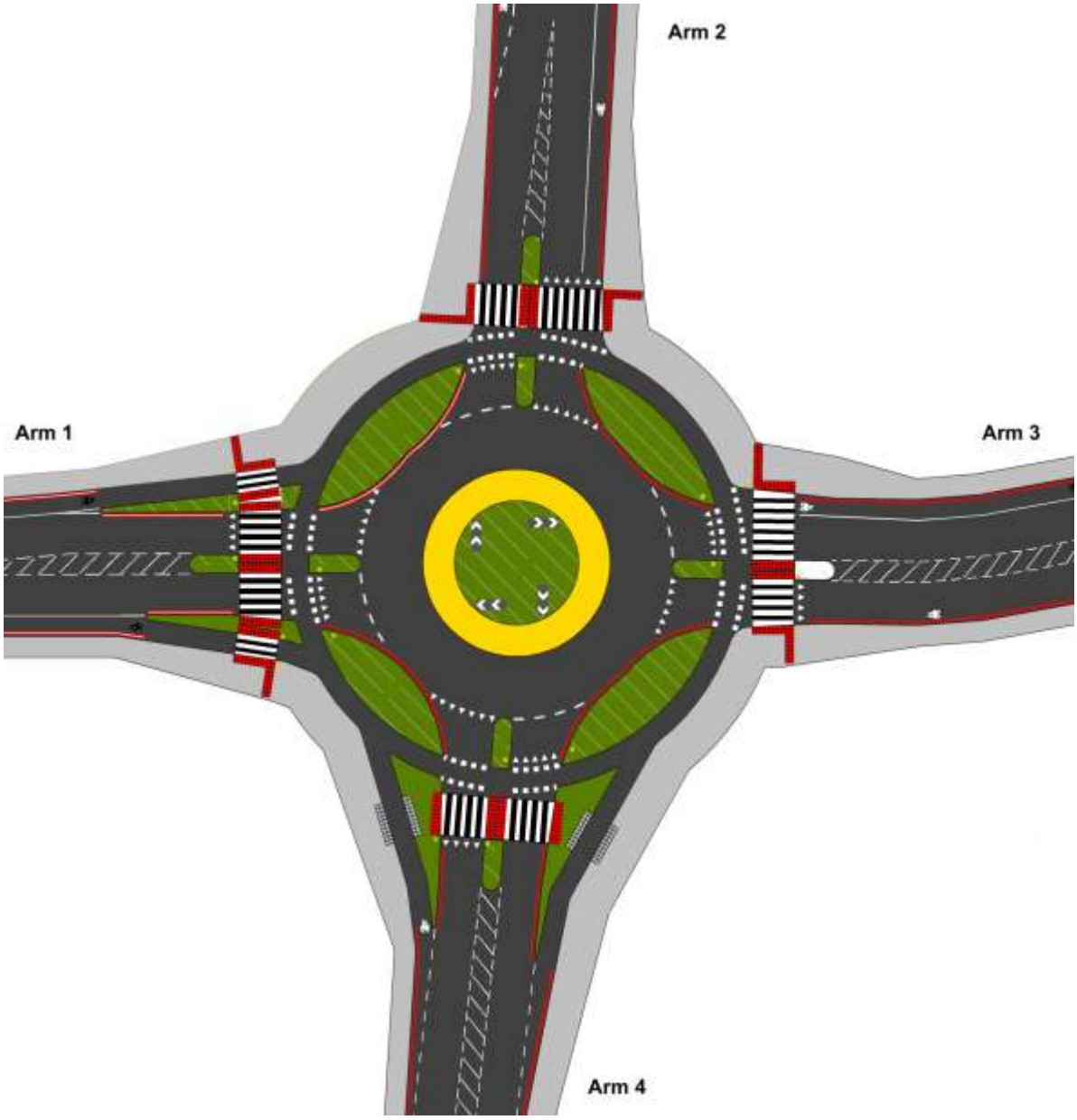

Figure 1: Layout of the Dutch-style Roundabout with Dutch road markings

1.2 Introduction to the M5 trials

The primary objective of the M5 trials was to establish the reactions of a number of user groups (cyclists, car drivers, HGV drivers and motor cyclists) when encountering the roundabout to establish their understanding of the roundabout layout and how they used it with Dutch-style markings. In particular, their interpretation of the markings and understanding of the priorities where the cycle lane crosses the arms was investigated. The M5 trials were also an important precursor to later, more complex trials which will investigate how different user groups interact when using the roundabout. The M5 trials were held between 25th and 28th March 2013.

2 Methodology

The participants were required to undertake a series of predetermined movements under instruction from the trials' facilitators. Each participant started on one of the arms of the roundabout and was asked to drive or ride up to the roundabout, and either turn left, go straight on, or turn right. No participant had seen the roundabout before the trials started, and they were not told how to negotiate the roundabout. In this trial, there were no interactions between participants or user groups while using the roundabout.

At the end of each movement, each participant was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and, in the case of cyclists, whether they used the orbital cycleway.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed questions (e.g. did you understand marking "x") and open questions (e.g. do you have any suggestions for making "y" clearer).

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings can be used as a baseline against which the effect of interactions in subsequent trials can be measured.

Data were provided by the questionnaires, the focus group transcripts and video analysis. Statistical analysis of the questionnaire and video data has made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted that if a finding has occurred with a probability that it occurred by chance of 5% or less, then it is statistically significant.

3 Summary of Findings

12 cyclists, 12 car drivers, 8 goods vehicle drivers and 15 motorcyclists took part in the trials.

3.1 Questionnaire Analysis Findings

The on-track questionnaire investigated how easy the participants felt that the movement they had just undertaken was, on a scale of 1 to 10. The results are shown in **Table 1**, which give the average of the scores participants assigned to each movement.

Table 1: Average scores for ease of use

	Direction of Turn		
Vehicle	**Left**	**Straight**	**Right**
Cars	9.1	8.9	8.8
Cycles	8.4	8.3	8.0
Goods Vehicles	9.4	9.3	9.1
Motorcycles	8.9	8.7	8.0

This shows that, in the absence of any other vehicles, all turns were generally felt to be easy for all user groups. It can also be seen that the left turn was the easiest and the right turn the most difficult, although the difference is not statistically significant. Note that the cyclists were free to use either the roundabout or cycle orbital lane.

The extent to which participants understood how to navigate the roundabout can be inferred from whether they noticed the cycle lane, their understanding of the markings, drivers' preparedness to give way, and whether cyclists considered using the orbital lane in an anti-clockwise direction.

Initially, almost all of the cyclists said they noticed the cycle lane approaching the roundabout, except at Arm 3 (where cyclists were not guided into the lane), and a large proportion of all the cyclist participants understood that the "elephants feet" markings are intended to indicate a cycle lane or crossing.

However fewer of the drivers noticed the cycle lane crossings and these participants gave a variety of interpretations of the 'sharks teeth' markings, mainly interpreting them as give way/caution markings or marking a pedestrian crossing.

In their responses to the post-trial questionnaire about a third of cyclists said they would consider using the cycle lane in an anti-clockwise direction under certain circumstances (e.g. deserted roads); in practice none did during this trial, although this has been observed in subsequent trials. Participants said that the decision on whether to use the cycle lane or the car lane was dependent on traffic conditions, direction of travel, and what was perceived to be "safe". This is supported by the behaviour measured in the video analysis.

About half of the car drivers and a larger proportion of lorry drivers said they had prepared to give way to cyclists as they approached the roundabout, but most said they would have given way if they had seen a cyclist crossing.

However, on leaving the roundabout, fewer of the drivers said they had prepared to give way to cyclists crossing (a quarter of the car drivers and two thirds of the lorry drivers). Although all but one of the lorry drivers said they would have given way to a cyclist crossing the exit, only half of the car drivers said they would have done so. This indicates that many car drivers did not understand that, with this design of roundabout (using Dutch markings), cyclists crossing a roundabout exit would have priority over traffic leaving the roundabout. The apparent increase in understanding of the cyclist priority by lorry drivers (or at least willingness to give way) may be due to lorry drivers being more likely to be professional drivers, and hence more experienced, than car drivers.

Motorcyclists using the road mainly found it 'easy' or 'very easy' to join the roundabout and none found it difficult to join at any of the entry points. None of the motorcyclists used the cycle lane for any of the manoeuvres during the trial

When asked whether they would choose the cycle lane, all motorcyclists said they would use the road for all manoeuvres, whether the traffic was busy or quiet. In general comments, two of the motorcyclists said they were uncertain about whether they could use the cycle lane.

Regarding specific aspects of the layout, cyclists were initially less likely to notice the cycle lane at Arm 3 (denoted by cycle symbols but with no lane marking) and may be

less likely to use the cycle lane round the roundabout if they approach the roundabout at this point. Cyclists found it more difficult to join the orbital cycle lane here (this involved a sharp left turn). Also, some cyclists found it difficult to leave the roundabout from the cycle lane at Arm 1 and Arm 2 – sharp turns and the markings and 'mini junctions' were mentioned as explanations.

Some cyclists preferred not to use the cycle lane. The main reasons given for this was the greater distance to be travelled in the cycle lane (particularly when turning right), and the fact that using the cycle lane resulted in more traffic crossings. Regarding the effect of approach layout, fewer cyclists said they would choose to use the cycle lane from Arm 3 than the other three arms, although the difference was too small to be statistically significant.

The only other difference between the layouts which was apparent from the questions asked in this trial was that there was some indication that lorry drivers were more prepared to give way to cyclists at the entry point where the cycle lane 'peeled off' into a segregated lane before the approach to the roundabout (Arm 4). However the reason for this is not clear and the proportion who said they would have given way if they had seen a cyclist crossing did not vary between the layouts.

Just under half of the drivers and motorcyclists said they noticed differences in layout between the entry points as they approached the roundabout for the first time, but few were specific about describing the differences.

3.2 Focus Group Findings

Six cyclists, six drivers and eight goods vehicle drivers took part in three separate focus groups which were held following the trial. Motorcyclists did not take part.

After participating in the trial, all groups of participants commented that there was a great deal of information (e.g. road signs, markings and the novel road layout) to consider throughout the trial, particularly at the roundabout. Cyclists, car drivers and Goods Vehicle (GV) drivers each had different concerns regarding the layout of the roundabout but were in agreement that the road markings incorporated within the roundabout increased uncertainty because they did not understand their meaning. This observation may be considered consistent with the use of unfamiliar Dutch markings on this particular layout. When making the first trip around the roundabout all groups were wary of the roundabout approach and exit; for drivers this was primarily due to the unfamiliar road markings (principally sharks' teeth and elephants' feet) and lack of signs to suggest mode priority.

Several car and GV drivers did not see the cycle lane until they approached the roundabout for a second time. Questions were raised over priority and right of way and it was clear that car drivers, GV drivers and cyclists did not think other road users would stop to give priority to cyclists. Should this be required many respondents felt a change to the law, additions in the Highway Code and signs around the roundabout would be needed to reiterate mode priority at roundabouts with a segregated orbital cycle lane.

Not all cyclists used the orbital cycle lane, with some cyclists preferring to join the main traffic if travelling straight on or turning right. Reasons given for this in the questionnaire responses were related to safety, other modes of traffic crossing the cycle lane and the need to stop and start when using the orbital cycle lane to check for traffic leaving the roundabout.

Participants had the opportunity to try the different designs of entry and exit on the test track. For cyclists, a segregated lane on the roundabout approach made the entry to the roundabout easier; however it did force cyclists into the orbital cycle lane.

Car drivers and GV drivers agreed that this design of roundabout did encourage them to travel slower around the roundabout than around a conventional roundabout and to check for pedestrians crossing at the exit arms. Whilst participants were not asked for their age, observation indicated that many of the participants in this trial were from older age groups. These participants felt that vehicles always have priority unless there are traffic lights or pedestrian crossings. A few drivers indicated that they would be more inclined to stop for pedestrians than for cyclists when travelling on the existing road network.

Some participants correctly described the roundabout as smaller than standard roundabouts; this was felt by drivers to be due to some of the road space being sectioned off to incorporate the segregated cycle lane. GV drivers did comment that for some turnings they needed additional road space due to the tight turnings exiting the roundabout.

Respondents from all groups agreed that the trial was not very realistic as there was little else to consider other than making their own journey around the roundabout due to no other road users participating in the trial at the same time. The trial was designed in order to allow participants to focus purely on the design of the roundabout without having to think about other road users or other distractions. All respondents felt that if the trial was made more realistic, this would make them more wary. Participants indicated that, without additional road features, other road users and education/briefing it was not possible to think of their journey as anything other than a trial in a static environment.

3.3 Video Analysis Findings

As mentioned, the video analysis in the M5 trials was principally designed to get baseline timings for comparison with subsequent trials where the effects of interactions will be measured. Figure 2 shows the average time taken for vehicles to use the roundabout from each of the four entry arms, showing the difference between the times taken by each of the vehicle types.

Cyclists were not told whether to use the orbital cycle lane or not. As some chose to use the cycle lane and others did not, the times for the cyclists have been split into those cycles using the main car lane (Cycle M), and those using the orbital cycle lane (Cycle O). The other vehicle types are Cars, Goods Vehicles (GV) and motorcycles (Powered Two Wheelers, PTW). Each column also has "error bars", showing the standard deviation[1] of the times. The Standard Deviation gives an indication of the spread of times. Where there is a significant overlap between error bars, this indicates that the observed difference between results could reasonably have come about due to random variation.

[1] Standard Deviation is a measure of the spread of results. For normally distributed data, about two-thirds of results will be within one standard deviation of the average.

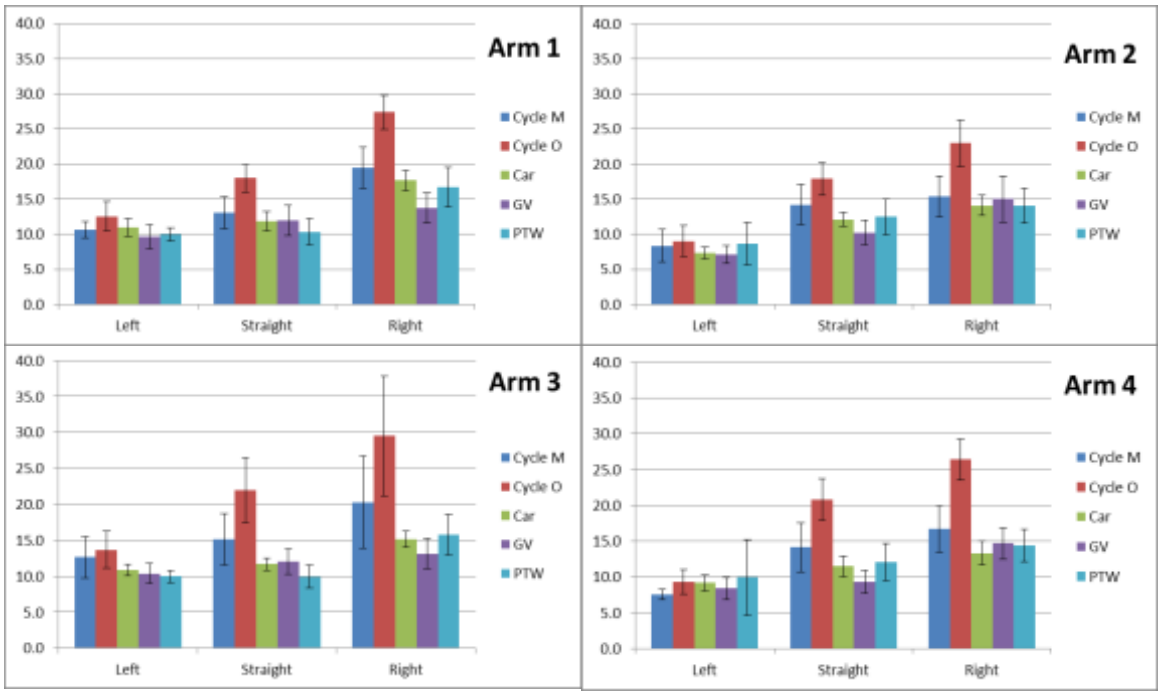

Figure 2: Time taken for vehicles to negotiate the roundabout

These graphs show a level of consistency in the variation of times between vehicle types. For example, from Arm 1 there is a relatively small difference in time between turning left and going straight for all vehicle types (except cycles using the cycle lane), whereas from Arm 2 there is a much larger difference for all vehicle types. It is clear that cyclists using the cycle lane take longer than those using the main vehicle lane, even when turning left where the distance travelled using the cycle lane is shorter. The reason is unclear – it could be due to the narrower cycle lane inhibiting speed, but could equally reflect the (probable) increased level of confidence of cyclists who chose to use the car lane. It also seems that, apart from cyclists using the cycle lane, the time taken to negotiate the roundabout is broadly similar for all other vehicle types.

It was also found that cyclists' choice of whether to use the cycle lane was influenced by the direction in which they were turning as shown in the table below.

Table 2: Percentage of cyclists using the cycle lane

Turning direction:	% using cycle lane
Left	82%
Straight	41%
Right	33%

This shows that the choices made by cyclists of which lane to use is consistent with the preferences expressed in the questionnaire and focus groups.

B.2 M6a Cyclists Findings Report, Dutch Markings

Findings report: Dutch Roundabout Cyclists' Interaction (M6a) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. These were placed directly alongside the cycle path where it crosses the car lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBa.M5). The layout is shown in Figure 1.

The different designs of entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

An important aspect of this initial build of the roundabout is that it used standard Dutch-style road markings including 'sharks teeth' (white triangles) to show where drivers should give way and 'elephants feet' (white squares) to highlight the orbital cycle lane as it crossed the entry and exit arms. This design has been used to establish a baseline of

participant behaviour against a design which is used in the Netherlands. Dutch markings were used for the initial M5 individual participant trial and for the M6a and M6b trials which investigated the interactions between cyclists and drivers respectively. After these initial trials, the roundabout was changed to use UK style markings for subsequent trials.

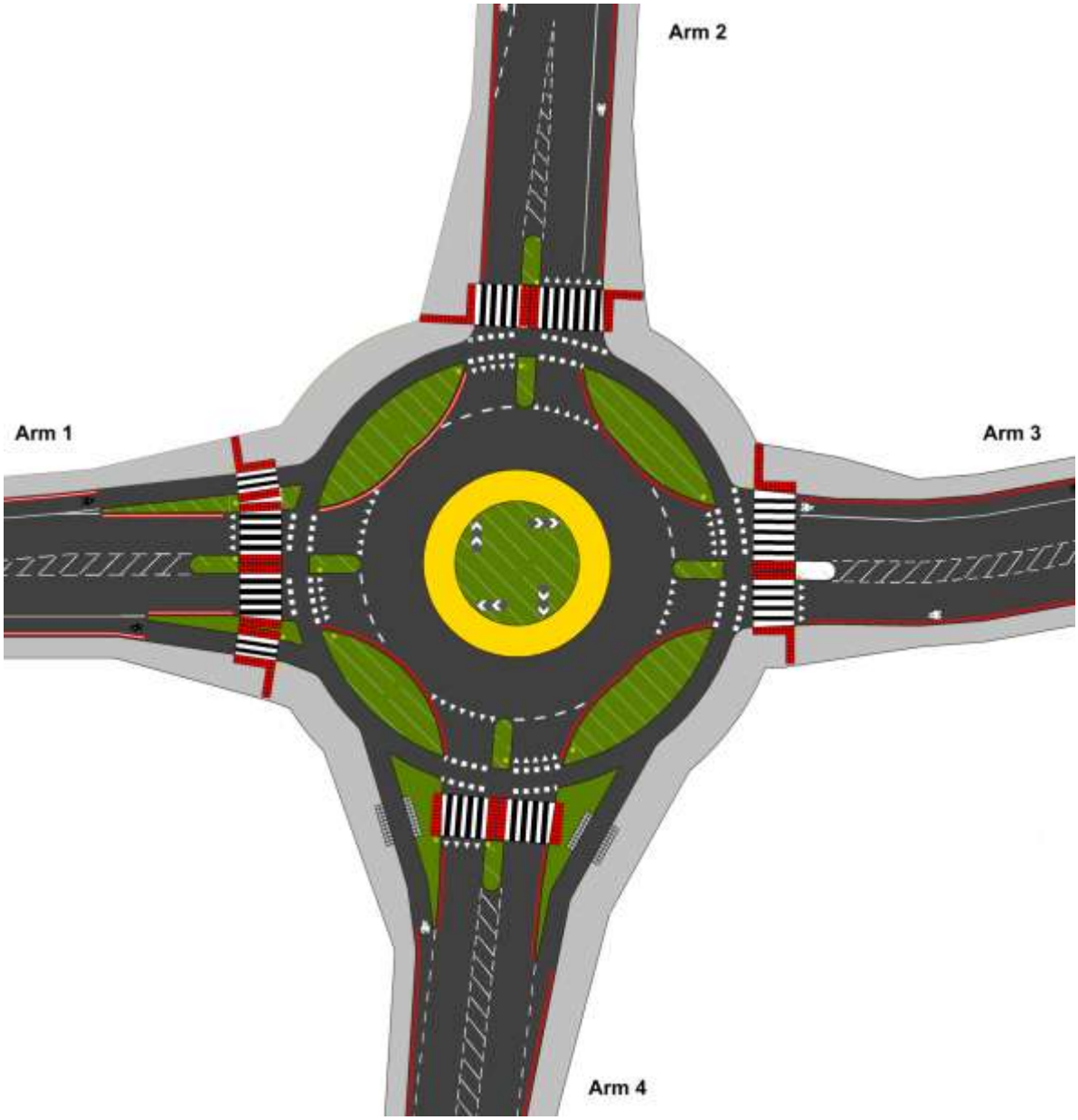

Figure 3: Layout of the Dutch-style Roundabout with Dutch road markings

1.2 Introduction to the M6 trials

The M6a trials were held between the 11th and 17th April 2013. The primary objective of the M6a trials was to establish the reactions of cyclists when encountering cars at the entrance to and exit from the roundabout. Cyclists were asked similar questions to those posed in the M5 trials to enable a comparison to be made between their understanding and perceptions of the roundabout without, and then with, other vehicles present.

2 Methodology

The participant cyclists were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant started on one of the arms of the roundabout and was asked to ride up to the roundabout, and either turn left, go straight on, or turn right using the orbital cycleway. No participants had seen the roundabout before the trials started. A total of 8 cyclists were on track at any one time with cyclists setting off in pairs.

At the same time, 8 cars (two on each arm) driven by trained drivers also negotiated the roundabout and engineered a "conflict[2]" with the cyclist either at the entrance to or exit from the roundabout. All 8 cars were on track at once with cars setting off in pairs.

At the end of each movement, each participant cyclist was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed questions (e.g. did you understand marking "x"?) and open questions (e.g. do you have any suggestions for making "y" clearer?).

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings are used in this report to isolate the give way behaviour of the participants and the resulting effect on journey times. They can be used to compare the effect of interactions compared to the individual trials in M5, and also as a baseline against which the effect of interactions in future trials can be measured, including the effect of changing to UK markings.

Data were provided by the questionnaires, the focus group transcripts and video analysis. Statistical analysis of the questionnaire and video data has made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted that if a finding has occurred with a probability that it occurred by chance of 5% or less, then it is statistically significant.

3 Summary of Findings

91 cyclists took part in the trials in 6 sessions spread over 3 days. The trials group included both male and females and included a wide range of ages from 18 to over 75.

3.1 Questionnaire Analysis Findings

The extent to which participants understood how to navigate the roundabout can be inferred from whether they noticed the cycle lane, their understanding of the markings, and whether the cyclists considered using the cycle lane in an anti-clockwise direction.

[2] A traffic *conflict* 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." (Amundsen & Hyden, 1977)

Most of the cyclists said they noticed the unusual road markings at the entrance to the roundabout, but were less likely to say that they noticed them as they left the roundabout.

The proportion of drivers who gave the correct interpretation for the sharks' teeth (give way) was relatively low: 25% approaching the roundabout and 30% leaving it. Most of the others who gave an explanation for the sharks' teeth tended to give a 'safe' interpretation - 'caution', 'slow down', or marking the pedestrian crossing. However a significant minority of cyclists (38%) said they did not know their meaning and several said they were confusing.

The white squares either side of the cycle crossings were correctly interpreted by about half of participants (54% of drivers, 46% of cyclists) as marking the cycle crossing. Some thought they meant 'give way' and some comments indicated a degree of confusion about which road users should have priority.

Only about half of the cyclists said that when going round the roundabout, they would have expected a driver approaching the roundabout to give way to them, and even fewer (about 40%) would have expected a car leaving the roundabout to give way to them.

Only a few cyclists said they would consider using the cycle lane anti-clockwise for turning right, more often in light traffic (12%) than in heavy traffic (7%). Cyclists were reluctant to ride "the wrong way" and were concerned about collisions with cyclists, confusion, the space available for two-way traffic and the angles of the kerbs.

Thus general understanding of how to navigate the roundabout was good, but there was some confusion about priorities, and the meaning of the sharks' teeth markings was not obvious to most participants.

Joining the cycle lane around the roundabout was described as being more difficult and less safe at Arm 3 than at the others by a significant margin – only 20% of cyclists found Arm 3 entry to be "very easy" compared to over 70% for the other arms. For cyclists leaving the roundabout, Arm 2 was felt to be the most difficult; at this point cyclists leaving the roundabout make a sharp left turn onto the road, without a separate cycle lane.

Cyclists felt that entering the cycle lane round the roundabout was easiest at Arm 1 with the longer segregated lane. Joining the cycle lane round the roundabout was thought to be easiest at Arm 4 where there was a gentle fork in the cycle lane.

The cyclists were largely in favour of taking advantage of the cycle lane around the roundabout. Over 90% said they would use the cycle lane in preference to the road in heavy traffic, and over 70% in light traffic. Most cyclists said it was easier for cyclists to use than an ordinary roundabout. Almost all of the participants thought cyclists would benefit from it, many thought motorists and pedestrians would benefit, and a majority made positive comments. The positive comments were focused on safety and segregation of cyclists from traffic.

There were indications that some cyclists, particularly those who are less confident, would be encouraged to cycle at roundabouts, but that some more confident cyclists would prefer to stay on the road.

A few suggestions for making it easier to understand were made by participants. These were: a coloured cycle lane surface, cycle symbols and turn left arrows where cyclists

join the orbital cycle lane, signs for 'give way to cyclists' and to warn cyclists leaving the roundabout that they are about to re-join the road.

There was a small minority of participants who did not mention any groups who would benefit and who made only negative comments about it. The negative comments were about risks, confusion, delays and allocation of priority between cyclists and vehicles.

3.2 Focus Group Findings

24 Cyclists took part in 3 separate focus groups, one on each day of the trials.

After participating in the trial all groups of participants commented that there was a great deal of information to consider throughout the trial, particularly at the roundabout. New behaviours would have to be learned e.g. traversing a roundabout leg by leg, looking over your shoulder rather than ahead / to the side to view oncoming traffic. Education on using the new design of roundabout was mentioned on various occasions.

> *"…when turning right, you needed to be more aware of the car coming up from the right".*

Each of the trial groups contained a mixture of cyclists with differing abilities. This enabled the debate to progress beyond the usual car v cyclist with contrasting attitudes and behaviours being expressed by cyclists of different ability and persuasion e.g. road cyclist, mountain biker etc. It was suggested that cyclists using road bikes would prefer to use vehicle lanes to travel through the roundabout as this would require fewer turns. However, cyclists using mountain bikes suggested their bikes would be better able to manage tight turns and therefore they would be comfortable using the cycle path.

> *"Road bikes are not as sturdy as mountain bikes so not so easy to negotiate the turns".*

> *"…didn't have to make hand signals as no-one behind to signal to…felt this was better".*

Some aspects of the trial of Dutch-style roundabouts appeared intuitive, though not necessarily reflecting actual practice. Cyclists traversed the roundabout in a clockwise direction, though sometimes it may have been quicker to travel in an anti-clockwise direction. However, all participants expressed natural caution, and indicated that they would stop for vehicles even when they had the right of way if they were concerned the vehicle would not stop, this was particularly apparent for less confident cyclists.

> *"…the layout looked like cyclist's right of way…but I wouldn't trust anybody (drivers) to stop, so it is meaningless"*

> *"Road markings indicated right of way for cyclists, however I can't ever imagine cyclists having right of way – this would lead to a 20 car tailback".*

During the focus group discussion participants expressed views on the entry / cycle lanes / exit layout of each of the roundabout arms. The majority of participants agreed that their preferred arms were 1 and 4 with arms 3 and 2 the least favoured.

> *"…arm three [entry] was definitely easy to miss"*

> "*One [unspecified] arm didn't have clear markings so I didn't realise it was a cycle lane*".

The majority of focus group participants suggested that the compulsory use of the cycle lanes on the Dutch-style roundabout would not be practical due to difficulties in enforcement. It was suggested if the layout was implemented then inclusion of guidance in the Highway Code would be required and would give an indication of their proper use. Depending on their levels of confidence and the time of day participants felt they should be given the choice as to whether they chose to use the roundabout. Less confident cyclists were in general agreement they would always choose the cycle path, however more confident regular cyclists suggested they would be less likely to use the cycle path.

3.3 Video Analysis Findings

Twelve video cameras captured the movements of cyclists and car drivers during the trial. In particular times of cyclists and car drivers entering, circulating around and exiting from, the roundabout were collected from the resulting recordings. These can be compared to assess which of the cyclists, or car drivers, went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if the cyclist and car driver came into close proximity within two seconds of each other. For example, whether they entered the roundabout within two seconds of each other from the same roundabout arm, or if the cyclists started to cross an exit arm within two seconds of a car driver arriving at the exit. Also, if the car driver and cyclist completed the interaction within one second of each other, then no priority was assigned.

3.3.1 Priority when negotiating the roundabout

The priorities taken by cyclists and car drivers have been investigated under three situations:

1. Entering the roundabout together
2. Cycle crossing an exit whilst a car driver is exiting the roundabout by that arm
3. Exiting the roundabout together

The results for them entering the roundabout together are summarised in Figure 4.

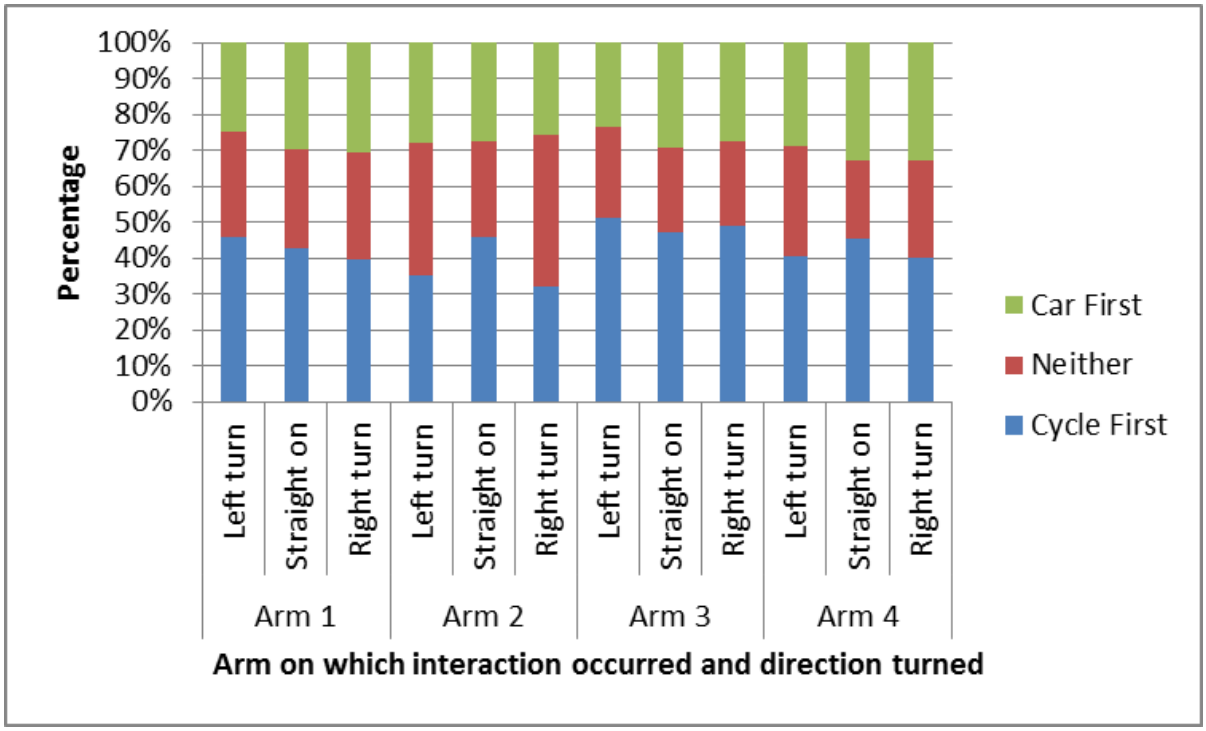

Figure 4: Priorities when a car driver and cyclist enter the roundabout at the same time

Car drivers aimed to enter the roundabout at the same time as the cyclist to create an interaction, or waited for them to enter first. The guidance given to the driver was that they should try to be parallel to the cyclists at the point where the cyclist reached the pedestrian crossing. An interaction was considered to have occurred if the cyclist and car driver crossed the far side of the pedestrian crossing within two seconds of each other.

When an interaction occurred, the cyclist entered the roundabout first on 35 to 51% of occasions: On average across all arms the cyclist went first in 42% of cases. Whilst the car driver entered first less often: between 23 to 33% of occasions.

This is in line with expectation as the cyclists were instructed to use the separate orbital cycle lane, and therefore their paths did not intersect with those of the car drivers.

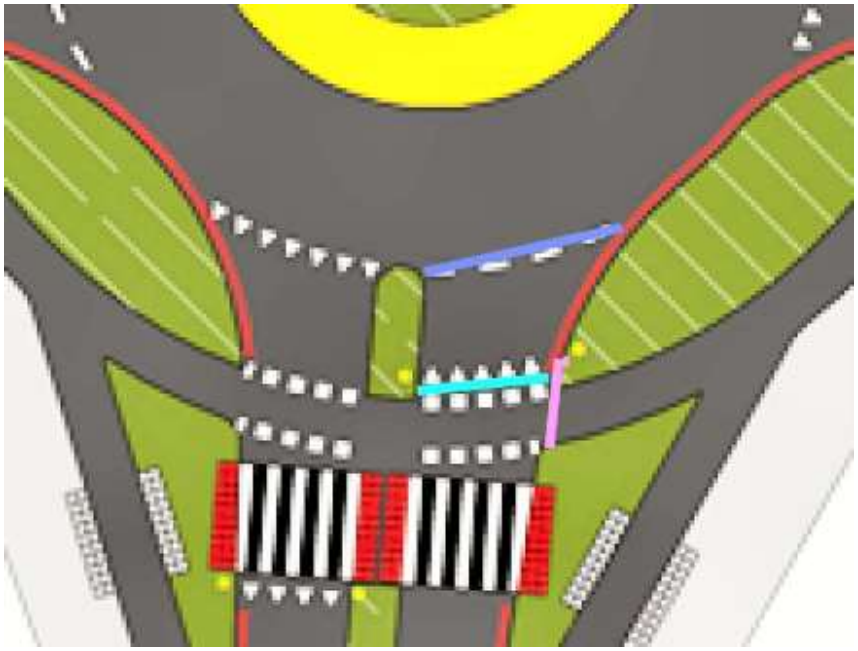

Figure 5: Timing points used to assess priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle lane

The second type of interaction was defined to have occurred when the cyclist crossed an exit arm of a roundabout and a car exited the roundabout from that arm. More specifically, an interaction occurred if the cycle crossed the purple line in Figure 5 within two seconds of the car crossing the dark blue line. The car was judged to have gone first if it crossed the light blue line before the cycle passed the purple line. The percentage of cars, and cycles found to have gone first when an interaction occurred is summarised in Figure 6.

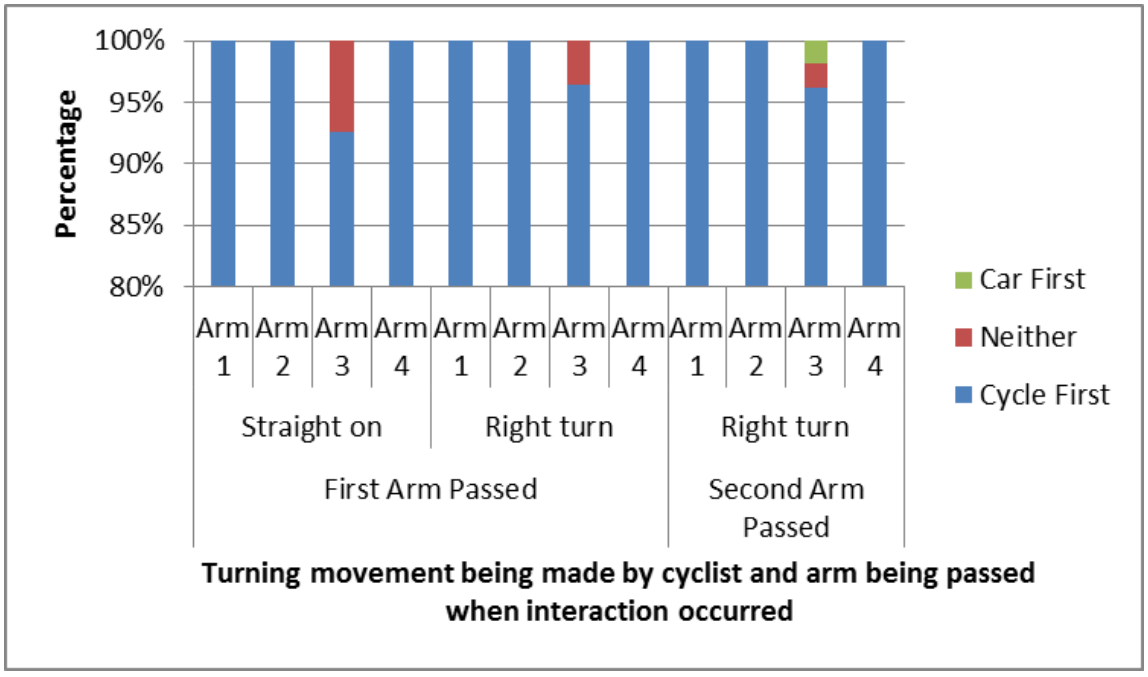

Figure 6: Priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle way

In nearly all such interactions, the cyclist went first, and the car gave way. This is expected as the car drivers were instructed to show caution and (if possible) give way to the cyclists.

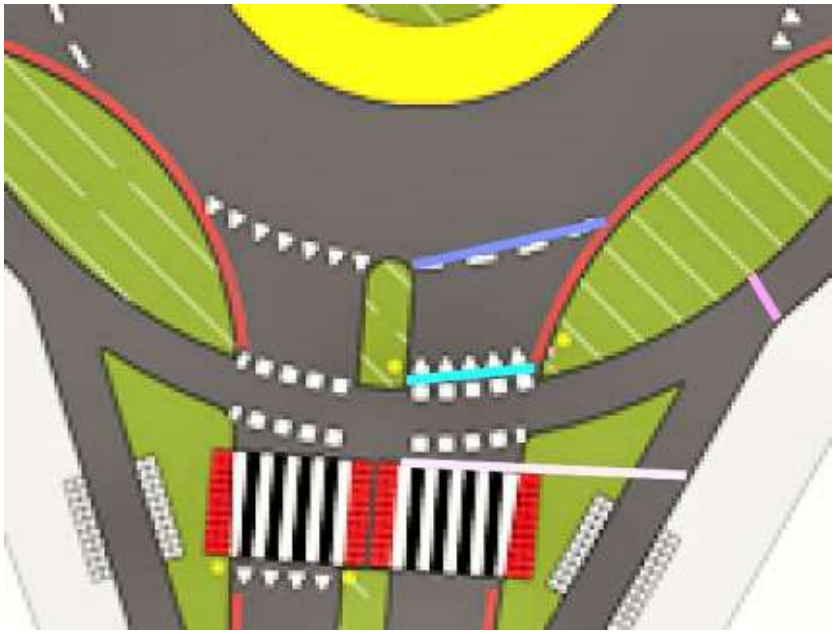

Figure 7: Timing points used to assess priorities when a car driver and cyclist exit the roundabout at the same time

The third type of interaction was defined to have occurred when the cyclist and car driver approached the exit of an arm within two seconds of each other. More specifically, the cycle crossed the purple line in Figure 7 within two seconds of the car crossing the dark blue line. The car was judged to have exited first if it crossed the light blue line before the cycle passed the purple line. The light purple line was also used as to time vehicles exiting the roundabout. The percentage of cars, and cycles found to have started to exit, and exited, first when an interaction occurred is summarised in Figure 8.

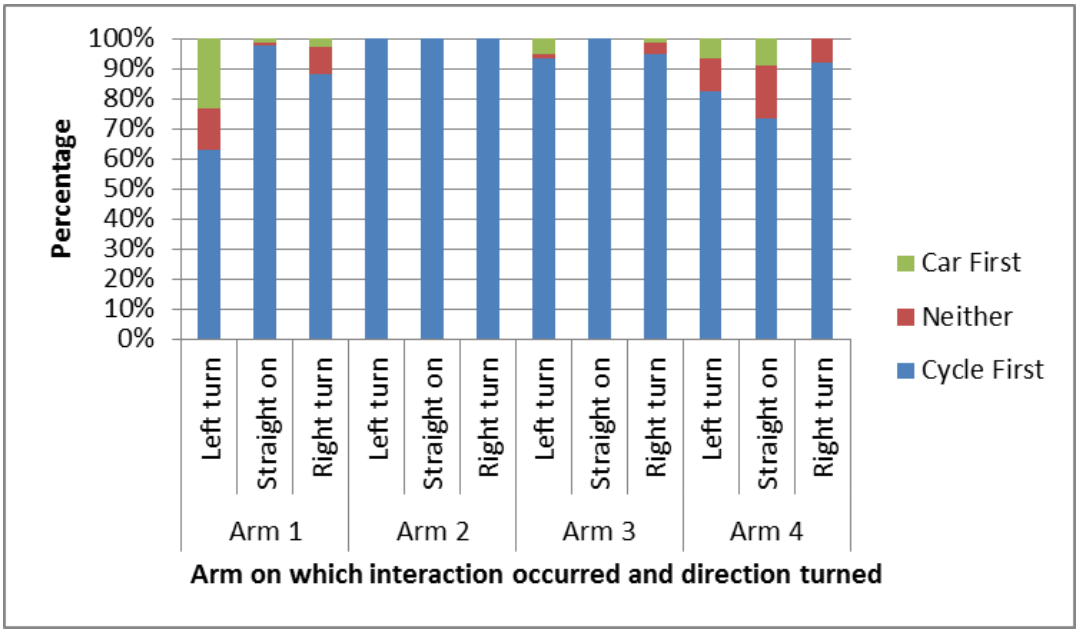

Figure 8: Priorities when a car driver and cyclist exit the roundabout at the same time

Overall, cyclists still generally (in over half the observed interactions) exited the roundabout before the car drivers. The percentage of car drivers leaving the roundabout first varied with the geometry of the arms.

Car drivers were more likely to exit Arms 1 and 4 earlier than the cyclist. These are the arms where the cyclist exits via a separate cycle lane, before reaching the main roundabout's exit.

Car drivers occasionally exited Arm 3 before the cyclists, at which cyclists exited into a separate cycle lane adjacent to the main carriageway. However, cyclists always exited Arm 2 first, where the car and cyclist had to initially merge at the exit.

3.3.2 Effects on cyclist journey time

Cyclists started on one of four arms and either turned left, right, or continued straight on at the roundabout. They could meet a car under one of three situations: 1. a car was entering the roundabout at the same time they entered;2. a car was exiting an arm whilst they cycled past in the orbital cycle lane; or 3. a car was exiting the roundabout at the same time as the cyclist exited. If the car was in the vicinity, that is. they crossed defined timing points (see below) on the approach to the "interaction area" within two seconds of each other, an interaction was said to have occurred.

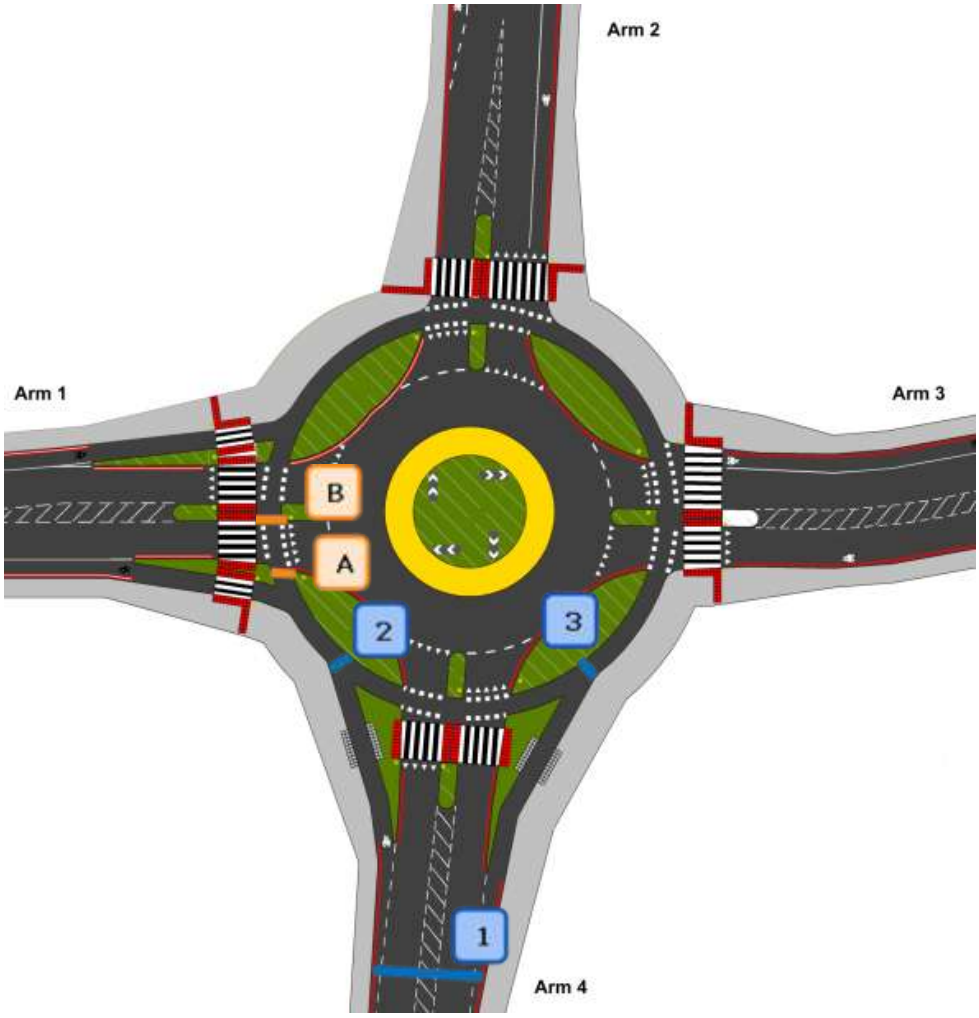

Figure 9: Journey timing points for cyclists

The average time for cyclists to enter the roundabout, circulate around the roundabout and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2; where Point 1 was fixed for the trials on the roundabout's arm. The time to circulate over Arm 1 was taken between Points A and B. The time to exit from over Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 9.

The average times for cyclists to enter, exit and circulate the roundabout are summarised in Figure 10.

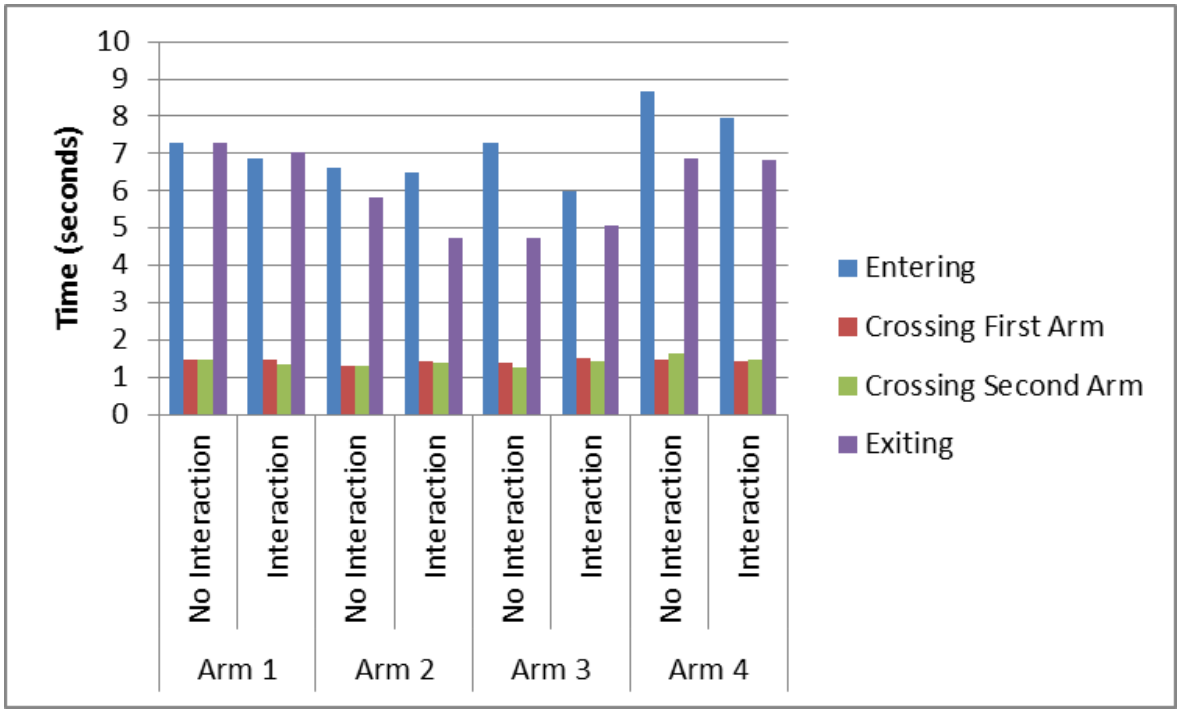

Figure 10: Cyclist journey time components

Cycle journey times were similar for all the roundabout's arms. There was also an indication that cyclists used slightly higher speeds if interacting with a car when they entered, or exited, the roundabout. The cyclists' overall journey times are summarised in Figure 11, and cyclists were generally between 1.0 and 5 seconds faster if they experienced one (or more) interactions with a car, and all cyclists in a session were involved in a similar number of conflicts, so no bias between different types of cyclists should have affected this result.

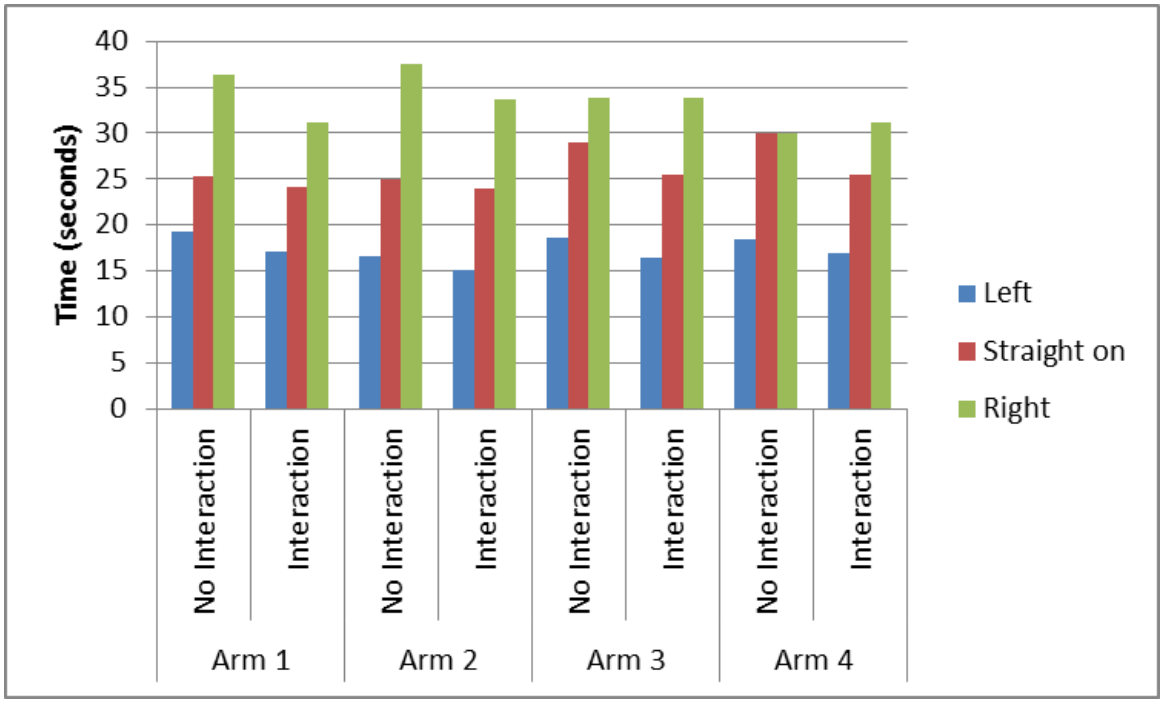

Figure 11: Cyclist overall journey time

3.3.3 Effects on car driver journey time

In this trial, the car drivers were trained users of the roundabout whose principal purpose was to engineer interactions with the cyclists. As such, it was not appropriate for them to take part in the questionnaire or focus groups activities. However it was felt that it would be appropriate to measure the effect of cyclists' interaction on their journey times as this was not significantly influenced by the fact that they understood the roundabout operation.

Car drivers started on one of four arms and turned left at the roundabout. They were instructed to enter at the same time as the cyclist on the same arm, or enter after them. They were also either asked to approach the left hand exit as a cyclist passed over the exit in the orbital cycle way, or exit at the same time as a cyclist. The car driver was under TRL instruction and was told to give way to the cyclist as a default.

The average time for car drivers to enter the roundabout, and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2; where Point 1 was fixed for the trials on the roundabout's arm. The time to exit from over Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 12.

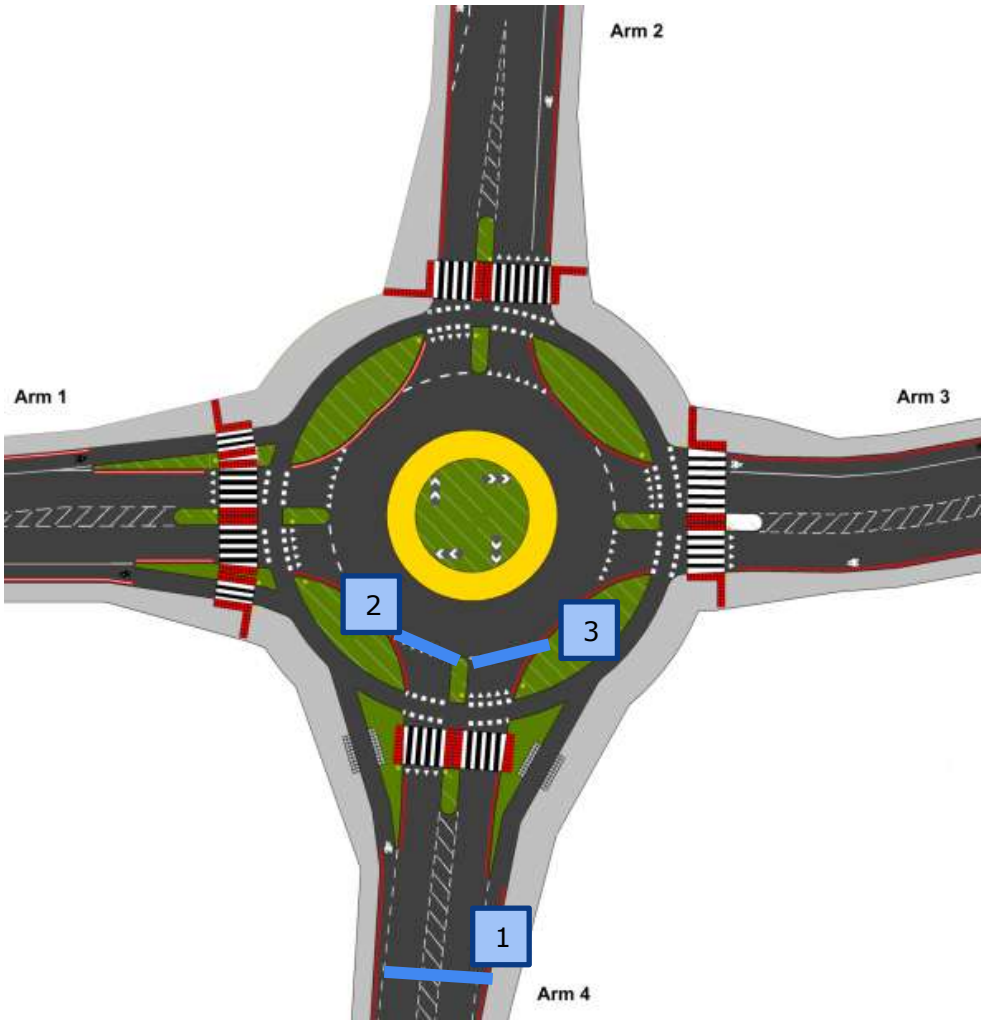

Figure 12: Journey timing points for car drivers

The average times for car drivers to enter, exit and circulate the roundabout are summarised in Figure 13.

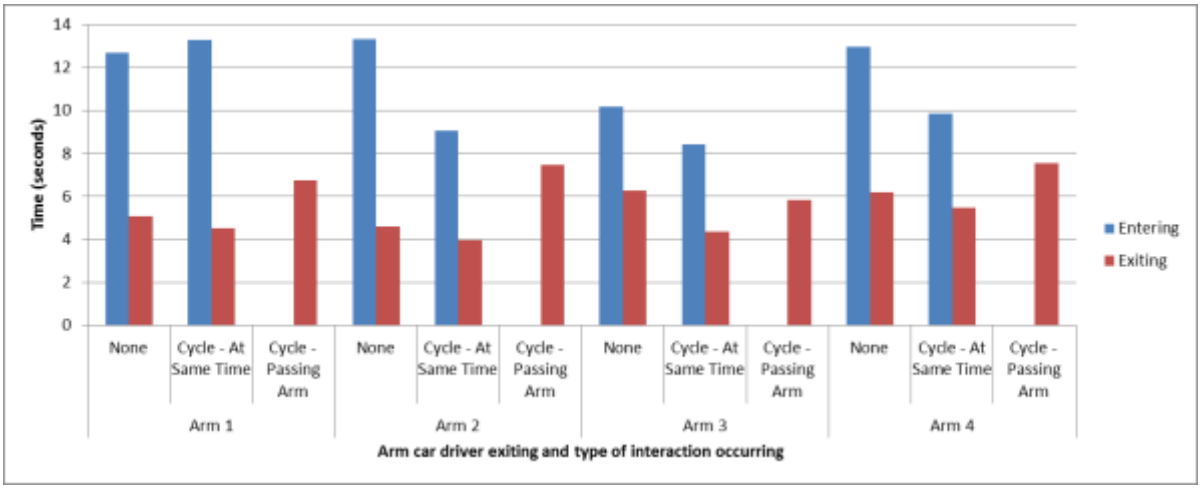

Figure 13: Car journey time components

The interaction with a cyclist had no observable adverse effect on journey time when entering the roundabout. The reduced journey time in conflict situations was probably a result of (TRL controlled) drivers using higher speeds to ensure a conflict situation occurred. The speed adjustment made by the drivers dominated over any effects of the roundabout's geometry including whether the cyclists were separated from the car drivers (Arms 1 and 4), and if the approach had an offset island (Arm 2) assisting in separating the cars and cycles, or not (Arm 3), see Figure 12.

There were also only slight reductions in delay when the cyclist and car driver exited the roundabout at the same time, for the same reason. However, there were average delays of between 1.4 to 3.0 seconds owing to the car driver exiting and giving way to a cyclist passing over the exit on three of the roundabout' arms.

Overall car journey times were between 0.8 and 7.5 seconds longer if there was one interaction on the journey with a cycle exiting the roundabout, see Figure 14.

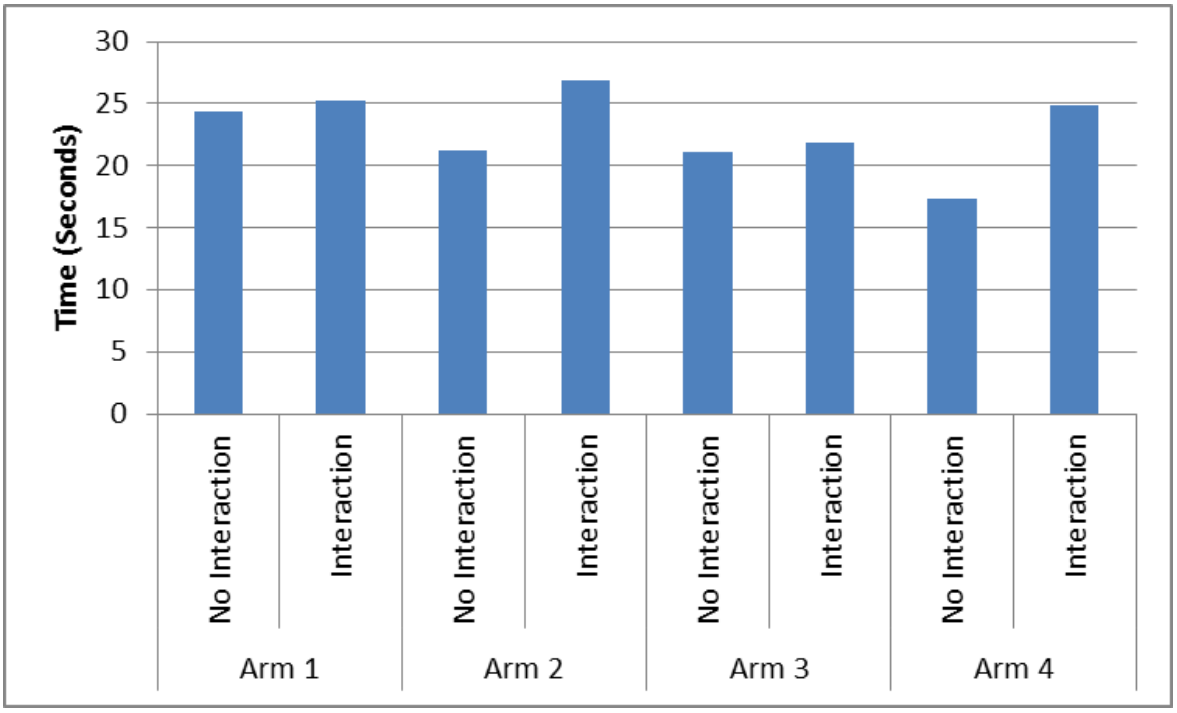

Figure 14: Car driver overall journey time

3.4 Cyclist on-track responses

During the trials cyclists were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'How easy it was to cycle from one arm to another?'
- 'How safe did you feel?'
- In busy traffic would you have chosen the cycle lane or the main roundabout?
- If using the cycle lane, would you have gone clockwise or anticlockwise?

The scoring for the first two was on a scale of one to ten, with ten being very easy, or very safe, respectively. The cyclists' average scores are summarised in Figure 15.

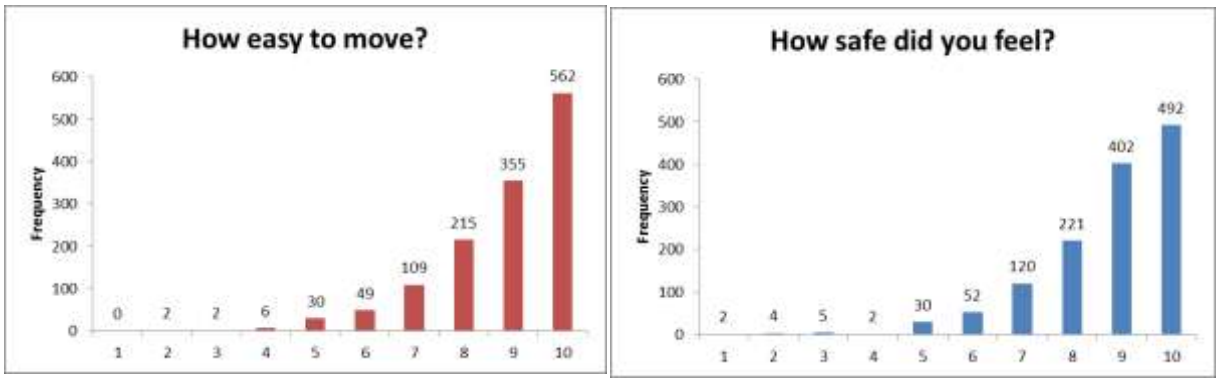

Figure 15: Cyclists' scores of safety and ease of using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority (97%) of runs were found to be both easy and safe. This is not overly surprising as cyclists were not placed in any difficult situations. However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 89% of the safety scores were with ±1 of the ease of negotiating scores.

For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same. The average scores for making individual turning movements is summarised across all arms, see Figure 16.

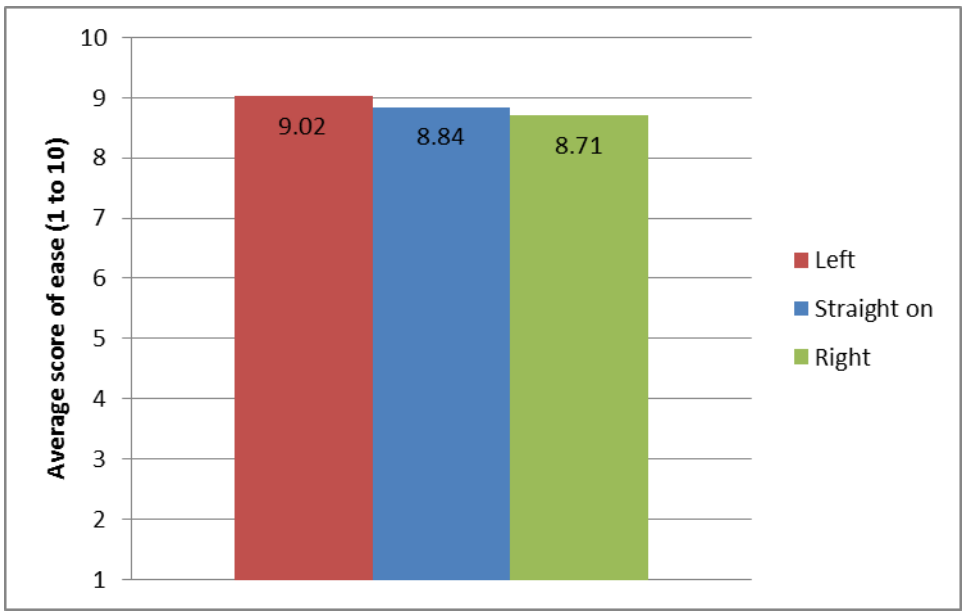

Figure 16: Cyclists' ease of negotiating the roundabout by turning movement

This implies that (on average) cyclists found it easier to turn left than straight on, than right. However, all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in Figure 17. This chart shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that the easiest manoeuvre was considered to be from Arm 4 turning left to go to Arm 1: i.e. turning *left* from and to an arm *with* a segregated cycle lane leading the cyclists separately onto and off of the roundabout. The most difficult was indicated to be from Arm 3 turning right to go to Arm 2: i.e. turning *right* from and to an arm *without* any segregated cycle lane leading the cyclists separately onto and off of the roundabout. Overall, there is an indication that turning out of Arm 3 was judged as slightly harder than the other arms.

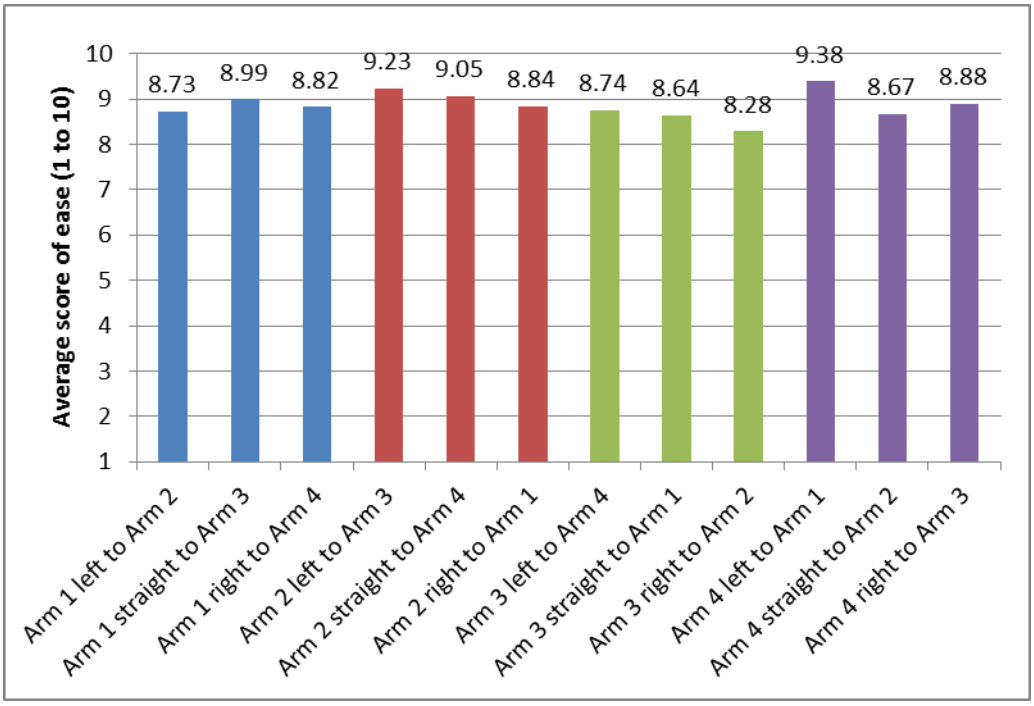

Figure 17: Cyclists' scores of ease of negotiating the roundabout by arm and movement

Further analysis was performed to ascertain the differential in scores between arms and turning movements using an Analysis of Variants (ANOVA) technique. The differences in the scores were too small for any statistical confidence in the findings. However, there was an indication that the turning movement made had slightly more effect on ease of use score than arm geometry differences.

Finally, cyclists were also asked if they would have used the cycle lane, or the main road, in heavy traffic, and if they would cycle clockwise or anti-clockwise if using the orbital cycle way:

- 94% of cyclists would use the orbital cycle way in heavy traffic
- 99% of cyclists would travel clockwise around the orbital cycle way.

B.3 M6b Car Drivers Findings Report, Dutch Markings

Insert findings report here

Findings report: Dutch Roundabout Car Drivers' Interaction (M6b) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. These were placed directly alongside the cycle path where it crosses the car lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBa.M5). The layout is shown in Figure 1.

The different designs of entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

An important aspect of this initial build of the roundabout is that it used standard Dutch-style road markings including 'sharks teeth' (white triangles) to show where drivers should give way and 'elephants feet' (white squares) to highlight the orbital cycle lane as it crossed the entry and exit arms. This design has been used to establish a baseline of

participant behaviour against a design which is used in the Netherlands. Dutch markings were used for the initial M5 individual participant trial and for the M6a and M6b trials which investigated the interactions between cyclists and drivers respectively. After these initial trials, the roundabout was changed to use UK style markings for subsequent trials.

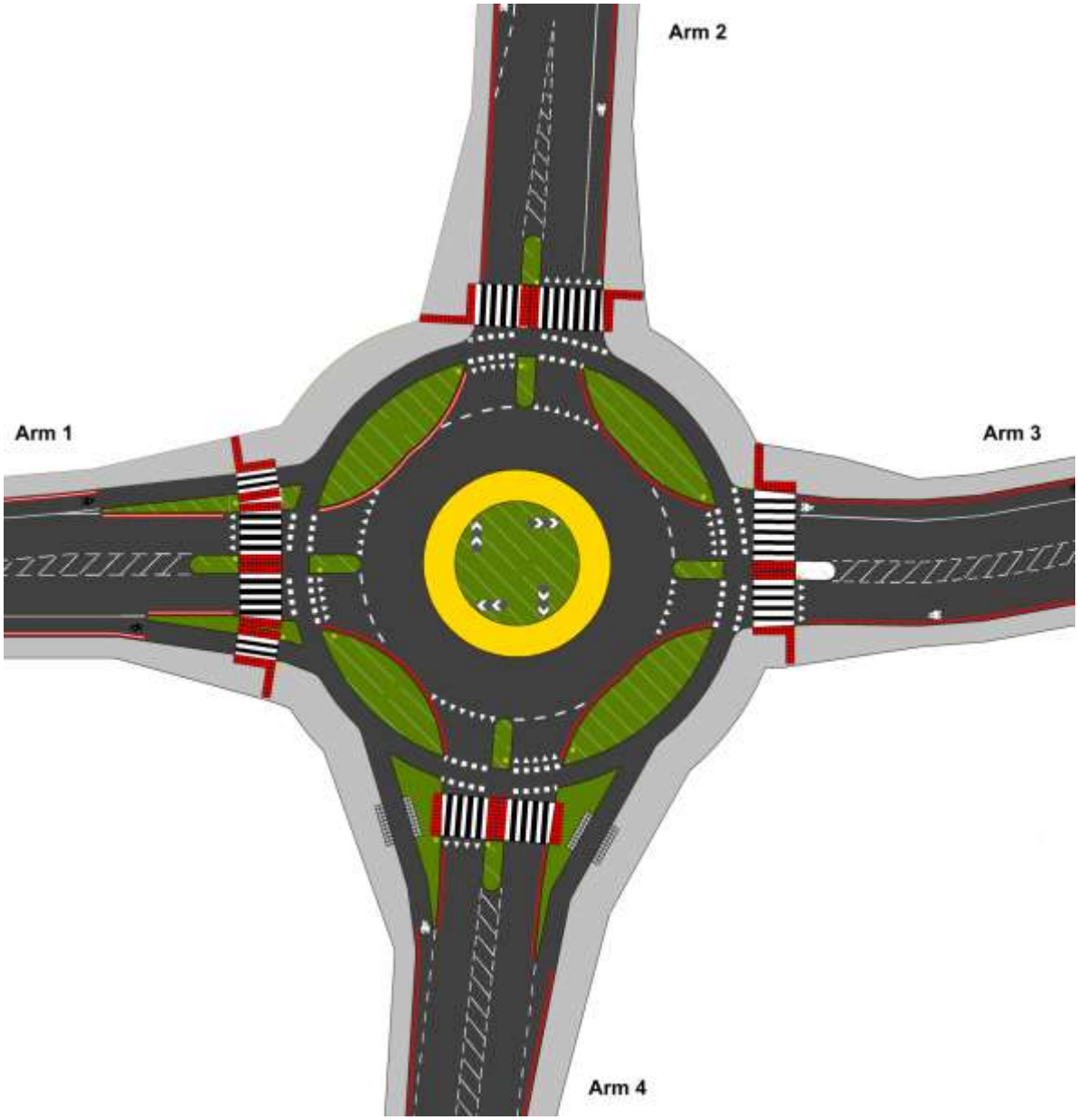

Figure 18: Layout of the Dutch-style Roundabout with Dutch road markings

1.2 Introduction to the M6b trials

The M6b trials were held between the 22nd and 26th April 2013. The primary objective of the trials was to establish the reactions of car drivers when encountering cyclists at the entrance to and exit from the roundabout. Drivers were asked similar questions to those posed in the M5 trials to evaluate if interacting with other users produced a change in their understanding and perceptions of the roundabout.

2 Methodology

The participant drivers were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant started on one of the arms of the roundabout and was asked to drive up to the roundabout, and either turn left, go straight on, or turn right. No participants had seen the roundabout before the trials started. A total of 8 drivers were on track at any one time with the cars setting off in pairs.

At the same time, 8 trained cyclists (two on each arm) also negotiated the roundabout and engineered a "conflict[3]" with the cars either at the entrance to or exit from the roundabout. All 8 cyclists were on track at any one time with the cyclists setting off in pairs. The conflicts were designed that the drivers would encounter cyclists at both the demerge and merge points on the roundabout, and they would also encounter cyclists crossing the car lane at either the entrance to or exit from the roundabout. Drivers were not told that the cyclists had right of way while on the orbital cycle lane.

At the end of each movement, each participant driver was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed (e.g. did you understand marking "x") and open (e.g. do you have any suggestions for making "y" clearer) questions.

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings can be used to compare the effect of interactions compared to the individual trials in M5, and also as a baseline against which the effect of interactions in future trials can be measured, including the effect of changing to UK markings.

Data were provided by the questionnaires, the focus group transcripts and video analysis. Statistical analysis of the questionnaire and video data has made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted that if a finding has occurred with a probability that it occurred by chance of 5% or less, then it is statistically significant.

3 Summary of Findings

93 drivers took part in the trials. The trials group included both male and females and included a wide range of ages from 25 to over 75. No drivers under 25 were included for insurance purposes.

[3] A traffic *conflict* 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." (Amundsen & Hyden, 1977)

3.1 Questionnaire Analysis Findings

The extent to which participants understood how to navigate the roundabout can be inferred from noticing the cycle lane, understanding of the markings and drivers' preparedness to give way.

The majority of drivers (three-quarters) said they noticed the cycle lane crossing as they approached the roundabout and a slightly higher proportion noticed it as they were about to leave the roundabout.

Most of the drivers said they noticed the unusual road markings at the entrance to the roundabout, but were less likely to say that they noticed them as they left the roundabout.

The proportion who gave the correct interpretation for the sharks' teeth (give way) was low: 10% approaching the crossing, 10% approaching the roundabout and 25% leaving the roundabout. Most of the others who gave an explanation for the sharks' teeth tended to give a 'safe' interpretation - 'caution', 'slow down', or marking the pedestrian crossing. However a significant minority of drivers (20%) said they did not know their meaning and several said they were confusing.

The elephants' feet either side of the cycle crossings were correctly interpreted by about half of participants as marking the cycle crossing. Some thought they meant 'give way' and some comments indicated a degree of confusion about which road users should have priority.

Almost all (91%) of the drivers said that on approaching the roundabout, they prepared to give way to cyclists and would have given way if they had seen a cyclist crossing on the cycle lane. This was also the case for drivers leaving the roundabout.

At the point where cyclists leaving the roundabout turn out of the cycle lane into the main carriageway, a few drivers said they would not give way to cyclists and over a fifth were unsure about whether to give way or not.

Thus general understanding of how to navigate the roundabout was good, but there was some confusion about priorities, and the meaning of the sharks' teeth road markings was not obvious to most participants.

A few suggestions for making it easier to understand were made by participants. These were: a coloured cycle lane surface, cycle symbols and turn left arrows where cyclists join the orbital cycle lane, signs for 'give way to cyclists' and to warn cyclists leaving the roundabout that they are about to re-join the road. One driver suggested signal-controlled cycle crossings "*to make it clear who was doing what*."

Initially, only half of the drivers noticed any differences between the four entry layouts. Those who did not notice said they were concentrating on what they were doing or the route the cyclists were taking. Some said they did notice differences later on in the trial.

Drivers, like cyclists, found joining the roundabout to be more difficult at Arm 3 than at the other entry points, at least for turning left and going straight on; drivers mentioned the same issues as cyclists, namely the lack of separate cycle lane and the sharp left turn which could involve the cyclist swinging out into the path of a vehicle. Drivers also rated joining the roundabout at Arm 3 to be less safe than elsewhere.

Almost all of the participants thought cyclists would benefit from the roundabout, many thought motorists and pedestrians would benefit, and a majority made positive

comments. The positive comments were focused on safety and segregation of cyclists from traffic.

Drivers were more divided in their opinions than cyclists on the benefits, with half saying it would be easier for drivers to use a roundabout like this than an ordinary roundabout and over a third saying it would be more difficult for drivers. Drivers were also more likely to rate the roundabout as unsafe in traffic than cyclists.

3.2 Focus Group Findings

23 drivers took part in 3 separate focus groups on the 3 trial days. All comments are from focus group participants.

After participating in the trials around 55% of the total number of participants in the focus groups suggested that there was either too much road furniture and markings or that they were not adequately explained. It was felt this made the junction confusing and could distract drivers from surrounding road users. The majority of drivers felt that signage was inadequate and that more signage and road markings should be located on the approach to the roundabout. Improvements to the road markings were recommended which included covering the cycle lane in coloured tarmac or painting bikes on the road to alert drivers to the cycle lane.

> *"…all the lights and markings made it look like a maze";*
>
> *"I liked all the paint on the ground – made the driver slow down and sent a good message to the driver to be cautious. Even though it was a little confusing my reaction was to slow down which is a good thing";*
>
> *"Didn't find it immediately obvious, no road markings and there were no signs to indicate it was for bikes".*

The road markings (elephants' feet and sharks' teeth) were unfamiliar to most participants creating ambiguity over whose right of way it was at the cycle crossings. Most assumed these inferred the driver should give way to the cyclist, however there was a general consensus amongst the focus group participants that the road markings should be used in addition to signage. Furthermore, it was noted these road markings were unfamiliar and upon further discussion participants agreed they needed to be included in the Highway Code if implemented. In addition, a small number of participants suggested if the roundabouts were implemented a media campaign should be launched. However, other participants suggested this may not reach all drivers and unless the roundabouts were launched nationwide then this would be unnecessary.

> *"Was unsure what the shark's teeth were for but I assumed the squares [Elephant's Feet] were to show continuation of the cycle lane";*
>
> *"There was a lack of clarity over whose right of way it was between the cyclist and the driver".*

A further common concern drivers had was not seeing cyclists approaching the crossing if they appeared out of their peripheral vision. Many drivers were concerned that cyclists entering the crossing may appear out of their line of sight and expect drivers to stop at the crossing. An added concern is that currently whilst on a roundabout drivers give way to the right, however with the addition of the cycle path they would need to give way to the left as well. In addition, a further concern was whether the direction cyclists can

travel would be restricted, it was felt cyclists turning right would be unlikely to travel around the entire roundabout and would be likely to travel in an anti-clockwise direction.

> *"…the crossing is so close to the roundabout it would give the driver little time to see them";*

> *"…the cyclist in danger isn't the one on the crossing but the one in the peripheral of driver cycling parallel to the car and then suddenly in front of the car on the crossing".*

Another common theme that arose throughout the focus groups was the concern for drivers stopping on the roundabout whilst giving way to cyclists. Large numbers of participants expressed concern and suggested they would feel vulnerable if stationary on the roundabout, participants had concerns about tailbacks, their vehicle being clipped and other vehicles beeping them and urging them onwards. In addition, on the approach to the roundabout it was suggested that vehicles stopping for cycle lanes could block pedestrian crossings. One participant suggested a solution of moving both the zebra and cycle crossings further from the roundabout, the remainder of the group agreed with this suggestion. This would also have the added benefit of allowing the driver longer to assess the crossing when leaving the roundabout. The immediate left turn off the roundabout was flagged as the biggest concern for drivers as it was felt this gave limited time for drivers to adequately see the crossing and whether cyclists were approaching. The straight on and right hand turns were the preferred manoeuvres as this provided a wide view of the crossing.

> *"Is it ok to stop on a roundabout? If you stop for the cyclists you will create a traffic jam and lorries will cover the whole roundabout".*

> *"I think this layout is a bad idea. If drivers are expected to give way to cyclists there will be a risk that cars will get hit from behind whilst waiting on the roundabout"*

The conclusion to the group's trials were that the majority of participants felt there was a safety benefit to segregating cyclists and vehicles, however there was concern about potential conflict at crossings.

> *"…definitely positive to separate cars and bikes".*

There was a general feeling that the layout would be best suited to mid-sized roundabouts, with it viewed as superfluous for mini roundabouts as there would be fewer safety benefits. It was also felt this layout would not be suitable for large roundabouts with a number of roads leading off it, traffic lights were the preferred method here.

3.3 Video Analysis Findings

Twelve video cameras captured the movements of cyclists and car drivers during the trial. In particular times of cyclists and car drivers entering, circulating around and exiting from the roundabout were collected from the resulting recordings. These can be compared to assess which of the cyclists, or car drivers, went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if the cyclist and car driver came into close proximity within two seconds of each other. For example, whether they entered the roundabout within two seconds of each other from the same roundabout arm, or if the

cyclists started to cross an exit arm within two seconds of a car driver arriving at the exit. Also, if the car driver and cyclist completed the interaction within one second of each other, then no priority was assigned.

1.1.1 Priority when negotiating the roundabout

The priorities taken by cyclists and car drivers have been investigated under three situations:

4. Entering the roundabout together
5. Cycle crossing an exit whilst a car driver is exiting the roundabout by that arm
6. Exiting the roundabout together

The results for the participants entering the roundabout together are summarised in **Figure 19**.

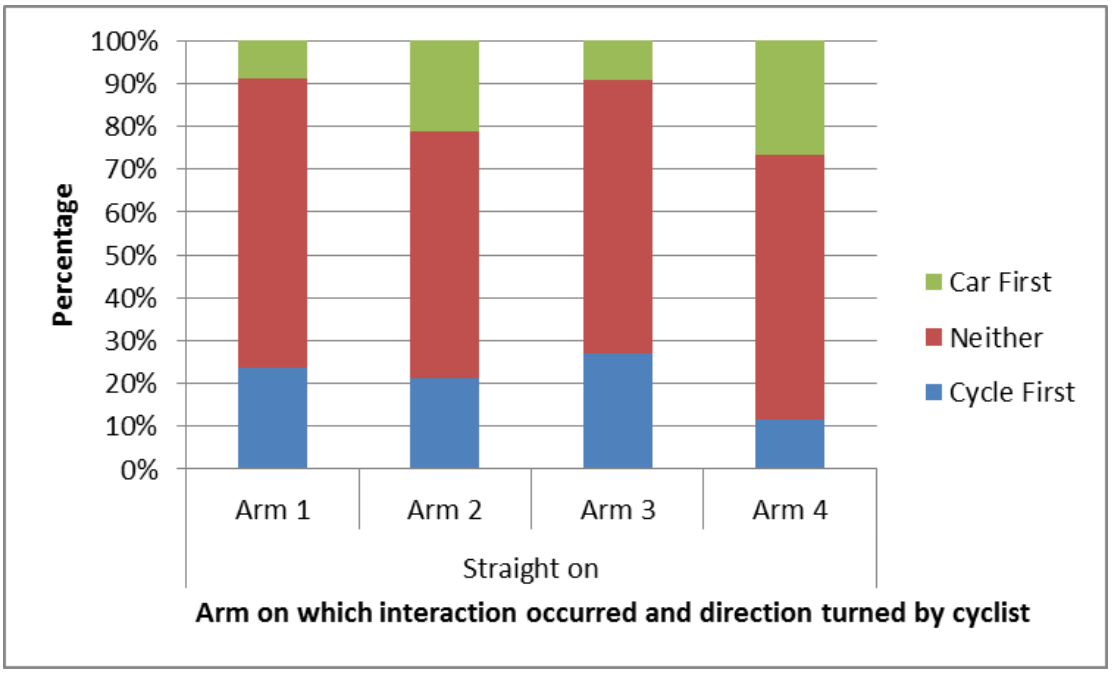

Figure 19: Priorities when a car driver and cyclist enter the roundabout at the same time

Cyclists aimed to enter the roundabout at the same time as the car drivers to create an interaction, or avoided entering at the same time as the car driver, depending on the instructions they were given. The guidance given to the cyclist was that if creating a conflict on the roundabout's entrance they should try to be parallel to the car drivers when they reached the pedestrian crossing. An interaction was considered to have occurred if the cyclist and car driver crossed the far side of the pedestrian crossing within two seconds of each other. The cyclists were always instructed to go straight ahead for each run.

As can be seen on **Figure 19**, when an interaction occurred, the cyclist entered the roundabout first on 12 to 27% of occasions. Also the car driver entered first between 9 to 27% of occasions. On most occasions the car driver and cyclists entered the

roundabout within 1 second of each other, indicated as 'neither' in Figure 2. This is in line with expectation as the cyclists were instructed to use the separate orbital cycle lane, and therefore their paths did not intersect with those of the car drivers.

The second type of interaction was defined to have occurred when the cyclist crossed an exit arm of a roundabout and a car exited the roundabout from that arm. More specifically, an interaction occurred if the cycle crossed the purple line in **Figure 20** within two seconds of the car crossing the dark blue line. The car was judged to have gone first if it crossed the light blue line before the cycle passed the purple line. The percentage of cars, and cycles found to have gone first when an interaction occurred is summarised in **Figure 21**.

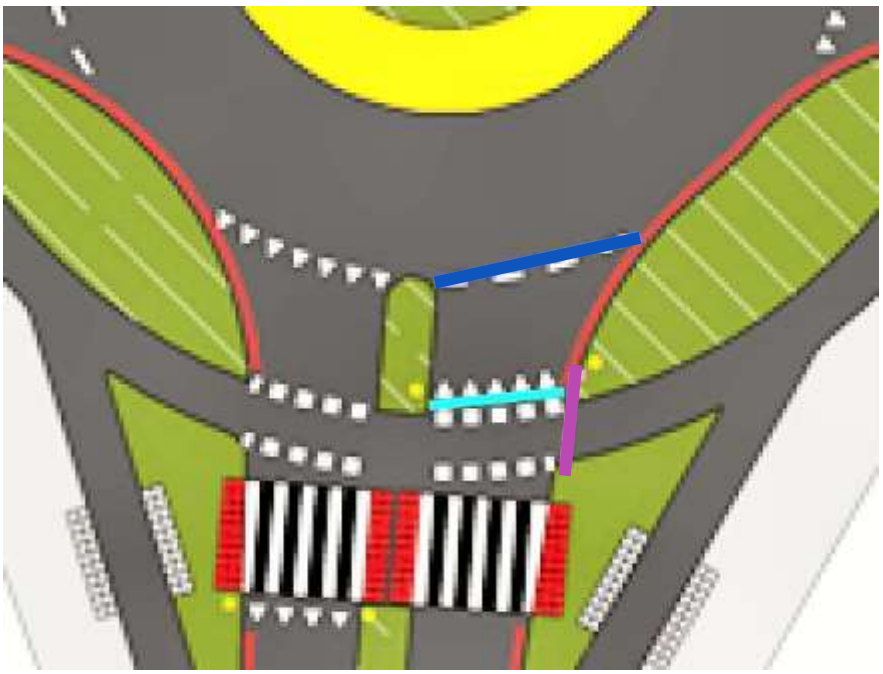

Figure 20: Timing points used to assess priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle lane

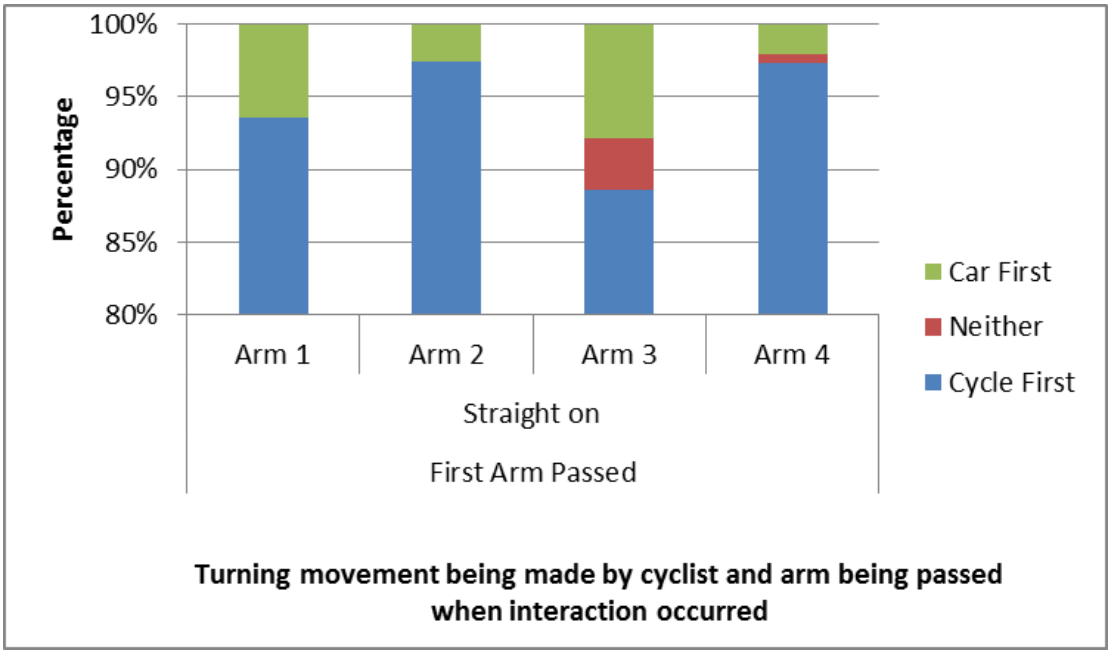

Figure 21: Priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle way (Arm indicated is the arm being crossed)

In nearly all such interactions, the cyclist went first, and the car gave way. So most drivers gave cyclists priority whilst the cyclists crossed the exit on the orbital cycle lane, as required by the design. However, on Arm 3, 12% did not, and 8% of drivers went in front of the cyclists. This behaviour was particularly notable for cyclists crossing Arm 3 in the latter part of the trial, with 21% behaving in this way between 16:00 and 17:00. Such driver decisions are of concern given that whilst cyclists in the trial were briefed to stop if the driver did not give way, they may assume they will receive priority in real life situations.

The third type of interaction was defined to have occurred when the cyclist and car driver approached the exit of an arm within two seconds of each other. More specifically, the cycle crossed the purple line in Figure 7 within two seconds of the car crossing the dark blue line. The car was judged to have exited first if it crossed the light blue line before the cycle passed the purple line. The yellow line was also used to time vehicles exiting the roundabout. The percentage of cars, and cycles found to have started to exit, and exited, first when an interaction occurred is summarised in **Figure 23**.

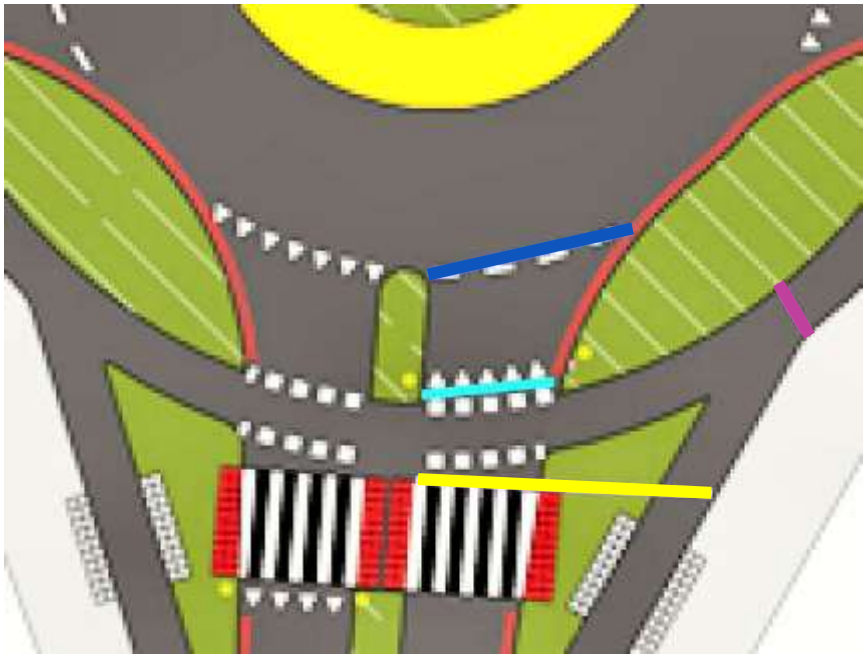

Figure 22: Timing points used to assess priorities when a car driver and cyclist exit the roundabout at the same time

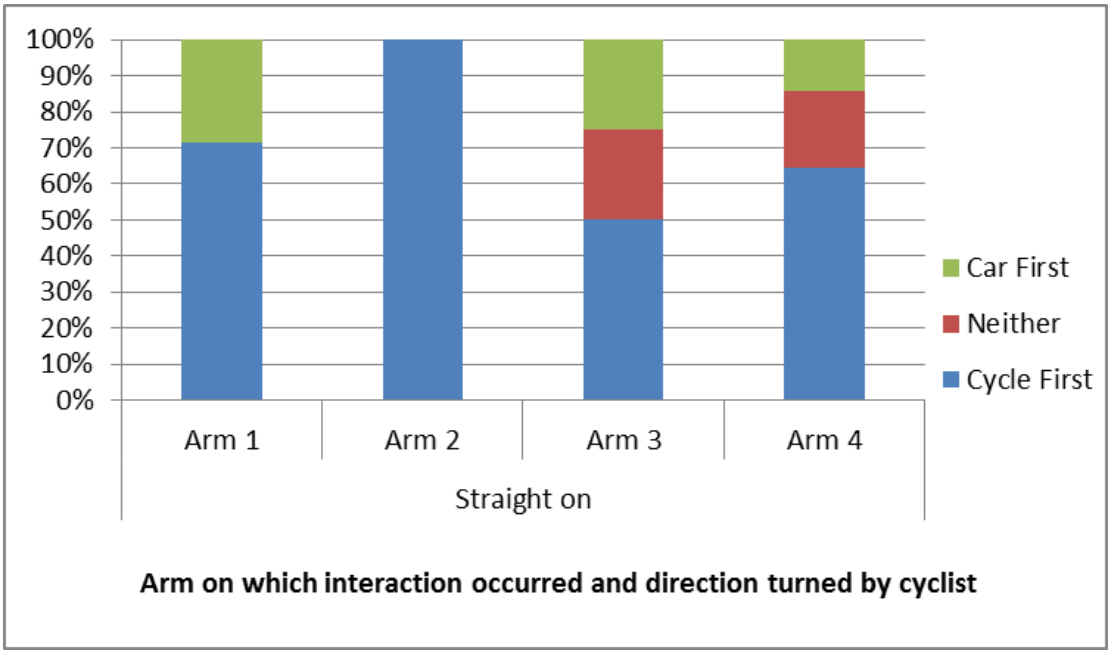

Figure 23: Priorities when a car driver and cyclist exit the roundabout at the same time

The numbers of exit interactions achieved was very low in comparison with the other interactions. Thus, the results of this section should be treated with caution. In the majority of these interactions, the cyclist went first, particularly on Arm 2 where there was no separate cycle lane on the exit of the roundabout.

3.3.1 Effects on car driver journey time

Car drivers started on one of four arms and turned left, right or continued straight on at the roundabout. The average time for car drivers to enter the roundabout, and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2, where Point 1 was fixed for the trials on the roundabout's arm. The time to exit from over Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 12.

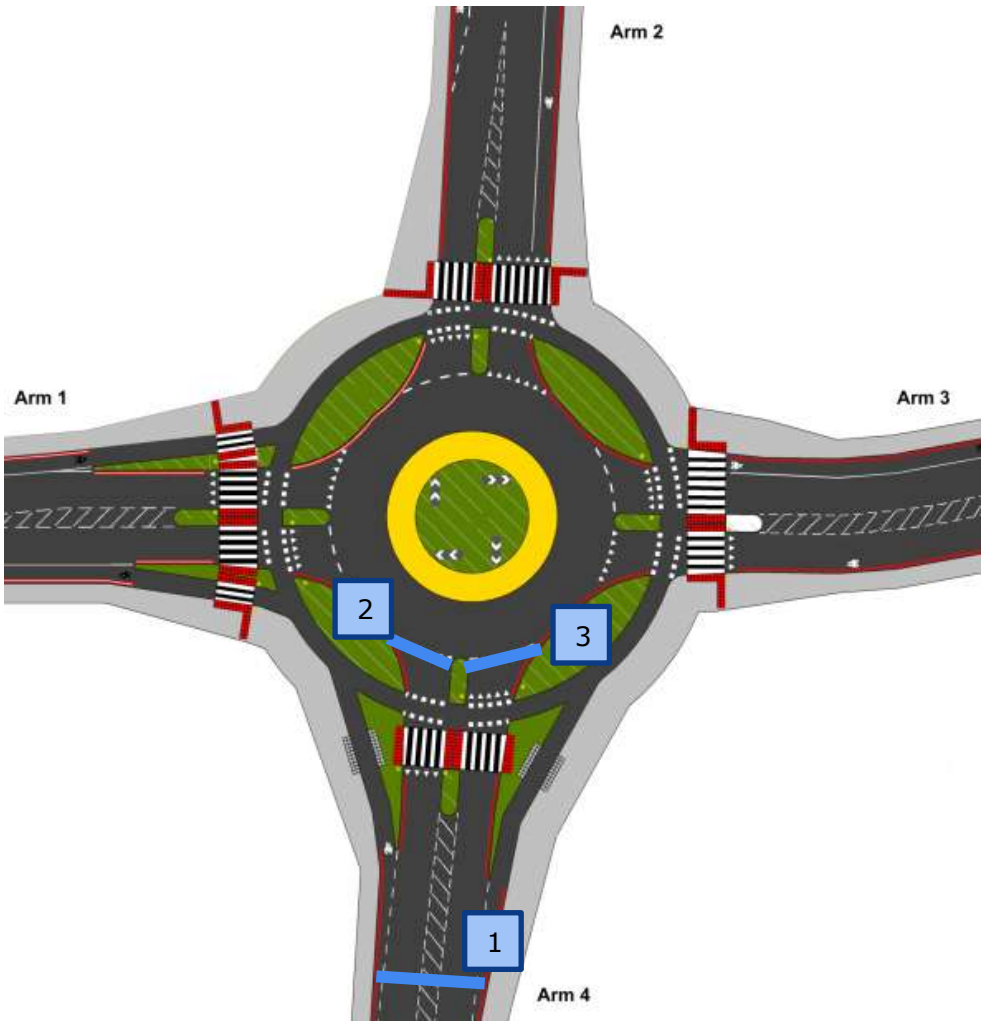

Figure 24: Journey timing points for car drivers

The average times for car drivers to enter and exit the roundabout are summarised in Figure 13. This shows the times for car entering (from timing point 1 to point 2 in Figure 12, shown in blue in Figure 13) and exiting (from timing point 3 to point 1 in Figure 12, shown in red in Figure 13) for three types of interation:

1. No interaction with cyclists (None)
2. A cycle travels alongside the vehicle when entering/exiting (Cycle – At same time)
3. A cycle on the orbital cycle lane crosses in front of the vehicle forcing the car to stop (Cycle – At crossing arm). This was only measured for exiting cars.

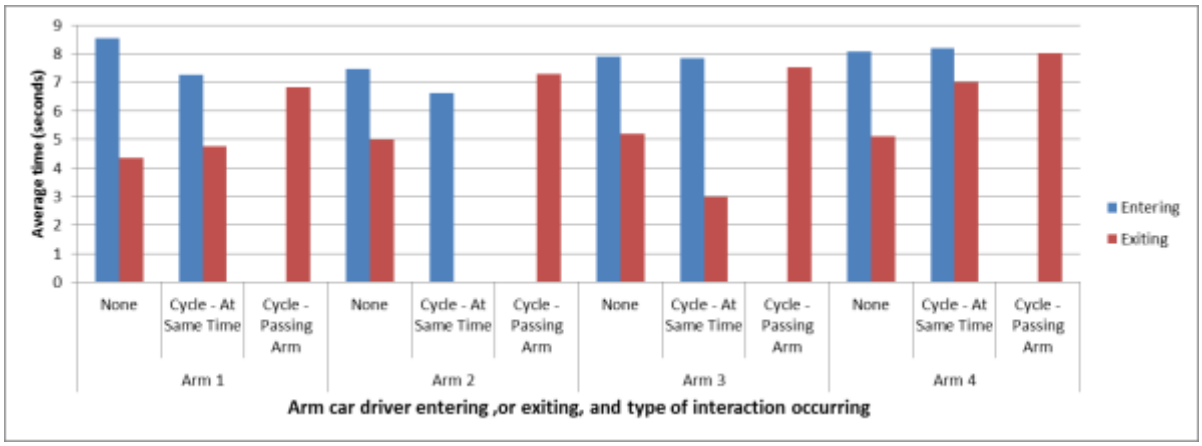

Figure 25: Car journey time components

The interaction with a cyclist had no observable adverse effect on journey time when entering the roundabout. The times when the car drivers and cyclists exited together have to be treated with caution owing to small sample sizes, and in fact for Arm 2 no interactions were observed, hence why there is no data for this interaction. However, there were average delays of between 2.3 to 2.9 seconds owing to the car driver exiting and giving way to a cyclist passing over the exit on all the roundabout' arms.

Figure 14 shows the overall journey times for cars using the roundabout, measured from timing point 1 to the equivalent timing point on the exit arm, both with and without an interaction on the exit arm. This shows that when turning left, overall car journey times (averaged across all arms) were approximately 0.8 seconds longer if there was one interaction on the journey with a cycle when exiting. However, there was no consistent effect for other turning movements, possibly owing to a higher variability in journey times.

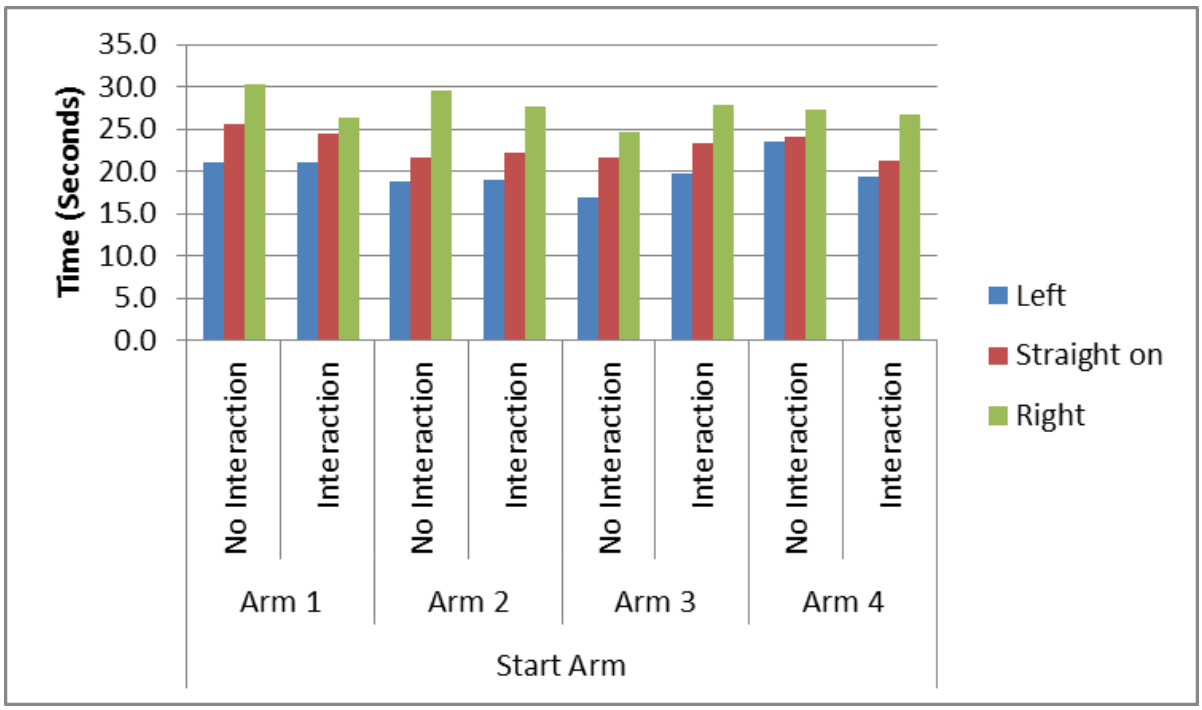

Figure 26: Car driver overall journey time with exit interaction

The greatest average delay was 3.3 seconds for cars turning right from Arm 3 to Arm 2, where they were not separated from the cyclists whilst entering and exiting the roundabout. There were also some movements which were quicker if an interaction took place. The manoeuvres which were comparatively quicker were from Arm 4 turning left to Arm 1 (4.3 seconds) and from Arm 1 turning right to Arm 4 (3.9 seconds): although these must be treated with caution owing to small sample sizes.

3.3.2 Effects on cyclist journey time

In this trial, the cyclists were trained users of the roundabout whose principal purpose was to engineer interactions with the car drivers. As such, it was not appropriate for them to take part in the questionnaire or focus groups activities. However it was felt that it would be appropriate to measure the effect of interaction on their journey times as this was not significantly influenced by the fact that they understood the roundabout operation.

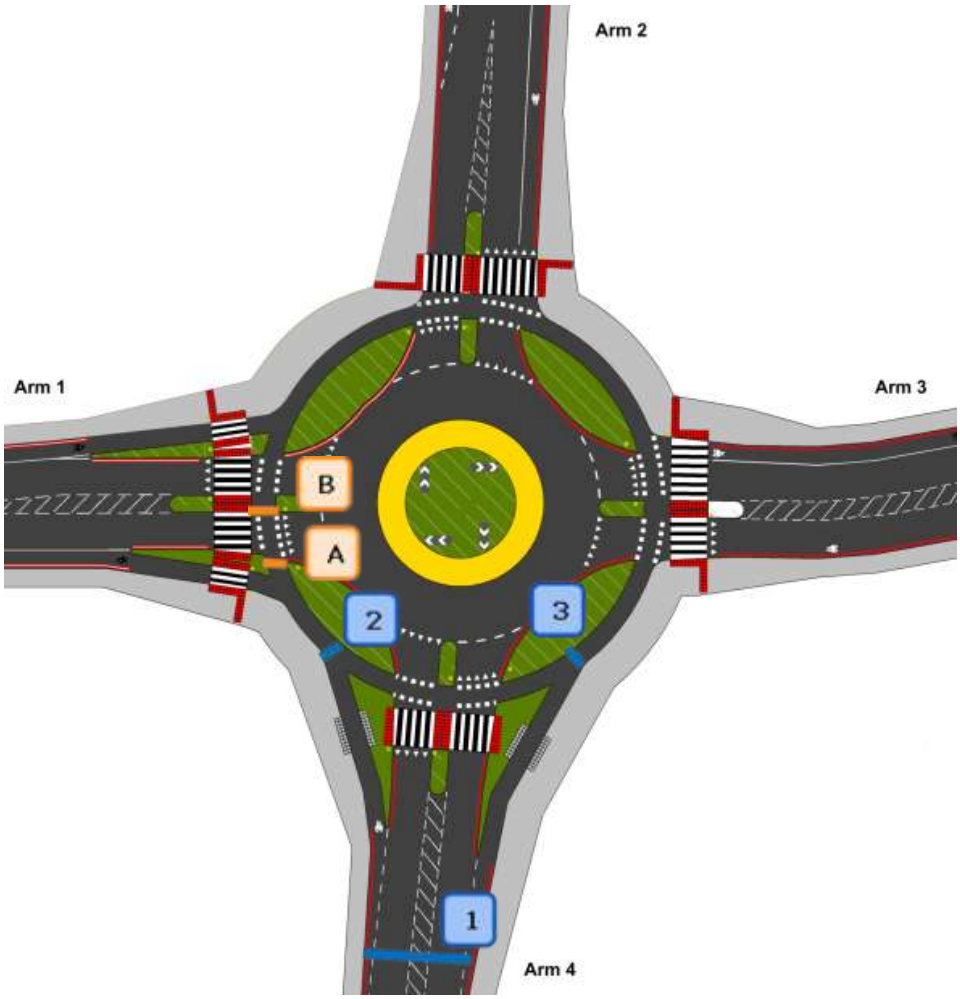

Figure 27: Journey timing points for cyclists

Cyclists started on one of four arms and went straight on at the roundabout. They could be instructed to meet a car under one of three situations:

1. a car was entering the roundabout at the same time they entered;
2. a car was exiting an arm whilst they cycled past in the orbital cycle lane; or

3. a car was exiting the roundabout at the same time as the cyclist exited.

The cyclists were under TRL instruction and for safety reasons were told to give way to car drivers if they were not certain that a car driver would give way to them.

If the car was in the vicinity, that is they crossed defined timing points (see Figure 27) on the approach to the "interaction area" within two seconds of each other, an interaction was said to have occurred. The average time for cyclists to enter the roundabout, cross the traffic lane while circulating the roundabout, and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2, where Point 1 was fixed for the trials on the roundabout's arm. The time to cross the exit car lane at Arm 1 was taken between Points A and B – the time at Point A was taken when the cyclist arrived at Point A, so included the stopping time. The time to exit from Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 27.The average times for cyclists to enter, exit and circulate the roundabout are summarised in Figure 28.

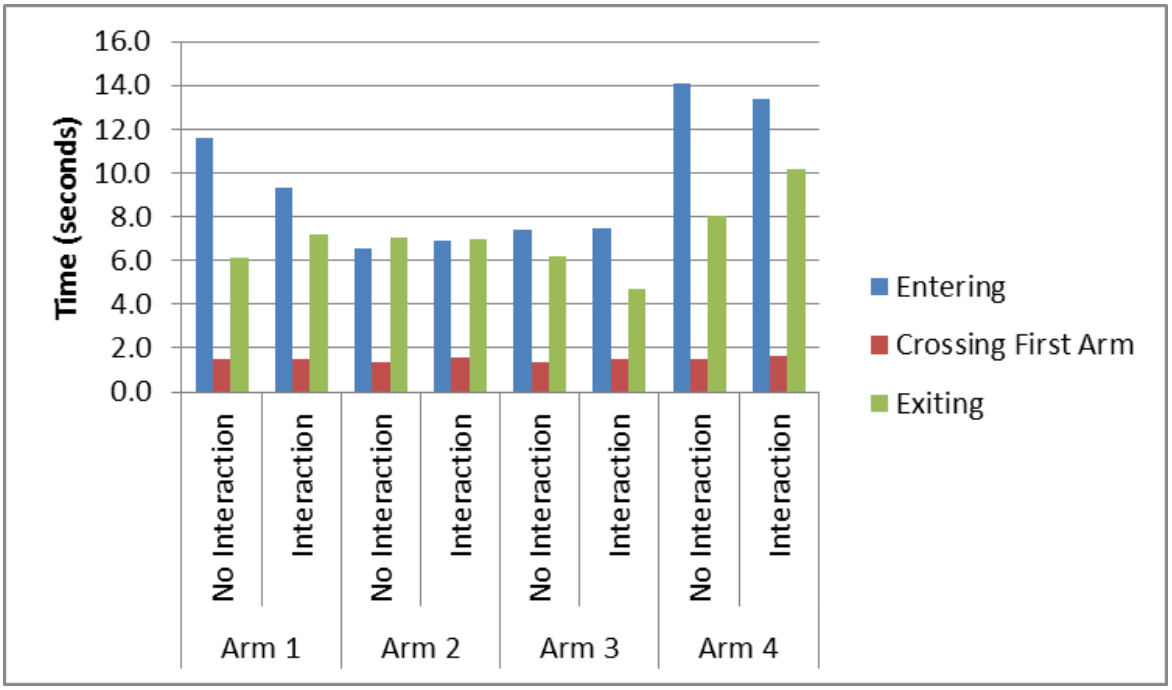

Figure 28: Cyclist journey time components

Cycle journey times on exiting with an interaction must be treated with caution owing to small sample sizes. Cycle times when crossing an arm were consistent, which is in agreement with cyclists generally having right of way in the orbital cycle way. Cyclists took longer to enter Arms 1 and 4, where a separate cycle lane lead them into the orbital cycle way

The cyclists' overall journey times are summarised in Figure 29, and cyclists were generally between 1.6 and 2.1 seconds faster if they experienced one (or more) interactions with a car.

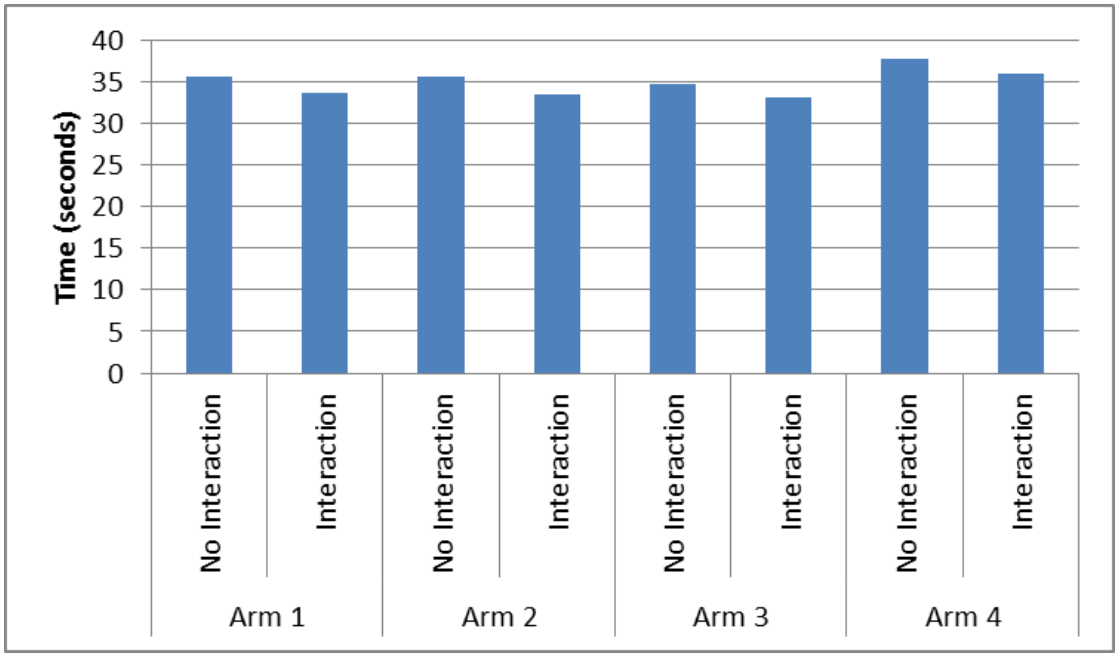

Figure 29: Cyclist overall journey time

3.4 Car driver on-track responses

During the trials drivers were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'On a scale of 1 to 10 where 10 is Very Easy, how easy it was to negotiate the roundabout?' i.e. 'How easy it was to cycle from one arm to another?'
- ''On a scale of 1 to 10 where 10 is Very Safe, how safe did you feel?'

Figure 30 gives the responses to these questions showing a count of all responses from all drivers.

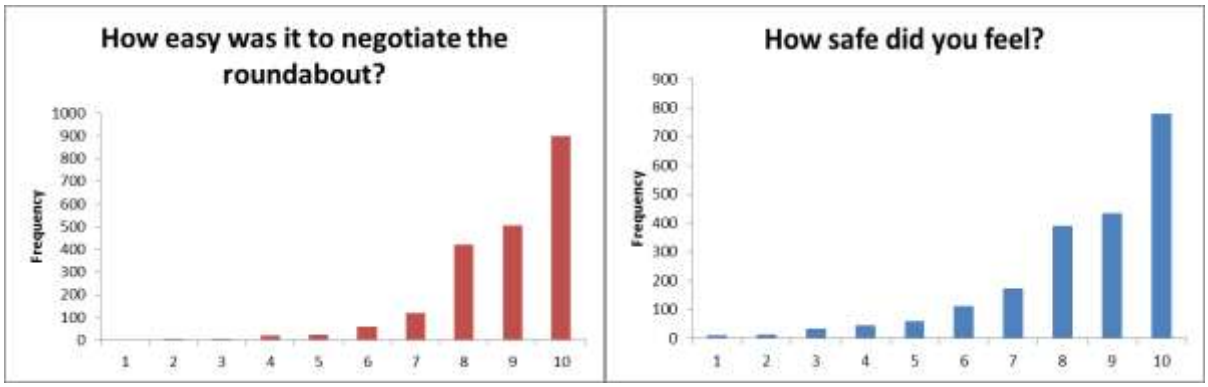

Figure 30: Driver's scores of safety and ease of using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (97%) and safe (92%). This is not overly surprising as drivers were not placed in any difficult situations. However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 83% of the safety scores were within ±1 of the ease of negotiating scores.

For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same. The average scores for making individual turning movements is summarised across all arms in **Figure 31** which makes it clear that there is virtually no difference between the various turning movements.

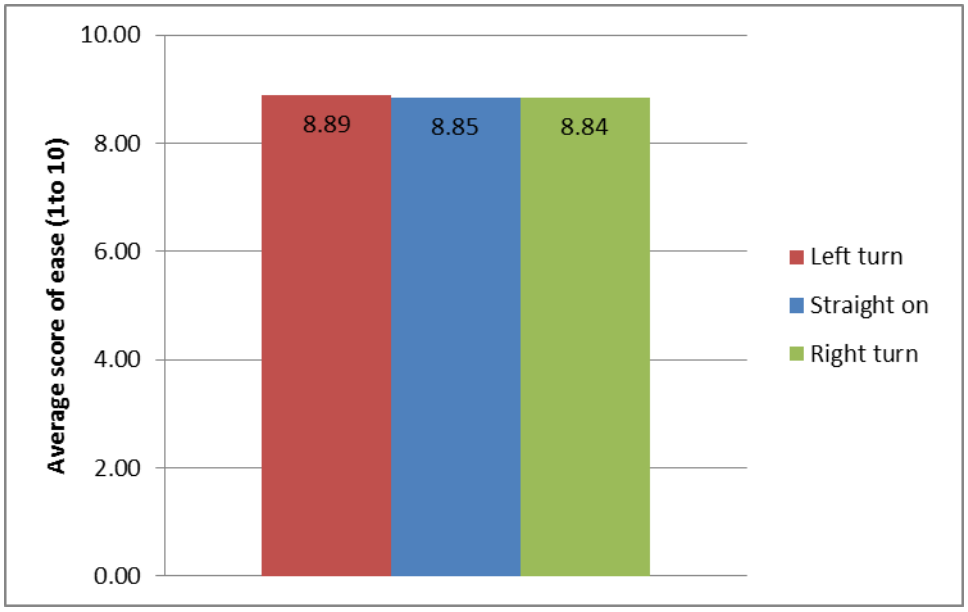

Figure 31: Drivers' ease of negotiating the roundabout by turning movement

This implies that (on average) car drivers found it as easy to turn in any direction at the roundabout: that is, the scores are very similar (within 0.05) and all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in **Figure 32**.

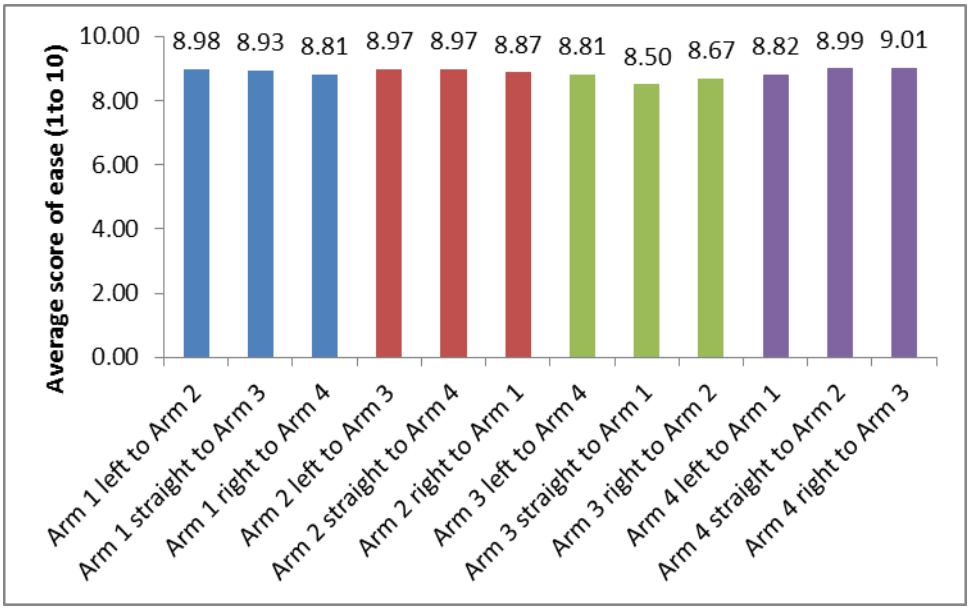

Figure 32: Drivers' scores of ease of negotiating the roundabout by arm and movement

The above chart shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that there was little difference between Arms 1, 2 and 4 with the average ease of use score only varying by 0.2. The scores for Arm 3 were marginally lower than those on the other arms. Overall, there is an indication that turning out of Arm 3 was judged as slightly harder than the other arms.

B.4 M21 Cyclists Findings Report, UK Markings

Findings report: Dutch Roundabout Individual Reaction (M21) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. On Arms 1, 3 and 4 the Zebra crossing are directly alongside the cycle path where it crosses the car lane, whereas on Arm 2 there is a 5m gap between the Zebra crossing and the cycle lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority
- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

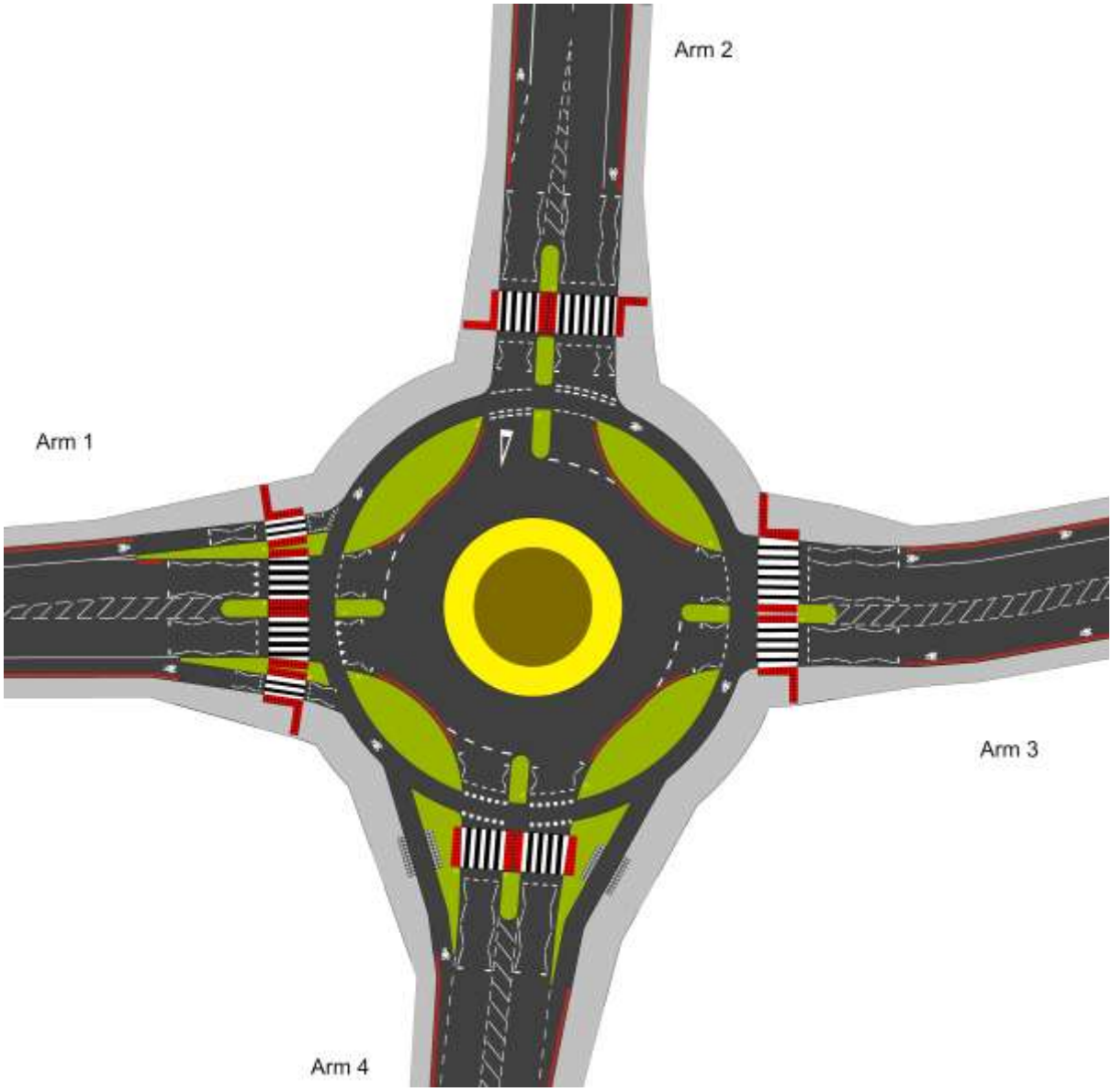

Figure 33: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes.

1.2 Introduction to the M21 trials

The M21 trials were identical to the M6a trials held earlier, but using the UK markings on the roundabout. They were held between the 11th and 17th April 2013. The primary objectives of the M21 trials were to establish the reactions of cyclists when encountering cars at the entrance to and exit from the roundabout, and to see if the understanding of the roundabout was improved by the use of UK markings. Cyclists were asked the same questions as those posed in the M6a trials.

2 Methodology

The participant cyclists were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant started on one of the arms of the roundabout and was asked to ride up to the roundabout, and either turn left, go straight on, or turn right using the orbital cycleway. No participants had seen the roundabout before the trials started. A total of 8 cyclists were on track at any one time with cyclists setting off in pairs from each arm.

At the same time, 8 cars (two on each arm) driven by trained drivers also negotiated the roundabout and engineered a "conflict[4]" with the cyclist either at the entrance to or exit from the roundabout. All 8 cars were on track at once with cars setting off in pairs.

At the end of each movement, each participant cyclist was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed questions (e.g. did you understand marking "x"?) and open questions (e.g. do you have any suggestions for making "y" clearer?).

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings are used in this report to isolate the give way behaviour of the participants and the resulting effect on journey times. They can be used to compare the effect of interactions compared to the individual trials in M5 and the equivalent trials with Dutch markings in M6a, and also as a baseline against which the effect of interactions in future trials can be measured, including the effect of changing to UK markings.

[4] A traffic *conflict* 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." (Amundsen & Hyden, 1977)

3 Summary of Findings

88 cyclists took part in the trials in 6 sessions spread over 3 days. The trials group included both male (66%) and females (34%) and included a wide range of ages from 18 to over 75.

3.1 Questionnaire Analysis Findings

3.1.1 Understanding of how to navigate the roundabout

The extent to which participants understood how to navigate the roundabout can be inferred from responses to questions on noticing the cycle lane, understanding of the markings, giving way, and whether the cyclists considered using the cycle lane in an anti-clockwise direction.

Most of the cyclists noticed the 'new' road markings (the white squares between the zebra crossing and the roundabout); two-fifths gave a correct explanation of their meaning and most of the rest were 'safe' explanations indicating 'caution' or 'give way'.

When going round the roundabout on the cycle lane, over half of cyclists said they expected a driver approaching the roundabout to give way to them; a higher proportion expected a driver approaching the zebra crossing to give way than expected a driver already on the zebra crossing to give way. When a car was approaching the exit to the roundabout, just over 60% of cyclists said they would expect the car to wait for them while almost 20% said they would wait for the car. Cyclists who said they would wait for the car did so for safety reasons or because they thought the car would have right of way.

Cyclists' expectations about giving way when they were leaving the roundabout varied with the layout of the cycle lane at the exit point but the most common response (45% – 55% depending on arm) was that cyclists expected the car to wait for them. Turning out of the cycle lane into the road, just over a quarter of cyclists said they would wait for the car, but turning into a cycle lane, just under 20% said they would wait for the car.

Less than a fifth of cyclists said they would consider using the orbital lane as a two way cycle lane: 14% in heavy traffic and 17% in light traffic, and another 20% would do so in certain conditions. Cyclists were reluctant to ride "the wrong way" and were concerned about collisions with other cyclists and motorists. There was also concern about confusion, some concern about the cycle lane being too narrow for two way traffic, or the design being for cycling clockwise.

Thus cyclists' general understanding of how to navigate the roundabout was good, but not all were confident that drivers would give way when cyclists had priority crossing the roads entering and leaving the roundabout.

3.1.2 Influence of different aspects of layout

Cyclists found that joining the cycle lane round the roundabout was more difficult at Arm 3 than at the other arms. This was because as they approached at Arm 3, cyclists were sharing the road with vehicles and were required to make sharp left turn close to the zebra crossing to enter the cycle lane. The geometry and signage were such that it was not obvious that this was the intended route for cyclists This approach was also seen by

cyclists to be the least safe, for similar reasons. These findings are consistent with previous trials.

Some cyclists described difficulties entering at other points. At Arm 2 the lack of cycle lane markings after the pedestrian crossing, the narrow entry and need to make a tight turn to join the roundabout were mentioned. The sharp turn to join the roundabout was also mentioned at Arm 1.

For cyclists leaving the roundabout, Arm 2 was felt to be the most difficult – this involved making a sharp turn onto the road without a separate cycle lane. Some cyclists explained that they had to slow down or pull out into the middle of the road; some were uncertain about priority here and cyclists were more likely to say that they would give way to traffic there than at Arm 3 where they turn into a cycle lane from behind the 'shelter' of a kerb.

Cyclists found entering the cycle lane easiest where there was a long segregated lane at Arm 1 and easiest to join the cycle lane round the roundabout at Arm 4 where there was a gentle fork in the cycle lane.

Cyclists' views on safety of the different layouts reflected their views on ease of use.

3.1.3 Perceived benefits and influence on cycling in London

The majority of cyclists were in favour of taking advantage of the cycle lane round the roundabout. In heavy traffic, over 90% said they would use it in preference to the road, and around 80 – 90% said they would use it in light traffic (90% for turning left, around 80% for going straight on or turning right). Most cyclists said it was easier to use than an ordinary roundabout. They tended to say this was because they found it safer and appreciated being separated from traffic; some saw advantages in not having to change lanes to turn right. There were indications that some cyclists, particularly those who are less confident or cycle less frequently, would be encouraged to cycle at roundabouts, and that it would give such cyclists more confidence.

Almost all of the cyclists thought cyclists would benefit from the cycle lane round the roundabout and many thought that motorists and pedestrians would benefit. A few cyclists did not agree that any user groups would benefit from it. The small number of negative comments were about design issues affecting cyclists, inconvenience to pedestrians and risks, confusion or drivers having to give way to cyclists.

Turning left using the cycle lane in traffic was seen as 'safe' or 'very safe' by almost all of the cyclists. Safety ratings were lower for turning right and going straight on; turning right in heavy traffic was rated as least safe, with 6% saying it would be 'unsafe' and 1% saying it would be 'very unsafe'.

Just over a third of cyclists thought it would affect how often they cycle in London if there were cycle lanes like this on roundabouts there. The reasons given were about safety and increased confidence. However most of them do not currently cycle in London and many do not currently cycle at all, so the results can only be used to indicate some potential for increasing cycling in London. Some said that other factors would also affect their decision to cycle in London. Many participants said that they have no need to cycle in London, or they have negative views about it. Others said they already cycle in London as often as they need to.

3.1.4 Differences between UK and 'Dutch' markings

The main difference between this trial and the one with 'Dutch' markings was the use of UK markings to indicate points where vehicles should give way to cyclists and pedestrians crossing the road as described in the introduction, although the markings delimiting the cycle crossings were similar in the two trials.

Cyclists' expectations about priorities at the crossing points differed, with more cyclists expecting the car to wait for them in the trial with UK markings (60% and 65% for cars leaving and entering the roundabout respectively) than with Dutch markings (41% and 46% for cars leaving and entering the roundabout respectively).

A (relatively small) proportion of cyclists said they did not understand the markings delimiting the cycle crossings, and some who mentioned confusion.

In other key respects the responses of cyclists were similar in the two trials: as indicated by:

- Willingness to use the cycle lane as intended
- Willingness to use the cycle lane in traffic
- Willingness to cycle in London
- Views on how easy it was to use the roundabout
- Views on overall safety of the roundabout.

Thus from the cyclists' point of view, the UK markings appear to have been associated with some improvement in participants' understanding of priority at the cycle crossings. There may be scope for improving the UK markings, particularly with respect to improving understanding of priorities and cycle-lane delimiters.

3.2 Focus Group Findings

23 Cyclists of varying ability and confidence levels took part in 3 separate focus groups, one on each day of the trials.

3.2.1 Overview

Most participants were impressed with the road layout in the trial, most found it easy to use and thought the road markings were self-explanatory. However a number remarked there were excessive road markings and in some areas it would be beneficial to replace these with signage. Participants felt the segregation between cyclist and vehicle would significantly add to the safety of road systems and this was particularly noted to apply to the London road network.

"Found the layout to be self-explanatory"

"…if it was your first time to use it, you may worry and think what do I do".

"Road markings helped to know the cars had to give way to you so you knew you had a free run of the roundabout"

"There was too much going on, if you have double decker buses and HGVs, there is a lot to take in within a compact area".

Although participants were impressed by the concept, a number suggested the layout would require some adapting prior to introduction. There were concerns that drivers may

not give way to cyclists and if they did this could lead to long tailbacks either across the roundabout or blocking the pedestrian crossing. It was recommended an improvement could be to locate the crossings further from the roundabout. It was felt that this would ease congestion and improve safety as motorists would have more time to see the pedestrian crossing. There were further comments suggesting that the layout simply would not work without the addition of traffic lights. This was due to the concern that drivers would not give way to cyclists and the knock on effects of delays if they did give way.

"Tight turns with junctions for bikes is undesirable. Braking isn't easy"

"…too narrow, with hard kerbs – there could be glass, potholes – nowhere to pull out and avoid and wouldn't be able to overtake"

A further criticism of the layout was its visibility to road users. It was recommended that the cycle lane could be highlighted to both pedestrians and drivers by covering the cycle lane with coloured tarmac. It was suggested this would prevent pedestrians walking in the cycle lane and also alert drivers to its presence. There was also concern that this layout would be less safe for pedestrians as there were a number of crossings where the pedestrian would need to cross the cycle lane.

"…could be confusing for drivers, you could miss it and drive across the crossing without realising";

"…didn't think at times that it was obvious that it was a cycle path and pedestrians might wander into it if joining the roundabout from a midpoint"

As part of the cycle trial the exits from the cycle lane varied and participants were asked their opinions on the different layouts. Participants all agreed they liked the segregation between cyclists and vehicles and all felt considerably safer than on traditional roundabouts. A number of participants criticised the exits as being very narrow, with some feeling like the cyclist had to leave the cycle lane at a right angle straight into the flow of traffic. It was felt this would mean that cyclists have to slow down to a near stop and that long wheel based bikes (tandems and tricycles) would struggle to get around the tight angles of the cycle lane as well as through the entry and exit points.

"If a cyclist was travelling quite fast, when they turned off the cycle lane into the road because the turn was so tight they could end up in the flow of the traffic"

"Tight turns with junctions for bikes is undesirable. Braking isn't easy"

It was also noted that the cycle lane was too narrow which would prevent cyclists from overtaking each other and this may lead to faster more confident cyclists opting to use the road rather than the cycle path. The height of the kerbs were also criticised as a safety issue as it was felt during wet or dark conditions cyclists may hit these, in addition they prevent the cyclist from being able to swerve around broken glass or potholes.

"…too narrow, with hard kerbs – there could be glass, potholes – nowhere to pull out and avoid and wouldn't be able to overtake"

Whilst all the participants initially used the orbital cycle lane, confident cyclists decided at quiet junctions they were likely to use the main carriageway to travel straight on as it was quicker. In addition, it was noted there was no signage to show cyclists that they should travel clockwise around the roundabout. Therefore a number of participants opted to travel anti-clockwise when turning right as it was quicker. It was noted this could pose an added danger as drivers may not expect cyclists to be traversing the roundabout in

both directions; in addition, it was again commented that the cycle path was too narrow to allow cyclists to pass other cyclists.

"…travelled anti-clockwise around the roundabout, it was the quicker and smarter route. It doesn't make sense to go all the way around the roundabout to turn right"

"…wouldn't attempt to go anti-clockwise as it is against the flow"

A number of participants commended the design of the roundabout as considering the cyclist rather than vehicles. In addition, it was noted that usually cycle lanes come to an end at more complex road junctions. It was agreed that this sort of roundabout would be a good addition to cycling safety on the roads. A number of participants shared concerns for safety including visibility of the cyclists particularly children cycling around the roundabout.

"*I've seen cycle lanes along straight roads which disappear when you get to the junction…even if the lane doesn't continue on the road then it's much more sensible to have it here*"

"*This concept considers the cyclist before the driver for the first time*".

It was felt that, if implemented correctly, this concept would save lives and encourage less confident cyclists. It was suggested that in London this would add to the safety of cyclists at the expense of motorists. It was felt the layout would be most beneficial to mid-sized roundabouts.

"*I felt so much safer than on a normal roundabout…I've nearly been run over so many times by careless drivers not using the right lanes and changing lanes and cars too close to the kerb…felt 100 times safer*"

"*It causes a separation between cars and more vulnerable users like bikes and pedestrians*"

3.3 Video Analysis Findings

Twelve video cameras captured the movements of cyclists and car drivers during the trial. In particular times of cyclists and car drivers entering, circulating around and exiting from, the roundabout were collected from the resulting recordings. These can be compared to assess which of the cyclists, or car drivers, went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if the cyclist and car driver came into close proximity within two seconds of each other. For example, whether they entered the roundabout within two seconds of each other from the same roundabout arm, or if the cyclists started to cross an exit arm within two seconds of a car driver arriving at the exit. If the car driver and cyclist entered the interaction zone within one second of each other, then no priority was assigned. Otherwise the vehicle entering first is assumed to have taken priority.

3.3.1 Priority when negotiating the roundabout

The priorities taken by cyclists and car drivers have been investigated under three situations:

1. Entering the roundabout together

2. Cycle crossing an exit whilst a car driver is exiting the roundabout by that arm
3. Exiting the roundabout together.

The results for them entering the roundabout together are summarised in Figure 2.

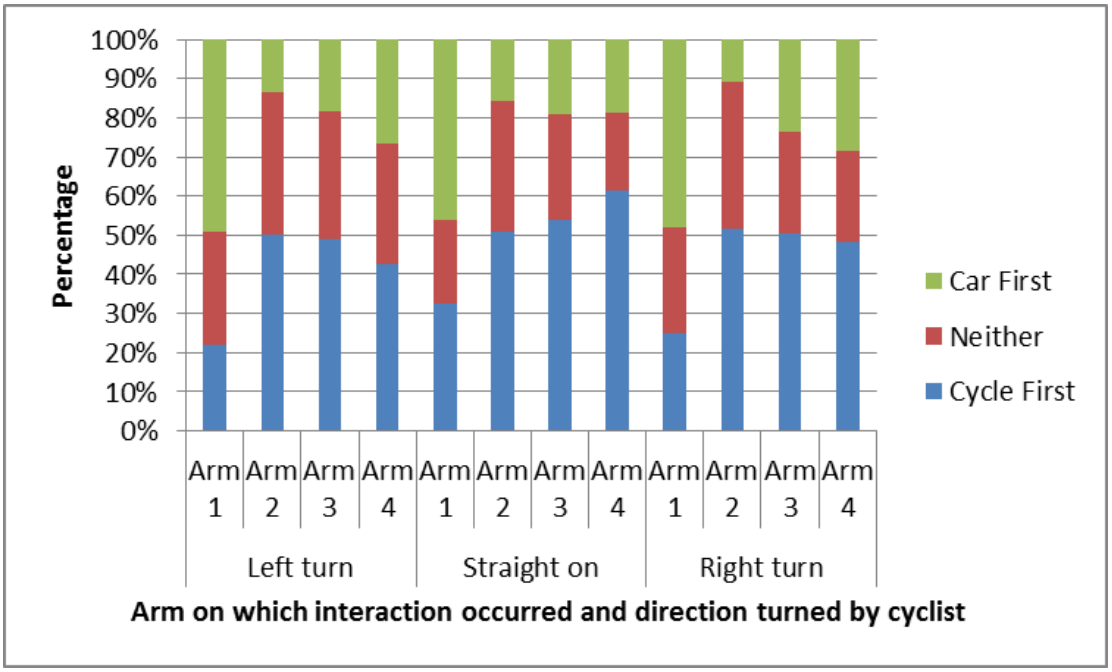

Figure 34: Priorities when a car driver and cyclist enter the roundabout at the same time

Car drivers aimed to enter the roundabout at the same time as the cyclist to create an interaction, or waited for them to enter first. The guidance given to the driver was that they should try to be parallel to the cyclists at the point where the cyclist reached the pedestrian crossing. An interaction was considered to have occurred if the cyclist and car driver crossed the far side of the pedestrian crossing within two seconds of each other.

When an interaction occurred, the cyclist entered the roundabout first on 22 to 61% of occasions: On average across all arms the cyclist went first in 45% of cases. Whilst the car driver entered first less often: between 11 to 49% of occasions, on average 27% of the time.

This is in line with expectation as the cyclists were instructed to use the separate orbital cycle lane, and therefore their paths did not intersect with those of the car drivers, and therefore the car and cycle times to enter the roundabout were most likely to be independent on Arm 1.

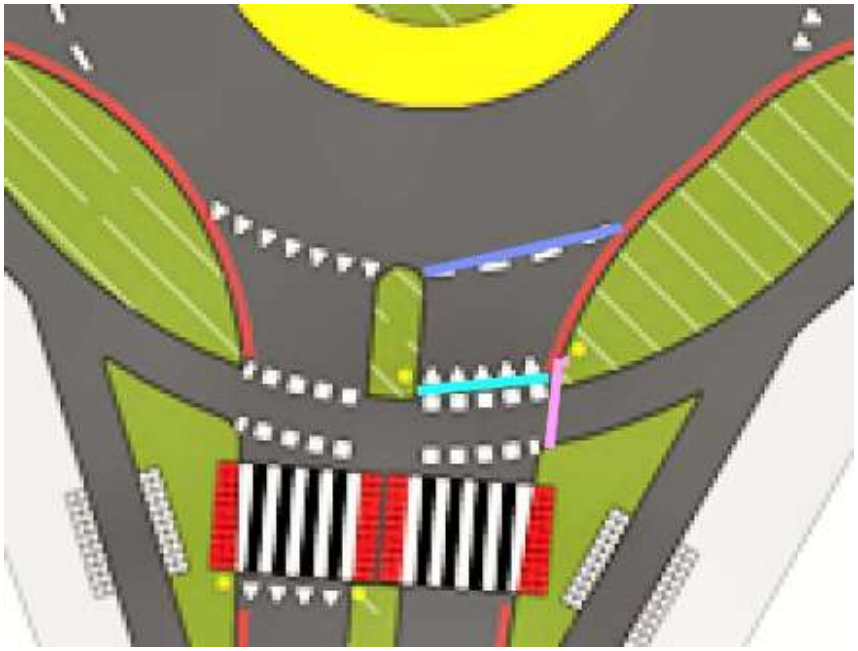

Figure 35: Timing points used to assess priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle lane

The second type of interaction was defined to have occurred when the cyclist crossed an exit arm of a roundabout and a car exited the roundabout from that arm. More specifically, an interaction occurred if the cycle crossed the purple line in Figure 5 within two seconds of the car crossing the dark blue line. The car was judged to have gone first if it crossed the light blue line before the cycle passed the purple line. The percentage of cars, and cycles found to have gone first when an interaction occurred is summarised in Figure 6.

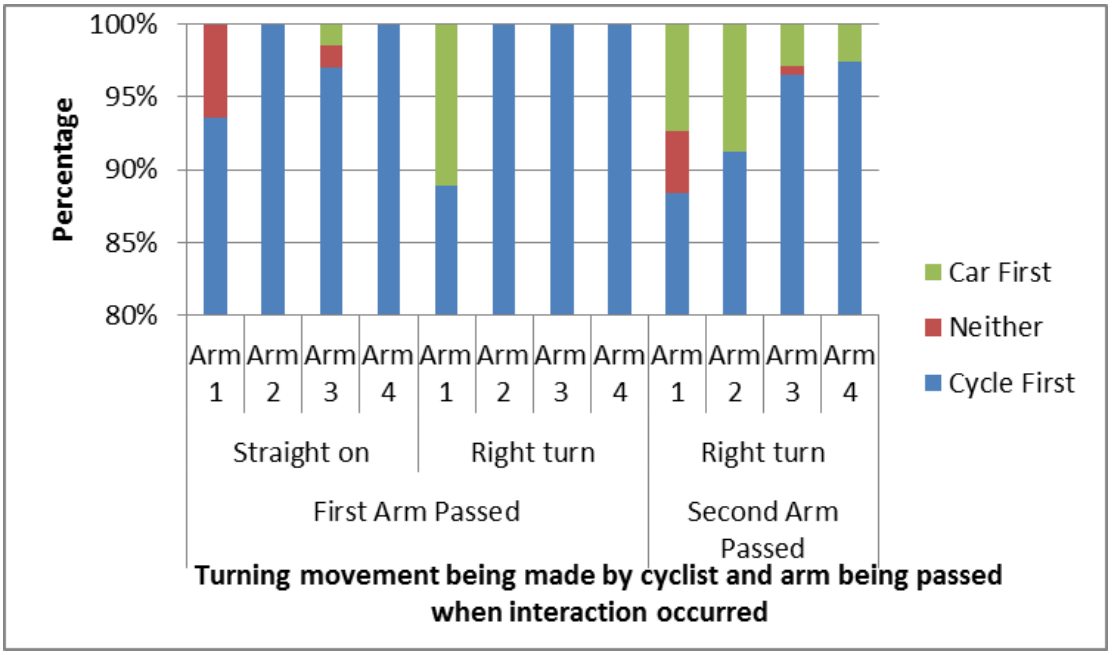

Figure 36: Priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle way

In nearly all such interactions (over 85%), the cyclist went first, and the car gave way. This is expected as the car drivers were instructed to show caution and (if unsure) give way to the cyclists.

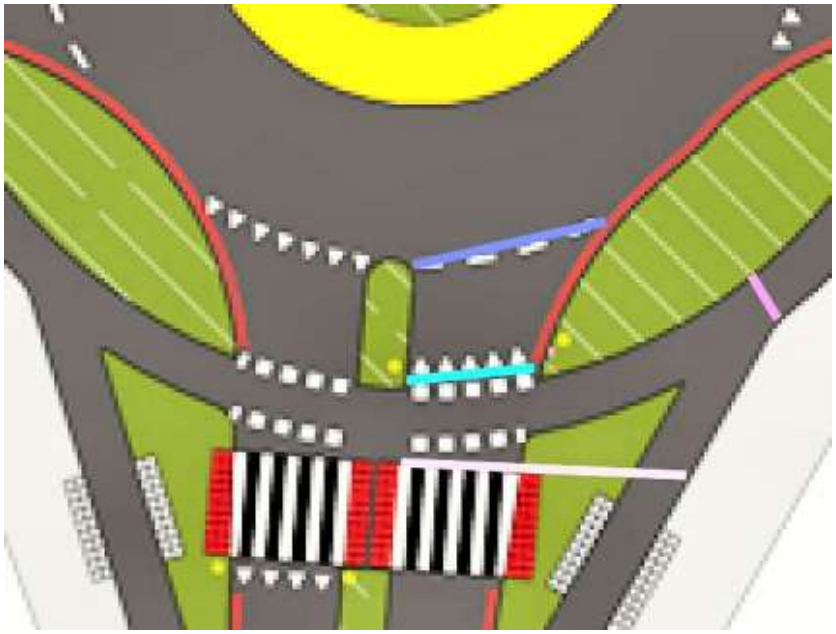

Figure 37: Timing points used to assess priorities when a car driver and cyclist exit the roundabout at the same time

The third type of interaction was defined to have occurred when the cyclist and car driver approached the exit of an arm within two seconds of each other. More specifically, the cycle crossed the purple line in Figure 7 within two seconds of the car crossing the dark blue line. The car was judged to have exited first if it crossed the light blue line before the cycle passed the purple line. The light purple line was also used to time vehicles exiting the roundabout. The percentage of cars, and cycles found to have started to exit, and exited, first when an interaction occurred is summarised in Figure 8.

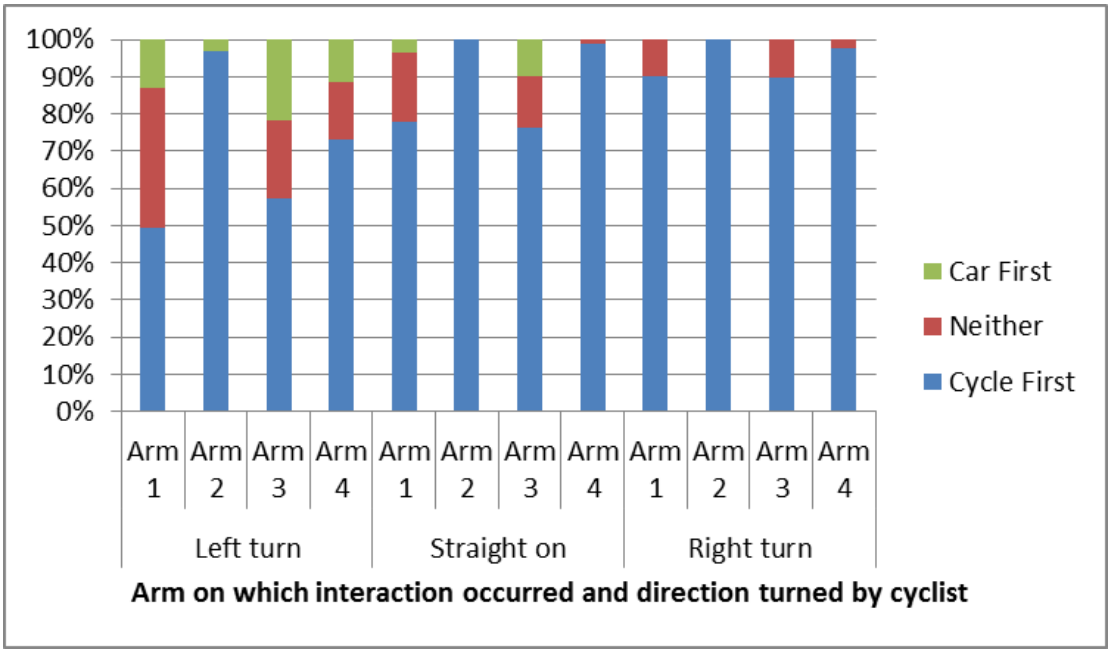

Figure 38: Priorities when a car driver and cyclist exit the roundabout at the same time

Overall, cyclists still generally (in over 49% of the observed interactions) exited the roundabout before the car drivers. The percentage of car drivers leaving the roundabout first varied with the geometry of the arms.

Car drivers were more likely to exit Arms 1 and 3 earlier than the cyclist. Arm 1is where the cyclist exits via a separate cycle lane, before reaching the main roundabout's exit. Arm 3 also has a separate cycle lane when outbound from the roundabout.

Car drivers occasionally exited Arm 4 before the cyclists, where cyclists exited into a separate cycle lane adjacent to the main carriageway before merging. However, cyclists exited Arm 2 first on all but three occasions, where the car and cyclist had to initially merge at the exit.

3.3.2 Effects on cyclist journey time

Cyclists started on one of four arms and either turned left, right, or continued straight on at the roundabout. They could meet a car under one of three situations:

1. a car was entering the roundabout at the same time they entered;
2. a car was exiting an arm whilst they cycled past in the orbital cycle lane; or
3. a car was exiting the roundabout at the same time as the cyclist exited.

If the car was in the vicinity, that is, they crossed defined timing points (see below) on the approach to the "interaction area" within two seconds of each other, an interaction was said to have occurred.

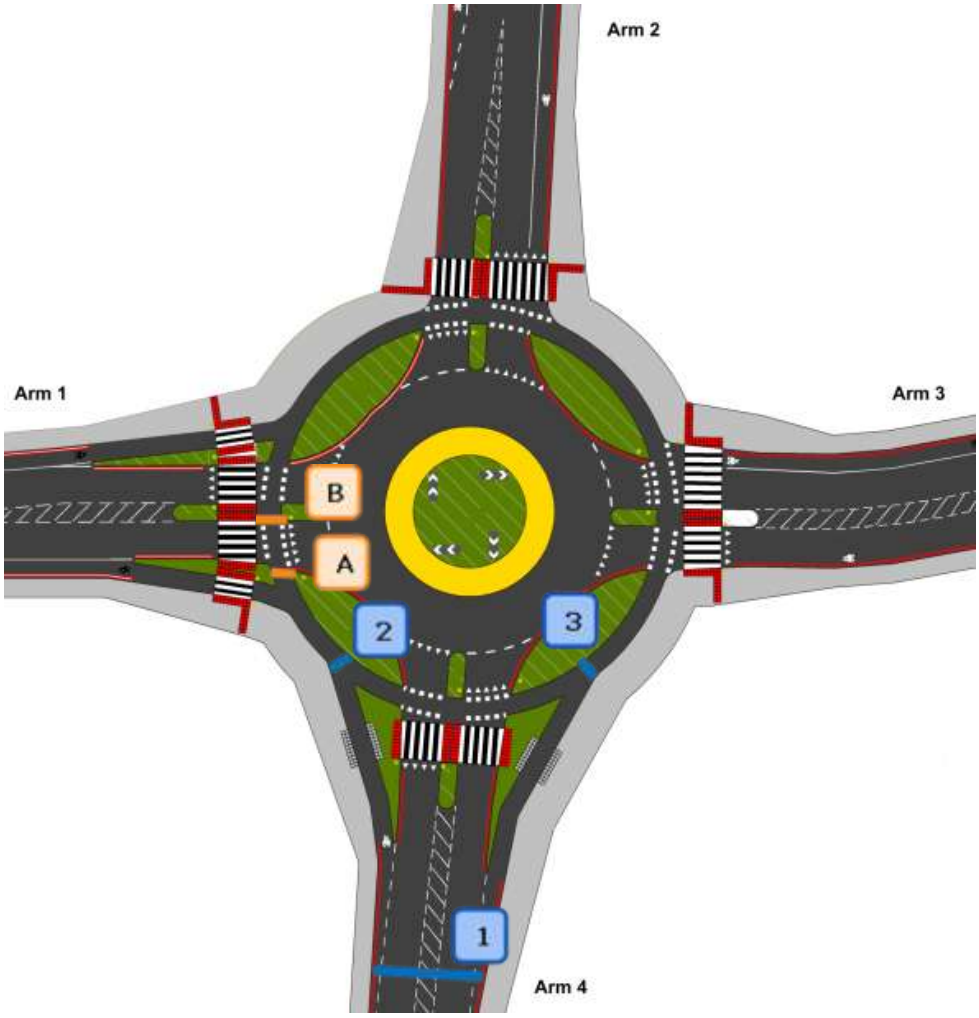

Figure 39: Journey timing points for cyclists

The average time for cyclists to enter the roundabout, circulate around the roundabout and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2; where Point 1 was fixed for the trials on the roundabout's arm. The time to circulate over Arm 1 was taken between Points A and B. The time to exit from over Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 9.

The average times for cyclists to enter, exit and circulate the roundabout are summarised in Figure 10.

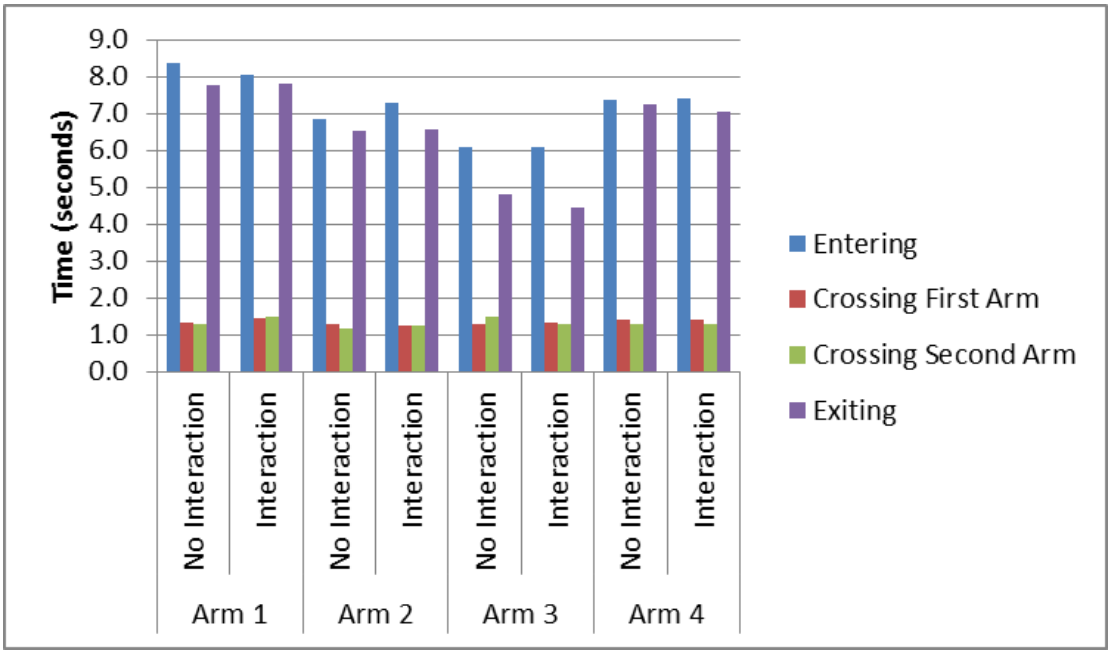

Figure 40: Cyclist journey time components

Cycle journey times were similar for all the roundabout's arms. The cyclists' overall journey times are summarised in Figure 11, and cyclists were generally ranged between 2.0 seconds faster and 2.0 seconds slower if they experienced one (or more) interactions with a car. The largest variation was from Arm 3 turning right to Arm 2 which on average took 4 seconds longer with an interaction indicating that the difficulty of entering and exiting from these arms. All cyclists in a session were involved in a similar number of conflicts, so no bias between different types of cyclists should have affected this result.

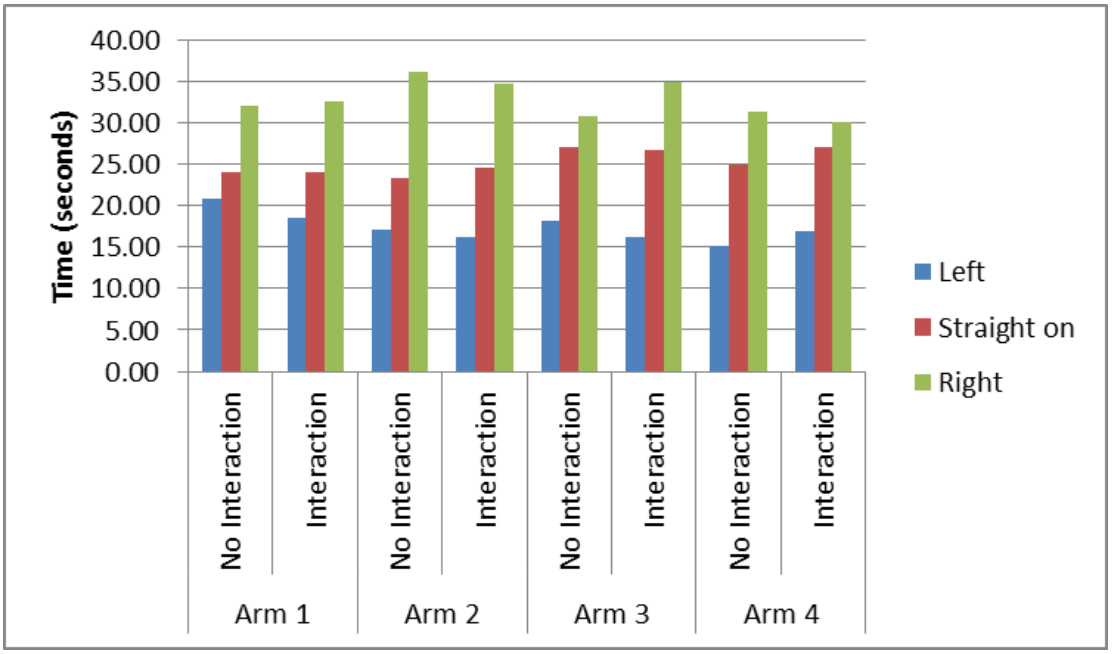

Figure 41: Cyclist overall journey time

3.3.3 Effects on car driver journey time

In this trial, the car drivers were trained users of the roundabout whose principal purpose was to engineer interactions with the cyclists. As such, it was not appropriate for them to take part in the questionnaire or focus groups activities. However it was felt that it would be appropriate to measure the effect of cyclists' interaction on their journey times as this was not significantly influenced by the fact that they understood the roundabout operation.

Car drivers started on one of four arms and turned left at the roundabout. They were instructed to enter at the same time as the cyclist on the same arm, or enter after them. They were also either asked to approach the left hand exit as a cyclist passed over the exit in the orbital cycle way, or exit at the same time as a cyclist. The car driver was under TRL instruction and was told to give way to the cyclist as a default.

The average time for car drivers to enter the roundabout, and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2; where Point 1 was fixed for the trials on the roundabout's arm. The time to exit from over Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 12.

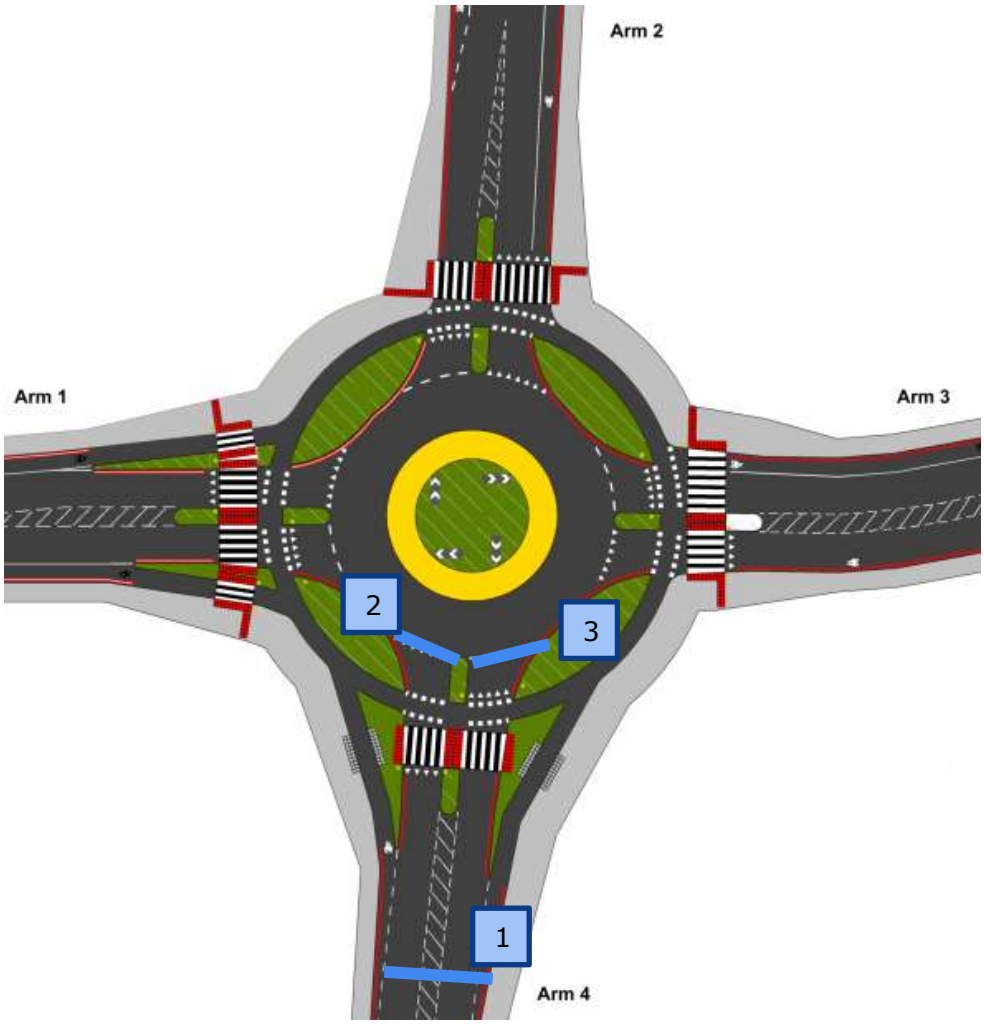

Figure 42: Journey timing points for car drivers

The average times for car drivers to enter, exit and circulate the roundabout are summarised in Figure 13.

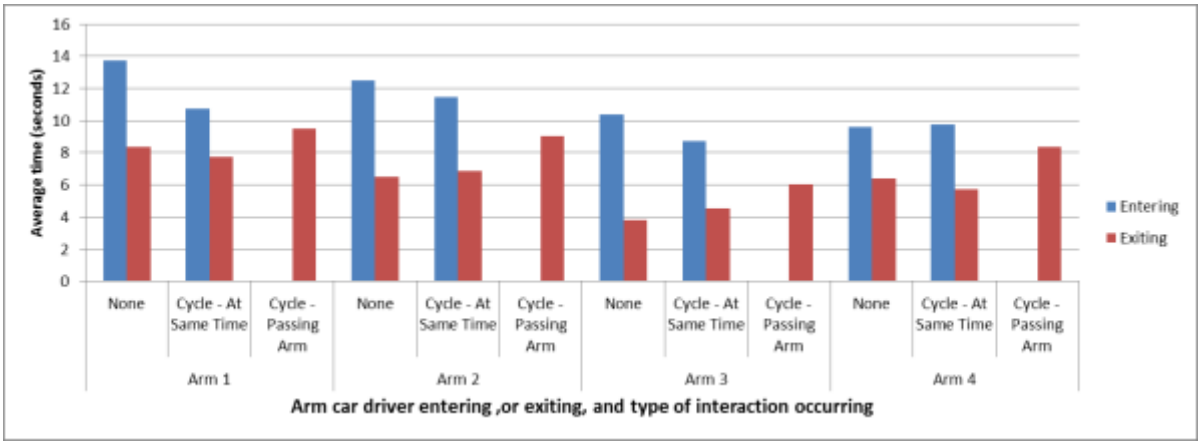

Figure 43: Car journey time components

The interaction with a cyclist had no observable adverse effect on journey time when entering the roundabout. The reduced journey time in conflict situations was probably a result of (TRL controlled) drivers using higher speeds to ensure a conflict situation occurred. The speed adjustment made by the drivers dominated over any effects of the roundabout's geometry including whether the cyclists were separated from the car drivers (Arms 1 and 4), and if the approach had an offset island (Arm 2) assisting in separating the cars and cycles, or not (Arm 3), see Figure 12.

There were also only slight variations in delay when the cyclist and car driver exited the roundabout at the same time, for the same reason. However, there were average delays of between 1.2 to 2.5 seconds owing to the car driver exiting and giving way to a cyclist passing over the exit on the roundabout' arms. The longest delays were on Arm 2 followed by Arm 3.

Overall car journey times were between 0.3 and 7.2 seconds longer if there was one interaction on the journey with a cycle exiting the roundabout, see Figure 14.

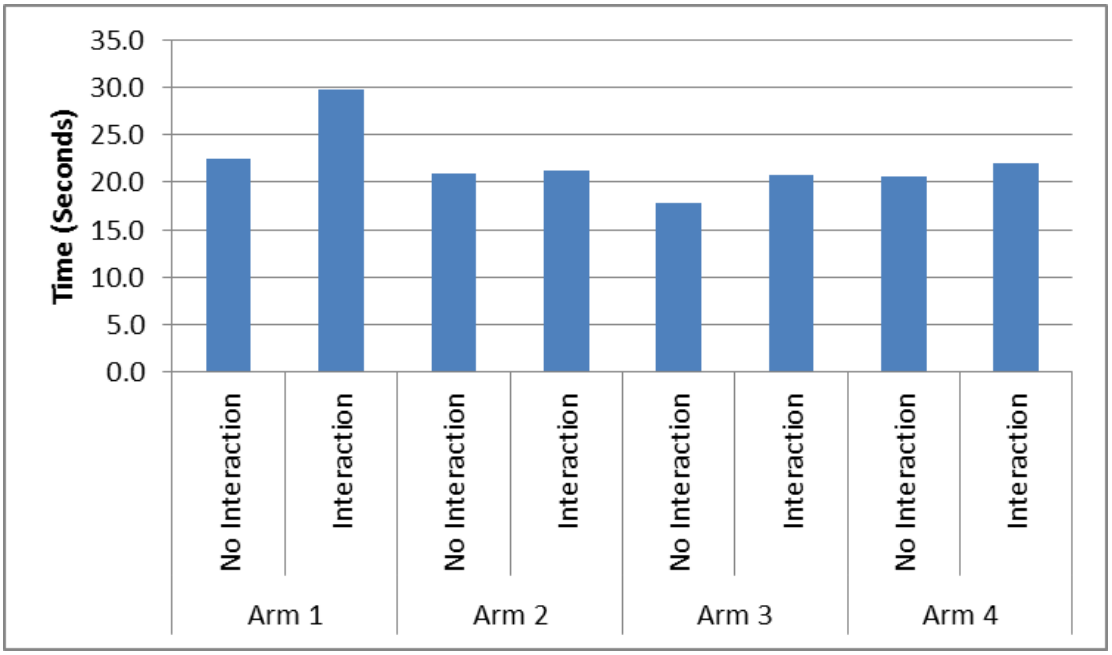

Figure 44: Car driver overall journey time

3.4 Cyclist on-track responses

During the trials cyclists were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'How easy it was to cycle from one arm to another?'
- 'How safe did you feel?'
- 'In busy traffic would you have chosen the cycle lane or the main roundabout?'
- 'If using the cycle lane, would you have gone clockwise or anticlockwise?'

The scoring for the first two was on a scale of one to ten, with ten being very easy, or very safe, respectively. The cyclists' average scores are summarised in Figure 15.

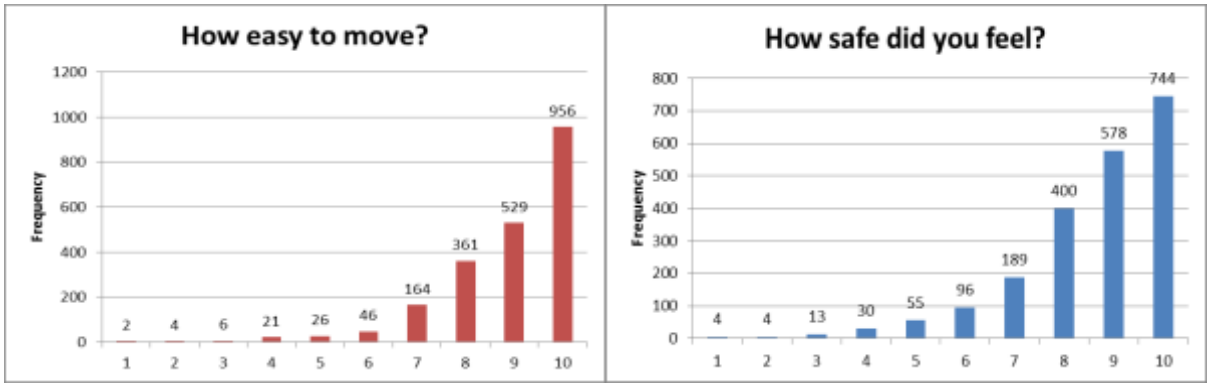

Figure 45: Cyclists' scores of safety and ease of using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (97%) and safe (95%). This is not overly surprising as cyclists were not

placed in any difficult situations. However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 78% of the safety scores were with ±1 of the ease of negotiating scores. For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same.

The average scores for making individual turning movements is summarised across all arms, see Figure 16.

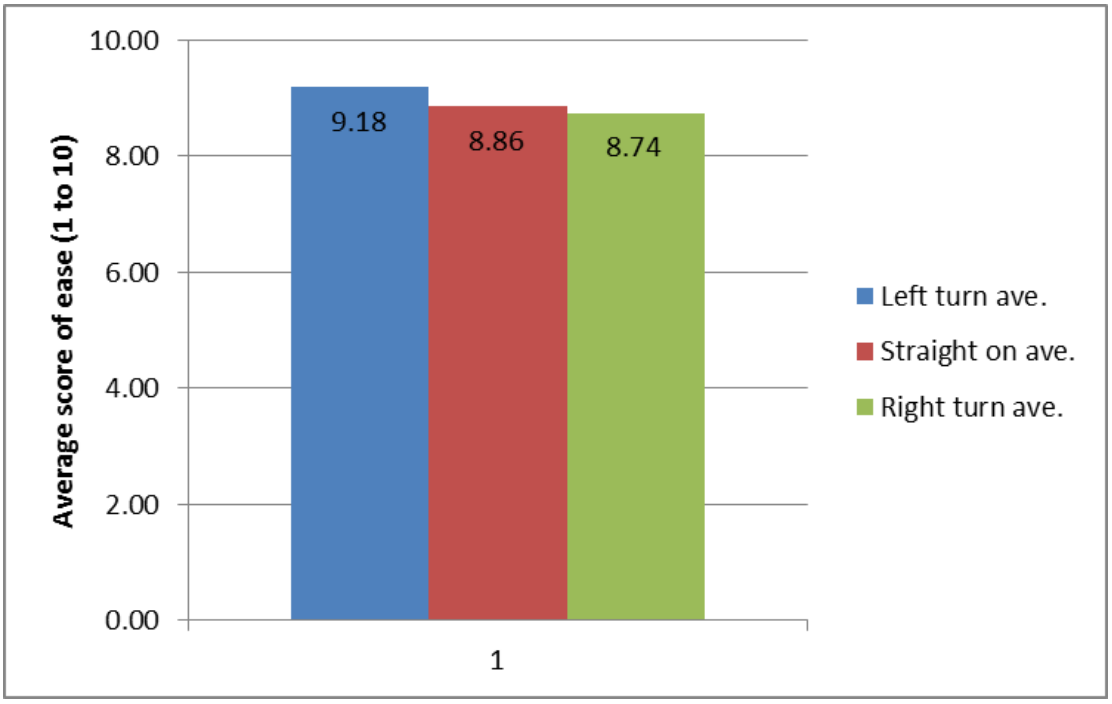

Figure 46: Cyclists' ease of negotiating the roundabout by turning movement

This implies that (on average) cyclists found it easier to turn left than straight on, than right. However, all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in Figure 17.

This chart shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that the easiest manoeuvre was considered to be from Arm 4 turning left to go to Arm 1: i.e. turning *left* from and to an arm *with* a segregated cycle lane leading the cyclists separately onto and off of the roundabout. The most difficult was indicated to be from Arm 3 turning right to go to Arm 2: i.e. turning *right* from and to an arm *without* any segregated cycle lane leading the cyclists separately onto and off of the roundabout. Overall, there is an indication that turning out of Arm 3 was judged as slightly harder than the other arms.

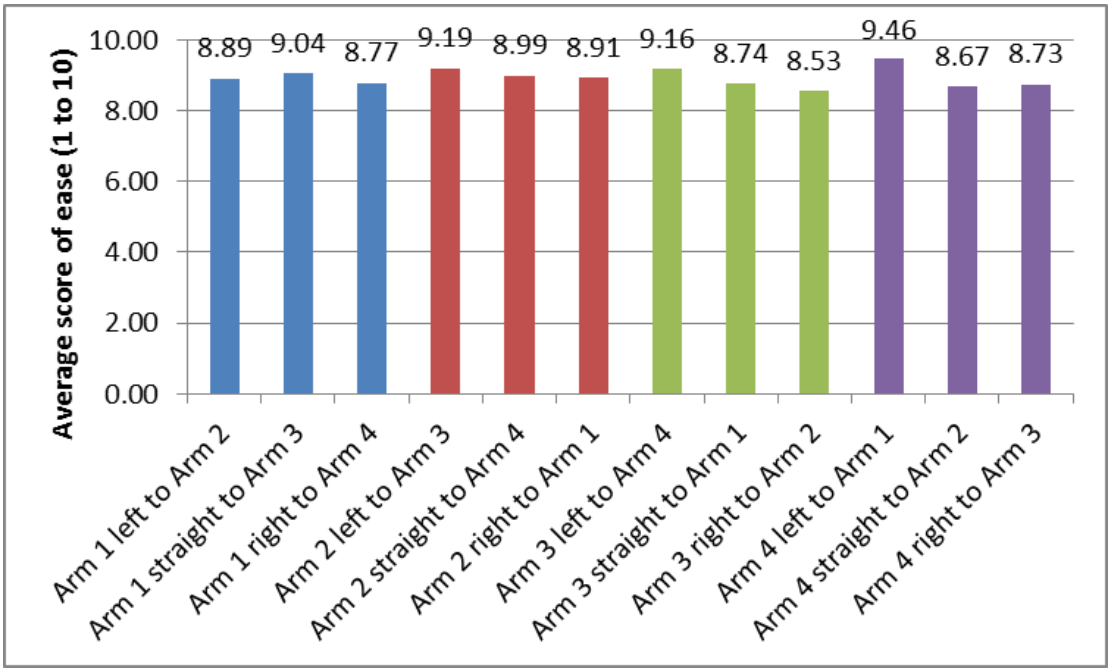

Figure 47: Cyclists' scores of ease of negotiating the roundabout by arm and movement

Finally, cyclists were also asked if they would have used the cycle lane, or the main road, in heavy traffic, and if they would cycle clockwise or anti-clockwise if using the orbital cycle way:

- 93% of cyclists would use the orbital cycle way in heavy traffic
- 98% of cyclists would travel clockwise around the orbital cycle way.

B.5 M22 Car Drivers Findings Report, UK Markings

Findings report: Dutch Roundabout Individual Reaction (M22) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. On Arms 1, 3 and 4 the Zebra crossing are directly alongside the cycle path where it crosses the car lane, whereas on Arm 2 there is a 5m gap between the Zebra crossing and the cycle lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority
- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

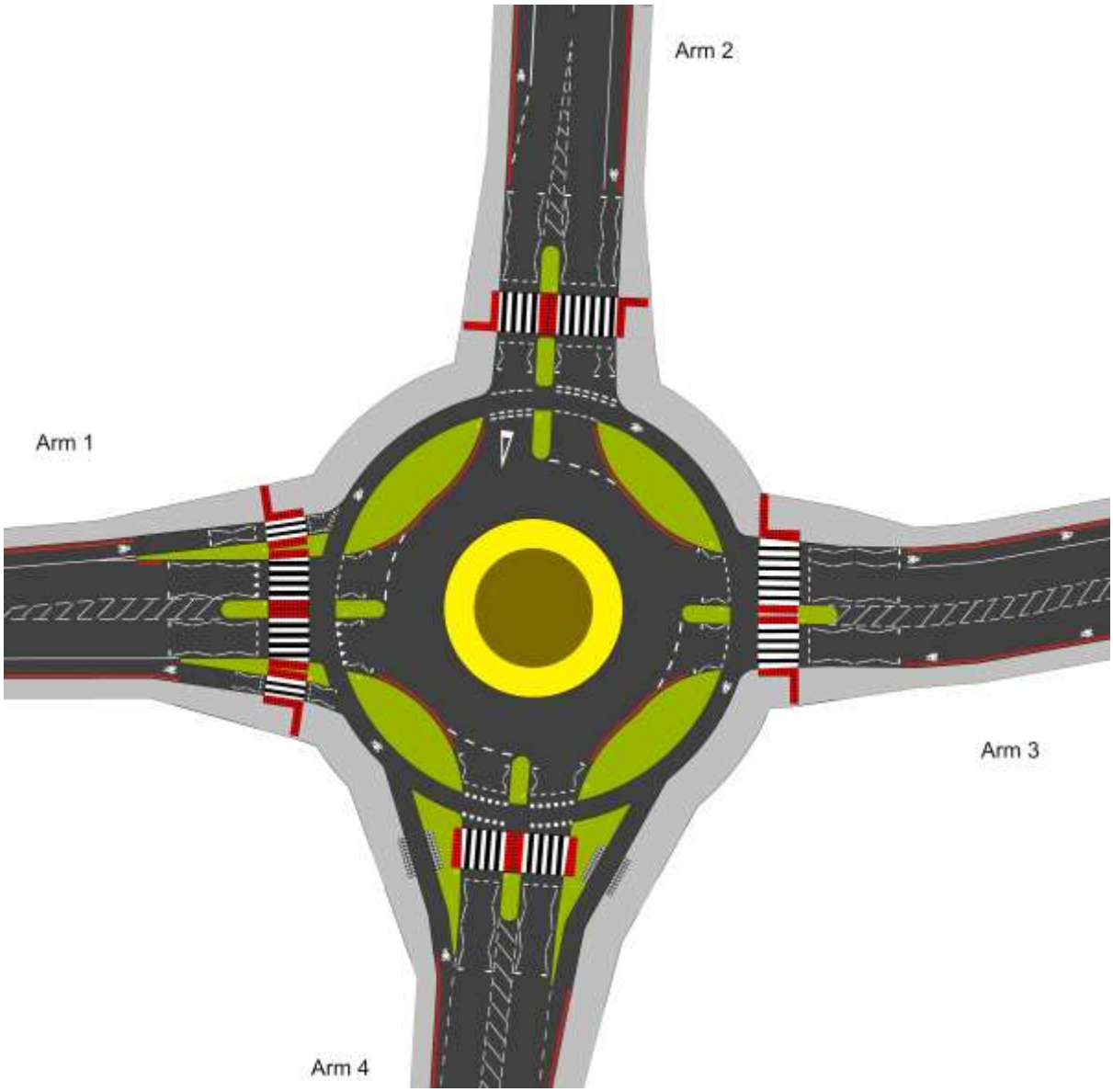

Figure 48: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes.

1.2 Introduction to the M22 trials

The M22 trials were identical to the M6b trials held earlier, but using the UK markings on the roundabout. They were held between the 22nd and 26th April 2013. The primary objectives of the M22 trials were to establish the reactions of car drivers when encountering cyclists at the entrance to and exit from the roundabout, and to see whether their understanding of the roundabout was improved by the use of UK markings. Drivers were asked the same questions to those posed in the M6b trials to evaluate if the use of UK markings changed their understanding of using the roundabout.

2 Methodology

The participant drivers were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant started on one of the arms of the roundabout and was asked to ride up to the roundabout, and either turn left, go straight on, or turn right. No participants had seen the roundabout before the trials started. A total of 8 drivers were on track at any one time with the cars setting off in pairs.

At the same time, 8 cycles (two on each arm) ridden by trained riders also negotiated the roundabout and engineered a "conflict" with the cars either at the entrance to or exit from the roundabout. A total of 8 cyclists were on track at any one time with the cyclists setting off in pairs. The conflicts were designed that the drivers would encounter cyclists at both the demerge (the point where the cycle lane separates from the main car lane) and merge (the point where the cycle lane merges back into the main traffic lane) points on the roundabout, and they would also encounter cyclists crossing the car lane at either the entrance to or exit from the roundabout. Drivers were not told that the cyclists had right of way while on the orbital cycle lane.

At the end of each movement, each participant driver was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed (e.g. did you understand marking "x") and open (e.g. do you have any suggestions for making "y" clearer) questions.

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings can be used to compare the effect of interactions on previous trial of the roundabout with Dutch style markings, and also as a baseline against which the effect of interactions in future trials with UK markings can be measured.

Data were provided by the questionnaires, the focus group transcripts and staff observations of participant behaviour. Statistical analysis of the questionnaire data have made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted that if a finding has occurred with a probability of 5% or less (expressed throughout this report as 'p<.05'), then it is statistically significant.

Sometimes the probability of a chance finding will be less than 5% and this is expressed accordingly (e.g. p<.0005 means probability was less than .05%).

3 Summary of Findings

84 drivers took part in this trial. The trials group included both male and females and included a wide range of ages from 25 to over 75. No drivers under 25 were included for insurance purposes.

3.1 Questionnaire Analysis Findings

The extent to which participants understood how to navigate the roundabout can be inferred from responses to questions on noticing the cycle lane, understanding of the markings, and giving way.

3.1.1 Understanding the layout

Most of the drivers (just over three-quarters) said they noticed the cycle lane crossing as they approached the roundabout and rather more (86%) said they noticed it as they were about to leave the roundabout.

Most of the drivers (71%) said they noticed the unusual road markings – the white squares near the zebra crossing. A quarter of drivers correctly understood these to be marking the cycle crossing. Most of the others gave 'safe' explanations such as 'give way to cyclists' or 'caution'. However some 15% of the drivers were confused by the multitude of different markings, or misunderstood the markings.

The great majority of drivers (88%) said that on approaching the roundabout, they prepared to give way to cyclists and even more said they would have given way if they had seen a cyclist crossing on the cycle lane. Rather more drivers (93%) said they prepared to give way to cyclists as they were leaving the roundabout and almost all said they would have given way if they had seen a cyclist crossing.

These responses indicate that drivers' interpretation of how to navigate the roundabout was good but a small proportion did not understand that cyclists crossing the entry and exit points had priority over vehicles entering and leaving the roundabout.

3.1.2 Influence of different aspects of the layout

Initially, two thirds of drivers noticed differences between the entry layouts. Differences between shared and segregated lanes for cyclists and in road markings were mentioned. On leaving the roundabout at Arm 3, there were rather fewer drivers who said they noticed the cycle lane crossing and fewer who prepared to give way to cyclists, where there were less distinctive markings, than at the other exit points. There were no significant differences in behaviour at the other arms.

Drivers mainly said it was 'easy' or 'very easy' to join the roundabout to turn left, right or go straight on, with few reporting difficulties and only small differences between the different layouts. Difficulties reported were about cyclists in the blind spot, taking account of cyclists, and the complexity of the driving task when joining the roundabout and watching out for pedestrians, cyclists, and cars stopping to give way to cyclists. About three-quarters of drivers thought joining the roundabout was 'safe' or 'very safe' and 12-16% described it as 'unsafe' at each point.

Commenting on how easy it was to go round the roundabout, some drivers also mentioned stopping at the roundabout exit while cars give way to cyclists as an issue, but most drivers rated this manoeuvre as 'easy' or 'very easy'.

Leaving the roundabout was rated as more difficult than joining it, with between 13% and 18% of drivers saying it was difficult. Rather fewer said it was difficult to leave at Arm 3 than at Arm 1 and Arm 2. The difficulties mentioned concerned seeing cyclists, judging their speed, uncertainty about cyclists' manoeuvres, stopping on the roundabout to give way and confusion about markings. Leaving the roundabout was also rated as less safe than joining it, with between 18 and 26% of drivers saying each exit was 'unsafe' and a few rated leaving as 'very unsafe'. The safety issue mentioned most frequently was concern about 'shunts' on the roundabout as drivers stopped to give way to cyclists crossing.

There was little difference between the various layouts in drivers' responses to several aspects of the roundabout:

- The proportion of drivers who said they noticed the cycle lane crossing as they approached the roundabout
- The proportion of drivers who, on approaching the roundabout, said they prepared to give way to cyclists or who would have given way to cyclists crossing
- The proportion of drivers who, as they were leaving the roundabout, said they would have given way to cyclists crossing
- Drivers' perceived ease of joining the roundabout to turn right
- Drivers' perceived safety of joining and leaving the roundabout.

3.1.3 Perceived benefits and influence on cycling in London

Drivers were more divided in their opinions than cyclists (in the M21 trials), with nearly half saying it would be 'easier' or 'much easier' for drivers than an ordinary roundabout and two-fifths saying it would be 'more difficult' or 'much more difficult' for drivers. The main concern for drivers was increased workload, however stopping on the roundabout, blocking the roundabout, delays and risks for cyclists were among other concerns mentioned.

Almost all of the drivers thought cyclists would benefit from the cycle lane round the roundabout and many thought motorists and pedestrians would benefit. The negative comments from drivers were mainly about safety for cyclists and motorists.

Addressing drivers' ratings of safety under different traffic conditions , about 7% thought it would be 'very unsafe' in heavy traffic, 21% 'unsafe' in heavy traffic and about 10% 'unsafe' in quiet traffic. Drivers' safety ratings for the roundabout in quiet and heavy traffic did not vary between turning left, right and going straight on.

3.1.4 Differences between UK and "Dutch" markings

The main difference between this trial and the one with 'Dutch' markings (M6b) was the use of UK markings to indicate points where vehicles should give way to cyclists and pedestrians crossing the road. The markings delimiting the cycle crossings were similar in the two trials.

The different markings appear to have had some influence on the extent to which drivers responded to the cycle crossing at two points on the roundabout: less distinctive UK markings of the cycle crossing at Arm 3 were associated with fewer drivers noticing it than in the trial with 'Dutch' markings; this difference can be seen in Figure 49.

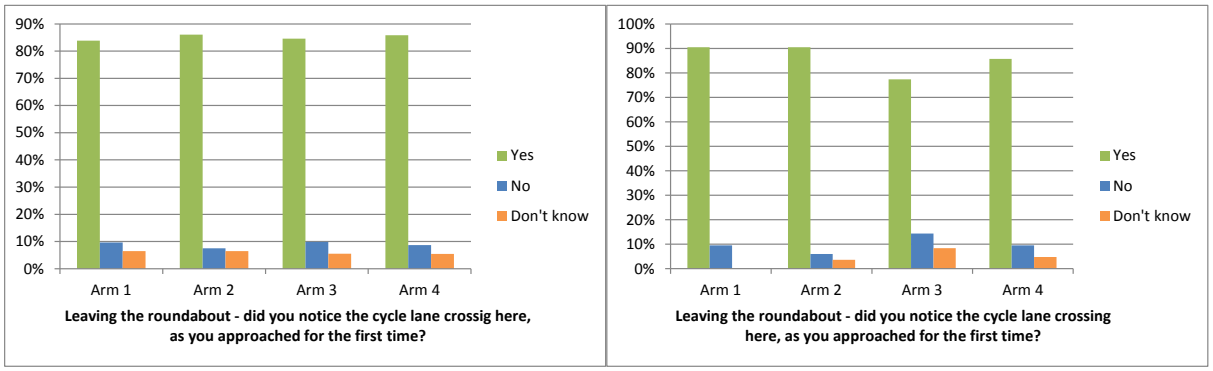

Figure 49: Noticing the road markings with Dutch (left) and UK (right) markings

Rather fewer drivers said they would have given way to cyclists crossing with less distinctive 'Dutch' markings at Arm 2, than with the UK markings, as shown in Figure 50.

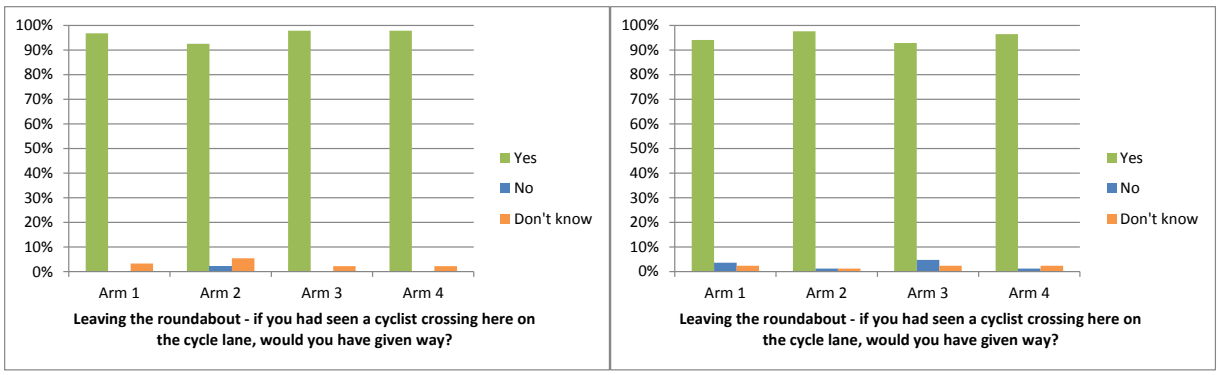

Figure 50: Giving way to Cyclists with Dutch (left) and UK (right) markings

With the UK markings, more drivers reported leaving the roundabout to be more 'difficult' than with Dutch markings.

There was a (relatively small) proportion of participants who said they did not understand the markings delimiting the cycle crossings, and some who mentioned confusion.

Thus the UK markings appear to have been associated with some improvement in participants' understanding of priority at the cycle crossings but there may also be scope for improving the UK markings, as fewer drivers noticed the cycle crossing where there were less distinctive 'UK' markings at Arm 3.

3.2 Focus Group Findings

20 drivers took part in 3 separate focus groups on the 3 trial days.

Following the participant trials and focus groups there were mixed views over the use of the orbital cycle lane. The majority of participants felt that segregating cyclists and vehicles was a positive step which would benefit cyclist safety. However, five participants felt that although safety was improved whilst circulating the roundabout, the crossings created potential conflict points between cars and cyclists.

"Separation is very good – stops cyclists from mixing with the traffic"

"The separation between road and cyclist is a good thing…obviously much safer".

Although nine participants found the road markings excessive or confusing, all assumed they should give priority to cyclists. This assumption was based on the fact cyclists are more vulnerable than the vehicles and the fact the roundabout appeared to be very cycle-centric. It was noted that on parts of the cycle lane there were no markings to indicate who had the right of way – this applied to both cyclists and vehicles. Although all gave priority to cyclists it was felt that in a real-life scenario drivers may be reluctant to do this. In addition, there were fears that cyclists may appear from blind-spots or try to race with a vehicle to get to a crossing before the vehicle which could lead to accidents.

"Had eyes peeled all the time – so it was a relief when the cyclist had left the roundabout";

"…it felt alien and unnatural".

Five commented they felt unsafe and vulnerable whilst waiting on the roundabout in order to give priority to cyclists before exiting. Three participants were concerned that vehicles coming onto the roundabout would be held up by those giving priority and there was an increased chance of cars on the roundabout being clipped. In addition, three participants shared a concern that vehicles may bump into the back of other vehicles when leaving the roundabout if they did not anticipate the vehicle in front stopping to give way.

"…didn't like stopping on the roundabout"

"…the natural instinct as leaving the roundabout is here's my exit and then start to accelerate"

"…felt unsafe stopping with just four cars, so in London when there are four thousand cars then I would feel really unsafe stopping on the roundabout".

Participants had a number of recommendations to improve the layout. Firstly this related to the location of the zebra crossing in relation to the roundabout, this was felt to be dangerous in its current location. Four participants agreed with the suggestion that the zebra crossings should be moved 15-20 yards away from the roundabout allowing drivers to have a clearer view of the crossing and reducing the build-up of traffic which could gridlock the roundabout. Secondly, four participants agreed with the suggestion that additional signage be installed in the approach to the roundabout to warn drivers of the cycle lanes and to inform cyclists and drivers as to who has right of way. Thirdly, participants suggested cycle lanes could be covered in coloured tarmac to highlight their presence to pedestrians and motorists.

"The zebra crossing was too close to the roundabout. During the trial there was a clear view – however in real life it would be less clear than this"

"…no road markings to indicate whose right of way".

Some participants felt uncomfortable about having to give way to both the left and right, when usually a driver would just give way to the right on a roundabout. Some participants felt that pedestrians may be less safe in this layout as pedestrians needed to cross cycle lanes on a number of occasions and some cyclists may be inclined to use the pedestrian path rather than the cycle path if they wanted to overtake.

"…used to giving way to the right, now you have to give way to everyone on the roundabout"

"…pedestrians will be less safe due to the bikes crossing the pedestrian path"

There were mixed views over whether the layout would encourage more cyclists, some participants felt that this would encourage less confident cyclists and some suggested this would just add to the safety of existing cyclists. A limited number of participants suggested they would feel happier for their children to cycle when there was an orbital cycle lane and they may be encouraged to cycle to school.

"…cycling for leisure may be increased, won't make any difference to commuters as they are cycling anyway"

3.3 Video Analysis Findings

Twelve video cameras captured the movements of cyclists and car drivers during the trial. The time taken for cyclists and car drivers entering, circulating around and exiting from the roundabout were collected from the resulting recordings. These can be compared to assess which of the cyclists, or car drivers, went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if the cyclist and car driver came into close proximity within two seconds of each other. For example, whether they entered the roundabout within two seconds of each other from the same roundabout arm, or if the cyclists started to cross an exit arm within two seconds of a car driver arriving at the exit. If the car driver and cyclist entered the interaction zone within one second of each other, then no priority was assigned. Otherwise the vehicle entering first is assumed to have taken priority.

3.3.1 Priority when negotiating the roundabout

The priorities taken by cyclists and car drivers have been investigated under three situations:

1. Entering the roundabout together
2. Cycle crossing an exit whilst a car driver is exiting the roundabout by that arm
3. Exiting the roundabout together

The results for the participants entering the roundabout together are summarised in Figure 2.

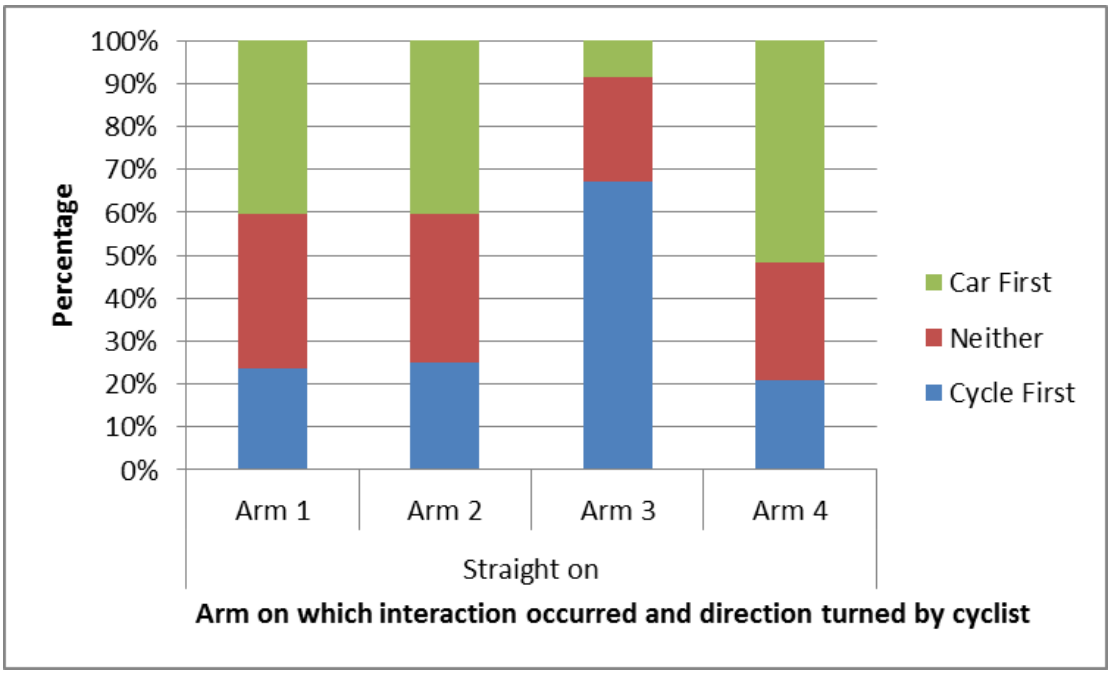

Figure 51: Priorities when a car driver and cyclist enter the roundabout at the same time

Cyclists aimed to enter the roundabout at the same time as the car drivers to create an interaction, or avoided entering at the same time as the car driver, depending on the instructions they were given. The guidance given to the cyclist was that if creating a conflict on the roundabout's entrance they should try to be parallel to the car drivers when they reached the pedestrian crossing. An interaction was considered to have occurred if the cyclist and car driver crossed the far side of the pedestrian crossing within two seconds of each other. The cyclists were always instructed to go straight ahead for each run.

When an interaction occurred, the cyclist entered the roundabout first on 21% to 67% of occasions. Also the car driver entered first between 8% to 52% of occasions. Car driver and cyclists entered the roundabout within 1 second of each other on 24 to 36% of occasions. This is generally in line with expectation as the cyclists were instructed to use the separate orbital cycle lane, and therefore their paths did not intersect with those of the car drivers.

The second type of interaction was defined to have occurred when the cyclist crossed an exit arm of a roundabout and a car exited the roundabout from that arm. More specifically, an interaction occurred if the cycle crossed the purple line in Figure 3 within two seconds of the car crossing the dark blue line. The car was judged to have gone first if it crossed the light blue line before the cycle passed the purple line. The percentage of cars, and cycles found to have gone first when an interaction occurred is summarised in Figure 4.

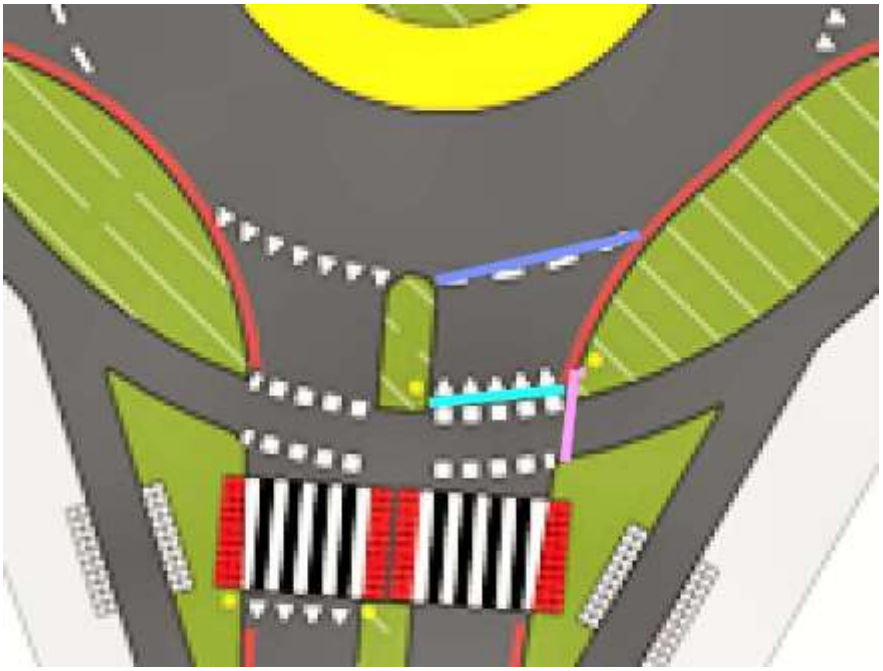

Figure 52

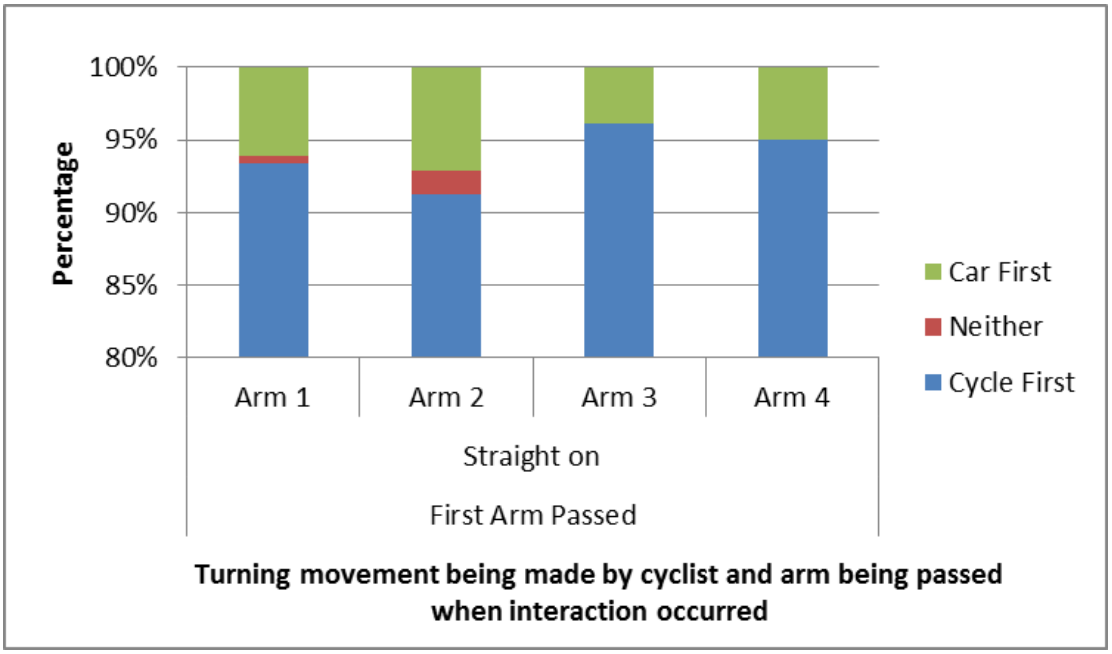

Figure 53: Priorities when a car driver exits roundabout as a cyclist crosses the exit in the orbital cycle way (Arm indicated is the arm being crossed)

In nearly all such interactions, the cyclist went first, and the car gave way. So, most drivers gave cyclists priority whilst they crossing the exit, as required by the design. However, on Arm 2, 9% did not, and 7% of drivers went in front of the cyclists.

The third type of interaction was defined to have occurred when the cyclist and car driver approached the exit of an arm within two seconds of each other. More specifically, the cycle crossed the purple line in Figure 7 within two seconds of the car crossing the dark blue line. The car was judged to have exited first if it crossed the light blue line

before the cycle passed the purple line. The yellow line was also used to time vehicles exiting the roundabout. The percentage of cars, and cycles found to have started to exit, and exited, first when an interaction occurred is summarised in **Figure 55**.

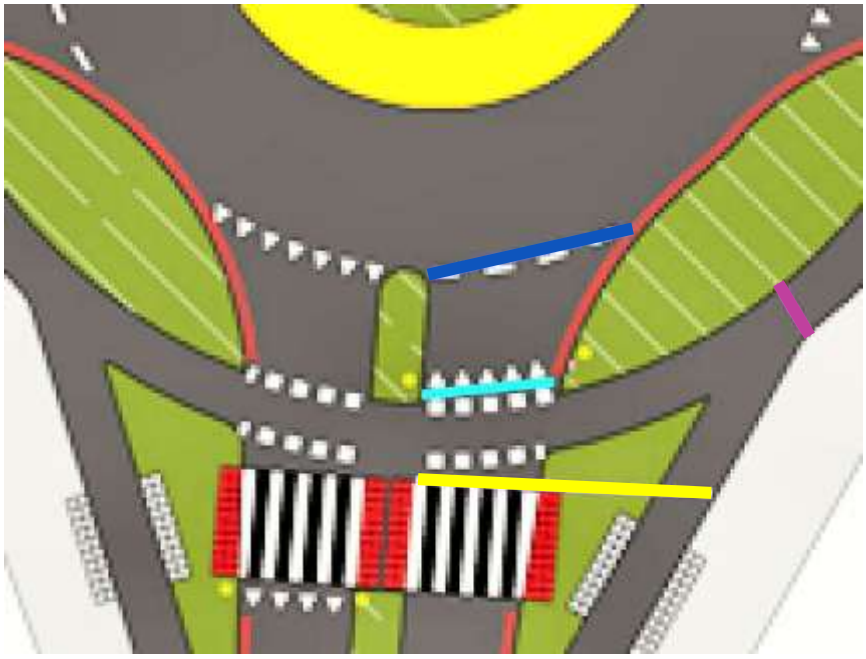

Figure 54: Timing points used to assess priorities when a car driver and cyclist exit the roundabout at the same time

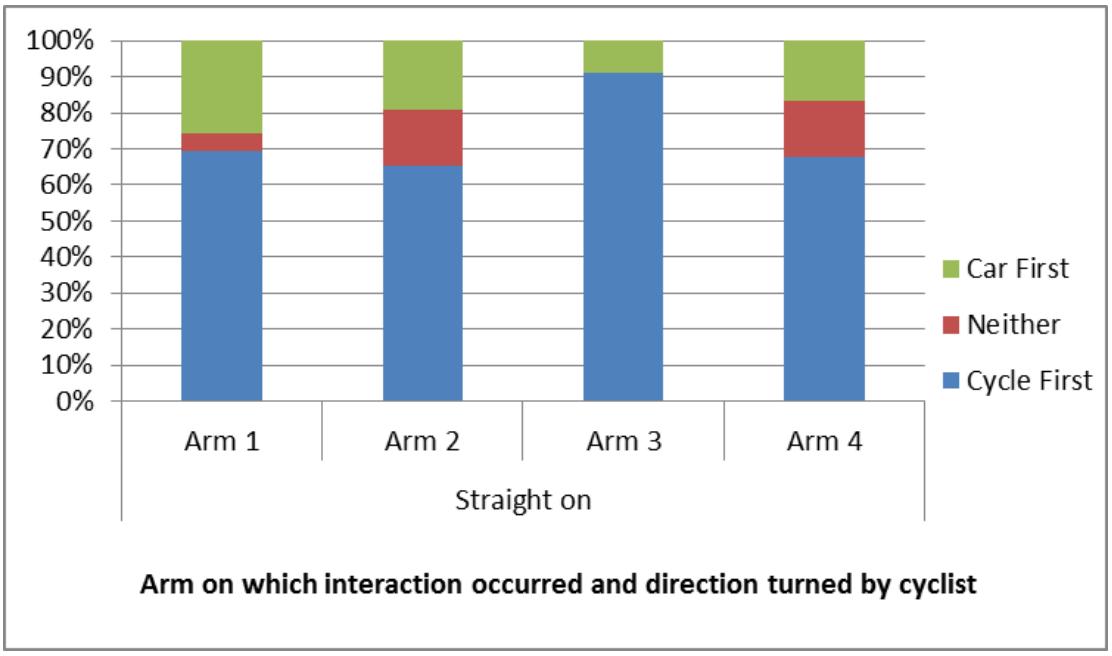

Figure 55: Priorities when a car driver and cyclist exit the roundabout at the same time

The numbers of exit interactions achieved was low in comparison with the other interactions. The results of this section should therefore be treated with caution, particularly for Arm 3 which had only eleven such interactions. In the majority of these interactions, the cyclist went first.

3.3.2 Effects on cyclist journey time

In this trial, the cyclists were trained users of the roundabout whose principal purpose was to engineer interactions with the car drivers. As such, it was not appropriate for them to take part in the questionnaire or focus groups activities. However it was felt that it would be appropriate to measure the effect of interaction on their journey times as this was not significantly influenced by the fact that they understood the roundabout operation.

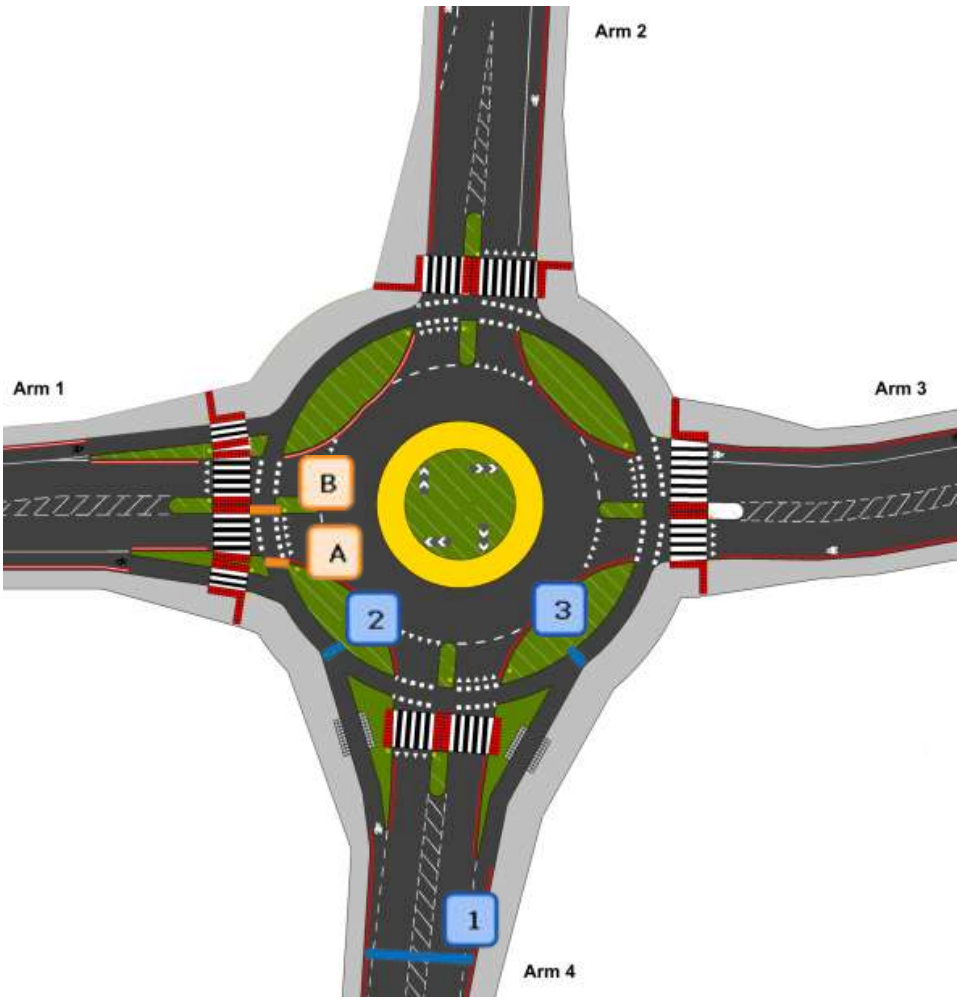

Figure 56: Journey timing points for cyclists

Cyclists started on one of four arms and went straight on at the roundabout. They could be instructed to meet a car under one of three situations:

4. a car was entering the roundabout at the same time they entered;
5. a car was exiting an arm whilst they cycled past in the orbital cycle lane; or
6. a car was exiting the roundabout at the same time as the cyclist exited.

The cyclists were under TRL instruction and for safety reasons were told to give way to car drivers if they were not certain that a car driver would give way to them.

If the car was in the vicinity, that is they crossed defined timing points (see above) on the approach to the "interaction area" within two seconds of each other, an interaction was said to have occurred. The average time for cyclists to enter the roundabout, cross

the traffic lane while circulating the roundabout, and leave it was measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2, where Point 1 was fixed for the trials on the roundabout's arm. The time to cross the exit car lane at Arm 1 was taken between Points A and B – the time at Point A was taken when the cyclist arrived at Point A, so included the stopping time. The time to exit from Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 9. The average times for cyclists to enter, exit and circulate the roundabout are summarised in **Figure 57**.

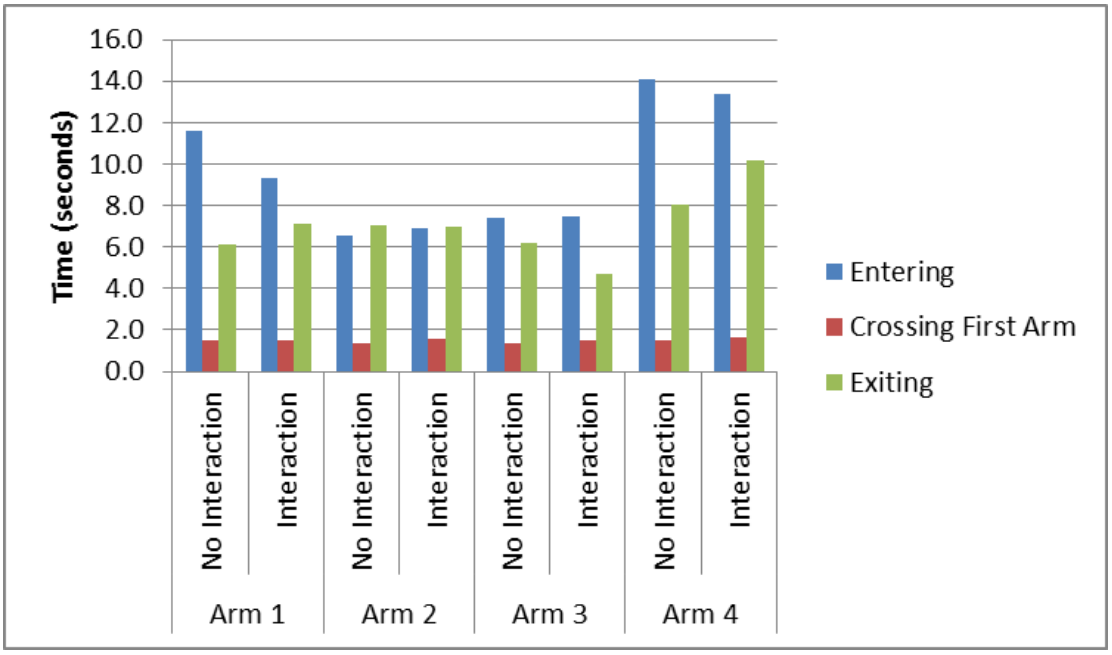

Figure 57: Cyclist journey time components

Cycle journey times on exiting with an interaction must be treated with caution owing to small sample sizes. Cycle times when crossing an arm were consistent, which is in agreement with cyclists generally having right of way in the orbital cycle way.

Cyclists were quicker to enter Arms 1 and 4, where a separate cycle lane lead them into the orbital cycle way. It is difficult to accurately explain this trend, however, it may be a result of the cyclists being asked to create entrance interactions with the drivers on certain runs. On Arms 1 and 4 the cyclists have a separate cycle lane, thus giving drivers more opportunity to accelerate up to speed. Creating this entrance interaction could therefore require the cyclists to travel quicker to the timing point.

The cyclists' overall journey times are summarised in **Figure 58**, and cyclists were generally between 2.1 and 5.1 seconds faster if they experienced one (or more) interactions with a car.

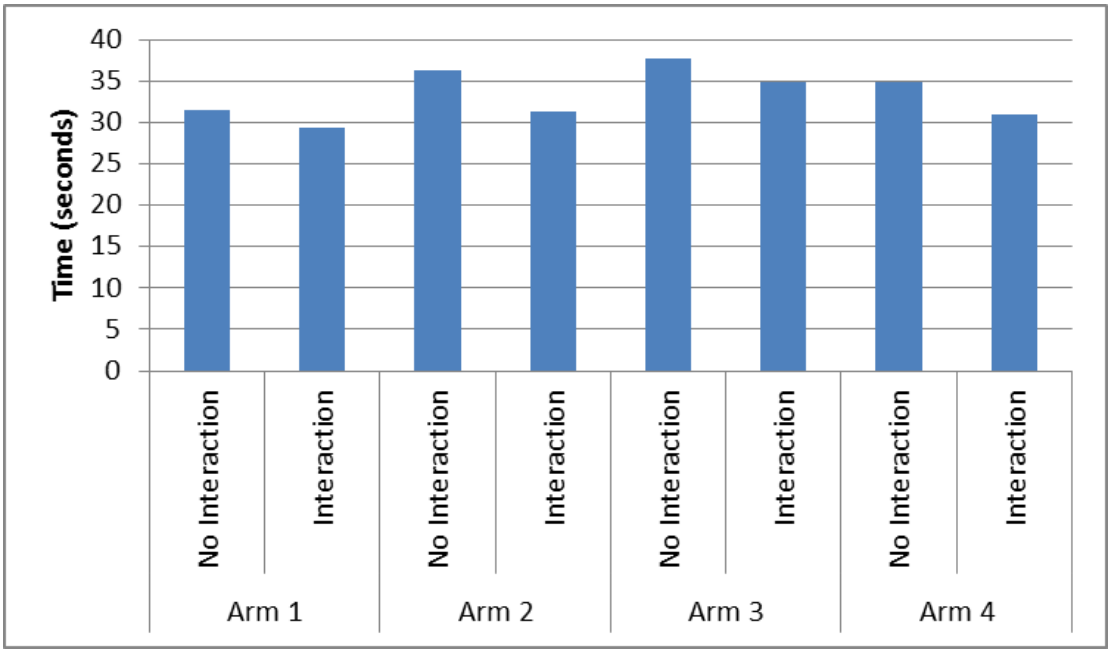

Figure 58: Cyclist overall journey times

3.3.3 Effects on car driver journey time

Car drivers started on one of four arms and turned left, right or continued straight on at the roundabout. The average time for car drivers to enter the roundabout, and leave it were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 2, where Point 1 was fixed for the trials on the roundabout's arm. The time to exit from Arm 4 was taken between Points 3 and 1. Such timing points were defined for all arms of the roundabout, see Figure 12.

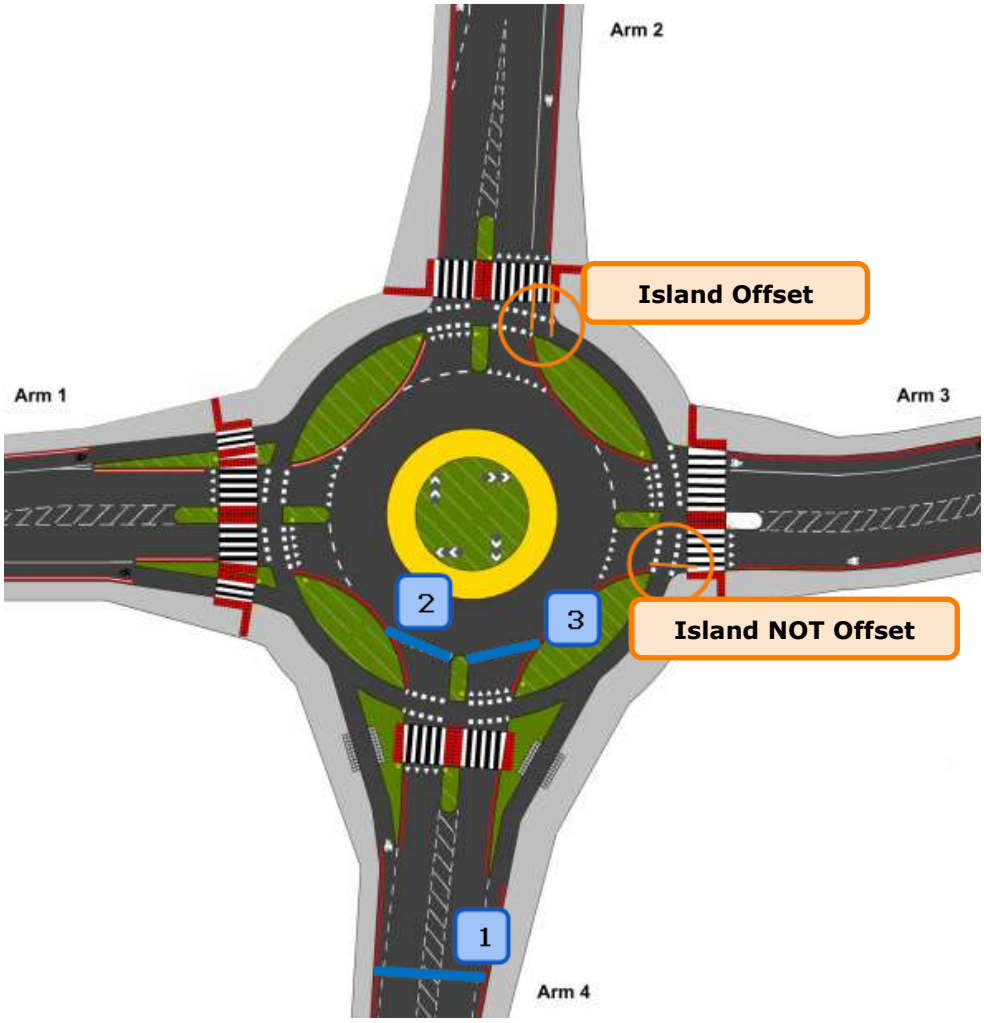

Figure 59: Journey timing points for car drivers

The average times for car drivers to enter, exit and circulate the roundabout are summarised in **Figure 60**.

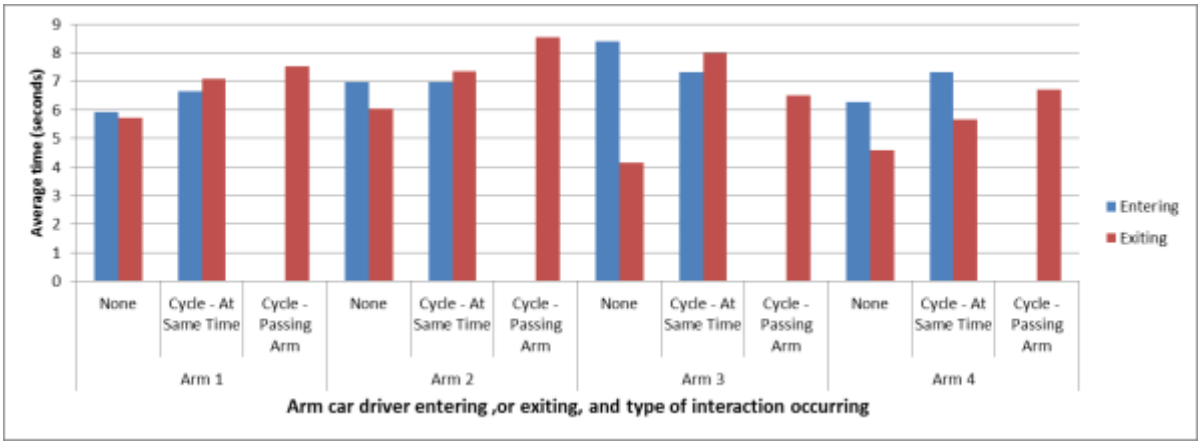

Figure 60: Journey time components

The interaction with a cyclist had a small observable adverse effect on journey time when entering the roundabout on Arms 1 and 4. It appeared to have a beneficial effect on Arm 3, but this was owing to larger times for entering the roundabout without an interaction than on the other arms. When the car drivers and cyclists exited together there were average delays of between 1.1 to 3.8 seconds owing to the car driver exiting

and giving way to a cyclist either passing over the exit, or exiting at the same time as the car, on all the roundabout' arms.

Overall car journey times (averaged across all arms) were approximately 1.9 seconds longer if there was one interaction on the journey with a cycle when exiting the roundabout after turning left, and 2.5 seconds if going straight on, see **Figure 61**. However, there was no consistent effect for turning right, possibly owing to a higher variability in journey times. The greatest average delay was 5.4 seconds for cars going straight on from Arm 3 to Arm 1.

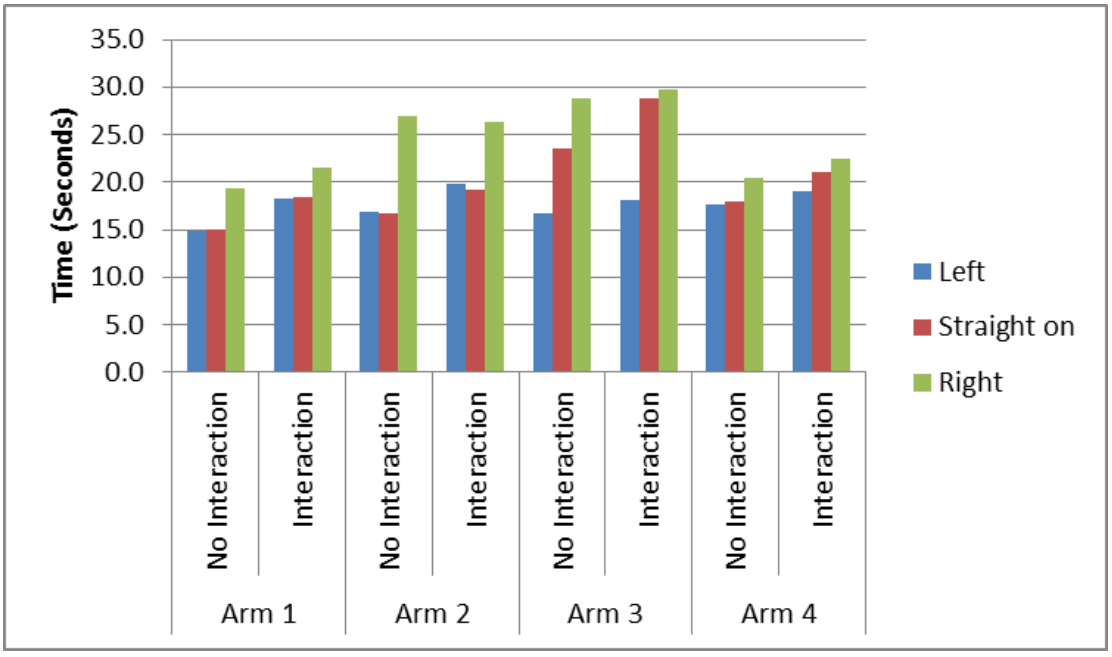

Figure 61: Car driver overall journey time

3.4 Car driver on-track responses

During the trials drivers were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'On a scale of 1 to 10 where 10 is Very Easy, how easy it was to negotiate the roundabout?' i.e. 'How easy it was to cycle from one arm to another?'
- 'On a scale of 1 to 10 where 10 is Very Safe, how safe did you feel?'

Figure 62 gives the responses to these questions showing a count of all responses from all drivers.

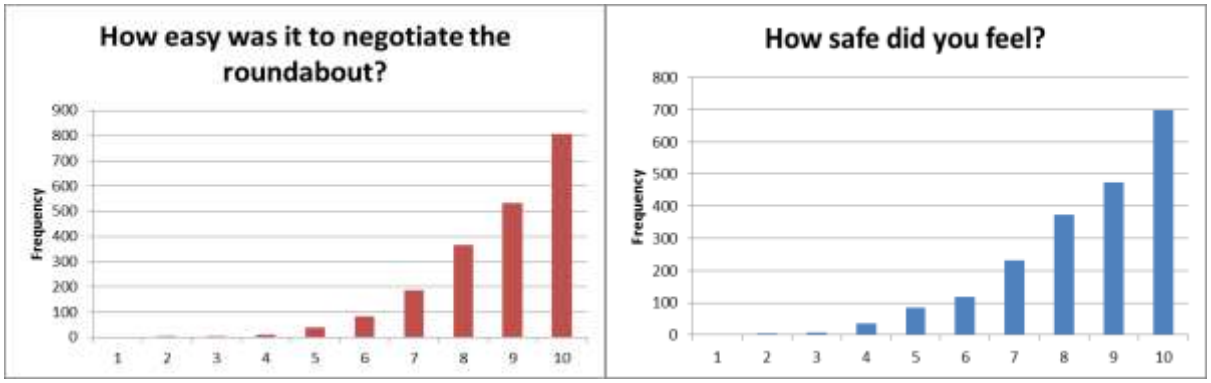

Figure 62: Drivers' scores of safety and ease of use using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (97%) and safe (93%). This is not overly surprising as drivers were not placed in any difficult situations. However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 89% of the safety scores were within ±1 of the ease of negotiating scores. For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same.

The average scores for making individual turning movements is summarised across all arms, see **Figure 63**.

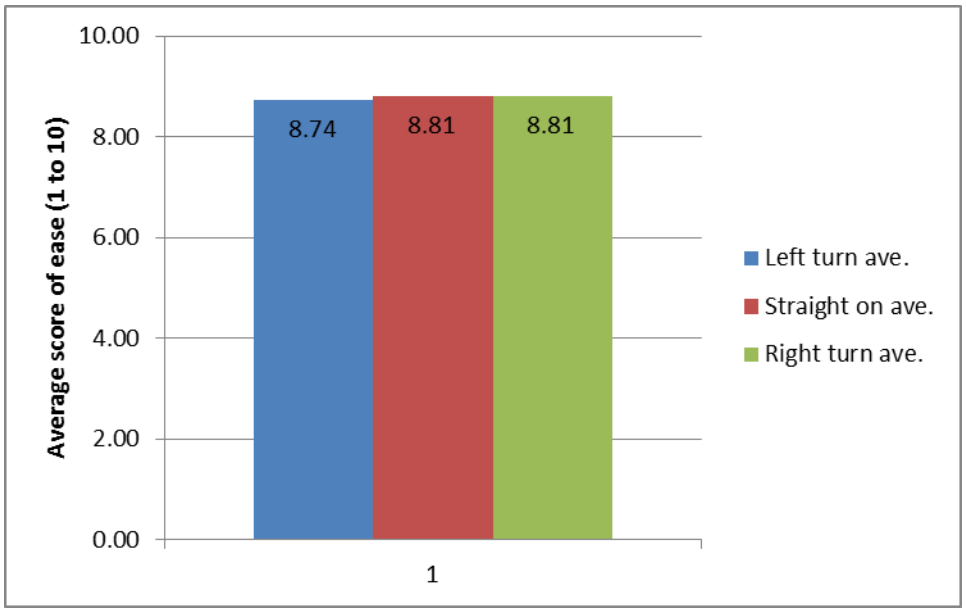

Figure 63: Drivers' ease of negotiating the roundabout by turning movement

This implies that (on average) car drivers found it as easy to turn in any direction at the roundabout: that is, the scores are very similar (within 0.07) and all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in **Figure 64**. These scores are very similar to the values from the M6b trial.

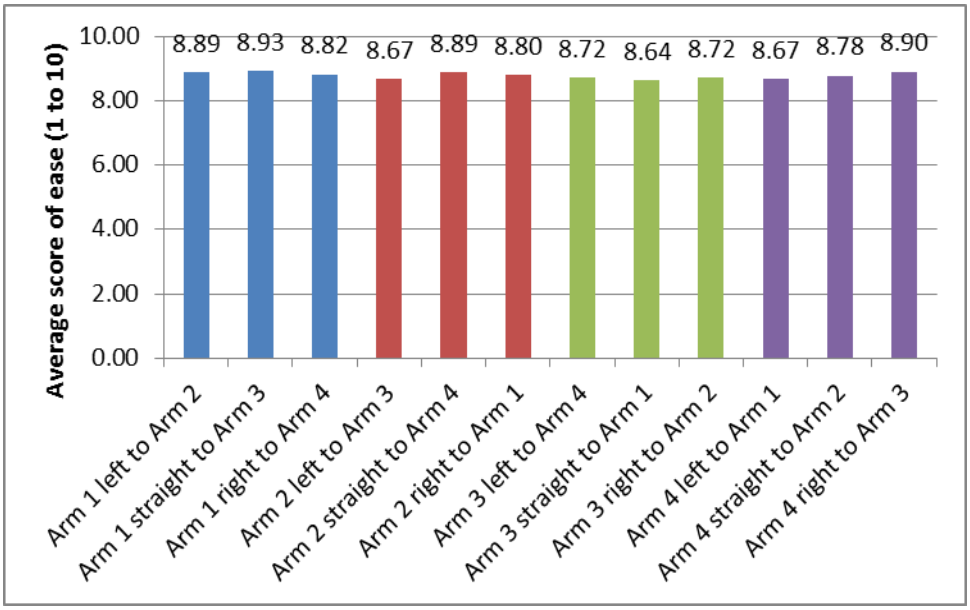

Figure 64: Drivers' scores of ease of negotiating the roundabout by arm and movement

The above chart shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that there was little difference between Arms 1, 2 and 4 with the average ease of use score only varying by 0.2 or less. The scores for Arm 3 were marginally lower than those on the other arms. Overall, there is an indication that turning out of Arm 3 was judged as slightly harder than the other arms.

B.6 M25 Cycle-Pedestrian Interaction Findings Report

Findings report: Dutch Roundabout Pedestrian-Cyclist Interaction (M25) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project that TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. On Arms 1, 3 and 4 the Zebra crossing are directly alongside the cycle path where it crosses the car lane, whereas on Arm 2 there is a 5m gap between the Zebra crossing and the cycle lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority
- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

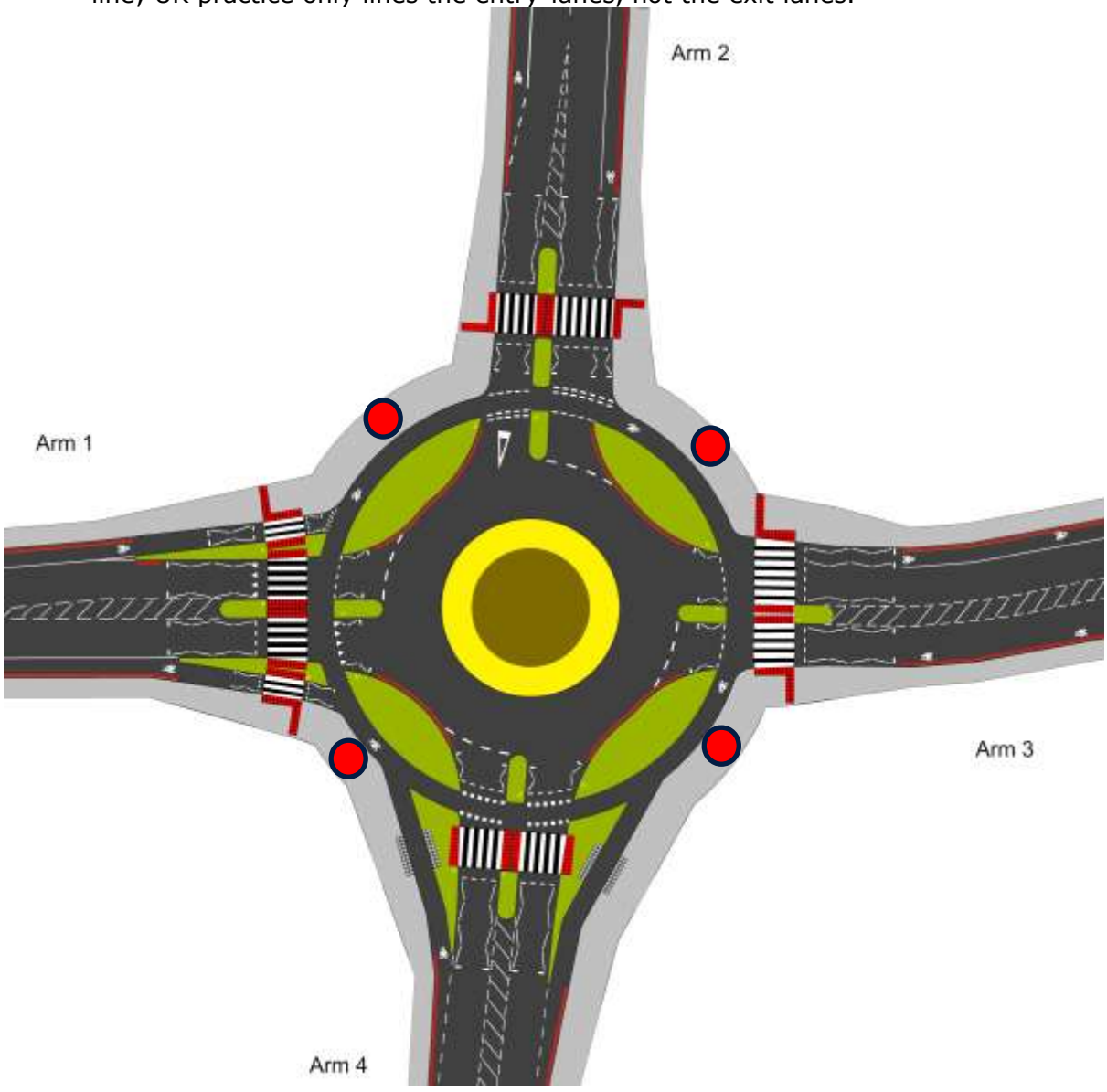

Figure 65: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes. Note also that the red dots shown on the pedestrian paths in Figure 1 are the start points for pedestrians (see later) and are not actually markings on the roundabout.

1.2 Introduction to the M25 trials

The primary objectives of the M25 trials were to establish how cyclists and pedestrians interacted when using the roundabout and how cyclists and pedestrians interpreted the layout and markings. This could then be used to assess the potential safety of the roundabout with respect to misinterpretation/misuse which could lead to conflicts and reduced safety margins (with respect to distance) between the users.

This was the first trial in which two sets of public participants interacted on the roundabout. In previous interaction trials, TRL staff took the place of one of the sets of participants so that trial scenarios were controlled and safety managed. It was also the first trial involving pedestrians.

The trials were held between the 11th and 13th June 2013.

2 Methodology

The aim of the trial design was to present different routes (turning movements) to cyclists and observe how they understood and used the roundabout, and how they interacted with pedestrians. Cyclists were asked to either turn left, turn right or to go straight on after approaching the roundabout on each of its arms. Pedestrians were asked to cross the road over each of the arms of the roundabout.

Ten cyclists and ten pedestrians were "on track" at the same time. Each cyclist started with a facilitator on a different arm of the roundabout and was asked to approach it and turn in a specified direction. After making the manoeuvre they travelled on the exit arm to a turnaround point and then waited with another facilitator. A short questionnaire was administered whilst they waited for their next turn to use the roundabout.

Pedestrians also had defined start and end points (shown by the red dots in Figure 1) and were asked to travel from one to another in either a clockwise or anti-clockwise direction in order to create a conflict situation with a cyclist flow. In all cases they started and ended with a facilitator and were required to use a pedestrian crossing in order to complete each "trip".

Both cyclists and pedestrians undertook their manoeuvres either singly, or in groups of 4. This made it possible to investigate if cyclist/pedestrian behaviour was influenced by the number of participants they encountered during the manoeuvre.

Participants were not given any information on the background to the Dutch roundabout design.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed (e.g. did you understand marking "x") and open (e.g. do you have any suggestions for making "y" clearer) questions.

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

Data were provided by the questionnaires and the focus group transcripts. No analysis of video data was undertaken for this trial.

3 Summary of Findings

108 cyclists and 110 pedestrians took part in this trial. The trials group included both male and females and included a wide range of ages from 18 to over 75, but 38% of those who participated as cyclists and 22% of those who participated as pedestrians were aged 18 – 24. The age spread of cyclists and pedestrians is shown in **Figure 66**.

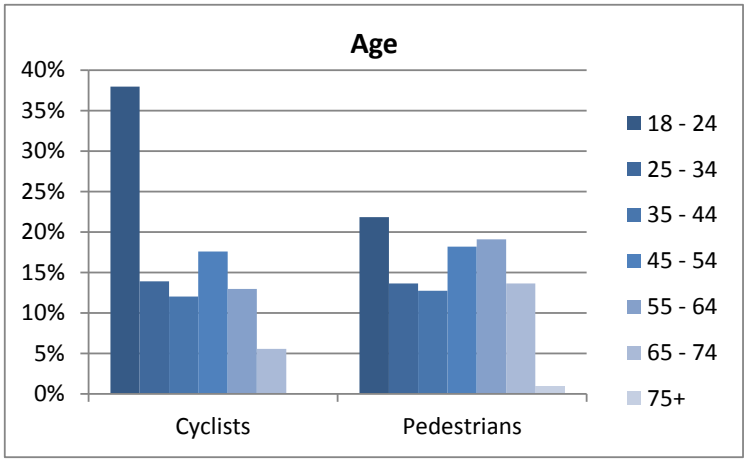

Figure 66: Participant ages

Just over a third of cyclist participants and 11% of pedestrian participants cycle once a week or more often. The range of cycling experience is shown in **Figure 67**. Note that this trial had an unusually high percentage of cyclists who cycle infrequently or not at all. While not ideal, sufficient experienced participants took part for the results of this trial to remain valid.

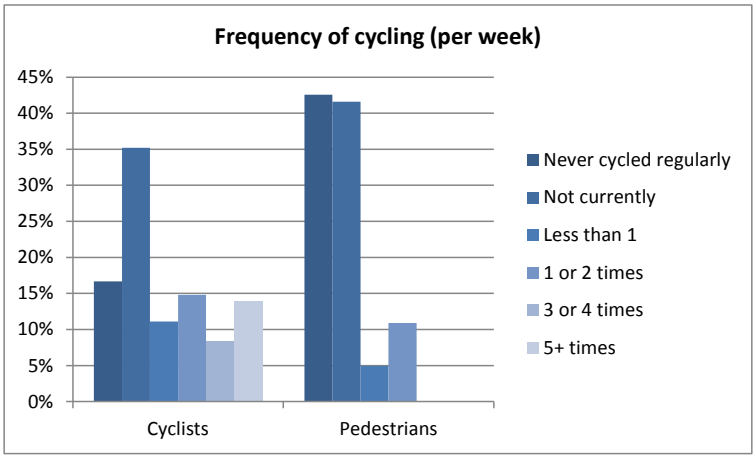

Figure 67: Participant cycling experience

3.1 Questionnaire Analysis Findings

3.1.1 Understanding how to navigate the roundabout

The extent to which participants understood how to navigate the roundabout can be inferred from responses to questions on noticing the cycle lane, understanding of the markings, cyclists giving way to pedestrians at zebra crossings, and whether the pedestrians considered crossing the cycle lane away from designated crossing points.

Cyclists

Most of the cyclists noticed the 'new' road markings (the white squares between the zebra crossing and the roundabout); just over a quarter gave a correct explanation of their meaning and most of the rest were 'safe' explanations including 'caution', 'warning' or 'give way'.

When approaching the roundabout at Arms 1, 2 and 3 where there were marked zebra crossings across the cycle lane, over 90% of cyclists understood who had priority, saying they prepared to give way to cyclists and that they would wait for the pedestrians to cross. At Arm 4, where there was no zebra crossing across the cycle lane, fewer cyclists (70%) understood the priority correctly and said they expected the pedestrians to wait for them; 14% said they would wait for the pedestrians, for reasons of safety, courtesy or because they thought the pedestrians had priority.

> *"No road markings signalling a crossing so I don't consider them to have right of way."*

Going round the roundabout while pedestrians cross, most pedestrians (85%) understood correctly that pedestrians waiting away from crossings should wait for the cyclist.

Understanding of pedestrian priority on leaving the roundabout was rather less complete, with around 80% of cyclists preparing to give way to pedestrians and between 81% and 94% saying they expected to wait for the pedestrians at Arms 1, 2 and 3. At Arm 4 68% correctly understood that they had priority over pedestrians; reasons for giving way to pedestrians were 'always' giving pedestrians priority, courtesy, confusion and thinking that pedestrians had right of way.

Some cyclists said that they thought the pedestrian crossings should be further from the roundabout to make it easier and safer for vehicles leaving the roundabout:

> *"Maybe pedestrian crossing needs to be a bit further away from exit points from roundabout.*

> *"Keep pedestrian crossing away from where cyclists come off roundabout to prevent a pile up."*

Pedestrians

Levels of understanding of the 'new' markings were rather lower among pedestrians than among cyclists. Two-thirds of pedestrians noticed these markings but 40% did not know their meaning; of those who did explain their meaning 19% gave the correct explanation although many of the others gave 'safe' explanations.

Most pedestrians said they looked for cyclists as they approached the crossing points, but relatively few (less than half) said they looked for vehicles, possibly because there were no vehicles in this trial.

At two of the designated crossing points where there was a segregated cycle lane, over 70% of the pedestrians said they noticed the cycle lane but only 41% did so where there was no segregated lane and therefore no break in the pedestrian crossing between the cycle lane and the road.

At the designated crossing points, most pedestrians (75 – 83%) correctly understood whether or not they had priority over cyclists who were approaching the roundabout,

and at Arms 1 and 4 where cyclists were leaving the roundabout. **There was a greater level of misunderstanding at Arm 2** where over 40% said they would wait for the cyclist leaving the roundabout even though there was a zebra crossing.

Few pedestrians (11%) said they considered crossing away from designated crossing points. Understanding of priority was also good, with over 90% correctly interpreting that cyclists had priority over them away from designated crossing points, although a few (2-4%) said they would expect the cyclist to wait.

One of the pedestrians remarked that there seemed to be a different approach to priority between single pedestrians and those walking in groups:

> *"There was a difference between a single pedestrian and in a group. As a single pedestrian I felt cycle groups seemed to "own" the crossing and the single pedestrian had to "ask permission" to cross."*

To gauge which arms were preferred by the pedestrians, they were asked how easy it was to cross the road at the various crossings. The results for the case where cyclists are leaving the roundabout are shown in **Figure 68**; the results when cyclists are entering are nearly identical. This shows that Arm 1 is the easiest, followed closely by Arm 2. Arm 4 is clearly the most difficult, almost certainly due to the lack of zebra crossing on the cycle path. Note that pedestrians were not questioned about Arm 3 as this is nearly identical to arm 2 from a pedestrian perspective.

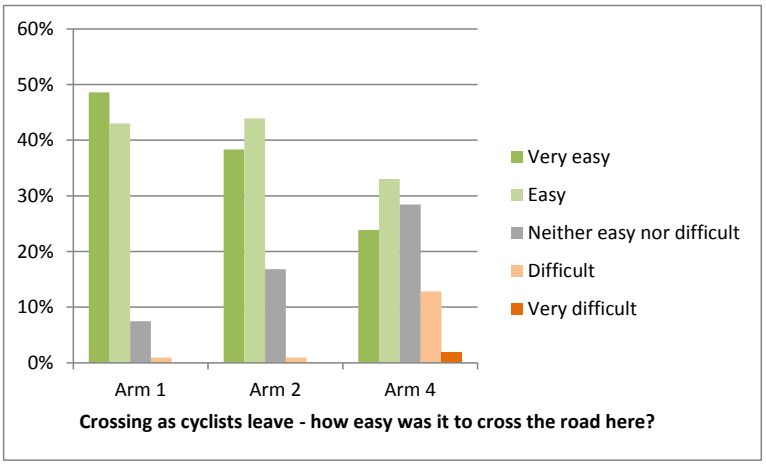

Figure 68: Ease of use at crossings

3.1.2 The influence of different aspects of layout

Cyclists

For cyclists entering the roundabout, Arm 3 was rated as more difficult and less safe than the other entry points owing to the lack of clear road markings, lack of cycle lane and the tight angle of the turn.

> *"Very tight turning into roundabout - essentially riding with flow of traffic."*
>
> *"Sharp turn onto the cycle lane - might miss cycle lane altogether."*
>
> *"Hard to see on approach plus left turn tricky to do without slowing."*
>
> *"This had the tightest turn into the cycle lane."*

For cyclists leaving the roundabout, Arms 2 and 3 were rated as more difficult and less safe than the other exit points owing to the sharp turn into the road at both exits and the proximity to the pedestrian crossing at Arm 3.

> *"Cycle lane disappears so with cars as well it would be difficult."*
>
> *"Joins main road which is dangerous as fast approaching cars could hit cyclist."*

The additional 5m separation between the pedestrian and cycle crossings at Arm 2 attracted little comment from cyclists. However there were some cyclists who said that it would be safer and easier for vehicles to leave the roundabout if there were a greater distance between the pedestrian crossings and the roundabout.

> *"Larger distance to stop and also to see if pedestrian will be crossing."* (rated 'Easy')
>
> *"More distance between exit and pedestrian crossing." (*rated 'very easy'*)*

Pedestrians

For pedestrians, crossing the entry and exit points to the roundabout were rated to be more difficult and less safe at Arm 4 than at Arms 1 and 2 – see **Figure 68**. The main concern was that there was no zebra crossing marked across the cycle lane at this point, only across the road. This led to uncertainty about who had priority, and therefore about predicting cyclists' actions.

> *"[A] lot of information to take in, unsure whether they'd stop - sometimes they did sometimes they didn't."*
>
> *"No road signs on cycle path so could easily be missed."*
>
> *"A cyclist was approaching as I got there and I was expecting it to stop."*

Some suggested that consistent zebra crossing markings at all of the crossing points would improve the scheme.

3.1.3 Perceived benefits and the influence on cycling in London

Cyclists

The majority of cyclists were in favour of taking advantage of the cycle lane around the roundabout. In heavy traffic, over 90% said they would use it in preference to the road and 75 - 84% in light traffic (depending on whether they were turning right, left or going straight on). Most cyclists said it was easier to use than an ordinary roundabout.

Almost all cyclists said they thought cyclists would benefit from the cycle lane round the roundabout, and many thought that motorists and pedestrians would benefit.

> *"London cycling is not for the faint hearted. This roundabout would vastly improve the status of cyclists on car dominated roads."*

Among the small number of negative comments, the most common topics were risk, uncertainty, which way to go or priority.

> *"It confuses a roundabout even more than it already is. We have the minority as cyclists in the UK and this sort of roundabout I don't think would be adhered to."*

Turning left using the cycle lane in quiet traffic was seen as 'safe' or 'very safe' by almost all cyclists; 4% said it was 'unsafe'. Safety ratings were slightly lower for going straight on and turning right in quiet traffic but similar proportions said it was 'unsafe'. Turning right in heavy traffic was rated as least safe, with a quarter describing this as 'unsafe' or 'very unsafe'; a fifth thought turning right or going straight on would be 'unsafe' or 'very unsafe' in heavy traffic.

Just over 40% of cyclists said they thought it would affect how often they cycle in London if there were cycle lanes like this on roundabouts there. The main reasons given were about safety and separation from traffic. However only 11% of these currently cycle in London and half do not currently cycle at all. A few mentioned that they would consider using Barclays Cycle Hire bicycles. Those who said that the Dutch roundabout would not influence cycling in London mainly said they do not or would never cycle in London. These results cannot therefore be used to assess the extent to which the orbital cycle lane would increase cycling in London, but do provide an indication that some would feel more positively about it. Note that as all participants were required to use the orbital cycle lane, these observations only relate to cyclists using the orbital lane.

> *"At the moment I refuse to cycle in London as the traffic is too dense. Cycle lanes would help enormously to separate cyclists/motorists and pedestrians."*
>
> *"It would encourage me as I would feel safer."*
>
> *"I might be tempted to use a Boris bike if it was safer."*

Pedestrians

A majority of pedestrians said it was easier or much easier to use for people walking than an ordinary roundabout but 16% said it was 'more difficult' and 2% 'much more difficult'. Difficulties mentioned were more lanes to cross, more to look out for and confusion. Some mentioned lack of signs and the absence of zebra crossings at some points.

> *"[I] did not like the fact that part of crossing was zebra and pedestrian priority and part was vehicle/cyclist priority – confusing."*
>
> *"To cross safely I expected the zebra crossing to cover all lanes, not just those used by motor vehicles."*

Almost all pedestrians thought cyclists would benefit from the cycle lane round the roundabout, almost half thought motorists would and two thirds thought pedestrians would benefit. The negative comments from pedestrians were about complexity, confusion and safety.

One third of pedestrians said they thought it would affect how often they cycle in London if there were cycle lanes like this on roundabouts there. However only 3% of these currently cycle in London and three-quarters do not currently cycle at all.

3.2 Focus Group Findings

3.2.1 Cyclist Focus Group Findings

Twenty eight cyclists took part in three separate focus groups. They included both males and females with a range of cyclist abilities and experience.

Participants had varying opinions of the layout of the roundabout and there were notable differences in views between confident and less confident cyclists. Participants with children were complimentary of the design and liked the segregation between vehicles and bikes. Some participants stated that they currently avoid roundabouts when cycling with their children but would be encouraged to cycle more if this concept was implemented.

> "*If with children would use it…if alone and in a hurry would avoid it*";
>
> "*…found the design disappointing…can see the benefit to less confident cyclists and children*".

A number of participants commented that there was a lack of signage and road markings to indicate whether cyclists or pedestrians had the right of way. In addition, although the trial did not include cars, participants expressed some concerns about interactions with vehicles. Firstly, there were concerns that drivers may not realise they should give priority to cyclists and secondly, there were concerns that if drivers gave priority to cyclists, tailbacks would develop.

> "*…big bike symbol at the entrance to the cycle lane let you know exactly what it is for*";
>
> "*Roundabouts are confusing anyway for a lot of drivers…if you then stick loads of lines in and then a crossing and a cyclist crossing there is a lot to consider for a driver*";
>
> *"At the junction with no markings you had to be extra careful and it felt dangerous".*

A number of participants felt that certain approaches to the roundabout were ambiguous. Cyclists felt the design of some approaches '*pulled the cyclist in*' whereas with other approaches, it was ambiguous as to whether cyclists should enter the cycle lane which could lead to some cyclists using the main carriageway rather than the cycle path. Some participants suggested that the cycle lane could be covered in coloured tarmac to highlight it to cyclists and other road users. From a safety point of view, a number of the participants suggested they felt they were 'in a safe tunnel' and unaware of their surroundings because of the segregation. There was also concern that drivers may be unaware of the cyclists on the cycle path which could pose a danger at the crossings.

> *"One turning had enough distance between the roundabout and the crossing, the others were too close…it was dangerous".*
>
> "*…felt tunnelled, makes it easy to forget about checking for cars*";
>
> "*The design separates the cyclists from the traffic and as such cyclists will become complacent of their surroundings and go into auto-pilot which could be dangerous*".

A further criticism was the height of the kerbs along the cycle lane. Participants suggested that if there was debris in the road or a pot hole the cycle paths were too narrow to be able to safely avoid these obstacles. In addition it was felt that the cycle path was too narrow for overtaking and therefore, faster, more confident cyclists would be delayed. More confident cyclists were therefore concerned about being forced to use the cycle lanes if this was made compulsory. Some participants thought that drivers would expect cyclists to use it at all times whereas more confident cyclists stated they

would rather use the road. There was a common theme amongst confident cyclists that they would use the cycle lane for turning left, however if travelling straight on or turning right the cycle path would cause an unnecessary delay and they would use the road instead.

"…not wide enough to overtake";

"…turning right was a real chore as so much further to go".

A further concern expressed by a regular and confident cyclist was maintenance and gritting of the cycle paths and whether the paths were wide enough to allow a street sweeper along. Some participants commented that cycle paths are generally badly maintained with pot holes common place. It was also felt that cycle paths are generally too narrow for road sweepers. One participant commented that it would be essential to grit these cycle paths during icy conditions otherwise they can become impassable.

"…kerbs were too high…you couldn't swerve away to avoid glass or overtake"

Overall, participants generally felt that the cycle path would benefit cyclist safety and it was felt this would benefit cyclists in London. There was a strong feeling that this would increase cycling safety for children and that parents would be encouraged to cycle more. However more confident cyclists were concerned that if the cycle lane was compulsory, their journeys would be hindered as they would be delayed. Suggestions made to improve the cycle lane included widening the cycle path, lowering kerbs to allow for overtaking and allowing the cycle path to be travelled in both directions.

3.2.2 Pedestrian Focus Group Findings

Participants generally felt the roundabout would contribute to the safety of cyclists, with a number of pedestrians suggesting they would be encouraged to cycle more if it was introduced. A small number of participants suggested the staged crossing meant there was more for a pedestrian to consider and that cyclists appeared from pedestrian blind spots as the cycle lane emerged from behind them. Other participants had contrasting views and felt that the staged crossing contributed to safety and they would be happier when crossing with children. However a limited number of participants suggested the crossings needed wider islands in the centre as these would be insufficient for those with buggies or for large numbers of pedestrians.

"…definitely felt safer crossing it";

"…as a pedestrian I felt safe; because it is easier to spot the cyclist…cyclists often spring out from behind cars";

"…the layout is not for pedestrians really, it is more for cyclists";

"…needed to warn pedestrians of the two lanes of traffic, followed by a cycle path to cross".

Participants reported that on first approaching the roundabout they found the layout to be very hectic and one participant suggested it was visually 'hammering'. However, having navigated the layout a few times, participants found the design straightforward and were able to navigate it. Participants were critical of the lack of signage and road markings suggesting that clearer markings were needed to clarify whose right of way it was and to inform pedestrians of the layout ahead. A number of recommendations were made to contribute to the safety of the roundabout, these included, colour coding cycle

lanes, increasing the number of bike symbols on the road and having road markings informing pedestrians of the direction traffic was approaching from. Participants suggested they would be concerned that cyclists would not stop at the crossings and the arms where zebra markings continued across the cycle path were preferred.

> *"…excessive black and white markings were visually hammering"*
>
> *"…didn't understand the white square markings on the road";*
>
> *"Cyclists are a rule to themselves; they don't stop for red lights let alone a zebra crossing".*

There were varying opinions over the location of the zebra crossings; it was felt by a number of participants that crossings which were close to the roundabout were hazardous. However some felt if crossings were placed further from the roundabout then pedestrians would be reluctant to walk to them and as such may not use the zebra crossings at all. A limited number of participants suggested installing railings to channel pedestrians to the zebra crossings.

> *"Crossings need to be further away from the roundabout for drivers to be able to assess the crossings clearly";*
>
> *"…there would be an inclination not to use the zebra crossings which were set back from the roundabout".*

Participants felt that the layout would contribute to safety in busy environments; however there was concern that on fast roads both cyclists and drivers may be less likely to give priority to pedestrians. Therefore it was suggested that the layout could incorporate speed limits and speed bumps to slow traffic or traffic lights to assist with safety and fluidity of traffic. In addition, there was concern that cyclists may opt to use the road rather than the cycle path if it was congested or if they did not see a need to use the cycle path. It was felt that this could pose a safety risk and as such the idea of whether use of the cycle path would be compulsory was discussed.

> *"…not confident of walking onto a zebra crossing and expecting the driver to stop";*
>
> *"…in a busy road in London people would definitely use it";*
>
> *"…cyclists need something to inform them that pedestrians are crossing".*

B.7 M26 Cycle-Cycle Interaction Findings Report

Findings report: Dutch Roundabout Cycle/Cycle interaction (M26) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. On Arms 1, 3 and 4 the Zebra crossing are directly alongside the cycle path where it crosses the car lane, whereas on Arm 2 there is a 5m gap between the Zebra crossing and the cycle lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority
- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

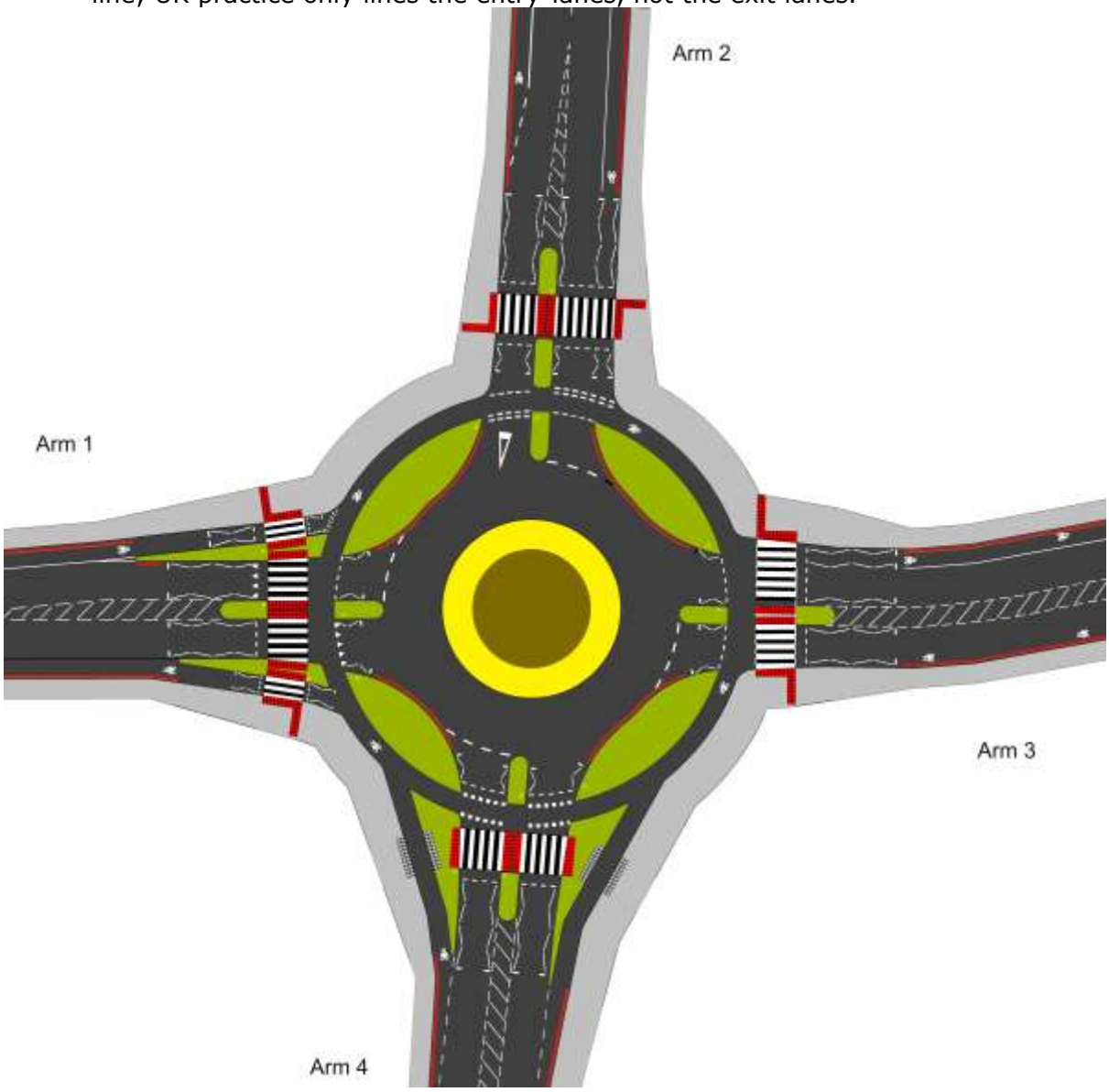

Figure 69: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes.

1.2 Introduction to the M26 trials

The primary objectives of the M26 trials were to establish how cyclists using the orbital cycle lane interacted with other cyclists using the vehicle lane (main circulatory lane) to

go around the roundabout. Therefore only cyclists were present on the roundabout throughout this trial.

The two participant groups (cyclists using the cycle lane and cyclists using the vehicle lane) were required to execute specific movements on the roundabout during which they would potentially come into managed conflict[5] with each other. In particular, the trials investigated:

- How cyclists understand/interpret the markings when other cyclists are present
- How cyclists use the roundabout when other cyclists are present
- To assess any delays occurring through variations in route choice (use of cycle lane or main lane) and uncertainties (reduction in speed as a precaution) occurring as a result of other users being present
- To assess the potential safety of the roundabout with respect to misinterpretation/misuse which could lead to conflicts, and reduced safety margins (with respect to distance), between the cyclists.

The trials were held on three days between 30th September and 3rd October 2013.

2 Methodology

The participant cyclists were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant started on one of the arms of the roundabout and was asked to ride up to the roundabout, and either turn left, go straight on, or turn right, and which lane to use (cycle or main car lane). No participants had seen the roundabout before the trials started. A total of 16 cyclists were on track at any one time.

The cyclists were divided into two groups, 'red' and 'blue'. At the start of each movement, there were two cyclists from each group at each start arm. One trial facilitator released a 'red' pair of cyclists. The cyclists were asked to ride up to the roundabout, and either turn left, go straight on, or turn right, and told which lane to use (cycle or main car lane). A second facilitator released a 'blue' pair of cyclists (from the same or a different start arm) with similar instructions, but using the other lane. The releases were timed so that the two pairs interacted at some point (entry, circulating or exiting) on the roundabout

At the end of each movement, each participant cyclist was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed (e.g. did you understand marking "x") and open (e.g. do you have any suggestions for making "y" clearer) questions.

Fourteen randomly selected participants were also invited to take part in a focus group where the roundabout was discussed.

[5] A traffic *conflict* 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." (Amundsen & Hyden, 1977)

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings were used to measure the effect of interactions on journey times.

Data were provided by the questionnaires, the focus group transcripts, video analysis and staff observations of participant behaviour. Statistical analysis of the questionnaire data have made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted that if a finding has occurred with a probability of 5% or less that it could have occurred by chance (expressed throughout this report as 'p<.05'), then it is statistically significant. Sometimes the probability of a chance finding will be less than 5% and this is expressed accordingly (e.g. p<.0005 means probability was less than .05%).

3 Summary of Findings

127 cyclists took part in this trial, of which just over 60% were males. There was a wide spread of age groups but two-thirds were aged 45 – 74. The distribution of participant ages is shown in **Figure 70**.

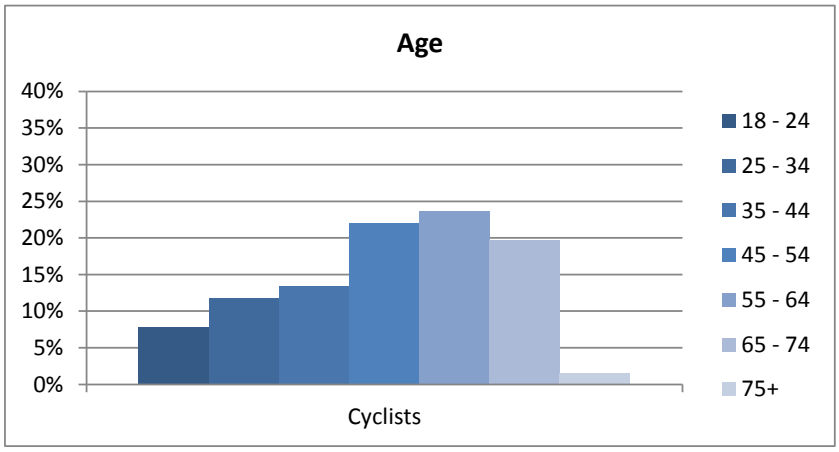

Figure 70: Ages of participants

Half of the participants said they cycle once a week or more often; 9% said they cycle at least 5 times a week. Just over a third said they do not usually cycle, but many of these had cycled regularly in the past. **Figure 71** shows how frequently the participants cycle.

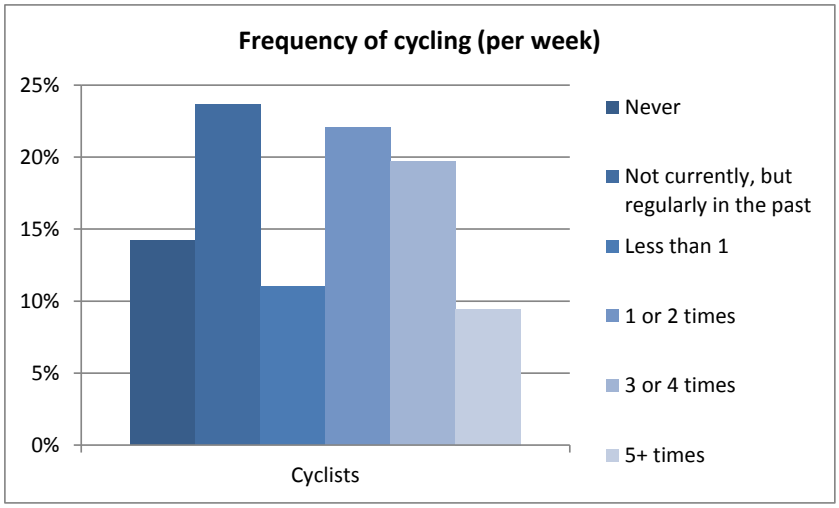

Figure 71: Frequency of cycling

When cycling, leisure journeys were the most frequent type of journey by 66% of participants; the next most frequent types of journey were for work or business (13%) and to work or education (12%).

One third (34%) of those who currently cycle said their most frequent cycling journey was over 5 miles and almost all (89%) said their most frequent journey was over a mile.

Most of those who currently cycle (64%) said they usually cycle on the roads (in traffic) or in cycle lanes on the road; 18% usually cycle on separate or shared paths and 18% usually cycle off road. Just under a third of those who currently cycle (30%) said they cycle in London; 8% once a week or more, 6% a few times a month and 16% less than once a month.

3.1 Questionnaire Analysis Findings

All participants completed a detailed questionnaire after completing the trials. This section gives details on these responses.

3.1.1 Understanding how to navigate the roundabout

3.1.1.1 Cyclists' preferred lane

The majority of cyclists were in favour of taking advantage of the cycle lane round the roundabout in a busy town or city, as shown in **Figure 72**. This shows that the decision on which lane to use is affected by both the direction of turning and weight of traffic. The effect of weight of traffic is considerably greater on cyclists going straight on or turning right than on left-turning cyclists.

As well as the amount of traffic and which way they were turning, the presence of a cycle lane on the approach to the roundabout and cycling speed were factors influencing the decision. The less frequent cyclists were rather more likely to prefer the cycle lane than those who cycle at least once a week.

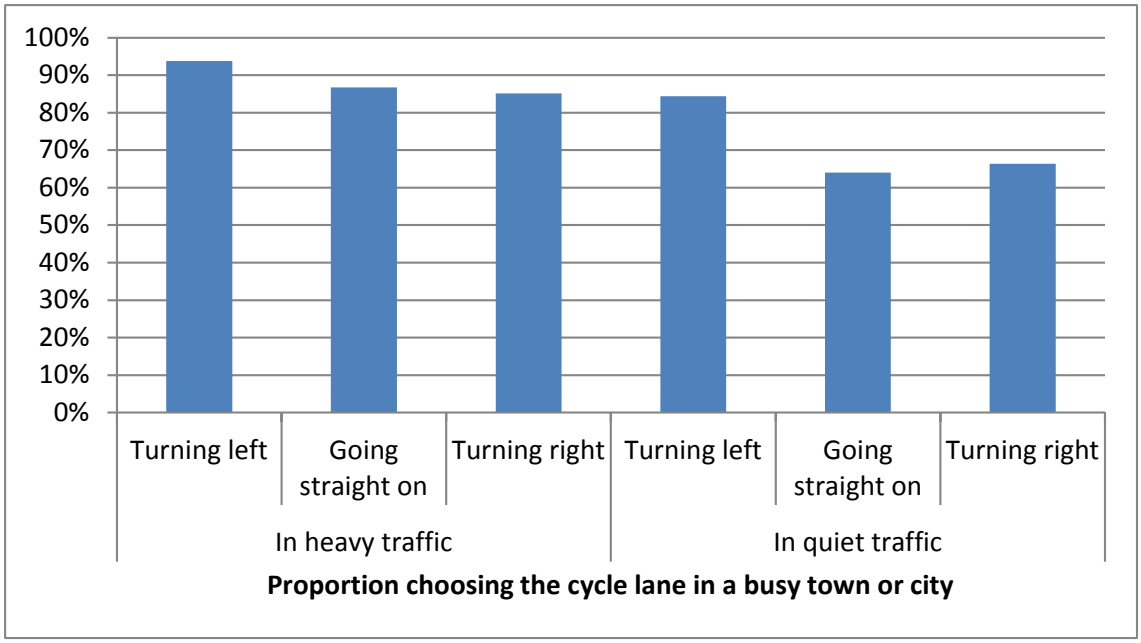

Figure 72: Choice of lane

3.1.1.2 Willingness of cyclists be to use the orbital lane as intended

A relatively small proportion of cyclists said they would consider using the cycle lane to take a short cut and go anti-clockwise roundabout to turn right (although it should be borne in mind that they experienced the roundabout without any other traffic present); 14% in heavy traffic and 13% in quiet traffic.

> *"Decision to use cycle lane or road depends heavily on approach. If I am already in cycle lane I would probably continue to use cycle route. If on road, I would only use cycle lane if entry was good (e.g. Arm 4) and I was turning left. For turning left I would use the cycle lane except from Arm 3."*
>
> *"On any roundabout I would always use the main roundabout for right turns."*
>
> *"Many regular cyclists would avoid this cycle path as the flow would be reduced and would go straight onto normal roundabout, thus bringing a cost into a balance against usage."*

A majority said they would not consider it (70% in heavy traffic and 72% in quiet traffic). Those who cycle less frequently were rather more likely to consider going anti-clockwise to turn right than those who cycle at least once a week

3.1.1.3 Cyclists' interpretation of the different types of markings and layouts

Just over two-thirds of the cyclists (68%) said they noticed the white squares near the crossing – markings which are 'new' to UK roads. Correct explanations of their meaning were given by 24% of cyclists. Most of the others gave 'safe' interpretations in their explanations: 'give way to cyclists', 'give way', 'caution', 'warning' or 'stop'. A minority (16%) said they did not know the meaning of the markings.

Details of the interpretation of markings are given in **Figure 73**.

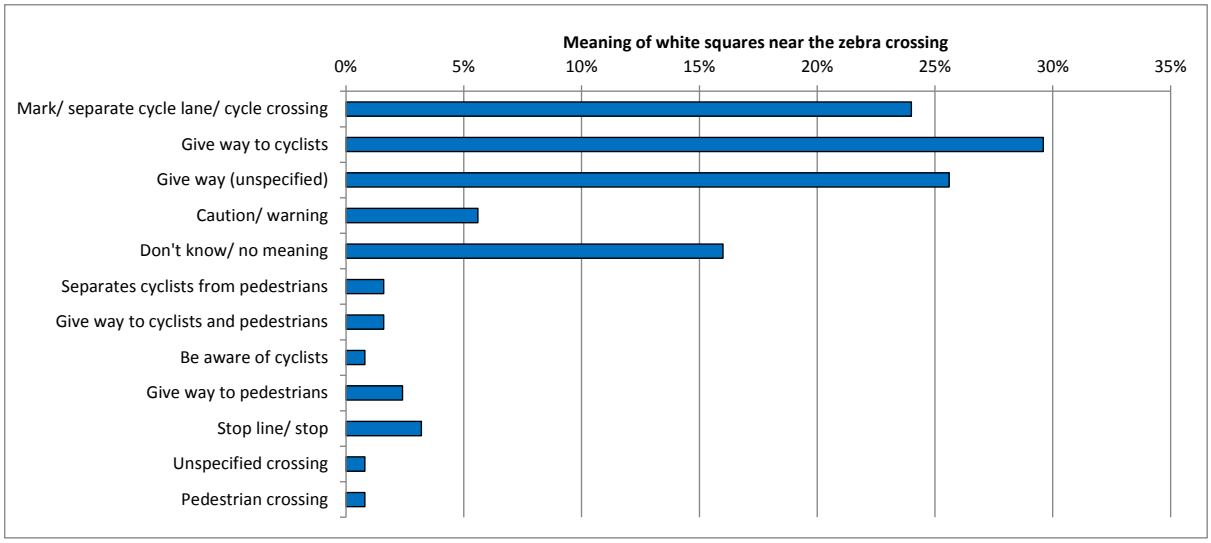

Figure 73: Interpretation of road markings

Many participants suggested improving the signs and markings to clarify priorities and make the cycle lane more noticeable.

> *"… mak[e] it obvious that exiting from roundabout they must give way to bikes and pedestrians."*
>
> *"Clearer give way markings."*

Some would have preferred fewer and simpler markings and some advocated traditional markings, for example to help users respond instinctively.

> *"Reduce road markings - use solid lines when you are expected to stop. Keep signage to a minimum near all roundabouts."*
>
> *"Clear signs explaining rights of way."*
>
> *"Give way signs for the cycle track all way round."*
>
> *"A new roundabout sign or notice explaining that roundabout is Dutch (pictures drawn) or some symbol to indicate bike lane round outside of motor roundabout."*

3.1.1.4 Willingness of cyclists to give way to other cyclists when entering and leaving the roundabout

Understanding of priorities was investigated both from the point of view of cyclists on the road and cyclists on the orbital lane.

Cyclists on the road

Normal traffic rules apply when entering the roundabout, so this scenario should be familiar to participants. On average 87% of cyclists said that when entering the roundabout on the road they prepared to give way to cyclists crossing, and 85% said they would have given way if they had seen a cyclist crossing on the cycle lane. These proportions did not vary much between the layouts.

The willingness of cyclists to give way when exiting the roundabout is shown in **Figure 74**. On average 75% of cyclists said when leaving the roundabout on the road they prepared to give way to cyclists crossing, and 76% said they would have given way if they had seen a cyclist crossing on the cycle lane. In each case the proportion was

higher at Arm 2 (84% prepared to give way and 85% said they would have given way) than at other arms. The 'give way' triangle on the road at Arm 2 increased the level of understanding and reduced uncertainty about priorities for cyclists on the road.

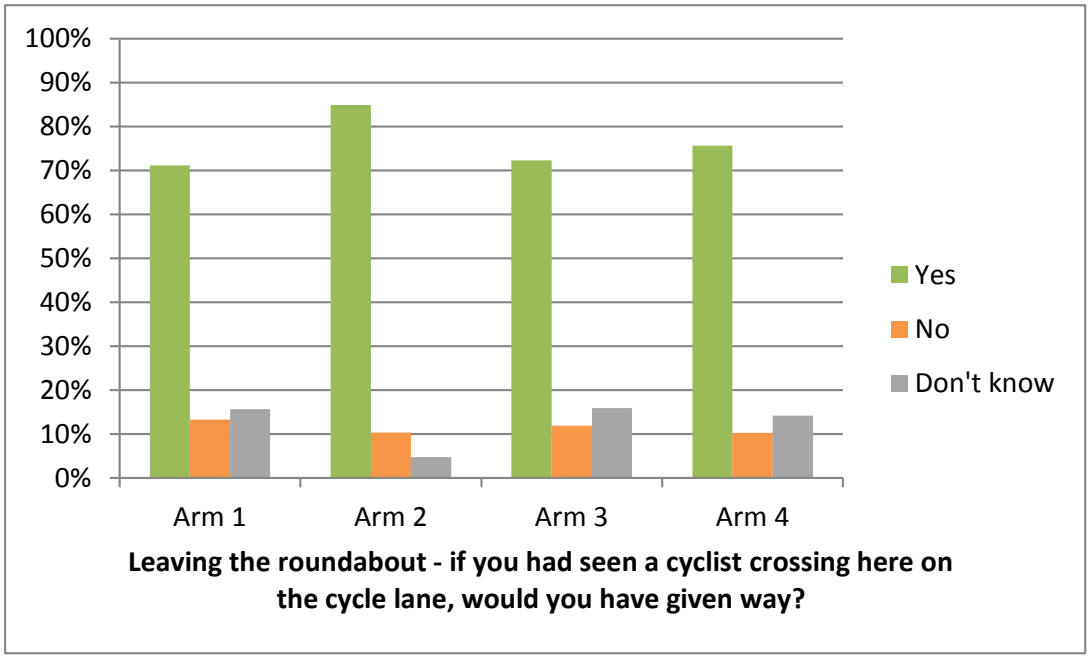

Figure 74: Willingness to give way on exiting the roundabout

Cyclists on the orbital lane

When using the orbital lane, there was also a reasonably good level of understanding that cyclists using the orbital lane had priority over other cyclists approaching the roundabout, but some were prepared to accede priority for reasons of safety or 'fitting in' to maintain flow, and a few did not understand that they had priority over cyclists approaching the roundabout.

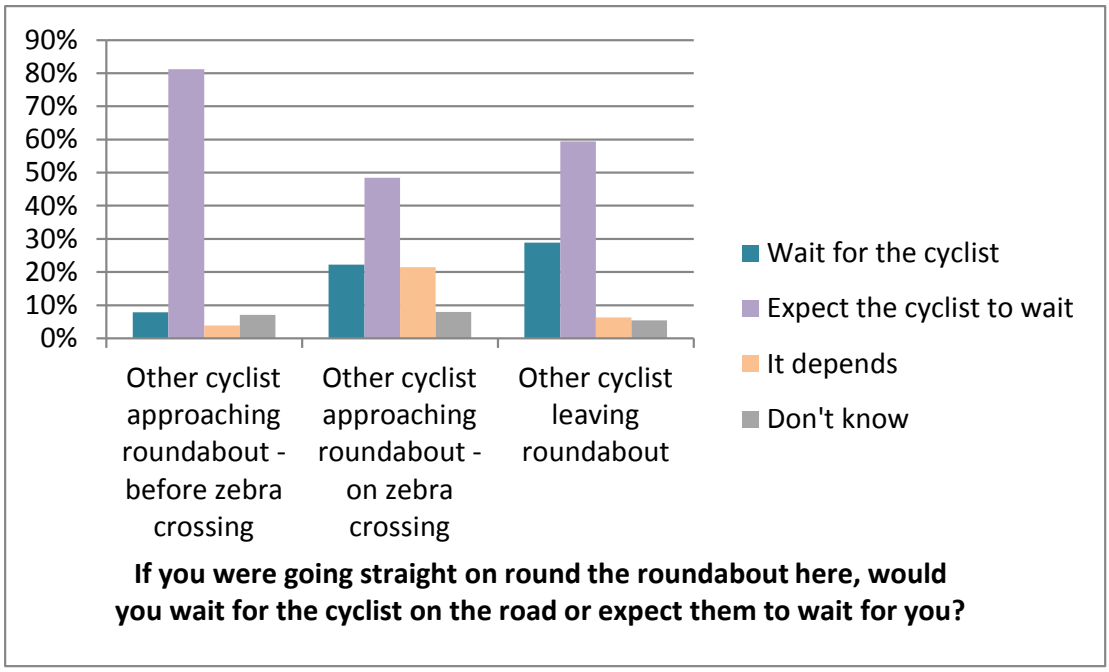

Figure 75: Willingness to give way

Cyclists on the orbital lane mostly expected cyclists approaching the zebra crossing before the roundabout to give way to them (81%) as shown in **Figure 75**, but if cyclists approaching the roundabout were on the zebra crossing and therefore closer to the orbital lane, cyclists on the orbital lane were less likely to expect the cyclists on the road to give way: 48%. Others thought it would be safer or avoid delays if they waited:

"It would be safer for me to stop rather than the cyclist on main road to stop."

"Cars behind them, more danger for them, keep the traffic flowing."

In the case of cyclists already on the zebra crossing, this was seen by some as being past the point where they should stop or where it would be safe for them to stop, so giving way to them was seen as the safest option for the other cyclists on the road.

"They are already into the crossing - me to give way."

Cyclists on the orbital lane were rather less likely to expect to give way to cyclists leaving the roundabout on the road; 59% said they would expect the cyclists on the road to give way to them. However, some said they would wait for cyclists on the road because it was more dangerous for cyclists on the road to give way than it was for cyclists on the orbital lane. There are therefore two contradictory opinions over who would give way, although most understood who should give way. Furthermore, 18% misunderstood the priority owing to assumptions made through familiarity with regular roundabouts, saying they would give way either because the cyclists were on the road, or would give way to the cyclists because they were approaching from the right.

"Because of the law for cars, give way to right."

"Coming from the right and being in the roundabout, he would have the right of way."

"He had priority - give way to the right."

When cyclists were leaving the orbital lane to exit the roundabout and re-join the exit arm there was also some confusion about priorities. At Arm 3 42% of cyclists said they expected the cyclists on the road to wait for them; a higher proportion (65%) did so at Arm 2 where the 'give way' triangle marked on the road helped to clarify who had priority. As in the case of cyclists continuing on the orbital lane, a number of cyclists leaving the orbital lane thought they should give way to cyclists leaving the roundabout on the road, either because they were on the road or because they were approaching from the right.

To clarify the priorities, some suggested using signs, stop lines, lights or a coloured surface on the cycle lane.

"Lights or similar warning to car drivers when cycle lane joins main carriageway."

"Make all areas where traffic crosses clear as to who has right of way."

"Signage is needed to better explain priorities as it was very confusing in places."

"To have more stop lines at junctions."

3.1.2 The influence of different aspects of layout

In general, participants rated the roundabout as 'easy' or 'very easy' and 'safe' or 'very safe' to use, but a minority found it difficult and unsafe. There were more differences in

ratings of ease of manoeuvring and safety between the various entry and exit treatments on the cycle lane than when cyclists were using the road.

In making general comments about the roundabout, several participants were in favour of implementing it on a wide scale. Several mentioned ideas for education, publicity and information signs to help users understand the roundabout. A few were concerned about potential detrimental effects – congestion and the amount of space taken up were mentioned.

When compared with an ordinary roundabout, the majority said it was easier to use (35% said it was 'much easier' and 39% said it was 'easier'); 9% said it was 'more difficult' and 2% said it was 'much more difficult'. This is illustrated in **Figure 76**.

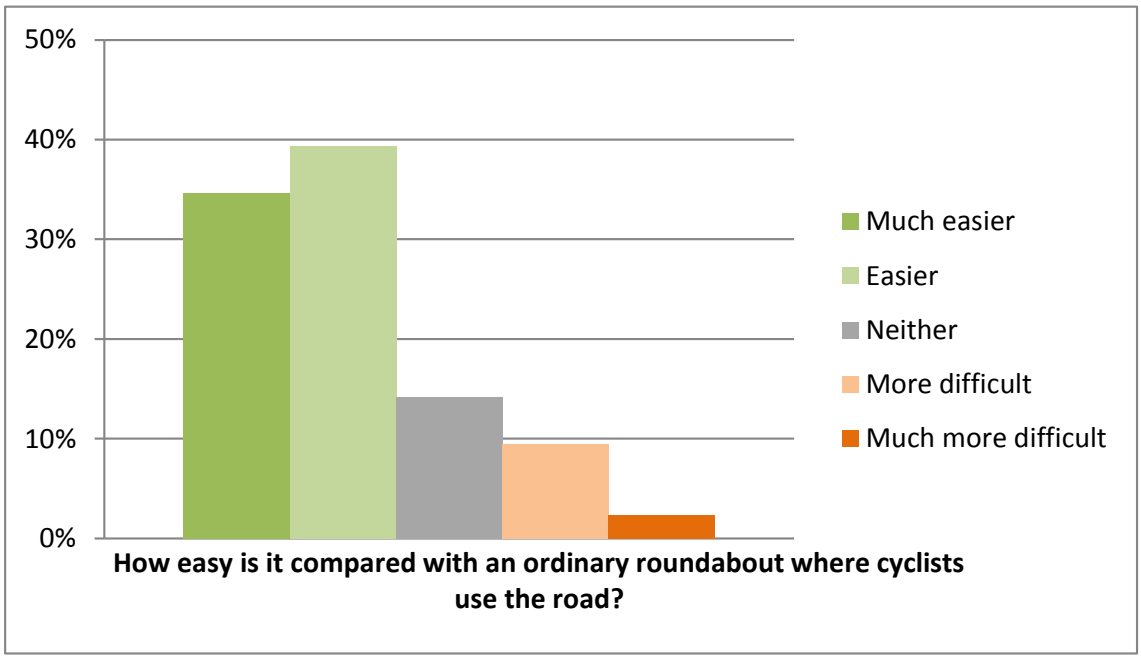

Figure 76: Compared to ordinary roundabouts

Cyclists who found it easier than an ordinary roundabout mainly explained this was because they were separate from traffic and felt safer; previous trials have shown a high correlation between participants' scores of ease of use and safety. Some said they could go at their own pace and did not need to position themselves in the traffic. Those who found it more difficult tended to say that the workload was greater, the priorities were uncertain, or that it is confusing or complex; a few said it was slower, and people needed to get used to it.

3.1.2.1 Cyclists on the cycle lane

Perception of ease of manoeuvring and safety

Unsurprisingly, cyclists thought it would be safer in quiet traffic than in heavy traffic. In traffic, cyclists rated turning left as the safest manoeuvre and turning right as the least safe. Some thought that the scheme would not be of benefit in heavy traffic.

A number of cyclists suggested improving the geometry of the orbital lane to make it easier and safer to use. Suggestions included a wider cycle lane with no sharp turns, raised crossings, continuing the cycle lanes after the roundabout and segregating the cyclists leaving the roundabout from those cyclists continuing round the orbital lane as

early as possible. Several said it would work better if the crossings were further from the roundabout. Some suggested that the layout at Arm 4 would be the best one to implement; one said the layout at Arm 4 with the zebra crossing further from the roundabout as at Arm 2 would be the best option, and another said Arm 1 would be best layout.

> *"I think that drivers would be confused and this junction would just cause accidents & traffic jams. If large numbers of cyclists used the cycle lane, motor traffic would hardly move & may accelerate quickly through gaps in the cycle traffic, causing problems with pedestrians crossing. Also, the crossings are too near to the cycle path."*

Variation of ease of manoeuvring and safety with different entry treatments

Ease of entry is shown in **Figure 77**. Cyclists found it easiest to enter the cycle lane before the roundabout at Arm 1 and Arm 4 (the segregated lanes). It was found to be most difficult at Arm 3 (9% said it was 'difficult' and 2% said it was 'very difficult'); here the cycle lane before the roundabout was marked by cycle symbols on the carriageway, so some cyclists were unsure about where the cycle lane was. At Arm 2 cyclists who found it difficult to enter the lane were also unsure about where it started.

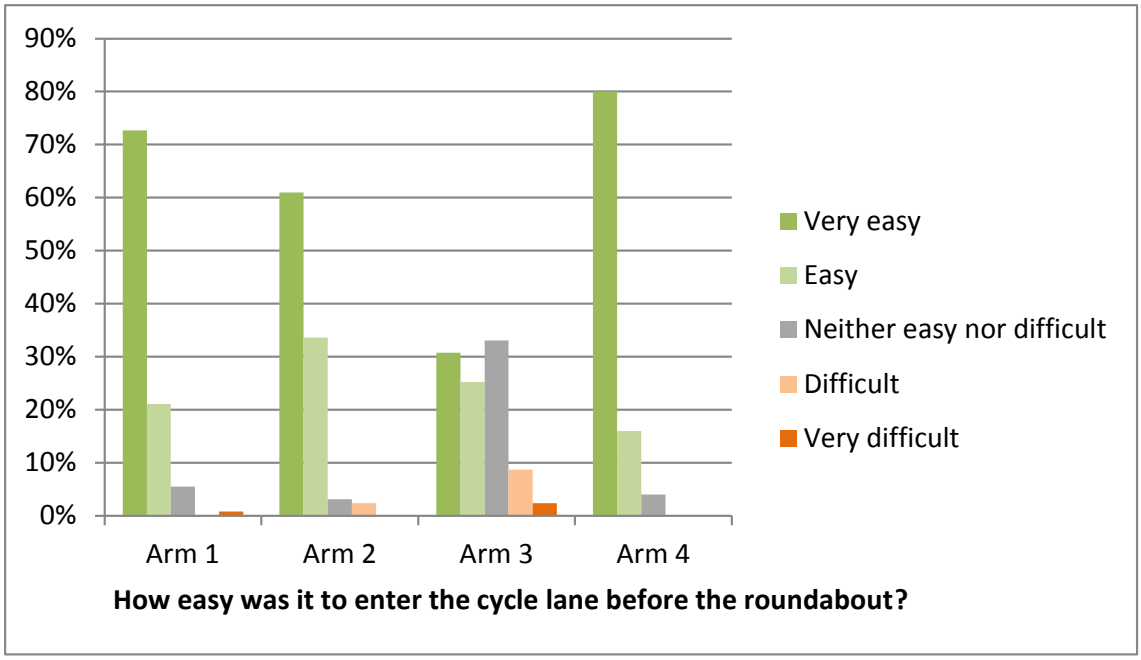

Figure 77: Ease of entering the roundabout

Joining the orbital cycle lane was also more difficult for cyclists at Arm 3 and least safe; 21% said it was 'difficult', 2% said it was 'very difficult', 7% said it was 'unsafe' and 1% said it was 'very unsafe'. The difficulties described here were that the turn into the orbital lane was very tight so cyclists had to slow down (or stop) and some found themselves pulling out into the centre of the road to make the turn; also the orbital lane was difficult to see especially while looking out for other road users.

> *"VERY tight unmarked corner! Needs to be signposted as to whereabouts with markings leading you into! Corner too sharp."*

> *"Not clear where cycle lane is - if anywhere."*

"Cycle way is not clear/non-existent!"

Some said there was too much to think about and thought it was unsafe to be stopping and starting separately for the zebra crossing and the cycle crossing.

A few cyclists described difficulties at other entry points. At Arm 1 (where there was a segregated lane) the sharp turn to the left into the lane and narrow entrance made it difficult to see and slowed some cyclists down, while some thought giving way to cyclists on the orbital lane would be unsafe.

"Slightly tight angle to turn if going at speed."

"The entrance was a bit narrow and the angle quite sharp."

Similar difficulties were mentioned at Arm 2, although one described it as better than Arm 1. Giving way to cyclists was also thought by some to be unsafe at Arm 4, where the sharp corner was found to be difficult. The high kerbs were mentioned as a hazard (catching wheels and pedals) at Arm 1 and Arm 3 particularly.

"The kerb might be a problem with more traffic."

Variation of ease of manoeuvring and safety with different exit treatments

As shown in **Figure 78**, cyclists found it easiest and safest to leave the orbital lane at Arm 4: almost all rated it as 'easy' or 'very easy' and 'safe' or 'very safe'. At this point there was a gradual fork in the segregated lane for cyclists leaving the roundabout.

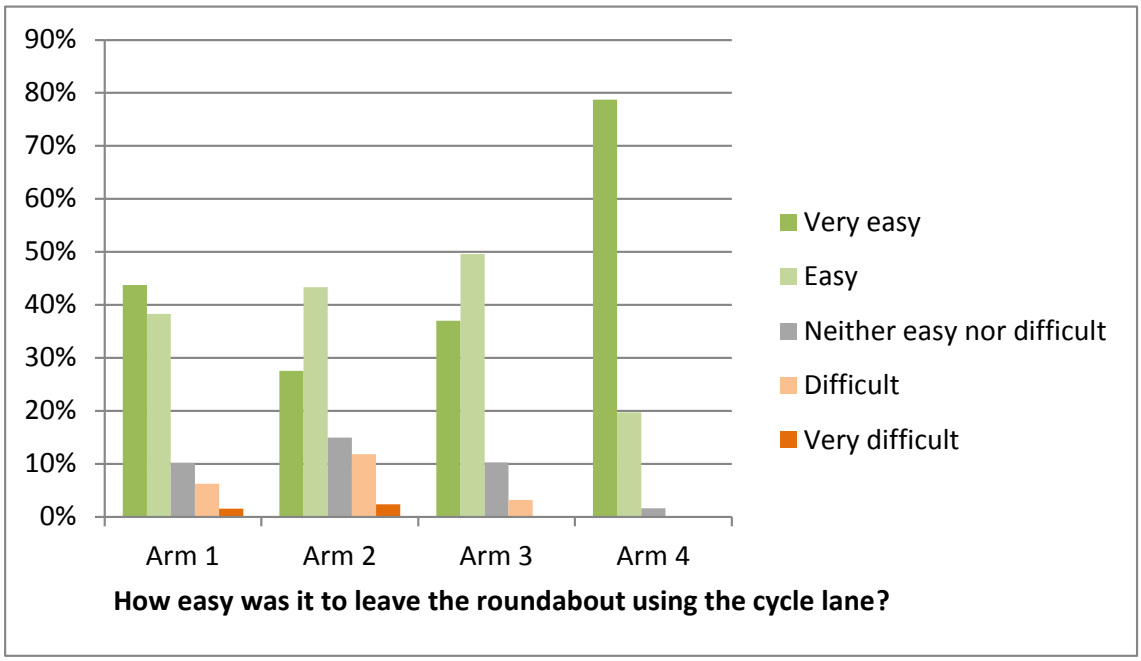

Figure 78: Ease of leaving the roundabout

Leaving the orbital lane was rated as most difficult and least safe at Arm 2: 12% said it was 'difficult' and 2% 'very difficult', 18% said it was 'unsafe' and 5% said it was 'very unsafe'. Leaving the orbital lane at Arm 2 involved a sharp left turn into the road – some pulled out into the middle of the road to make the turn and some were concerned at being in the driver's blind spot at this point; other difficulties mentioned were the unexpected end to the cycle lane, trying to look simultaneously for cars behind and pedestrians in front, uncertainty about priorities and the proximity of the pedestrian

crossing. In general comments, one participant said that the exit at Arm 2 would be the one to avoid.

> *"Cycle lane suddenly ends without warning, throwing cyclist into lane of traffic."*
>
> *"First time I didn't know if I had gone right way. Not a good entry into traffic even though cyclists should have priority."*
>
> *"Sharp corner into flowing traffic, not clearly marked as to who has right of way."*
>
> *"It is difficult in that regardless of whether I had priority, it would be challenging to do at any reasonable speed, while ensuring that traffic leaving the roundabout would not hit me. It almost certainly requires swinging out into the lane, hence difficulty."*

At Arm 1 8% found it difficult leaving the orbital lane, mainly due to the sharp turn but also watching out for pedestrians while making the turn. Leaving the orbital lane at Arm 3 also involved a sharp left turn but was 'sheltered' from vehicles leaving the roundabout by a kerb and 3% found it difficult; the angle of the turn, lack of cycle lane markings on the road and proximity to the pedestrian crossing were mentioned as difficulties.

> *"I believe this is the one I pulled out into the road as the cycle lane was not so well defined & separated."*
>
> *"The demarcation of the left hand cycle lane isn't clear."*
>
> *"Very tight turn. Still risk of vehicle on RHS impacting."*
>
> *"Slightly tight angle."*

3.1.2.2 Cyclists on the road

Cyclists' perception of ease of manoeuvring and safety

Just over three-quarters of participants said it was 'very easy' or 'easy' going found the roundabout using the road; the one who said it was difficult was not happy cycling on the main roundabout.

As expected, cyclists also thought it would be safer cycling on the road in quiet traffic than in heavy traffic. On the road in traffic, cyclists rated turning left as the safest manoeuvre (54% said 'very safe' and 30% said 'safe' in quiet traffic, 7% said 'very safe' and 46% said 'safe' in heavy traffic). Turning right was rated as the least safe manoeuvre (17% said it would be 'safe' or 'very safe' in heavy traffic and 41% did so in quiet traffic).

Safety issues mentioned for those joining the roundabout were negotiating the traffic, particularly for turning right, having a lot to watch out for, confusion and uncertainty about priorities. Some cyclists were concerned that if using the road, they would encounter difficulties if drivers expected them to be using the cycle lane and not the road.

Difficulties mentioned when leaving the roundabout on the road included confusion about the meaning of the road markings and about who had right of way, difficulty with judging the movements of the cyclists on the cycle lane, seeing the cyclists on the orbital lane due to the angle of view, and feeling vulnerable stopping on the roundabout to give way to cyclists.

In further comments about the scheme, some said that giving way to cyclists on the orbital lane would cause accidents and delays.

Variation of ease of manoeuvring and safety with different entry treatments

As shown in **Figure 79**, a majority of cyclists said it was 'easy' or 'very easy' to join the roundabout on the road; few described it as difficult (up to 2%) or unsafe (between 4% and 7%). The responses were fairly similar at the various arms of the roundabout.

Difficulties mentioned included judging where to stop between the pedestrian crossing and the cycle crossing at Arm 2, uncertainty about priority (Arm 3) and watching for cyclists alongside and cyclists crossing (Arm 3).

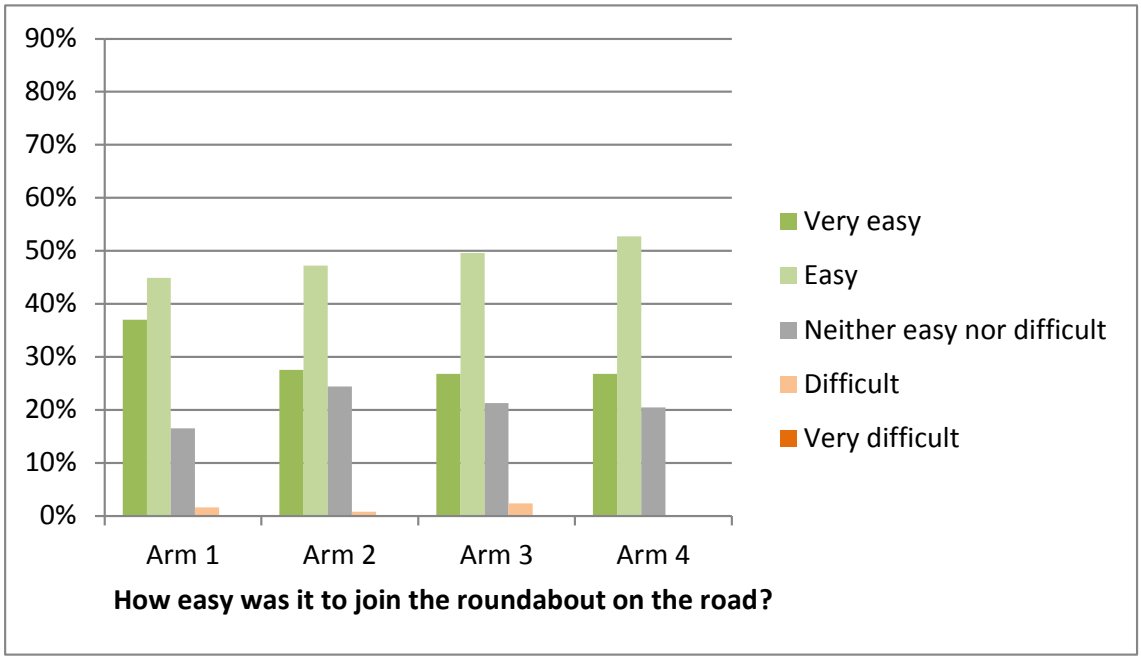

Figure 79: Ease of joining the roundabout

> *"Very difficult to find somewhere to stop in the road for cycle lane due to pedestrian crossing being so close."* (Arm 2)
>
> *"If there was a cyclist coming you would have to see them early so you wouldn't need to stop on the pedestrian crossing, and you would also have cyclists riding next to you."* (Arm 3)
>
> *"Not very clear if cycle lane is part of pedestrian crossing and this under the same rules."* (Arm 3)

Variation of ease of manoeuvring and safety with different exit treatments

As shown in **Figure 80**, around three-quarters of cyclists said it was 'easy' or 'very easy' to leave the roundabout using the road and between 60% and 65% said it was 'safe' or 'very safe'. The responses indicated that it was marginally easier to leave at Arm 3 and Arm 4 (where 2% said it was 'difficult') than at Arm 1 (where 8% said it was 'difficult' and 1% said it was 'very difficult') and Arm 2 (where 8% said it was 'difficult').

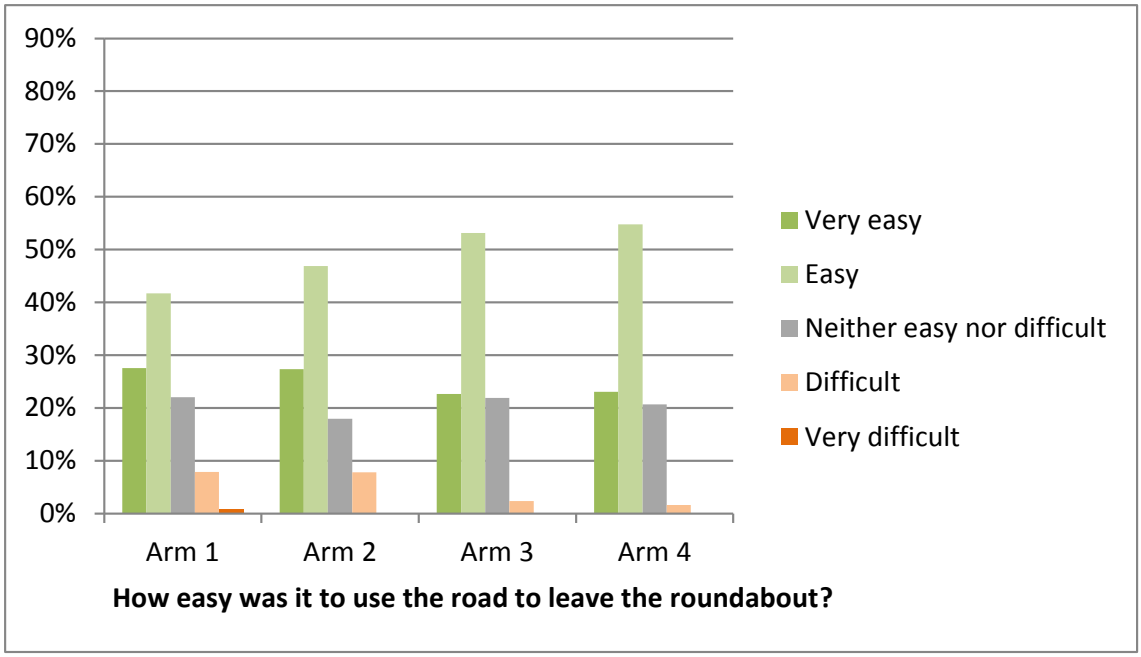

Figure 80: Ease of leaving the roundabout

3.1.3 Perceived benefits and the influence on cycling in London

3.1.3.1 Participants' view if this facility is beneficial or otherwise, for them and for other groups of road users

Almost all participants (92%) thought that cyclists would benefit from the cycle lane round the roundabout; 43% thought drivers would benefit from it and 33% thought pedestrians would benefit.

> *"Quite frankly, it's a no-brainer - just install them around the country!"*

A few participants did not identify any groups who would benefit.

The main advantages of the roundabout were the segregation of cyclists from traffic and improved safety.

> *"Correctly promoted, it would encourage cycling as being safer."*
>
> *"Currently strongly dislike roundabouts - this would make me feel much safer."*
>
> *"Cyclists and motorists don't mix well!"*

Other benefits mentioned by fewer people were that it is clearer or less confusing, easier, saves time, provides a defined route, gives priority to cyclists, improves flow, increases confidence, and improves awareness of cyclists. Some said it would benefit less experienced cyclists and children.

A few qualified their comments about improved safety, saying these benefits would depend on people learning how to use the roundabout and observing the priorities.

The participants who mentioned disadvantages thought the scheme was confusing or too complex, that it is dangerous and causes delays if cars stop on the roundabout, is difficult for cyclists to navigate and more difficult for pedestrians.

> *"Drivers in London are mad, this would just confuse them even more."*

Influence of facility on participants' willingness to cycle in London

Of the participants in this trial, 28% said they thought it would affect how often they cycle in London if there were cycle lanes like this on roundabouts there. For most of these this was a positive influence, with the separation from traffic and improved safety encouraging them to consider cycling or cycle more; some gave specific examples of how they might cycle more in London.

> *"Would feel better about cycling in London because cyclists would be given more space, their own lanes and more priority over other traffic."*

> *"I might consider cycling in London - certainly current busy roundabouts there put me off."*

However a few said it would put them off cycling in London because they found the layout complex and difficult to use.

> *"I would be less likely to cycle in London if I were to encounter these roundabouts, as they would create additional hazards and impede my progress. I'm not a fan of red-light junctions either, but I think the decreased complexity of those would at least reduce the likelihood of collisions with pedestrians."*

Of those who said it would affect cycling in London, 33% currently cycle in London; for most this is less than once a month.

While the responses indicate some increase in willingness to cycle in London, they cannot be used to estimate the extent to which cycling in London might change if Dutch style roundabouts were installed.

Those who said it would not influence cycling in London mainly said they do not cycle in London, and many said they would not consider it because they don't go there, it's not safe, or they use other modes. A few said they already cycle in London as often as they need to. One said that a cycle network is of higher priority than improving roundabouts and a few said they did not think that Dutch roundabouts would be suitable for London.

3.1.4 Difficulties associated with using the roundabout

One of the most commonly mentioned difficulties with using the roundabout was with understanding and complying with the priority for cyclists circulating in the orbital lane. Participants did not expect to have to give way, particularly on leaving the roundabout; the unfamiliar and complex road markings delineating the cycle lane and allocating priority made it more difficult for participants. Uncertainty about priorities affected cyclists on the orbital lane and those on the roundabout itself, but those on the roundabout felt particularly vulnerable as they had to stop in the traffic lane to give way to cyclists crossing on the orbital lane.

> *"Not sure on priorities."* (Arm 1).

> *"Unclear on right of way."* (Arm 3, Arm 4)

> *"I was never sure whether the cyclists were going to stop."* (Arm 2)

At the two points where the orbital lane for cyclists leaving the roundabout joins the main carriageway without a segregated cycle lane, the priority was also unclear. The cyclists' natural instinct was to give way to traffic coming from the right on the main road, but the markings implied to some participants that drivers should give way; the lack of cycle lane markings on the road at these points added to the confusion.

> *"Differing road markings did not make it clear whose priority it was & I wouldn't have wanted to stop if I had a car/truck behind me as I would have felt that they probably wouldn't have stopped."* (Arm 2)

Several participants said that the proximity of the cycle and pedestrian crossings to the main roundabout made it more difficult to use – it increased workload for cyclists both in the cycle lane and the road, as they had to think about the crossings and the traffic on the roundabout at the same time. Some thought it would also lead to more congestion on the roundabout.

> *"Unsafe for traffic/cyclists on the roundabout if traffic is stacked up around, giving way to cycle path & pedestrian crossing."*
>
> *"The proximity of the pedestrian crossing could cause cyclists to stop."* ('Unsafe')

Where there was no segregated lane, some cyclists found it difficult sharing the road with traffic. Noticing the point where they should join or leave the orbital lane was also more difficult for cyclists where there was no segregated lane.

Tight turning angles for joining and leaving the segregated cycle lane slowed cyclists down and many found it difficult to watch out for other hazards while negotiating the turn; where the tight turn occurred at a point where cyclists were in a cycle lane on the road, they tended to swing out into the middle of the road while making the turn.

3.1.5 View on who has or should have priority under the circumstances created

One of the benefits which cyclists see in the design is that they have priority over vehicles as they cross the roads on the orbital cycle lane, giving them an easy route around the roundabout. However when cyclists were leaving the roundabout at points where there was no marked cycle lane as they re-joined the road (Arm 2 and Arm 3), they were unsure about whether or not they had priority over vehicles; some cyclists on the road were also uncertain.

> *"Cycle lane suddenly ends without warning, throwing cyclist into lane of traffic."*
>
> *"Sharp corner into flowing traffic, not clearly marked as to who has right of way."*
>
> *"The road felt very narrow. Not having a dedicated lane didn't feel right."*

As a result cyclists on the cycle lane in particular were more concerned about safety of the layout at these exit points than at the exits where they either filtered into the road from a segregated lane or continued in a cycle lane after the roundabout (Arm 1 and Arm 4). Some cyclists said the layout would be improved by having segregated lanes at all arms of the roundabout.

> *"Please use full segregation of the cycle route (Arm 1). The rejoining with cyclists will be problematic…though I appreciate that this is probably the most complex/expensive solution!"*

Some cyclists on the road were uncertain about right of way where the cycle lane crossed the roundabout's arm; between 5% and 10% said they would not have given way if they had seen a cyclist crossing as they approached the roundabout, and between 10% and 15% said they would not have given way to a cyclist crossing in front of them as they were about to leave the roundabout. To help clarify priorities, some cyclists

suggested adding a coloured surface or other markings on the orbital cycle lane or signs depicting the layout and the priorities.

> *"Coloured tarmac for cycle lane."*

> *"Maybe make the cycle lane in a different colour to make it more clear to road users."*

Two particular disadvantages of giving cyclists on the orbital lane priority over vehicles leaving the roundabout were described by participants. Vehicles waiting for cyclists to cross were seen as a cause of 'blocking' the roundabout, resulting in delays to traffic.

> *"All the zebra crossings could back up traffic on the roundabout leading to gridlock on the approaches."*

Cyclists on the road waiting for cyclists to cross were seen as being vulnerable to being hit by vehicles leaving the roundabout as drivers would expect to have priority and not expect to find cyclists stopped in the road.

> *"I would hesitate to stop before the cycle path as vehicles behind may hit me."*

3.2 Focus Group Findings

3.2.1 Overview

A total of fourteen cyclists took part in the focus groups, seven male and seven female. They ranged in experience from occasional to very experienced cyclists.

Cyclists hold a variety of views regarding the layout of the 'Dutch' roundabout. This isn't surprising as cyclists are not a homogenous group. There is a clear divide between those who are regular, confident cyclists and those who are less confident and occasional cyclists. There are also differences between types of cyclist e.g. road racers, mountain bikers and leisure cyclists. Less confident cyclists prefer segregation between cyclists and vehicles, suggesting this assists with cycle safety and means that they do not need to worry about traffic encroaching into their space.

> *"If there was traffic on the roundabout I would personally feel safer using the cycle lane"*

However, confident participants who cycled regularly would prefer to remain on the main carriageway. This raises concerns that 'cyclists' would use both the cycle lane and the main carriageway, whilst powered vehicle drivers and pedestrians only have one means of traversing the roundabout. Some felt that this choice, with drivers and pedestrians not knowing by which means a cyclist may utilise to traverse the roundabout, may be to the detriment of road safety.

The varying arms from the roundabouts had differing layouts and road markings. Participants expressed clear preferences for some arms over others. Arm 4 was the clear preference as it was considered to define the cycle lane more and was more intuitive to use. This was considered important as the fewer decisions that needed to be made the better. Arm 1 was the second favourite with Arms 2 and 3 receiving limited support.

> *"[Arm1] is too busy with too many markings, there is too much going on"*

> *"Arm 2 went through a sharp corner"*

> *"[Arm 3] this came right out and we felt that could be dangerous"*

"[Arm 4] you just naturally integrate in to the orbital path without complex give ways"

Whilst there were differing views over whether participants would choose to use the cycle lane based on confidence level, the majority of participants felt that the layout would contribute to cycle safety. It was discussed that the layout would be beneficial in some areas more than others, though there were questions about the likelihood of suitable space being available in London. Concerns were expressed about some specific aspects of the design, e.g. distance of crossings from the roundabout and the effect of the roundabout on congestion.

3.2.2 Understanding how to navigate the roundabout

Participants were directed as to how to use the roundabout in the first instance i.e. using the cycle lane or the main carriageway. A number of participants indicated that it was unclear how to navigate the roundabout due to the ambiguous nature of the road markings.

"It just looked so busy, so many lines everywhere"

It was felt that some form of user education would be required to ensure safe usage of the roundabout.

"There would have to be information, television adverts and this sort of thing to explain to people how it works"

Despite initial misgivings, participants had an intuitive grasp of priority – pedestrian – cyclist – motor vehicle, regardless of the layout / markings on the roundabout. However, in this trial there was uncertainty raised as to how cyclist (orbital cycle lane) v cyclist (main carriageway) interaction should be handled. There was no consensus as to which cyclist had priority at that point.

"I didn't know who had priority"

The vast majority of participants used the roundabout in a clockwise direction, even when turning right, although a couple of participants used it in an anti-clockwise direction for the right turn, realising that this is a shorter distance. It is anticipated that use of the roundabout travelling anti-clockwise might grow as users grew in familiarity with the roundabout design. This would however be subject to the orbital cycle path facilitating two-way traffic.

"I prefer to stay in the cycle lane until I was well after the roundabout"

"[To turn right] I would go round the cycle path the wrong way"

3.2.3 Interpretation of road markings and layouts

There was no explanation of the road markings prior to the trial starting. Participants guessed at the intention of some of the markings e.g. sharks' teeth, elephants' feet etc. However there was some confusion during the trial as to their exact meaning.

Participants suggested that there was too much information provided by the road markings, but that they did not know who had priority. People did not know or recognise that they should give way at the dotted lines. It was thought that motorists would not know to give way to cyclists.

"It was really confusing trying to work out what each arm wanted you to do"

"There seemed to be a lot of priority markings which required somebody leaving the roundabout to give way to the cyclists which I found rather counterintuitive and tended to ignore"

The approach layout on each arm differed slightly and participants expressed their preferences. Across the two focus groups arms 1 and 4 received the most favourable comments with arms 2 and 3 receiving limited approval. One participant didn't like the single file arm and two participants did not like the exit on arm 2. It was commented that the kerbing at the entrance of arm 3 could be a danger if you wanted to get out of the cycle lane onto the roundabout.

3.2.4 Comfort, safety, ease of manoeuvring on the roundabout

A variety of views were expressed as to the safety of the roundabout design. Three participants stated a perception that it was more dangerous for motorists, whilst one participant thought it was safer for motorists. Five participants stated a view that it was safer for cyclists. It was felt that there was no difference in safety for pedestrians.

There were mixed views regarding use of the orbital cycle path and the main carriageway of the roundabout. Some participants stated that they preferred to use the cycle lane with no cars, whilst others preferred to use the main road with no cars. Some participants would choose to use the cycle lane, expressing the view that they thought it was safer, whilst others thought it would be more natural to use the carriageway and preferred the right turn on the carriageway.

"I think to separate cyclists from motor cars is definitely of benefit"

Participants stated that if there was traffic on the roundabout it would be safer to use the cycle lane, though commented that cycle lanes gave a false sense of security as they had to cross the main road at each arm of the roundabout. It was suggested that zebra crossings were needed where the cycle lane crosses the road.

"Given that those crossings are so close it's going to make them think pedestrians… they're going to slow down and the cyclists are going to benefit from that"

Whilst a number of participants suggested the cycle path would provide cyclists with protection from road traffic, there was concern that this protection would be limited to the roundabout. Participants suggested that further investment would be needed to extend the cycle lanes either side of the roundabout in order to have a further impact on cycling numbers.

The general consensus was that for turning left it was better to use the cycle lane and for going straight on is was OK to use the cycle lane. For turning right too much time would be spent in the cycle lane. However some would choose to make a right turn using the cycle lane as although it was longer distance than using the main carriageway it was considered safer, especially on large busy roads. One participant stated that they would travel in the shorter, anti-clockwise direction, when making a right turn.

3.2.5 Willingness use the orbital cycle lane as intended

There was a mixture of responses as to whether participants would or wouldn't use the cycle lane. It was felt that cyclists and drivers would benefit from being separated from

each other. Some suggested that they would take the safe route and use the cycle lane, whilst others would take the shortest route and would go straight across.

> *"I would try to use the main roundabout if I could, because it would be quicker"*

Participants stated that if there was traffic on the roundabout it would be safer to use the cycle lane, though commented that cycle lanes gave a false sense of security as they had to cross the main road at each arm of the roundabout. It was suggested that zebra crossings were needed where the cycle lane crosses the road.

> *"If there was traffic on the roundabout I would personally feel safer using the cycle lane"*

One participant commented that they preferred to stay in the cycle lane when coming off the roundabout.

There was some debate around the pros and cons of cyclists being compelled to use the cycle lane. The outstanding question in participants' minds was how this would be enforced.

3.2.6 Willingness of drivers to give way to cyclists when entering and leaving the roundabout

The focus group was conducted from the point of view of a cyclist; however a number of participants were also drivers and therefore were able to offer their opinions from a driver's perspective.

A number of participants expressed their concern about tailbacks during busy periods, particularly with regard to the positioning of the pedestrian / cyclist crossing close to the roundabout.

> *"Where would all the cars go, they would fill the roundabout in two minutes…..It would be gridlock"*

> *"I don't like them at all, the way that they're built like that, I think that they should be a lot further back from the roundabout"*

One participant stated that as a car driver they would find it complex driving around the roundabout. It was felt that drivers would benefit from being separated from cyclists, however if cyclists had the choice of using the main carriageway as well as the cycle path that may complicate the situation.

3.2.7 Influence on participants' willingness to cycle in London

If it could be made to work in London then it would be good, but the availability of suitable space for this scale of roundabout in London was questioned (mainly due to participants not identifying how existing road space could be reallocated).

> *"There is no space in London to double the size of a roundabout"*

It was suggested that the cycle track would need to be wider.

Whilst a number of participants suggested the cycle path would provide cyclists with protection from road traffic, there was concern that this protection would be limited to the roundabout. Participants suggested that further investment would be needed to extend the cycle lanes throughout London beyond the roundabout in order to have a further impact on cycling numbers.

3.2.8 Influence of the layout on participants' behaviour and responses

First responses indicated that the roundabout looked 'busy 'with the white lines and one stated that as a car driver they would find it complex to negotiate.

"It needs to be very simple, preferably with less noise in the environment"

It was clear that the participants were aware that each of the arms differed and they had clear preferences for arms 1 and 4. One participant commented that they had to stop when leaving the roundabout on arm 2. Another commented that it felt as if they were suddenly shooting off into the road when exiting arm 2. Two further participants concurred with this view. It was suggested that it should not push you out as much, but another participant thought that it made you look more. A couple of comments were made that entry to the roundabout was a struggle as there were tight corners for bikes which made cycling uncomfortable. One participant thought that arm 3 was too sharp.

"Entering the [arm 3] cycle lane was a bit of a struggle sometimes"

There was uncertainty as to how cyclist (orbital cycle lane) v cyclist (main carriageway) interaction should be handled. There was no consensus as to which cyclist had priority at that point.

"I didn't know who had priority"

The general consensus from the participants was that for turning left it was better to use the cycle lane and for going straight on is was OK to use the cycle lane. For turning right too much time would be spent in the cycle lane. However some would choose to make a right turn using the cycle lane as although it was longer distance than using the main carriageway it was considered safer, especially on large busy roads. One participant stated that they would travel in the shorter, anti-clockwise direction, when making a right turn.

"I would go the opposite way, a safer route around the roundabout"

3.3 Video Analysis Findings

Twelve video cameras captured the movements of the cyclists during the trial. In particular, times of cyclists entering, circulating around and exiting from, the roundabout were collected from the resulting recordings. All participants were told what manoeuvre to make at the roundabout and when to start. However, no other instructions were given and therefore interactions between them occurred in the most natural way possible, although those travelling at "non-average" speed could miss having an interaction.

The participant timings can be compared to assess which of the cyclists went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if two cyclists making different manoeuvres came into close proximity. That is, arrived at an interaction zone within three seconds of each other, **Figure 81**. Cyclists were released in pairs to improve the chances of an interaction occurring.

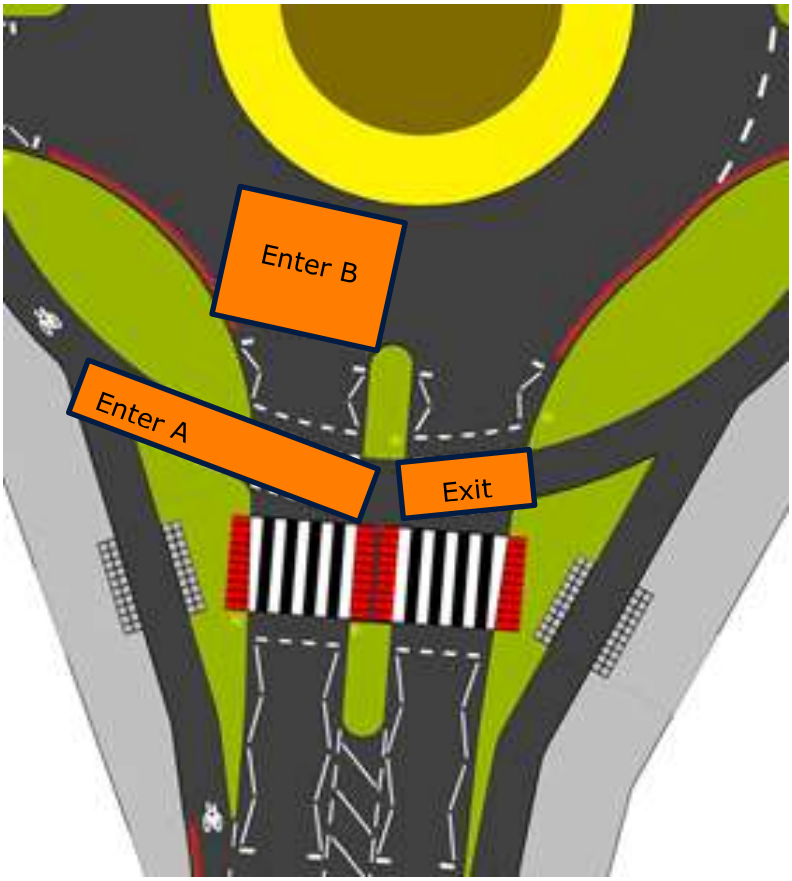

Figure 81: Interaction zones

For example, an interaction occurred if a cyclist approached the roundabout to use the orbital cycle lane and another cyclist was crossing the same entrance in the orbital cycle lane (Enter A Interaction Zone) within three seconds of each other, or if cyclists approached the roundabout to use the main part of the roundabout and another cyclist was crossing the same entrance in the main traffic lane (Enter B Interaction Zone) within three seconds of each other, or if a cyclist exited the roundabout from the main traffic lanes and another cyclist was crossing the same exit in the orbital cycle lane (Exit Interaction Zone) within three seconds of each other.

3.3.1 Priority when negotiating the roundabout

The priorities taken by cyclists have been investigated under six situations; these are shown in the simplified diagrams below. All the diagrams show the paths taken by cyclist 1 in blue and cyclist 2 in red, and also show the point of interaction between them.

The movements are summarised in **Table 3**.

Table 3: Movement made by participants and interaction location (O = Used Orbital Cycle Lane, M = Used Main Traffic Lane on Roundabout)

Interaction	Movement Made		Location of Interaction
	Blue Cycle	Red Cycle	
1	Turn Left (O)	Turn Right (O)	Enter A
2	Straight On (M)	Straight On (M)	Enter B
3	Turn Left (O)	Turn Left (M)	NONE
4	Turn Right (M)	Turn Right (O)	Enter A
5	Turn Right (M)	Turn Left (O)	Exit
6	Straight On (O)	Straight On (M)	Exit

The results as to whether the Blue cyclists went in front, between the two, or after the Red cyclists are shown in the results graphs after each movement diagram..

Figure 82 shows the first interaction where the Blue cyclists entered the orbital cycle lane when a Red cyclist was using it..

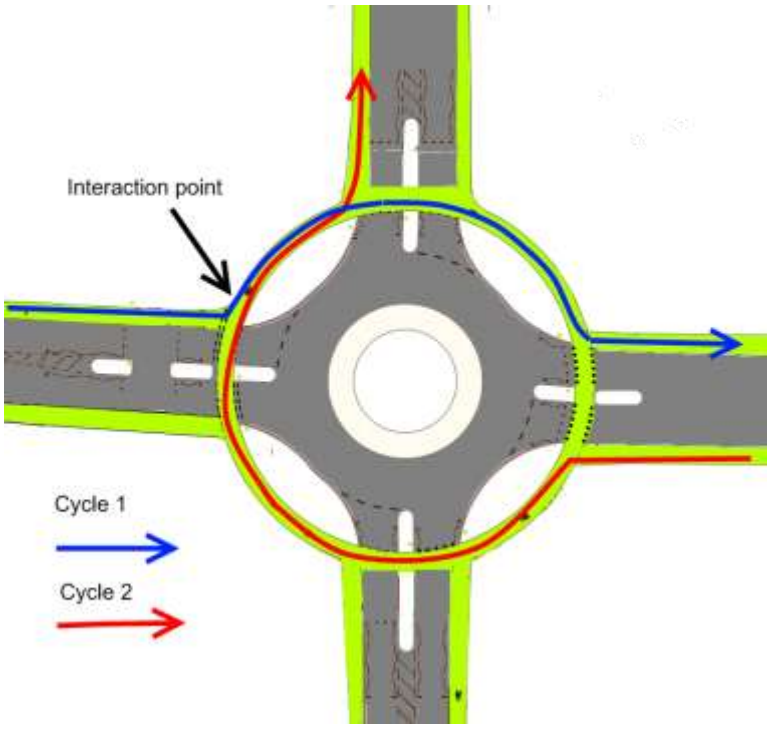

Figure 82: Interaction 1

Figure 83 shows that the Blue cyclists mainly went after the Red cyclists, suggesting they were giving way, but were often willing to merge in front of them. There is also evidence that they were less likely to wait for both Red cyclists on Arms 1 and 4, where

the separate cycle lane gave them more opportunity to merge owing to its angle of incidence.

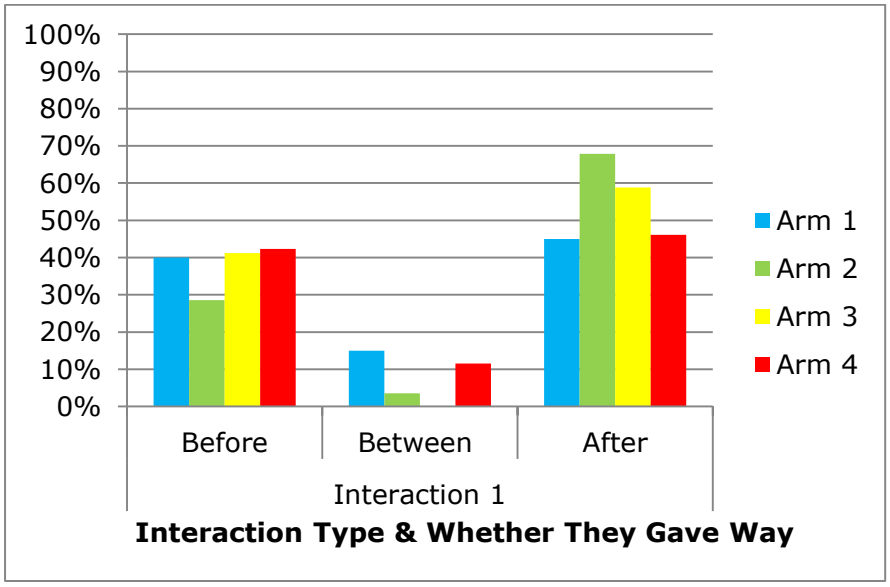

Figure 83: Interaction 1, who gave way

Figure 84 shows interaction 2 where the Blue cyclists used the main traffic lane on the roundabout to cross the entrance arm being used by the Red cyclists, who were also entering the main traffic lane on the roundabout.

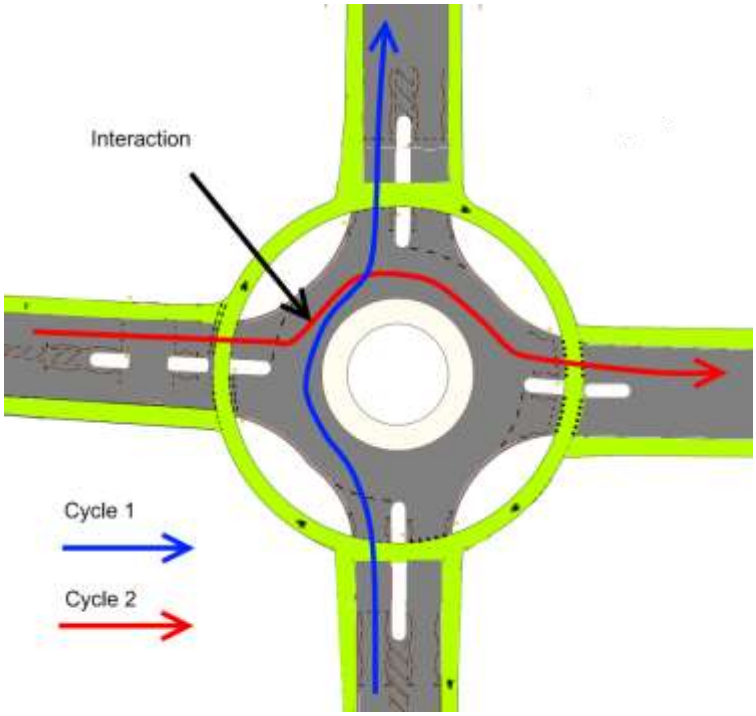

Figure 84: Interaction 2

Figure 85 shows that mainly, the Blue cyclists went first under these conditions: 60 to 82%. The smaller percentage going first on Arm 3 was owing to few of the second Blue cyclists going before the Red cyclists (22%). As normal roundabout priority rules apply here, this result is as expected.

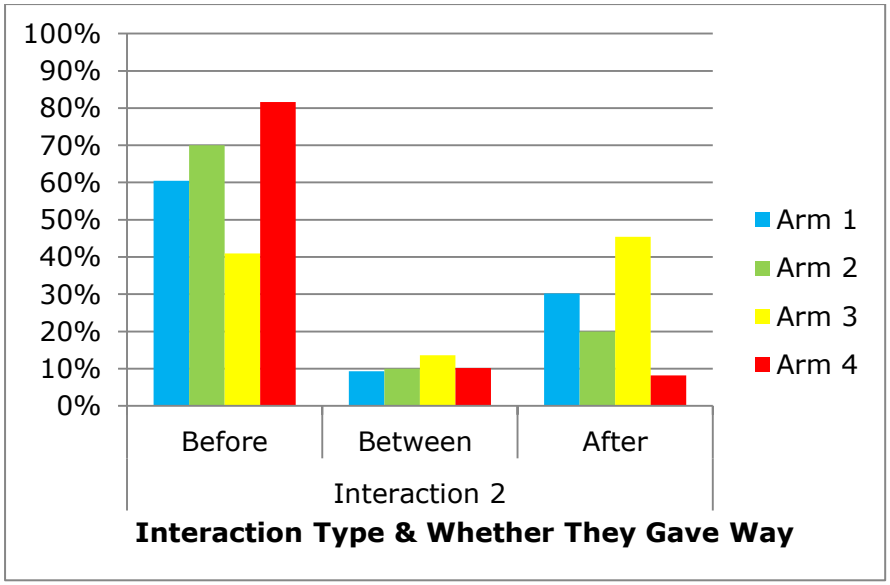

Figure 85: Interaction 2, who gave way

Figure 86 shows the blue cyclists leaving the orbital cycle lane at the same arm as the red cyclists join the main car lane. No interaction occurs, so there should be no giving way. The trial provided a "no interaction" reference case.

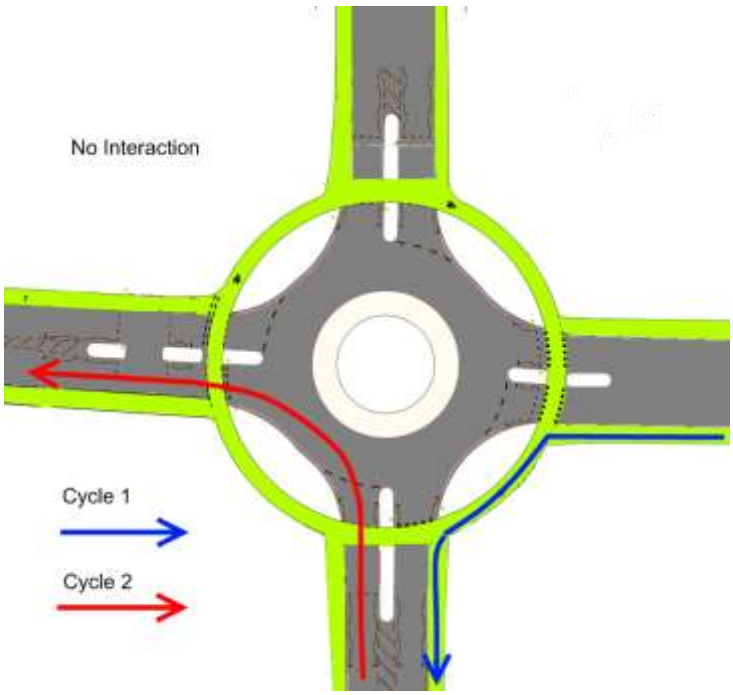

Figure 86: Interaction 3

Figure 87 shows the fourth interaction where Blue cyclists entered the main traffic lane on the roundabout whilst Red cyclists crossed the arm in the orbital cycle lane.

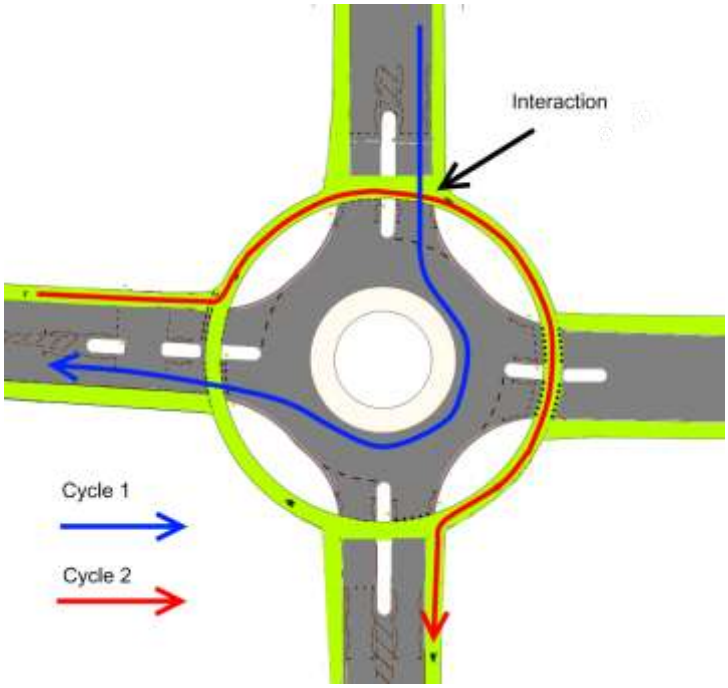

Figure 87: Interaction 4

Figure 88 shows that mainly, the Blue cyclists went after the Red cyclists: 66 to 74%. As long as participants saw the orbital cycle path as being a circulating lane of a roundabout, then normal roundabout priority rules apply. This result shows that in the main this is the case.

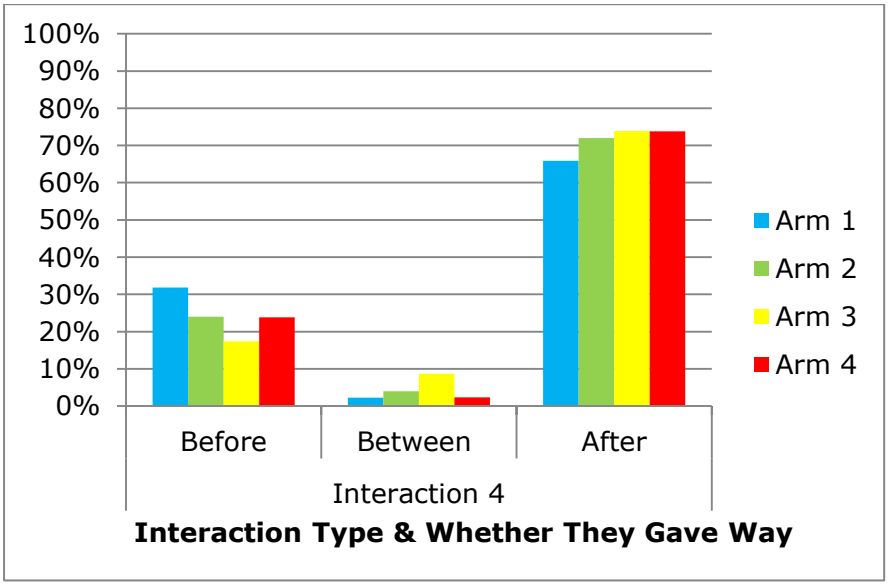

Figure 88: Interaction 4, who gave way

Figure 89 shows interaction 5 where blue cyclists exited the main traffic lane on the roundabout whilst Red cyclists exited the orbital cycle lane into the same arm.

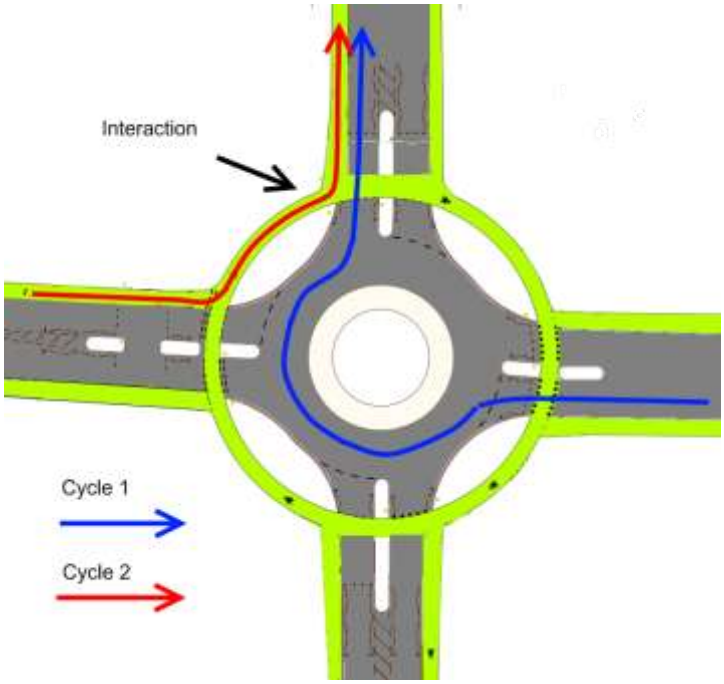

Figure 89: Interaction 5

Figure 90 shows that mainly, the Blue cyclists went after the Red cyclists. The percentage going after the Red cyclists on Arms 2 and 3 ranged between 71 to 83%, whilst on Arms 1 and 4 it ranged from 49 to 64%. This was almost certainly owing to the separate cycle lanes leading from the roundabout's orbital cycle lane on these arms.

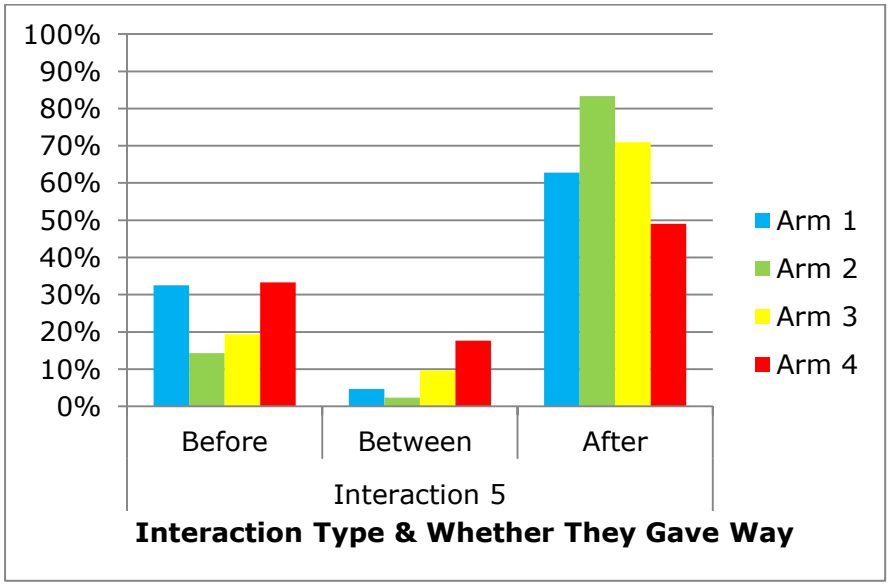

Figure 90: Interaction 5, who gave way

Figure 91 shows interaction 6 where Red cyclists exit the roundabout from the main traffic lane at the same time that Blue cyclists cross over the same arm in the orbital cycle lane.

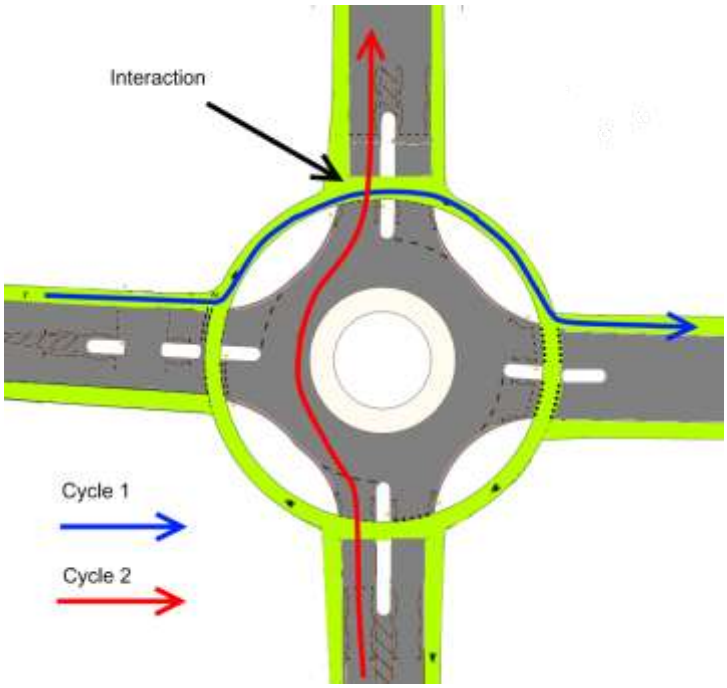

Figure 91: Interaction 6

Figure 92 shows that mainly, the Blue cyclists went before the Red cyclists: 59 to 64%.

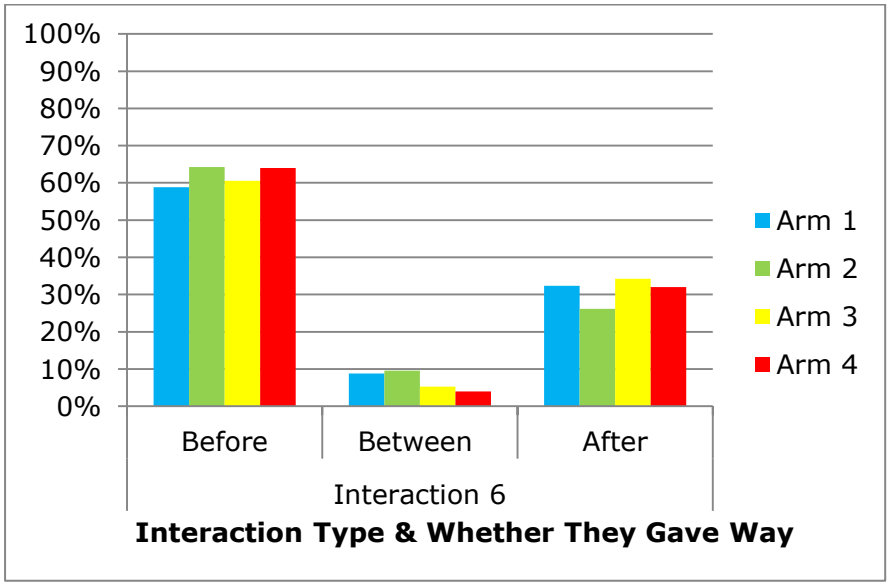

Figure 92: Interaction 6, who gave way

In all interactions there tended to be a flow that obtained greater priority, and these were in line with standard conventions. However, the lack of polarisation in the values indicates that cyclists were willing to merge together more readily than other modes of traffic.

3.3.2 Effects on cyclist journey time

Cyclists started on one of four arms and either turned left, right, or continued straight on at the roundabout. They could meet cyclists performing a different manoeuvre in one of the six interaction situations**Figure 118**. The interaction was said to have occurred if the cyclist was in the vicinity of the appropriate Interaction Zone (see **Figure 81**) at the same time (i.e. within 3 seconds) as one of the cyclists performing a different manoeuvre. The timing points used to define being in the vicinity were as shown in Figure 9 for Arm 4:

- Timing point 2 for interactions when entering the roundabout
- Timing point 6 for interactions when exiting the roundabout from the main traffic lane on the roundabout
- Timing point A for interactions with circulating and interacting with cars exiting the roundabout
- Timing point 5 for interactions when entering the main traffic lane on the roundabout
- Timing point 7 for interactions when exiting the orbital cycle lane on the roundabout

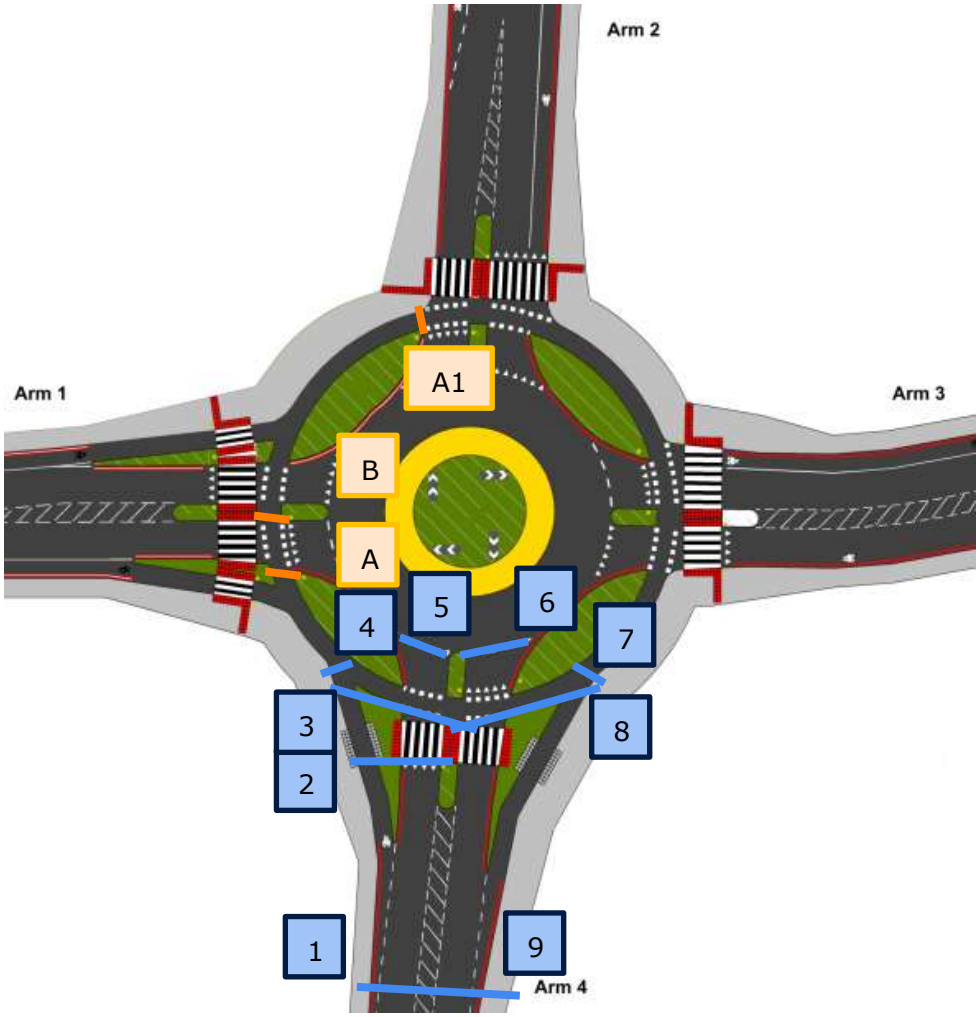

Figure 93: Journey timing points for cyclists

The average time for cyclists to enter the roundabout, circulate around the roundabout and leave it, were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 4, or Points 1 and 5. The time to circulate over Arm 1 was taken between Points A and B if interacting with a cycle leaving the roundabout. The time to circulate over Arm 1 was taken between Points B and A1 if interacting with a cycle entering the roundabout, or between Points B and 7 if interacting with a cycle entering the roundabout and leaving at the next arm. The time to exit from over Arm 4 was taken between Points 7 and 9, or Points 6 and 9, depending on whether they exited from the orbital cycle lane or not. Such timing points were defined for all arms of the roundabout.

The average times for cyclists involved in the interactions are summarised in Figure 94 to Figure 98.

Figure 94: Cyclist Journey Times – Interaction 1

In interaction 1, the Blue cyclists entered the orbital cycle lane when a Red cyclist was using it.

- The Blue cyclists mainly went after the Red cyclists, and this resulted in them being delayed by 1 to 2 seconds, suggesting they were giving way,
- Red cyclists' journey times were within 0.3 seconds of those without an interaction.

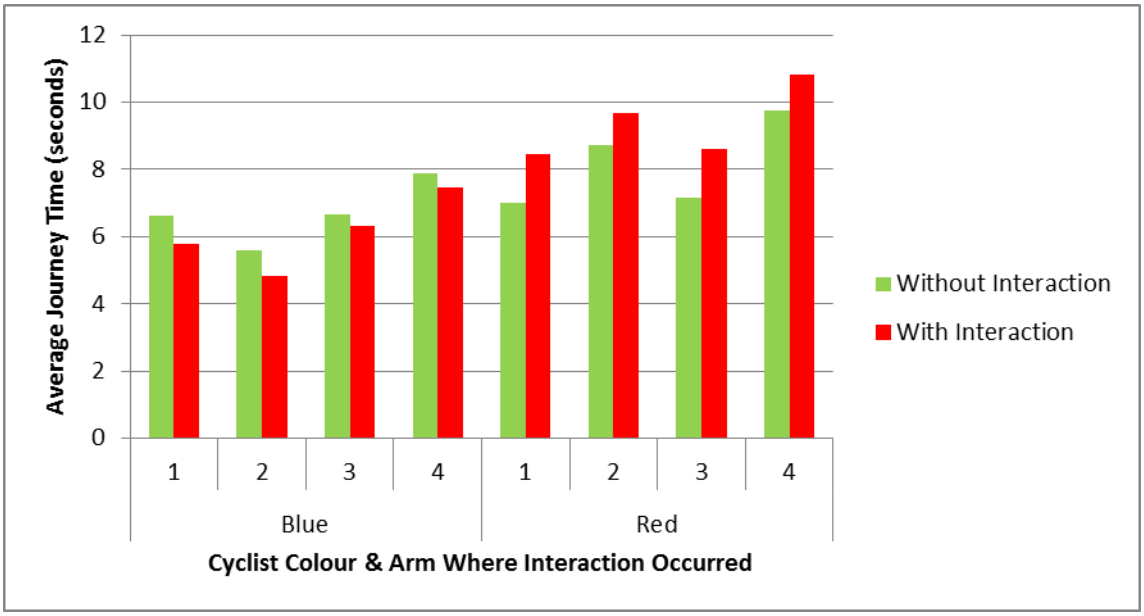

Figure 95: Cyclist Journey Times – Interaction 2

In interaction 2, the Blue cyclists used the main traffic lane on the roundabout to cross the entrance arm being used by the Red cyclists, who were also entering the main traffic lane on the roundabout.

- Mainly, the Red cyclists waited under these conditions, and they were delayed by 1 to 1.5 seconds.
- The Blue cyclists tended to go first and appeared to travel slightly faster when interacting: a reduction of 0.3 to 1.0 seconds.

Figure 96: Cyclist Journey Times – Interaction 4

In interaction 4, Blue cyclists entered the main traffic lane on the roundabout whilst Red cyclists crossed the arm in the orbital cycle lane.

- Mainly, the Blue cyclists went after the Red cyclists and this delayed them by 1.5 to 2.4 seconds.

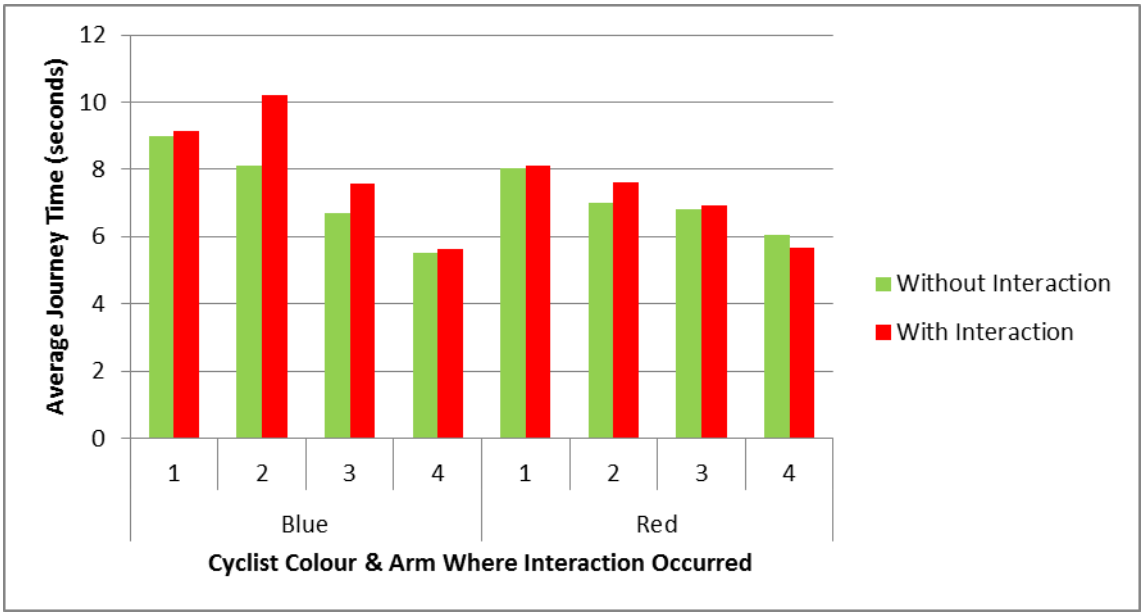

Figure 97: Cyclist Journey Times – Interaction 5

In interaction 5, Blue cyclists exited the main traffic lane on the roundabout whilst Red cyclists exited the orbital cycle lane into the same arm.

Mainly, the Blue cyclists went after the Red cyclists.

- On Arms 1 and 4 (with separate cycle lanes leading from the roundabout's orbital cycle lane) the Blue cyclists were able to exit in parallel with the Red cyclists and this caused no delay.
- On Arm 3 where they had to merge, but where kept slightly separate by the overhang of the roundabout island, it caused the Blue cyclists a 0.9 seconds delay.
- Arm 2 was the worst as the two cyclists came into direct conflict and had to merge, this resulted in the Blue cyclists being delayed by 2.1 seconds and appears to have caused a 0.6 seconds delay for the Red cyclists.

Figure 98: Cyclist Journey Times – Interaction 6

In interaction 6, Red cyclists exit the roundabout from the main traffic lane at the same time that Blue cyclists cross over the same arm in the orbital cycle lane.

- Mainly, the Blue cyclists went before the Red cyclists,
- This caused the Red cyclists to be delayed by 0.5 to 1.7 seconds, with the greatest delays on Arms 1 and 4.

3.4 On-track responses

During the trials cyclists were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'On a scale of 1 to 10 where 10 is Very Easy, how easy it was to negotiate the roundabout?' i.e. 'How easy it was to cycle from one arm to another?'
- 'On a scale of 1 to 10 where 10 is Very Safe, how safe did you feel?'

Figure 13 gives the responses to these questions showing a count of all responses from all drivers.

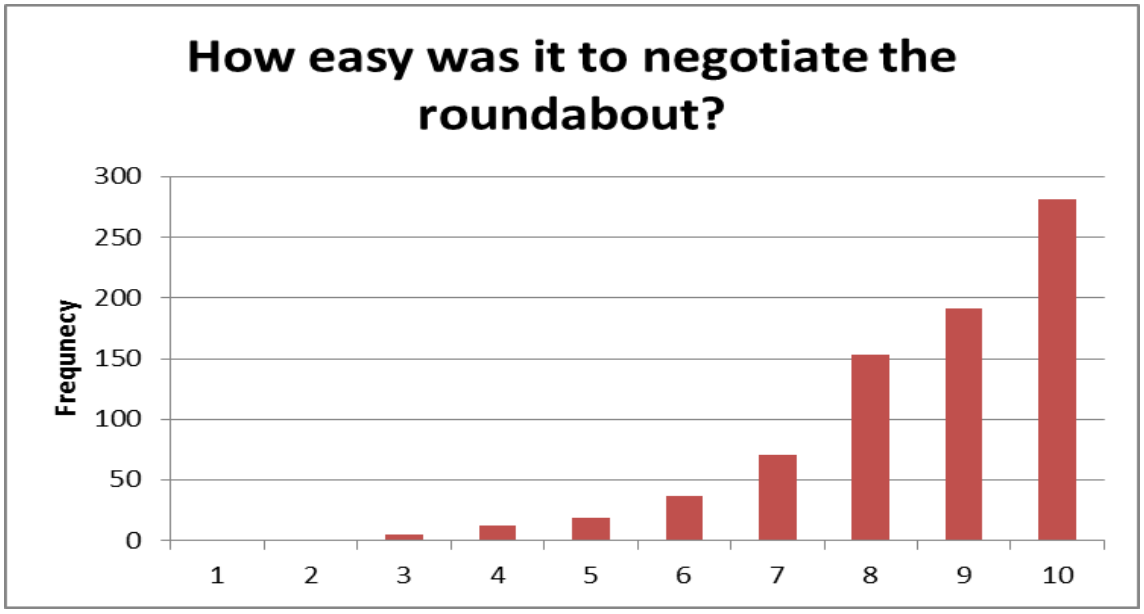

Figure 99: Cyclists' score for ease of using the roundabout

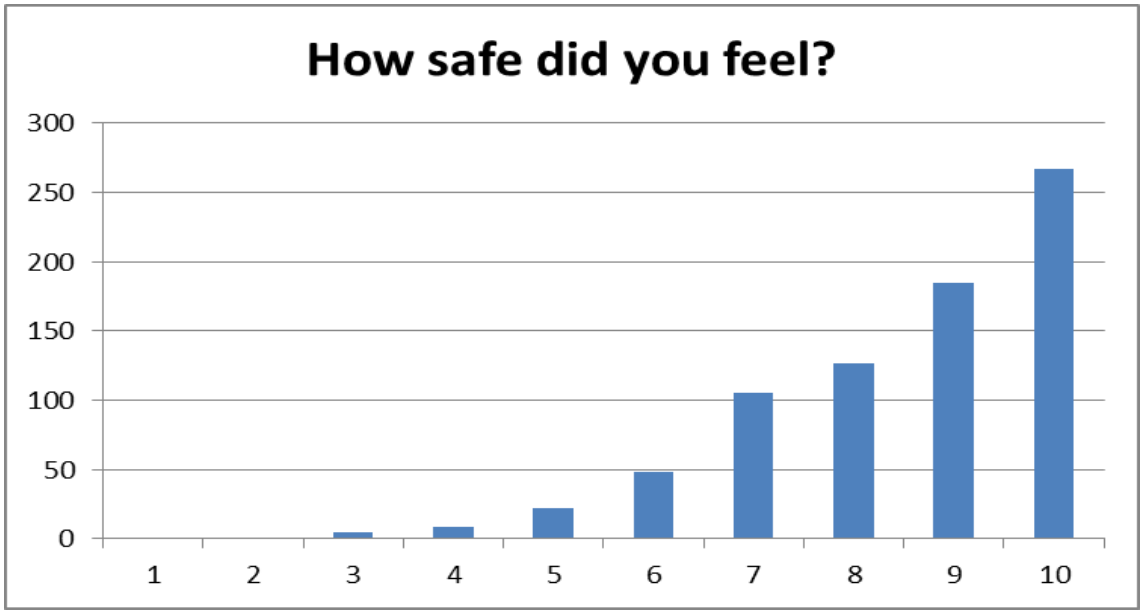

Figure 100: Cyclists' score for ease of using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (95%) and safe (95%). This is not overly surprising as drivers were not placed in any difficult situations. However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 87% of the safety scores were within ±1 of the ease of negotiating scores. For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same.

The average scores for making individual turning movements is summarised across all arms, see **Figure 101**.

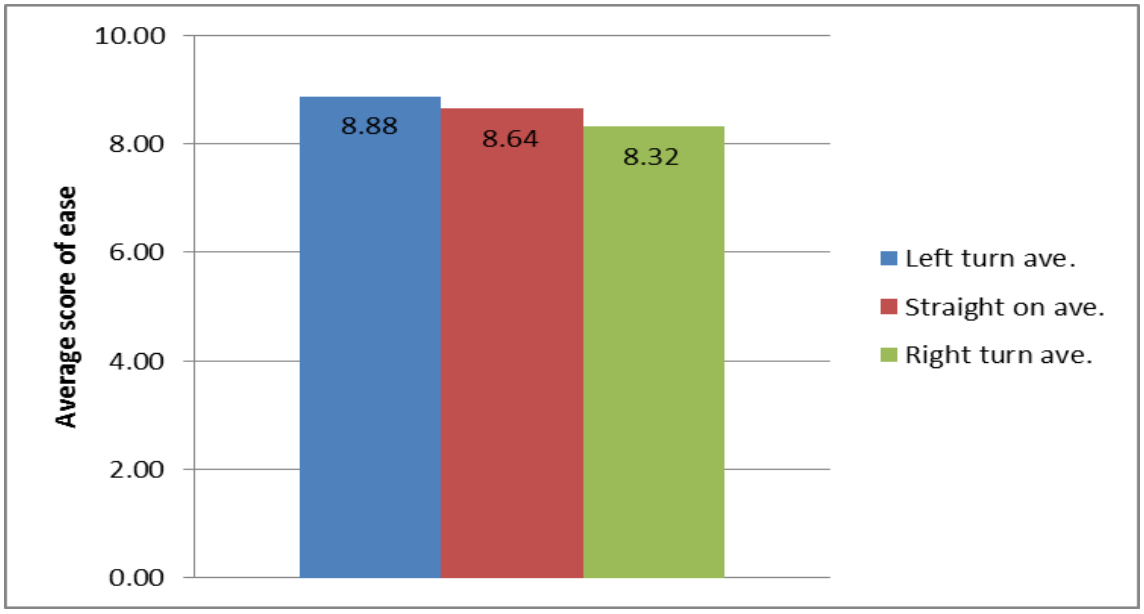

Figure 101: Cyclists' ease of negotiating the roundabout by turning movement

This implies that (on average) cyclists found it as easy to turn in any direction at the roundabout: that is, the scores are very similar (within 0.5) and all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in **Figure 102**.

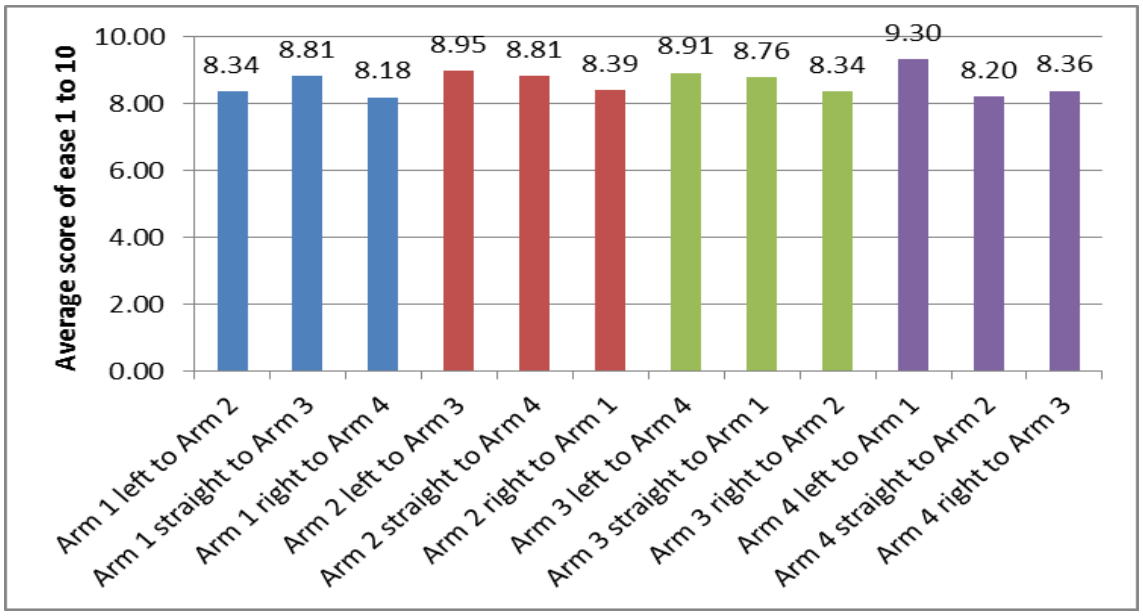

Figure 102: Cyclists' scores of ease of negotiating the roundabout by arm and movement

The above chart shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that there was little difference between all of the Arms with the average ease of use score only varying by a maximum of 1. The scores for Arm 1 were marginally lower than those on the other arms. Overall, there is an indication that turning out of Arm 1 was judged as slightly harder than the other arms. The easiest turning manoeuvre was thought to be starting at Arm 4 and turning left to Arm 1.

B.8 M27 Car-Cycle-Pedestrian Interactions Findings Report

Findings report: Dutch Roundabout Driver/Cyclist/Pedestrian Interaction (M27) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. On Arms 1, 3 and 4 the Zebra crossing are directly alongside the cycle path where it crosses the car lane, whereas on Arm 2 there is a 5m gap between the Zebra crossing and the cycle lane.

The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority
- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

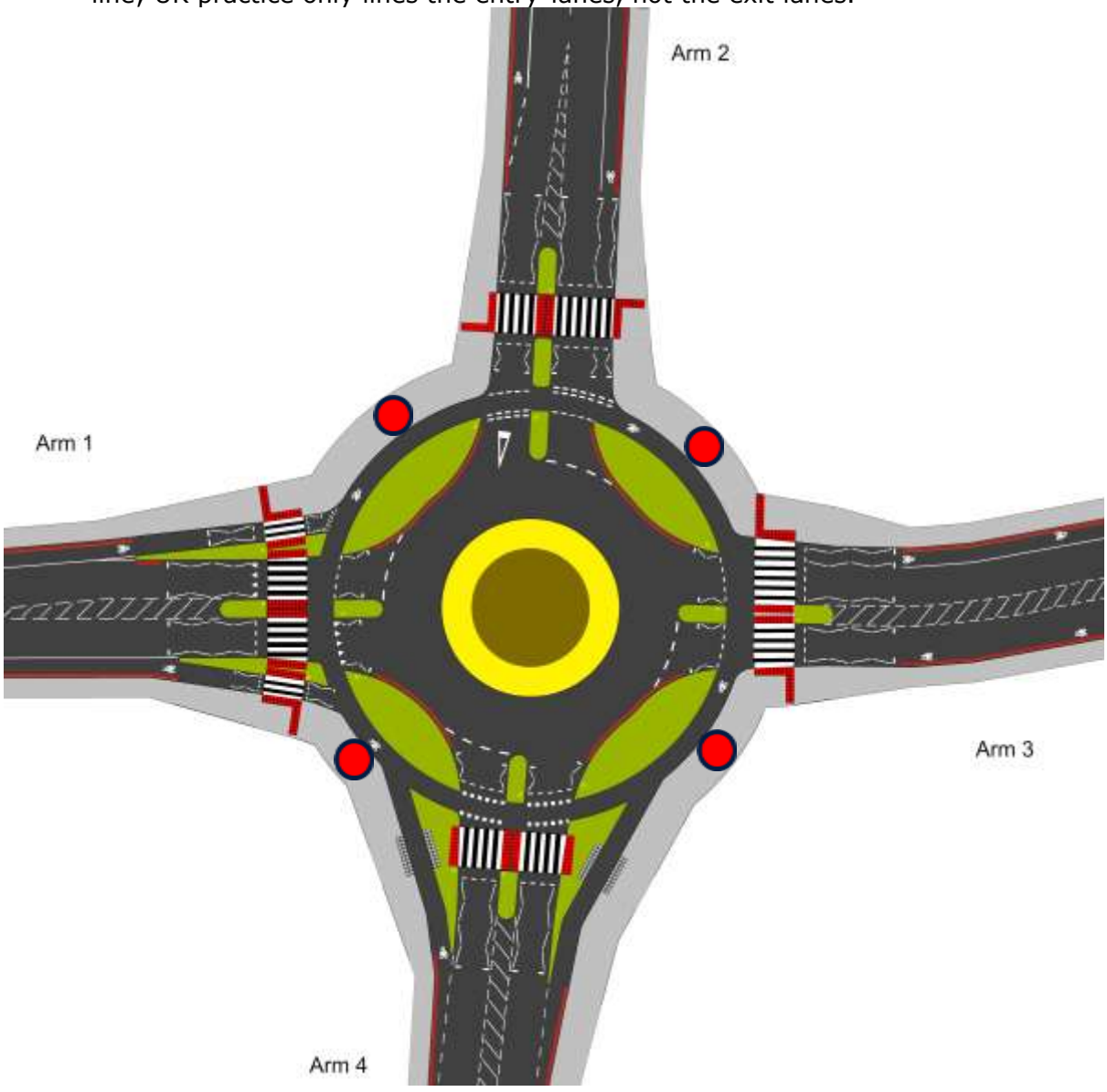

Figure 103: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes. Note also that the red dots shown on the pedestrian paths in Figure 1 are the start/end points for pedestrians (see later) and are not actually markings on the roundabout.

1.2 Introduction to the M27 trials

The primary objectives of the M27 trials were to establish how cyclists, car drivers and pedestrians interacted when using the roundabout and how they interpreted the layout and markings. This could then be used to assess the potential safety of the roundabout with respect to misinterpretation/misuse which could lead to conflicts and reduced safety margins (with respect to distance) between the users.

The M27 trials were the first to involve all three major road users (car drivers, cyclists and pedestrians) as participants. All three participant groups were required to execute specific movements on the roundabout during which they would potentially come into managed conflict[6] with other user groups. Car drivers were given specific instructions to ensure that the managed conflicts did not result in danger to other participants.

The trials were held between the 15th and 18th July 2013.

2 Methodology

The participants were required to undertake a series of predetermined movements under instruction of the trials facilitators. Each participant cyclist and driver started on one of the arms of the roundabout and asked to drive up to the roundabout, and either turn left, go straight on, or turn right. The cyclists were required to use the orbital cycle lane. The participant pedestrians started at one of the pedestrian start/end points as identified in Figure 1 and when released by the facilitator, walked to the next point, crossing the cycle and car lanes at the designated pedestrian Zebra crossings (where these existed – there was no pedestrian crossing on the cycle lanes of Arm 4, but the pavement and drooped kerbs made it abundantly clear where the pedestrians were expected to cross). No participants had seen the roundabout before the trials started.

Twelve cyclists were "on track" at the same time. Three cyclists on each arm were started by a facilitator a few seconds apart, were asked to approach the roundabout and turn in a specified direction. After making the manoeuvre they travelled on the exit arm to a turnaround point at a facilitator, this being the start point for their next movement.

Eight car drivers were "on track" at the same time. Two drivers on each arm were started by a facilitator a few seconds apart, were asked to approach the roundabout and turn in a specified direction. After making the manoeuvre they travelled on the exit arm to a turnaround point at a facilitator, this being the start point for their next movement.

Twelve pedestrians were "on track" at the same time. Three pedestrians at each starting point between two arms of the roundabout were started by a facilitator a few seconds apart, were asked to walk to the next pedestrian start/end point in a specified direction, where the there was another pedestrian facilitator.

The release of the participants was carefully timed to maximise the possibility of interactions occurring between the users at the entry to, circulating on and exiting from the roundabout.

[6] A traffic *conflict* 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." (Amundsen & Hyden, 1977)

At the end of each movement, each participant driver was asked a number of short questions regarding the movement they had just undertaken to assess how easy the movement was and how safe they considered the movement to be.

After the trials, all participants completed an extensive questionnaire on their experience of the roundabout. This included both closed (e.g. did you understand marking "x") and open (e.g. do you have any suggestions for making "y" clearer) questions.

About 25% of participants were also invited to take part in a focus group where the roundabout was discussed.

All trial movements were also recorded on video so that the time taken to execute movements could be measured. These timings can be used to measure the time taken for all or parts of the movements undertaken, and to evaluate the effect of interactions between the participant groups.

Data were provided by the questionnaires, the focus group transcripts and staff observations of participant behaviour. Statistical analysis of the questionnaire data have made it possible to identify findings that are 'statistically significant' (i.e. any pattern or relationship in the data that has a small probability of occurring by chance). It is commonly accepted **that if a finding has occurred with a probability of 5% or less that it occurred by chance** (expressed throughout this report as 'p<.05'), **then it is statistically significant**. Sometimes the probability of a chance finding will be less than 5% and this is expressed accordingly (e.g. p<.0005 means probability was less than .05%).

3 Summary of Findings

116 drivers, 170 cyclists and 178 pedestrians took part in this trial. Participants who cycled and drove in the trial were predominantly males (65%) whereas those who walked were more evenly divided, with 55% of them female as shown below.

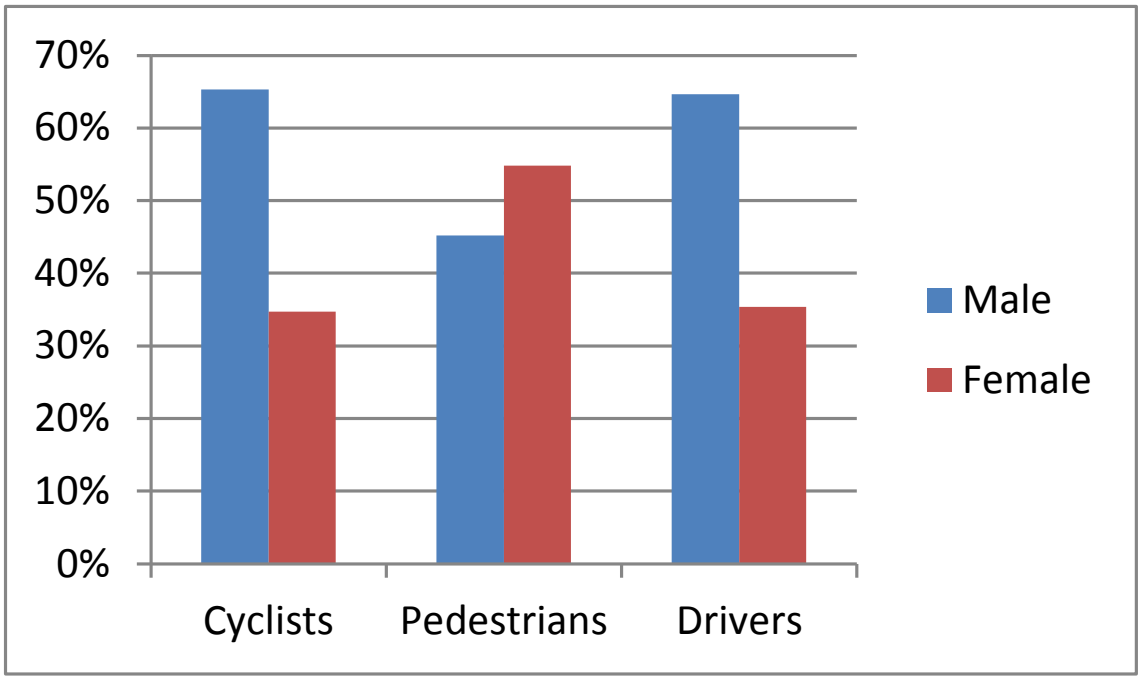

Figure 104: Trials group gender profiles

A wide spread of age groups was included but a quarter of those who participated as cyclists were aged 18-24 and a similar proportion of those who drove were aged 55 – 64. The profile is shown in **Figure 105**. Note that for insurance reasons, people under the age of 25 were unable to participate as drivers.

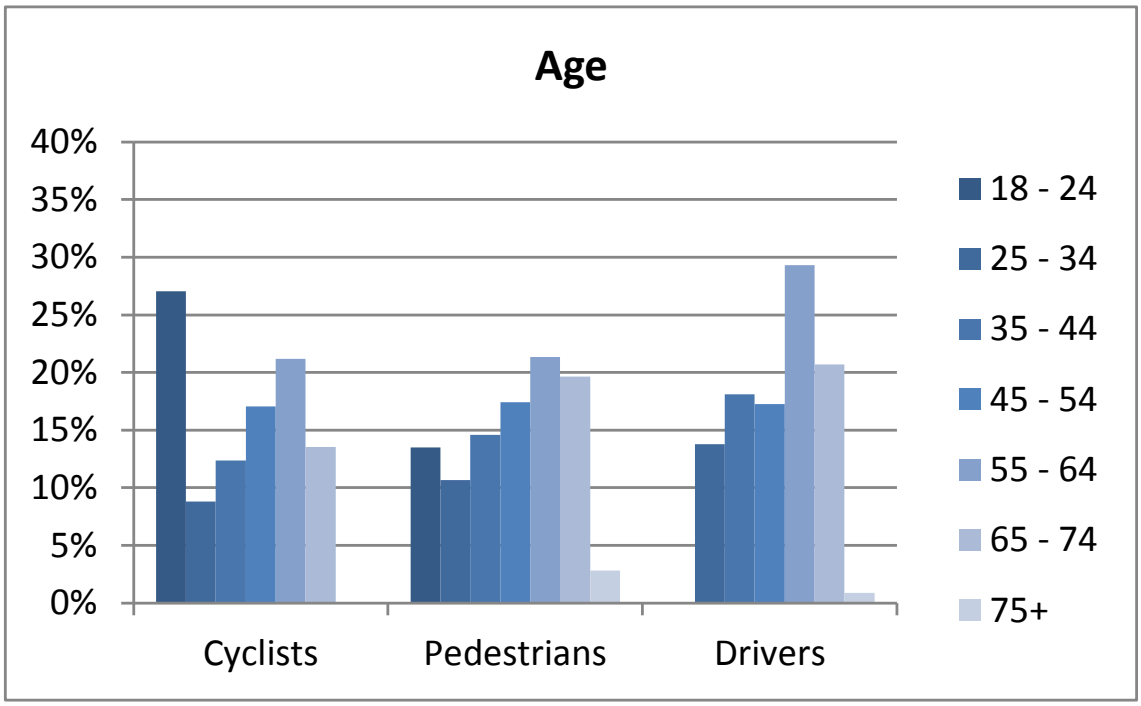

Figure 105: Trials group age profiles

3.1 Questionnaire Analysis Findings

The questionnaire analysis has focussed on addressing four areas of interest:

1. Understanding how to navigate the roundabout
2. The influence of different aspects of layout
3. Perceived benefits and the influence on cycling in London, and
4. Interactions between cyclists and road users

3.1.1 Understanding how to navigate the roundabout

3.1.1.1 Cyclists' lane preference

As shown in **Figure 106**, the majority of cyclists were in favour of taking advantage of the cycle lane round the roundabout. When asked to consider heavy traffic with crowds of pedestrians, around 90% of cyclists said they expected to use the cycle lane in preference to the road; rather more expected to use it for turning left (96%) than for going straight on (92%) or turning right (89%),.

In quiet traffic with few pedestrians, over 70% said they would use the cycle lane in preference to the road; more expected to use it for turning left (88%) than going straight on (78%) or turning right (73%).

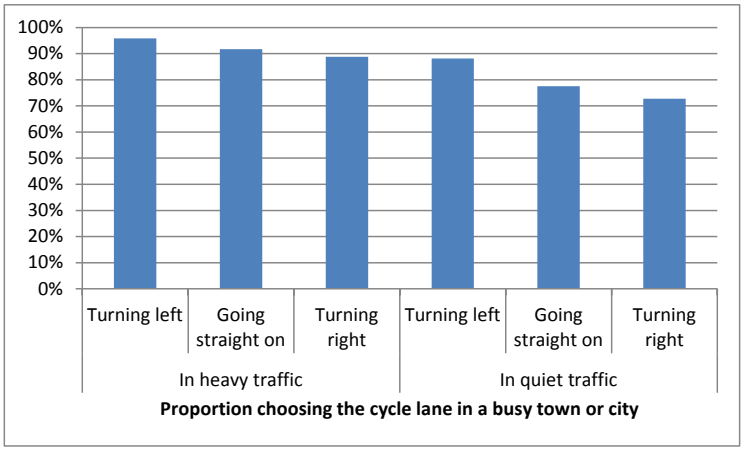

Figure 106: Cyclists Lane Preference

3.1.1.2 Interpretation of the different types of road markings and layouts by the different groups

Most of the participants (82% of cyclists, 84% of pedestrians and 75% of drivers) said they noticed the markings which were 'new' to UK roads – the white squares near the crossing.

Correct explanations of their meaning were given by 31% of cyclists, 33% of drivers and 23% of pedestrians. Most of the others gave 'safe' interpretations in their explanations: 'give way to cyclists', 'give way', 'warning', 'caution' or 'stop'. The full range of responses is given in **Figure 107**.

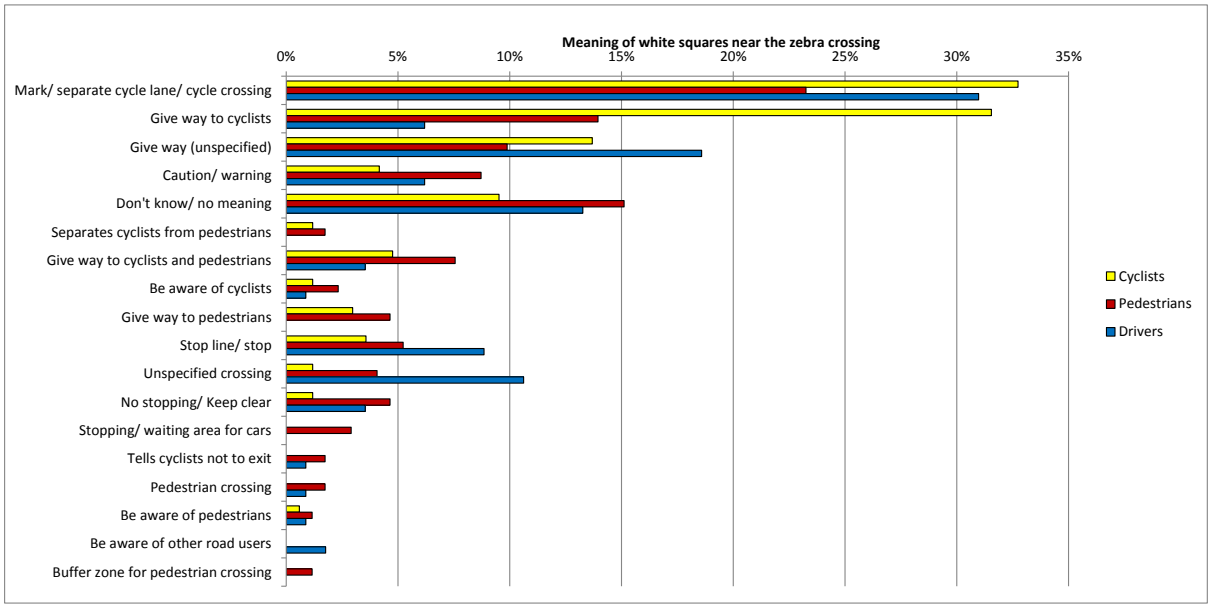

Figure 107: Interpretation of white square road markings

A minority said they did not know what the markings meant (10 - 15%). A few pedestrians (3%) misinterpreted the markings as indicating a stopping or waiting area for vehicles.

Cyclists

Almost all of the cyclists (around 95% on the approach and 91% on the exit) said that they prepared to give way to pedestrians crossing the cycle lane where the crossing was marked as a zebra crossing. At these zebra crossings, around 89% of cyclists said they would wait for the pedestrians on the approach and around 85% said they would do on the exit. The results for on all arms are given in **Figure 108**.

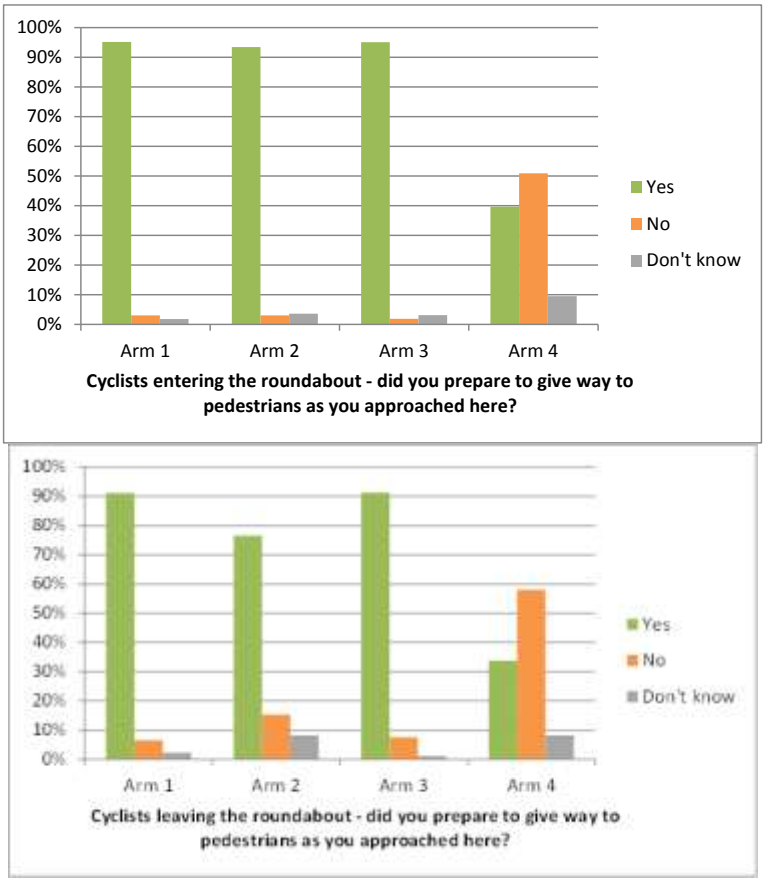

Figure 108: Cyclists' preparedness to give way on approach

At Arm 4 where the pedestrian crossing point was unmarked and cyclists would be expected to have priority, 40% of cyclists said they prepared to give way to pedestrians on the approach and 34% did so on the exit. **Figure 108** clearly shows the lack of clarity on who has right of way for arm 4 compared to the other arms. On the approach, 45% of cyclists understood correctly that the pedestrians should wait for them and 52% did so on the exit. Those who said they would wait for the pedestrians (about a quarter) could lead to collisions if any cyclists behind them did not expect them to stop for pedestrians. Those who said they would wait for pedestrians gave reasons of safety, courtesy ("*they may not have spotted you*") or because they thought pedestrians had priority ("*in any situation pedestrians come first*"). For some, this was because the unmarked pedestrian crossing was seen as an extension of the zebra crossing on the road, but others said they gave priority to pedestrians as a matter of courtesy or caution rather than through misinterpreting the layout.

> *"The cycle path is clearly crossing a footpath approaching the zebra."* (Cyclist, Arm 4)

If pedestrians were waiting to cross the cycle lane away from designated crossings, most of the cyclists said they would expect the pedestrian to wait for them (81% on the approach to the roundabout and 82% on the orbital lane).

Pedestrians

When deciding when to cross where there was a segregated cycle lane, almost all pedestrians (around 95%) said they looked for cyclists and most said they noticed the cycle lane (86% at one arm and 79% at another - **Figure 109**).

At the point where there was no segregated cycle lane (**Figure 109**, Arm 2), 81% said they looked for cyclists and 37% said they noticed the cycle lane 54% said they did not notice the cycle lane.

At each crossing point, almost all pedestrians said they looked for vehicles (ranging between 86% and 93%).

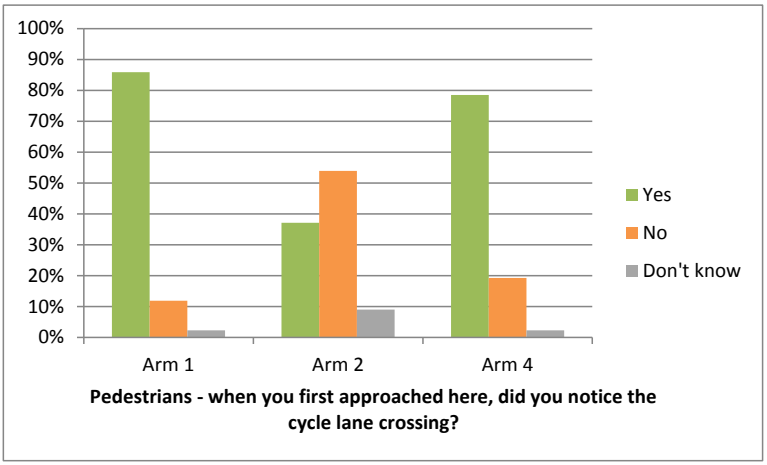

Figure 109: Noticing the cycle lane

Where there was a zebra crossing on a cycle lane, a majority of pedestrians understood the priority and said they expected the cyclist to wait for them to cross (75% at Arm 1); those who said they would wait for the cyclists before crossing tended to do so because they were not sure whether the cyclist could see them or could be trusted to stop, or because they were considering the speed and position of cyclists and how long it takes for cyclists to stop. A few thought the cyclist had right of way.

"Because you can never tell if the cyclist will stop so it's best to wait."

"I would not trust the cyclist to wait for me."

Where there was no zebra crossing on the cycle lane, a majority of pedestrians correctly understood the priority: 74% said they would wait for the cyclist before crossing. Most of those who said they would expect the cyclist to wait while they crossed misunderstood and thought that pedestrians had right of way, but a few were simply being cautious.

"Cannot see any indication the cyclist should give way."

Some thought that because there were no specific instructions that cyclists should give way, the pedestrians would have priority, while some saw the unmarked crossing as an extension of the zebra crossing, with the same priority.

"As road users they should give way to pedestrians."

Where there was no designated crossing on the cycle lane, the majority of pedestrians said they would wait for the cyclist before they crossed (88% on the approach lane, 96% on the exit lane and 93% on the orbital lane) but a few said they expected the cyclist to wait for them to cross (8% on the approach, 3% on the exit and 6% on the orbital lane). A few appeared to misunderstand the priority on the orbital lane.

Drivers

Just over half of the drivers said they noticed that there were differences between the four layouts as they approached them for the first time. The most frequently mentioned difference was that some had a segregated cycle lane and others had a cycle lane marked on the road.

> *"On arms 1 and 4 the cyclists were separated, 2 and 3 were more normal entry to the roundabout."*
>
> *"Some separated the cycle lane from the main carriageway others required the two road users to merge before the junction."*
>
> *"Markings for cycle lane varied."*
>
> *"Some had different road markings, some had different layouts/cycle separation."*

On average 68% of drivers said they noticed the cycle lane as they approached the roundabout and 76% did so as they left the roundabout. On the exit at Arm 3 where the markings were less distinctive, rather fewer drivers said they noticed the cycle lane (70%) than at the other exits but the different layouts did not appear to affect the number of drivers who noticed the cycle lane as they approached the roundabout.

3.1.1.3 Willingness of drivers to give way to cyclists when entering and leaving the roundabout

On average 94% of drivers said they would have given way if they had seen a cyclist crossing on the cycle lane. These proportions did not vary much between the different layouts as can be seen in **Figure 110**.

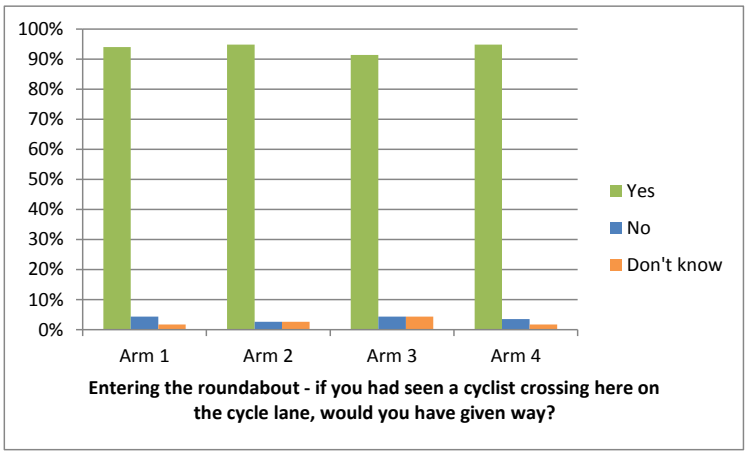

Figure 110: Drivers' willingness to give way to cyclists on entry

As they were leaving the roundabout, an average of 95% of drivers said they would have given way if they had seen a cyclist crossing on the cycle lane. Rather fewer said they willing to give way at Arm 3 where the markings were less distinctive and rather more

said they would give way at Arm 2 where the cycle lane was separated from the zebra crossing.

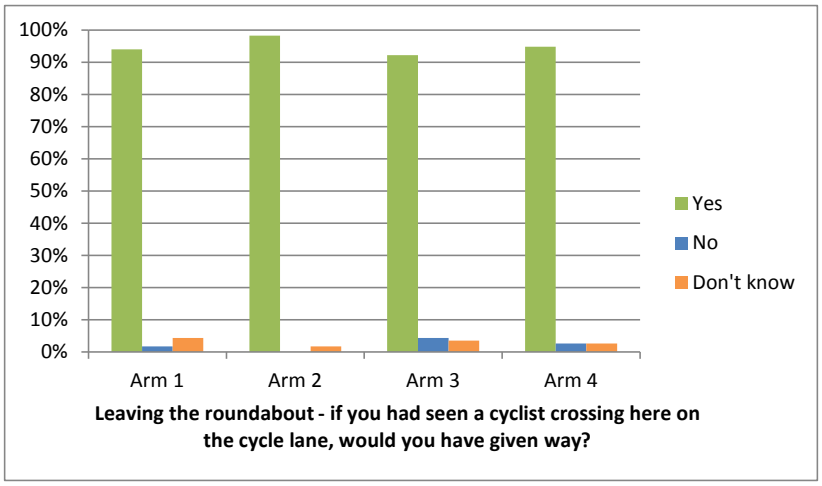

Figure 111: Drivers' willingness to give way to cyclists on exit

Fewer drivers said they would give way to cyclists emerging from the orbital lane to re-join the vehicle lanes: 77% said they would have given way, 1% said they would not have done and 22% were unsure. This indicates greater uncertainty among drivers about priority over cyclists at this point than where cyclists were crossing the road on the orbital cycle lane.

3.1.2 The influence of different aspects of layout

3.1.2.1 Perception of ease of manoeuvring and safety by the different groups

In general, participants rated the roundabout as 'easy' or 'very easy' and 'safe' or 'very safe' to use, but a minority said they found it difficult and unsafe. Detailed figures for cyclists entering, joining and leaving the roundabout are shown below.

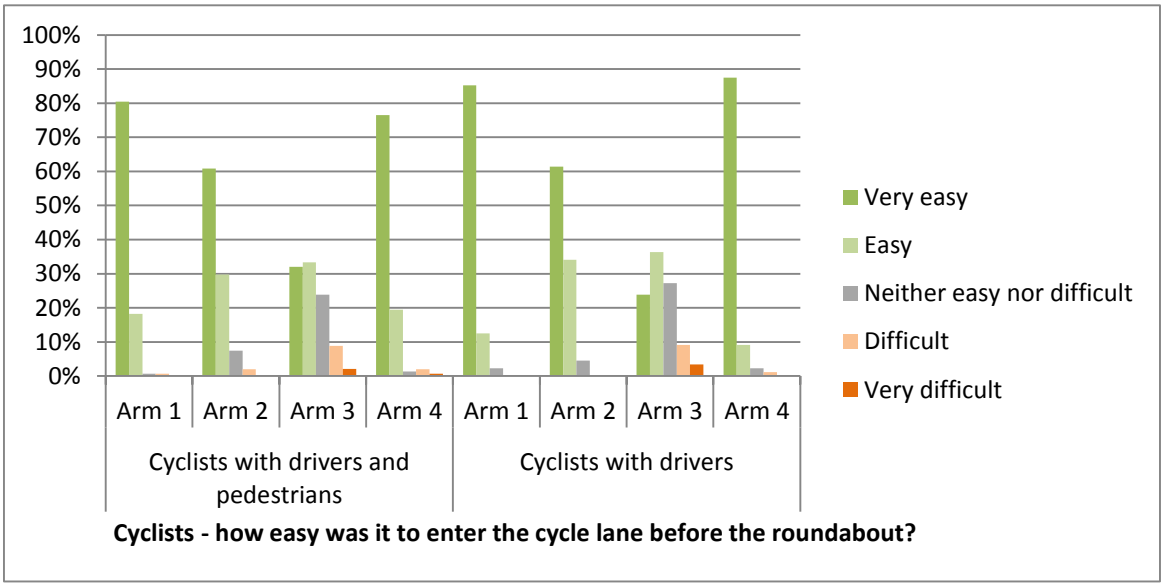

Figure 112: Ease of use, entering the roundabout

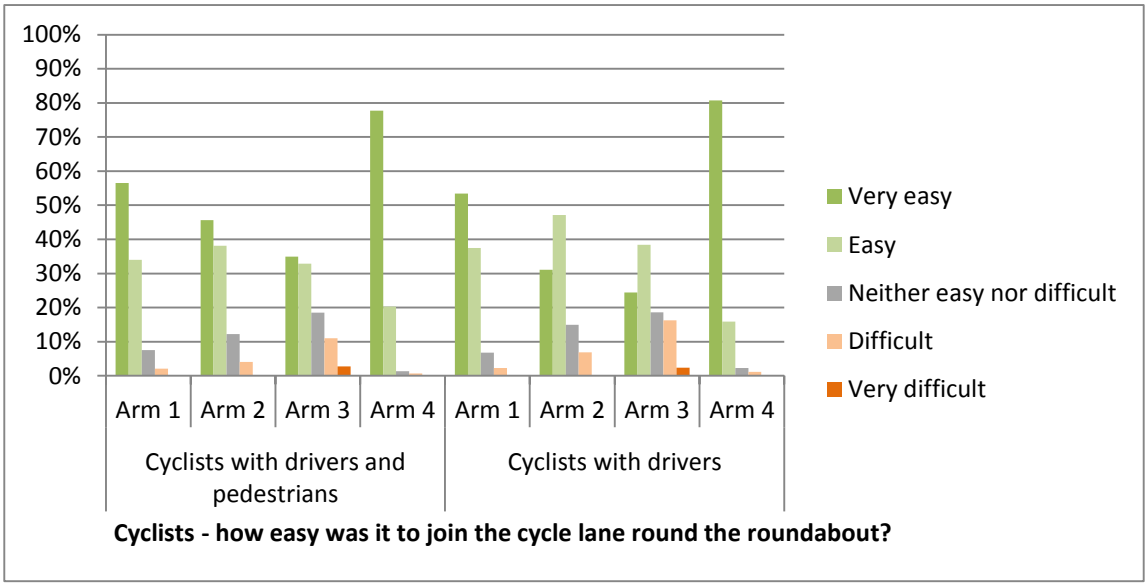

Figure 113: Ease of use, joining the roundabout

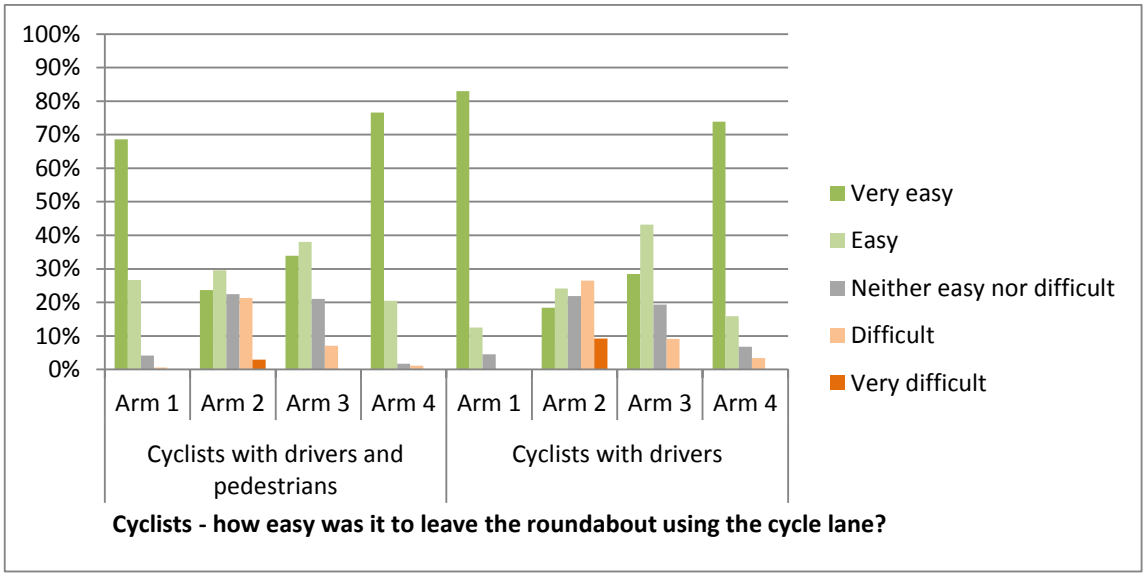

Figure 114: Ease of use, leaving the roundabout

Unsurprisingly, cyclists and drivers thought it would be safer in quiet traffic than in heavy traffic.

In traffic, cyclists rated turning left using the cycle lane as the safest manoeuvre and turning right as the least safe. However drivers' safety ratings were fairly similar for turning left, right and going straight on in traffic.

When compared with an ordinary roundabout, the majority of cyclists said it was easier to use (59% said it was 'much easier' and 30% said it was easier). Just over half of the pedestrians found it 'easier' (29%) or 'much easier' (24%). Drivers were more evenly split between those who found it easier or much easier (42%) and more difficult or much more difficult (41%).

Cyclists who found it easier to use mainly explained this because they were separate from traffic and felt safer.

"Allows cyclists and drivers to stay apart. Better flow of traffic overall."

"By keeping everyone mostly apart it keeps things moving and safer."

"Safer for cyclists because of separate lanes. Better for pedestrians because of all the crossings. Motorists are more likely to expect bikes and people to be there."

"Safety for all - cars would have speed reduced."

Cyclists who found it more difficult said they would need to get used to the layout, that the markings were unclear, corners were tight and workload greater than an ordinary roundabout.

Pedestrians who said it was easier to use tended to say this was because they had priority over traffic, they could see what was happening more easily, it was easier to know where cyclists would be and be aware of them, and that the traffic was slower than on an ordinary roundabout.

"Cyclists would be safer away from traffic. Pedestrians also become safer due to double crossings."

"The layout makes it clear for all to see the different users of the roundabout, keeps cyclists safer and allows pedestrians to check each user group when crossing."

"[I] felt safe having cycle track that did not affect me as a pedestrian and allows cyclists to move safely and more quickly."

Pedestrians who found it more difficult mainly said this was due to increased workload.

"Layout is too complex, current roundabouts are difficult enough as it is."

Drivers' reasons for it being easier to use than an ordinary roundabout reflected those of cyclists – that the cyclists were separated from traffic and it was safer; they also said it increased their awareness of cyclists. Drivers who found it more difficult tended to say this was due to increased workload and being unfamiliar or needing to get used to it.

"Very confusing and dangerous for drivers who are not familiar with the layout."

"[It would benefit] everyone except motorists as the cars would be left on the roundabout."

Views on safety reflected those on ease of use: if a feature was rated more difficult by a group of users it tended to be rated as less safe as well, highlighting a potential distinction between perceived and actual safety.

At several of the approaches to the roundabout, drivers mentioned difficulties with focusing their attention, having too much to watch out for and distraction by pedestrians. A few said that the crossings were too close to the roundabout.

Difficulties encountered by drivers going round the roundabout itself were about the right of way being unclear, having a lot to watch out for and having to drive slowly.

"If it was busy it would be a nightmare."

"It slowed vehicle traffic down so may annoy car drivers."

Drivers found leaving the roundabout to be more difficult and less safe than joining it. Some of the most frequently reported difficulties occurred at all exit points: too much to

watch out for, cyclists in the driver's blind spot, and holding up the traffic when they gave way to pedestrians or cyclists crossing the exit.

> *"Too much going on at the junction not knowing where to stop."* (Driver at Arm 3)

> *"As the bikes were in their own lane it's hard to see where they are going."* (Driver at Arm 4)

Among cyclists and pedestrians there were more differences in ratings of ease of manoeuvring and safety between the various entry and exit treatments than among drivers, and drivers' safety ratings did not show a clear preference for or dislike of, any of the entry or exit points.

3.1.2.2 Effect of different entry treatments

For cyclists, entering the cycle lane before the roundabout was found to be most difficult and least safe at Arm 3 where 9% described it as 'difficult' and 2% as 'very difficult' – see **Figure 112**. The cycle lane at Arm 3 was marked by cycle symbols on the carriageway, and the lack of segregation made it difficult for some, making them feel vulnerable. Joining the cycle lane round the roundabout was also more difficult for cyclists at Arm 3 and least safe; 11% said it was 'difficult', 3% said it was 'very difficult' (**Figure 113**), 10% said it was 'unsafe' and 1% said it was 'very unsafe'. This involved a sharp turn into the orbital cycle lane, which was not obvious to some, and led some cyclists to pull out into the centre of the road so that they could make this turn.

> *"It's not immediately obvious not signed and I would miss it, assume straight on. Quite a sharp turn."* (Cyclist, Arm 3 'difficult')

> *"There was a conflict with cycles and cars merging into a narrow entrance involving sharp breaking by a car and my bikes as I followed it."* (Cyclist, Arm 3 'difficult')

A few cyclists described difficulties at other entry points. At Arm 1 (where there was a segregated lane) the sharp turn to the left into the orbital lane slowed some cyclists down. At Arm 2 difficulties mentioned were cycling alongside vehicles because the cycle lane was not segregated, uncertainty in the unmarked area between the zebra crossing and the orbital lane, and the sharp turn into the orbital lane (as at Arm 2). At Arm 4 (where there was a segregated cycle lane) a few found the layout unclear and were unsure about who could use it and who had right of way.

Among drivers, the proportion who rated turning left, right and going straight on to be 'very easy' was rather higher at Arm 1 and 4 where cyclists were in a segregated lane than at Arm 2 and Arm 3. Difficulties mentioned particularly by drivers turning left and right here were seeing cyclists approaching from behind on the left.

> *"Awkward to see what was coming up on the left."* (Driver at Arm 1)

3.1.2.3 Effect of different exit treatments

For cyclists leaving the roundabout, Arm 2 was described as the most difficult and least safe: 21% described it as 'difficult' and 3% as 'very difficult' (**Figure 114**), 23% said it was 'unsafe' and 6% said it was 'very unsafe'. Leaving the orbital lane at Arm 2 involved a sharp left turn into the road and as well as this sharp turn, cyclists were concerned about whether cars would give way to them, lack of cycle lane at this point

and noticing the pedestrian crossing in time if they needed to give way to people crossing.

Leaving the orbital lane at Arm 3 also involved a sharp left turn but was 'sheltered' from vehicles leaving the roundabout by a kerb and 7% of cyclists found it difficult, 13% said it was 'unsafe' and 1% said it was 'very unsafe'. The main difficulties described were the lack of cycle lane, the sharp turn and the possibility of having to stop for pedestrians, thus blocking cyclists coming along behind. Some were unsure about whether the traffic would stop for them as they emerged from the cycle lane.

> *"Although the road markings give cyclists priority I wouldn't trust a vehicle - you also need a good look over your right shoulder."* (Cyclist, Arm 2 'difficult')

> *"Cyclist is effectively spat out into the middle of the lane exiting arm 2. The corner is sharp so you must either go slowly or very wide."* (Cyclist, Arm 2 'very difficult')

Pedestrians found it more difficult and less safe to cross the road at Arm 4 (where there was no zebra crossing marked across the cycle lane), than at Arm 1 and Arm 2; at Arm 4 18% said it was 'difficult', 18% said it was 'unsafe' and 1% said it was 'very unsafe'. The difficulties were mainly about having no zebra crossing on the cycle lane, uncertainty over priority and the cycle lane not being marked.

> *"Because I wasn't sure who has a right of way me or the cyclist."*

> *"No zebra crossing or markings for the pedestrian and cyclist to show who has right of way."*

Difficulties described by drivers leaving the roundabout which were specific to some of the layouts were the proximity of the crossings to the exit (mentioned at Arm 1 and 4 but was the same at Arm 3) and at Arm 2, there was confusion about priorities and surprise at the triangular give way marking before the crossings.

> *"Stop starting whilst trying to work out which direction the cyclists are travelling and who has right of way."* (Driver at Arm 1)

> *"Too many places to look for pedestrians and cyclists - very little warning and being immediately off the roundabout could be dangerous for following traffic."* (Driver at Arm 1)

> *"Although give way sign cars should have priority not cyclists as safer."* (Driver at Arm 2)

> "*Not expecting a stop sign on the floor exiting a roundabout."* (Driver at Arm 2)

3.1.2.4 Effect of separation of pedestrian and cycle crossings

At Arm 2 of the roundabout, the cycle crossing and the zebra crossing were separated by 5m. The drivers in the trial did not express a clear preference and only about 40% said the difference had an effect on their behaviour. Reasons given by some drivers for having the crossings together were also given by other drivers for separating them; if they are together there is one crossing to think about and stop for, the pedestrians and cyclists are more noticeable and priorities are clearer. For other drivers, it is easier to judge the crossings individually if they are separate, with separate decision points, distinguishing between pedestrians and cyclists in how the crossing is judged.

"As a driver, I only want to stop once - my focus is in front, once I move off I don't want to have to stop again almost immediately."

"I don't like the gap between the two also easier to watch cyclist and pedestrian traffic when closer together."

"The gap allows you to treat each type of road user individually. Thus making the waiting time to enter the roundabout shorter."

"Together they reinforce the idea that cyclists gets right of way."

Some drivers thought they drove more cautiously where the crossings were together and others thought they were more cautious where the crossings were separated.

3.1.3 Perceived benefits and the influence on cycling in London

3.1.3.1 Perception of users whether this facility is beneficial or otherwise, for them and for other groups of road users

As shown in **Figure 115**, almost all participants thought that cyclists would benefit from the roundabout: 95% of cyclists, 93% of pedestrians and 89% of drivers. Around 30 – 40% thought drivers would benefit from it. Pedestrians were seen as benefiting from it by 61% of cyclists, 40% of pedestrians and 45% of drivers. A few participants did not identify any groups of participants who would benefit.

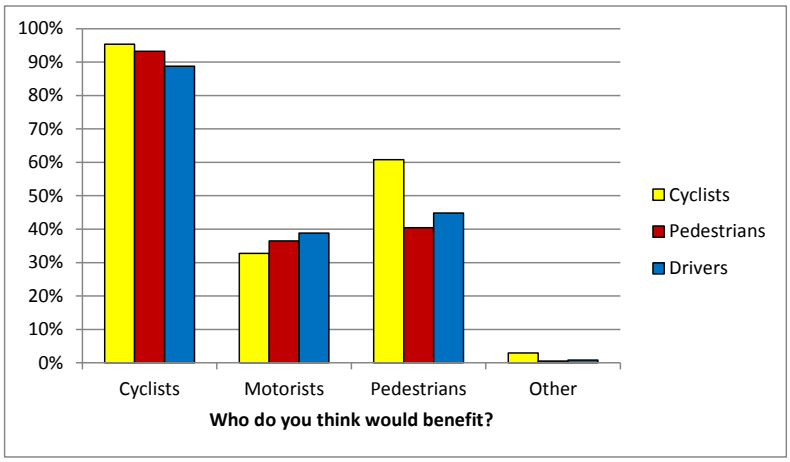

Figure 115: Perceived beneficiaries

The main advantages of the roundabout, mentioned by cyclists, pedestrians and drivers alike, were the segregation of cyclists from traffic and improved safety. Other benefits mentioned included priority for cyclists, improved awareness, visibility and clarity.

"Separation of cyclists from motorists is safer for cyclists - easier for cyclists to see pedestrians who may otherwise be dodging through cars. Therefore safer for pedestrians. Motorists will be happy not to have cyclists on their blind side."

"Cyclists benefit as they are given safe passage according to the road markings and they have a continuous journey. Pedestrians don't have to worry about cyclists or cars. Drivers can be sure they don't have a cyclist on their inside that they haven't seen - less stress all round."

"Cyclists can benefit from having their own designated lanes and it's safer for pedestrians and cars."

"Having a clearly defined route for cyclists which doesn't interfere with pedestrians would benefit all users."

Cyclists saw the disadvantages as being delays to motorists, and drivers finding it difficult giving way to cyclists as they leave the roundabout, both of which could affect standards of driving and safety.

"Motorists will be very frustrated by not being able to leave the roundabout with priority. In my view it will significantly slow movement through the junction by motor vehicles and lead to very bad behaviour."

Drivers who made negative comments were concerned about confusion, priorities, safety and traffic backing up on the roundabout.

"The constant stopping of cars etc. for cyclist and pedestrians might cause a back up of traffic on the roundabout so it may slow traffic flow."

For pedestrians, the disadvantages were about confusion and complexity, particularly over priority, with a resulting increase in risk.

"Layout is too complex, current roundabouts are difficult enough as it is."

"Much too confusing and so different to that we are used to."

"As a pedestrian I was never sure the cyclist would stop for me."

3.1.3.2 Influence of this sort of facility on participants' willingness to cycle in London

Of the participants, 43% of cyclists, 26% of pedestrians and 21% of drivers said they thought it would affect how often they cycle in London if there were cycle lanes like this on roundabouts there. The main reasons given were about safety; some mentioned confidence.

"I cycle in London and it would make it easier especially when turning right."

"It would affect where I go. I now avoid most of zone 1. e.g. Elephant and Castle might become a possibility for me, if this were implemented."

Of those who said it would affect cycling in London, 27% of cyclists and 14% of pedestrians currently cycle in London; for most this is less than once a week. A few of the comments were indicative of a willingness to cycle in London more frequently but some qualified their comments, saying the roundabouts would need to be on their routes or London-wide, or that the lanes would need to be wide enough for the peak cycle traffic.

"Yes if there was a route I used frequently."

Participants who said it would not influence cycling in London mainly said they do not cycle in London, and many said they would not consider it, but some said they cycle anyway or that they usually cycle in London traffic anyway. One said they might consider using the cycle hire scheme.

3.1.4 Interactions between cyclists and road users

3.1.4.1 Influence of having two other road users present, compared with one only

Comparing these results with the trial in which cyclists experienced the roundabout with drivers but no pedestrians indicated no statistically significant differences in how easy or safe cyclists said it was to use the roundabout.

For drivers, there some significant differences between the trials with and without pedestrians but most comparisons in their ratings of ease of use and safety showed no significant differences between the trials. The statistically significant differences were an increase in the proportion of drivers who said it was 'difficult' or 'very difficult' to turn left at Arm 1 and Arm 2 and an increase in the proportion who said it was 'very safe' leaving the roundabout at Arm 2 in this trial with pedestrians and cyclists, compared with the trial with cyclists but no pedestrians.

Thus in general the introduction of pedestrians as well as cyclists and car drivers had little effect on how easy or safe participants thought the roundabout was.

3.1.4.2 Opinions on who has (or should have) priority under the circumstances created

This question was not specifically asked in the questionnaire, so the findings below are derived from the comments made by the participants in the questionnaires. This also means that there is no value in noting the exact numbers of comments as not all participants commented on their experience.

For cyclists, one of the benefits of the design was having priority over vehicles as they crossed the roads joining and leaving the roundabout while using the orbital cycle lane. This provided them with a clear path without having to stop and start.

However when cyclists were leaving the roundabout at points where there was no marked cycle lane as they joined the road (Arm 2 and Arm 3), they were unsure about whether or not they had priority over vehicles; some drivers were also uncertain. As a result, cyclists were more concerned about the safety of the layout at these exit points than at the exits where they either filtered into the road from a segregated cycle lane or continued in a cycle lane after the roundabout (Arm 4 and Arm 1). It is worth noting that this observations reflects the difference between entry/exit treatments rather than the Dutch roundabout design per se.

Pedestrians appreciated having zebra crossings at all of the arms of the roundabout, giving them a safer and easier route around the roundabout than on a normal roundabout.

However where the pedestrian crossing over the cycle lane was not marked as a zebra crossing (Arm 4), a number of cyclists and pedestrians were confused about who had priority, and the pedestrians found this crossing point to be the most difficult one.

Away from designated crossing points, a few pedestrians were confused about whether or not they had priority over the cyclists on the cycle lane.

Some drivers were uncertain about right of way where the cycle lane crossed the road and a few said they would not have given way if they had seen cyclists crossing. Some drivers suggested that it would be easier for them to understand priorities if the orbital lane was marked with a coloured surface or if signs were provided.

A disadvantage of giving cyclists on the orbital lane priority over vehicles leaving the roundabout was recognised by drivers, cyclists and pedestrians; this was seen as a potential cause of 'blocking' the roundabout causing delays to vehicles and the risk of 'shunts' as vehicles waiting for pedestrians or cyclists to cross are hit by following vehicles whose drivers are expecting to have priority as they leave the roundabout.

3.2 Focus Group Findings

3.2.1 Cycle Focus Group

23 cyclists took part in two focus groups on two days. The participants included both males and females, and ranged in confidence from occasional (once a month) to very regular (daily including commuting).

3.2.1.1 Overview

Cyclist participants had varying views on the roundabout layout. There was a clear divide between those who were regular, confident cyclists and those who were less confident and occasional cyclists. Less confident cyclists liked the segregation between cyclists and vehicles, suggesting this assisted with cycle safety and allowed them to enjoy cycling whilst not worrying about traffic encroaching into their space. They also suggested this reduced risks known from HGVs and buses, and therefore felt it would contribute to cycle safety in London. However, confident participants who cycled regularly, expressed concern about their perception that the cycle lanes were narrow with high kerbs, suggesting leaving the cycle path mid-way would be problematic. In addition, it was suggested that the carriageway would be a faster option, as turning right would be more direct and there was less chance of becoming trapped behind a slower cyclist.

The varying arms from the roundabouts had differing layouts and road markings. Participants criticised arm 3, which was noted to have a particularly tight entry point; a number of participants suggested this entry could be easy to miss, as there was little signage or road markings to indicate its presence. Furthermore, it was noted to be so tight it would require cyclists to slow right down and swerve into the road to enter it.

Arm 2 was the least favoured exit design as participants felt the location for cyclists to merge with traffic was too close to the roundabout. However, arm 1 was commended with the entry and exit points described as seamless. Arm 1 was considered to have the most clarity surrounding priority. This was due to the continuation of the zebra crossing road markings continuing across the cycle lane. In contrast, however, a number of participants suggested they preferred arm 4 as there were no road markings and this was perceived to mean cyclists had priority. There was a general consensus amongst participants that clearer signage and road markings would assist with safety as priority would be clearer.

Whilst there were differing views over whether participants would choose to use the cycle lane based on confidence level, the majority of participants felt that the layout would contribute to cycle safety. It was discussed that the layout would be beneficial in some areas more than others, with a general feeling that the layout would be redundant in quiet areas; however there could be an issue with vehicle fluidity in busier locations.

3.2.1.2 Understanding how to navigate the roundabout

A number of participants indicated initially it was unclear how to navigate the roundabout due to the ambiguous road markings and lack of signage.

> *"…no signage…there was none at all"*
>
> *"It wasn't obvious what the rules were"*

Participants suggested the entrance onto the cycle lane from the road on one of the arms (Arm 3) was very tight, requiring the cyclist to swerve into the road. This arm was considered to be dangerous by a number of participants, suggesting there was no signage on the approach and therefore cyclists could miss the entrance. One participant suggested the lack of signage led to disorientation leading to them cycling in the wrong direction up the cycle lane.

> *"…with traffic approaching the roundabout and then a 90º turn to enter the cycle lane, if approaching at speed you have to make a quick decision whether to join the cycle lane"*
>
> *"…no signs with an arrow saying cyclists this way...wasn't anything that guided you".*

3.2.1.3 Interpreting the different types of road markings and layouts

Participants interpreted the elephant's feet road markings as outlining the cycle path; however a number were confused or did not observe the triangular markings.

A number of participants commented that priority was ambiguous on a number of the roundabout arms. Arms 1 and 3 were preferred as zebra crossing markings continued across the cycle path and this was felt to be safer as there was clear priority to pedestrians. Arm 4 was generally the least favoured as road markings were absent across the cycle path.

> *"…the cars had a broken line so assumed cyclist had priority"*
>
> *"…felt I had priority but didn't know if the car knew I had priority"*
>
> *"…not obvious what the rules were"*

3.2.1.4 Perceptions of comfort, safety, ease of manoeuvring on the roundabout

Less confident participants tended to suggest that the roundabout would contribute to cycle safety, particularly between cyclists and HGVs.

> *"…no one is going to knock me over on the roundabout".*

However cyclists who were more confident suggested ambiguity over road markings and priority could be dangerous, with a number suggesting they would prefer to use the carriageway as this was their usual method. In addition, there were concerns that the cycle lanes were too narrow for overtaking and that they may not be adequately maintained and cleaned. The kerbs were also criticised as being unusually high and not allowing any flexibility to the cyclist if they wished to leave the cycle lane mid-way. One participant suggested if he had a puncture and needed to leave the cycle lane this could be problematic.

"…was worried about the kerbs as seemed like the cycle lane entrances were small and kerbs were high"

"…the design was a big no no, (dangerous), if you hit the kerb on a bicycle"

Entries to the cycle lanes were criticised on a number of the arms, with arm 3 found to be particularly tight to enter and cyclists suggesting they would have to swerve into the road to enter the lane. Exit routes were also criticised. However arm 1 was favoured, as it carried the cyclist through the roundabout in a segregated cycle lane and beyond.

"…the 90º left turns that didn't have a slip road…seemed dangerous".

"…with traffic coming up to the roundabout and then a 90º turn into the cycle path"

"…wasn't anything to guide you into cycle lane"

Participants were also concerned drivers might become frustrated if there were high volumes of pedestrians and cyclists they had to give way to. It was felt that information would be needed to educate drivers about the road system and legislation needed to enforce priority.

3.2.1.5 Willingness of cyclists to use the orbital cycle lane as intended

Whilst less confident cyclists were impressed by the layout and suggested they may be encouraged to cycle as they would feel safer, more confident cyclists were less impressed.

"…the layout would give less confident cyclists more confidence"

Confident cyclists suggested they would be tempted to use the carriageway, as they considered that the cycle lanes were narrow preventing overtaking and they were concerned cycle paths would not be adequately maintained and cleaned of glass and debris.

"I wouldn't do it…just continue with the traffic and not enter the cycle path at all".

3.2.1.6 Do participants regard this facility as beneficial or otherwise, for them and for other groups of road users?

A number of participants suggested they would feel safer using the cycle path because of the segregation between cyclist and vehicle. A number of participants suggested they liked the location of the zebra crossing and cycle path, as vehicles tended to stop for the pedestrians so they knew the vehicle would stop for them.

3.2.1.7 Influence of this facility on cyclists' willingness to cycle in London?

Whilst a number of participants suggested the cycle path would provide cyclists with protection from road traffic, there was concern that this protection would be limited to the roundabout. Participants suggested that further investment would be needed to extend the cycle lanes throughout London beyond the roundabout in order to have a further impact on cycling numbers.

"In isolation this layout will help some…however it is just a roundabout, what about the roads and the rest of the junctions".

A number of participants had concern that if this layout was implemented in London, there would be lengthy delays due to the high volumes of pedestrians and cyclists.

> *"This will slow traffic down so much that it will lead to drivers getting frustrated"*

One participant suggested this layout could encourage more drivers out of their cars as the congestion would worsen for them but improve significantly for cyclists. In addition, it was felt by a large number of participants that the segregation between cyclist and driver would significantly improve safety, particularly between cyclists and HGVs.

> *"…people might try to overtake, might hop onto the pavement…in London people can be all over the place"*

Participants with children suggested the layout would encourage them to cycle with their children more. However, participants were concerned that if the layout was located in an area with heavy traffic then a segregated cycle lane leading from the roundabout would also be required. Furthermore, a number of participants expressed concern that children might be expecting priority at crossings or might not see emergency vehicles at crossings and continue into the road.

3.2.1.8 Influence of aspects of the layout on participants' behaviour and responses?

All cyclists travelled in the same direction, however a number of more confident cyclists suggested it was unrealistic to expect cyclists to travel the entire roundabout to turn right and for this manoeuvre they would be tempted to use the carriageway in a real life situation.

Participants suggested that whilst there was ambiguity over priority on certain arms between pedestrians and cyclists, they tended to make a judgement based on eye contact and mutual agreement of priority rather than road markings and signage. However a number suggested that at busier times this method would be inadequate and thus consistent road markings and signage would be required.

3.2.2 Driver Focus Groups

15 drivers took part in two focus groups on two days. The participants included both males and females, and ranged in confidence from occasional (3-4 journeys/week) to very regular (50 journeys/week) drivers.

3.2.2.1 Overview

The majority of participants favoured the segregation between cyclists and vehicles. A number suggested the layout felt safer than standard roundabouts as they knew where to expect cyclists. However, some participants had concerns that cyclists might expect priority, whilst drivers had a lot to assess at the roundabout and this could be dangerous. Participants specifically felt that turning left could be dangerous, as cyclists would appear in driver blind spots. Travelling straight on or turning right were preferred as they gave the driver longer to assess the crossing.

Participants were concerned the layout could lead to gridlock or long tailbacks if drivers were expected to give priority to all cyclists and pedestrians. In addition, there was concern that there could be an increased number of bumps from vehicles behind. Participants felt vulnerable whilst having to wait on the roundabout and that this was a new concept, as usually drivers accelerate away from the roundabout rather than stop

on the exit. A number of participants suggested relocating the crossings further from the roundabout, to allow all road users longer to assess the traffic from the roundabout and reduce congestion while waiting on the roundabout. Furthermore, one participant suggested moving the crossing on just the exit arms further from the roundabout to assist with traffic fluidity and allow longer for road users to assess the crossing.

Participants generally felt that the roundabout would contribute to safer roads, but that the concept would only work in certain environments. It was felt that it would be superfluous in quiet areas. However in busier cities cyclists and pedestrians would benefit from this layout, while vehicles might be gridlocked. Participants also suggested that for cycling to be further encouraged, further cycling infrastructure would be required such as more cycle lanes.

3.2.2.2 Understanding how to navigate the roundabout

A number of participants described the roundabout initially as confusing and daunting.

> *"Information overload and layout needs to be simplified"*

However after navigating it a number of times they became familiar with the layout. Participants suggested there were a lack of road markings and signage to inform drivers on how to navigate or infer priority. In addition, one participant stated they nearly drove up the cycle lane rather than the carriageway as the differences were not clear on approach.

3.2.2.3 Interpreting the different types of road markings and layouts

Participants' views of the road markings varied, with a number suggesting they negotiated the roundabout in the usual way and found the markings no different. However, some participants were unfamiliar with the markings and either ignored or were confused by them. Participants also commented on the perceived excessive number of markings and resulting confusion.

> *"Quite busy with markings…too many white lines, there was information overload"*

> *"Road markings were too busy to understand what they were asking you to do plus watch out for pedestrians and cyclists'.*

> *"The road markings didn't suggest give way to cyclists"*

Participants stated they were particularly unfamiliar with the Sharks' teeth (triangle markings), whilst the Elephants' Feet were interpreted as outlining the cycle path.

> *"Noticed some white triangle lines…but didn't know what these meant"*

All participants were familiar with the zebra crossing markings and a number read the close location of the zebra and cycle crossings to mean they should give priority to all other road users.

3.2.2.4 Perceptions of comfort, safety, ease of manoeuvring on the roundabout

A number of participants favoured the segregation between cyclists and vehicles, reducing the risk of hitting cyclists who might be wobbly or swerve into the road. However, participants did have concern at the crossing points, with the manoeuvres straight on and right preferred as it gave drivers longer to assess the crossing and look

for approaching cyclists. There were concerns, particularly for turning left, that cyclists might appear from the driver's blind spot and expect vehicles to stop.

> *"The dedicated cycle lane is great, but where there were the breaks for the cars this made me feel quite nervous, you didn't know if they (cyclists) were going to stop or not".*

Participants were further concerned for traffic fluidity if they were to give priority to all cyclists and pedestrians.

> *"It was awful…sitting on the roundabout to let all the pedestrians and cyclists go…I felt compromised"*

In addition, a number stated they felt vulnerable whilst waiting on the roundabout while giving priority. There were concerns that there could be an increased number of bumps from behind, as most drivers would expect to accelerate off the roundabout rather than stop at the exit.

> *"You stuck out and felt vulnerable"*

One participant suggested moving crossings on the exits further from the roundabout, to allow road users longer to assess the crossing and to remove waiting traffic from blocking the roundabout.

Furthermore, participants expressed concern that currently when changing lane or moving off the roundabout drivers look to the right. However this layout would lead to cyclists approaching from the left, so drivers would need to have an increased awareness of all traffic on the roundabout. In addition, it was discussed whether cyclists would be allowed to travel in both directions, which would further increase the alertness required by drivers.

> *"If you were turning left off the roundabout, it felt like you had only just got on the roundabout and then were coming straight off having to check the crossing straight away"*

> *"When turning right you would be looking to pull into the right hand lane and need to be vigilant of cyclists approaching from the left on the crossing as well".*

3.2.2.5 Willingness of drivers to give way to cyclists when entering and leaving the roundabout

During the trial, the majority of participants interpreted the layout to mean that drivers should give priority to cyclists. In terms of practicality, participants expressed concern that during busy periods with high volumes of pedestrians and cyclists, long tailbacks and gridlock could arise. Furthermore, it was discussed that one pedestrian or cyclist could potentially block up the entire roundabout whilst travelling through it.

> *"… negative to the design will be the long tailbacks "*

One participant suggested having a filter lane which gave vehicles priority to assist with fluidity. The addition of traffic lights was also recommended.

> *"Entering wasn't a problem, but there was an issue for exit, they needed a lane for cars coming off the roundabout without a crossing"*

3.2.2.6 *If this facility is beneficial for road users*

Participants suggested the layout would benefit cyclists and pedestrians. There were mixed views on the impact on drivers. A number of participants felt that the layout would hinder drivers' journeys, slowing them down considerably and potentially leading to gridlock in busy cities.

> *"Can't see any flow on the roundabout, especially on a major traffic junction…you could just be sat there"*

However, a number of drivers complimented the design, and liked the segregation of cyclist and vehicle as this reduced risk. In addition, it was noted that currently drivers were unsure of where to expect cyclists on roundabouts, whereas this layout would channel cyclists and therefore drivers would know where to expect them.

> *"…would be a 100% positive step to safety, but would need to be extended to all roads and be consistent".*

3.2.2.7 *Influence of this facility on participants' willingness to cycle in London*

Participants suggested the infrastructure would improve cycling safety. It was particularly noted that currently there were safety issues between HGVs and cyclists, and therefore segregating cyclists away would reduce the risk. However, participants suggested the infrastructure would need to continue beyond the roundabout to have a profound affect.

3.2.2.8 *Impact the facility would have on the willingness of others to cycle in London (other people, children etc.)*

A number of participants suggested they felt this layout would encourage more cyclists in London, particularly those with children or less confident cyclists.

3.2.2.9 *Influence of aspects of the layout on participants' behaviour and responses*

Participants noted that cyclists all rode in a clockwise direction on the cycle path and although cycled fast were unrealistically polite. However it was discussed whether it would be compulsory to use the cycle path and whether cyclists would be allowed to travel in both directions. Participants noted that the layout required them to have an increased awareness compared to standard roundabouts, so it was considered there were an increased number of potential conflict points.

> *"Pedestrian crossing was too close to the cycle lane…cyclists going quite quickly and pedestrians aren't…two things to consider going at different speeds"*

3.2.3 Pedestrian Focus Groups

21 pedestrians took part in two focus groups on two days. The participants included both males and females, and ranged from occasional (walks rarely) to very regular (daily) walkers.

3.2.3.1 *Overview*

The majority of participants suggested the roundabout would increase safety for cyclists, whilst frustrating drivers and slowing their journeys, but would have little impact on pedestrians. Participants suggested visibility of the cycle paths could be improved by

painting cycle symbols at cycle path entrances and having 'look left' and 'look right' markings to inform pedestrians of direction of traffic. Furthermore, it was recommended that the cycle path be covered in coloured tarmac or that the high kerbs be painted to increase visibility.

Participants criticised the location of the zebra crossing. Whilst acknowledging that this was consistent with pedestrians' desire lines, there was concern that road users would not have sufficient time to assess the crossing. Participants suggested the crossing was dangerous, as it was difficult to assess whether traffic was exiting the roundabout and whether priority would be given. Some participants deemed the zebra crossing to be dangerous and so would cross further from the roundabout.

Participants felt that the layout would contribute to cycle safety in London. However there were concerns there could be tailbacks as a result of high volumes of cyclists and pedestrians. It was therefore recommended the roundabout be developed with the addition of traffic lights to assist traffic fluidity. Participants suggested further infrastructure would be required in addition to the roundabout to encourage more cycling, with one participant suggesting there should be an increase in pedestrianized roads allowing cyclists.

3.2.3.2 Understanding how to navigate the roundabout

Participants generally understood how to navigate the roundabout. However a number suggested the layout was more confusing than that of traditional roundabouts and required increased awareness.

In addition, there were mixed views over the staggered crossing of the arms of the roundabout. Some found these to be helpful in safely crossing the road, whereas others felt they did not know which direction to expect traffic which was disconcerting.

3.2.3.3 Interpreting the different types of road markings and layouts

A number of participants suggested they did not pay attention to road markings as they felt these were for cyclists and drivers rather than pedestrians.

> *"As a pedestrian you assume the road markings are for cars not pedestrians"*

However, those that did observe the markings felt they were excessive and ambiguous with the triangular (shark's teeth) noted as particularly unclear.

> *"It wasn't clear what the road markings were".*

Participants commented that the cycle paths were not sufficiently visible and recommended having cycle symbols, 'look left' and 'look right' road markings and coloured tarmac to improve visibility and assist with crossing.

> *"Could paint look left and right road markings".*

Furthermore, kerbs were noted to be particularly high and it was suggested these could be painted to alert pedestrians.

3.2.3.4 Perceptions of comfort, safety, ease of manoeuvring on the roundabout

A number of participants suggested the layout was quite confusing and so they were unsure of the directions cyclists and vehicles would be approaching the crossing from. In addition, participants suggested due to the location of the zebra crossings close to the

roundabout, it was difficult to gauge whether it was safe to cross. One participant suggested if vehicles did not indicate whilst exiting the roundabout, which was common, then it would be difficult to gauge their direction and therefore make crossing problematic.

> *"Often vehicles don't indicate so because the crossings were so close to the roundabout it was really hard to assess whether the car was going to come towards you or not".*

Participants suggested safety would be improved if zebra crossings were moved further from the roundabout, as this would allow all road users longer to assess the crossing. However, it was noted that pedestrians may be less inclined to use the crossings if they were out of the desire line.

> *"Pedestrian crossings were well located and would be used less if located further from the roundabout".*

One participant stated they felt the location of the crossings was too dangerous and therefore they would be inclined to cross further from the roundabout.

Whilst there were mixed views on the crossings, with some participants favouring the staggered crossings, others felt unsure of where to expect traffic. In addition, it was noted the islands located in the centre of the carriageways were too narrow, with concerns for those with buggies; this was particularly apparent to arms 1 and 4.

> *"The sections in the middle were quite small…quite daunted to cross four carriageways to get across the road".*

Participants suggested that the ease of navigating the roundabout varied depending on the roundabout. The majority favoured arm 1 as this was felt to be less ambiguous, due to the continuation of zebra crossing markings continuing across the cycle lane. A limited number of participants preferred arm 4 as they interpreted that cyclists had priority.

> *"Arm 1 was easy but more to look at"*

However arm 4 was generally criticised as the most ambiguous, as there were no road marking to indicate priority. It was felt that adequate signage and markings were needed.

> *"On arm 4, there were a lot of directions to look for bikes and then cars"*

3.2.3.5 Willingness of cyclists to use the orbital cycle lane as intended

The focus groups were conducted from the perspective of pedestrians; however all participants agreed the layout would contribute to cyclist safety.

3.2.3.6 Willingness of drivers to give way to cyclists when entering and leaving the roundabout

Whilst the focus groups were formed of pedestrians, a number of participants were also drivers. Participants felt were concerned that if drivers were to give priority to cyclists and pedestrians during busy periods, there would be long tailbacks and gridlock.

> *"…there were two cars stopped behind each other to give priority at the zebra crossing…just two cars and that was blocking the roundabout…if in London with 20 cars…it will be gridlocked in the centre with cars and pedestrians going round"*

Therefore, participants suggested further consideration would be required to assist with traffic fluidity, with the potential of adding traffic lights.

3.2.3.7 Perceptions of whether this facility is beneficial or otherwise, for them and for other groups of road users

Participants suggested the roundabout would undoubtedly benefit cyclists, providing a safer environment. However it was felt that the layout would slow drivers' journeys, which would frustrate them.

> *"Drivers forced to slow down".*

Participants suggested the layout would not have a big impact on pedestrians. However arms 2 and 3, which had zebra crossings across the cycle lane, were felt to contribute to pedestrian safety. However, a number of participants suggested that the majority of cyclists expected priority at the crossings. This was particularly relevant to arm 4, which had no road markings crossing the cycle path.

> *"Where the road markings didn't continue across the road…you didn't know who had priority"*

3.2.3.8 Influence of facility on participants' willingness to cycle in London

A number of participants suggested they would not ever cycle in London because of high volumes of traffic. However, the majority of participants suggested cyclists would benefit from the layout and this was felt to be especially pertinent in heavy traffic. One participant suggested a better solution would be to increase the number of pedestrianized roads which allow cyclists.

3.2.3.9 Impact of the facility on the willingness of others to cycle in London (other people, children etc.)

Participants suggested the layout would contribute to cycle safety across London; however it would need to form part of wider safety infrastructure for cyclists. A limited number of participants suggested it was unsafe for children to cycle in London and therefore despite the infrastructure this would not encourage them to cycle with children.

3.2.3.10 Influence of aspects of the layout on participants' behaviour and responses

Participants discussed whether cyclists would be allowed to travel in both directions, it was noted if this was the case cycle paths would need to be widened. Participants observed that cyclists rarely indicated their chosen route, which pedestrians found unnerving and felt their journeys were delayed because of the ambiguity.

> *"Cyclists didn't indicate, they just seemed to think they had right of way"*

In addition, participants further stated their journeys were delayed due to the layout, as they felt it was more difficult to measure if a vehicle was exiting the roundabout and whether priority would be given.

> *"Often vehicles don't indicate so because the crossings were so close to the roundabout it was really hard to assess whether the car was going to come towards you or not".*

3.3 Video Analysis Findings

Twelve video cameras captured the movements of cyclists, car drivers and pedestrians during the trial. In particular, times of cyclists and car drivers entering, circulating around and exiting from, the roundabout were collected from the resulting recordings. Also, the times pedestrians started walking, when they entered each section of the pedestrian crossing and when they exit the crossing. All participants were told what manoeuvre to make at the roundabout and when to start. However, no other instructions were given and therefore interactions between them occurred in the most natural way possible, although those travelling at "non-average" speed could miss having an interaction.

The participant timings can be compared to assess which of the cyclists, car drivers, and pedestrians went first (were given priority) when they interacted with each other. They also provide a direct measure of how journey times are affected by such situations.

An interaction was defined to have occurred if two types of users (cyclist, car driver and pedestrian) came into close proximity. That is, arrived at an interaction zone within three seconds of each other, see **Figure 81**.

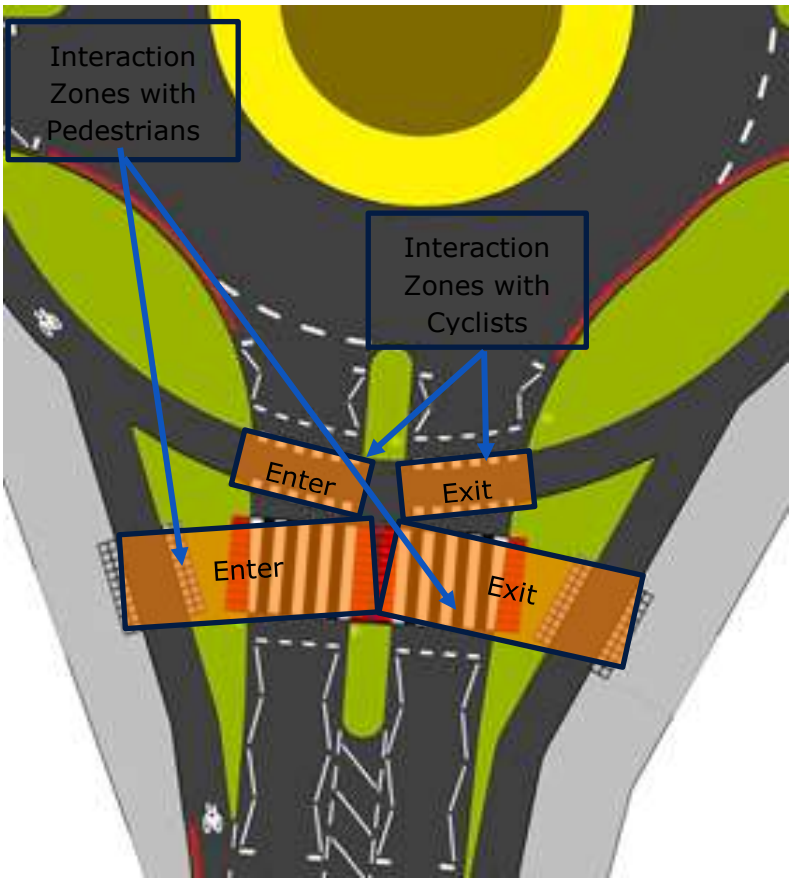

Figure 116: Interaction zones

For example, an interaction occurred if a car and a cyclist approached the same roundabout arm within three seconds of each other, or if the cyclists started to cross an exit arm within three seconds of a car driver arriving at that exit, or if a car moved over the pedestrian crossing within three seconds of a pedestrian entering/exiting it.

If two users entered an interaction zone within one second of each other, then no priority was assigned (recorded as "same"). Otherwise the participant entering first is assumed to have taken priority (recorded as "Before"), and the other participant was assumed to have given way (recorded as "After").

Furthermore, in addition to the simple interactions described above, an interaction was also said to have occurred in the following more complex situations: multiple and inherited (see **Figure 117**).

- An inherited interaction was recorded for Participant B with Participant C if Participant A and B were both cyclists, car drivers or pedestrians, Participant A interacted with Participant C and Participant B arrived within three seconds of Participant A.
- A multiple interaction for Participant A with Participant C was recorded if Participant A interacted with Participant B, who interacted with Participant C.

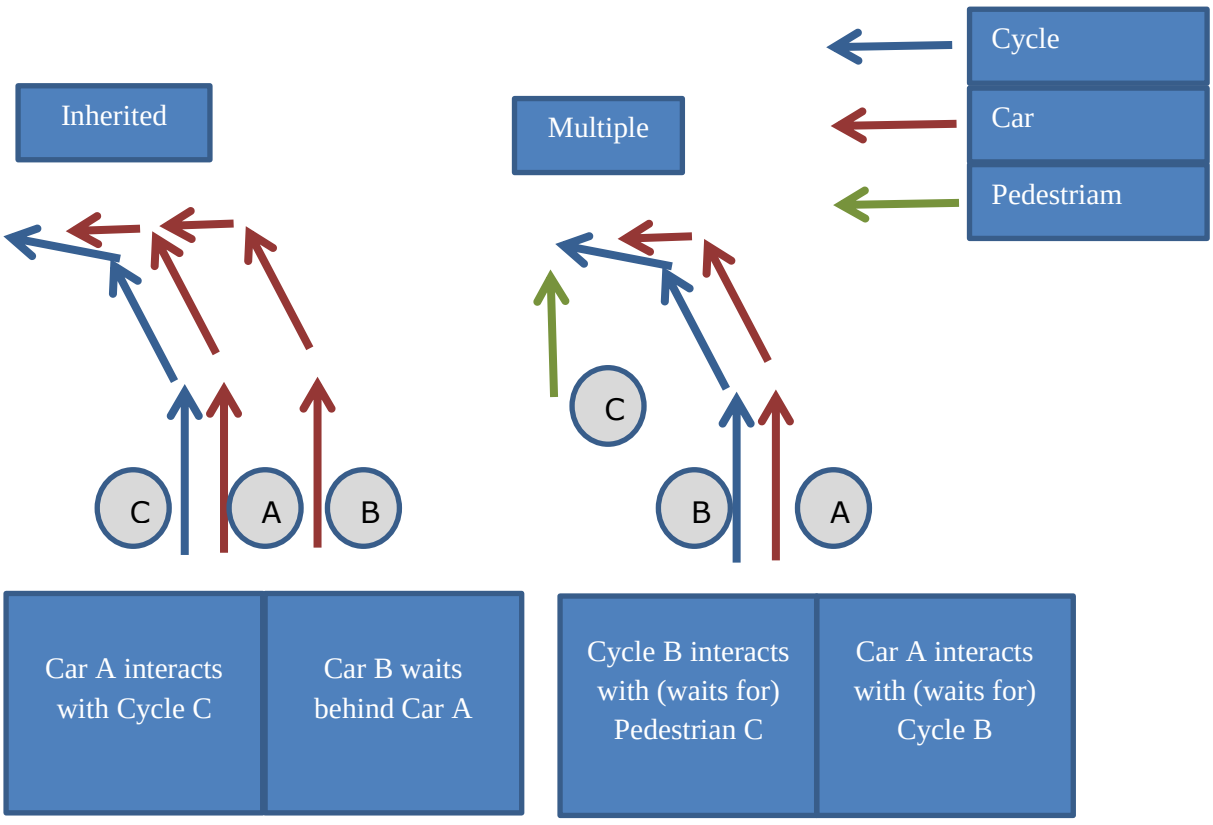

Figure 117: Examples of complex interactions

3.3.1 Priority when negotiating the roundabout

The priorities taken by cyclists, car drivers and pedestrians have been investigated under six situations; these are shown in **Figure 118**.

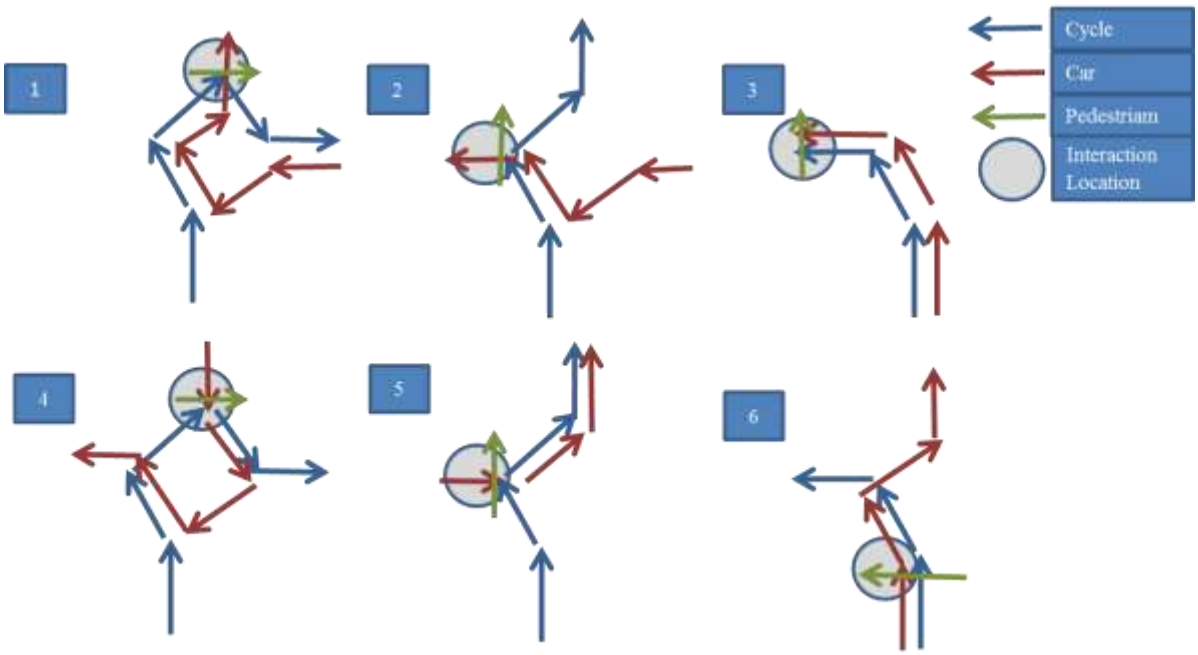

Figure 118: Types of interaction tested

Information on the turning movements made by the different types of participants (cyclists, car drivers and pedestrians) and where they could interact are described in **Table 4**.

Table 4: Movement made by participants and interaction location

Interaction	Movement Made			Location of Interaction		
	Car	Cycle	Pedestrian	Car	Cycle	Pedestrian
1	Turn Right	Turn Right	Crossing Clockwise	On Exit	Crossing 2nd Arm	On 1st Half Of Crossing
2	Straight On	Straight On	Crossing Clockwise	On Exit	Crossing 1st Arm	On 1st Half Of Crossing
3	Turn Left	Turn Left	Crossing Clockwise	On Exit	On Entrance	On 1st Half Of Crossing
4	Turn Right	Turn Right	Crossing Clockwise	On Entrance	Crossing 2nd Arm	On 2nd Half Of Crossing
5	Turn Left	Straight On	Crossing Clockwise	On Entrance	Crossing 1st Arm	On 2nd Half Of Crossing
6	Straight On	Turn Left	Crossing Clockwise	On Entrance	On Entrance	On 2nd Half Of Crossing

Observations without an interaction were when a participant made the same manoeuvre but not near other participants. They were taken under the situations shown in **Table 5**.

Table 5: Behaviour without Interaction: Locations Used

Interaction	Movement Made			Interaction Number		
	Car	Cycle	Pedestrian	Car	Cycle	Pedestrian
1	On Exit	Crossing 2nd Arm	On 1st Half Of Crossing	4	1 or 4	All
2	On Exit	Crossing 1st Arm	On 1st Half Of Crossing	6	2 or 6	All
3	On Exit	On Entrance	On 1st Half Of Crossing	5	3 or 5	All
4	On Entrance	Crossing 2nd Arm	On 2nd Half Of Crossing	1	1 or 4	All
5	On Entrance	Crossing 1st Arm	On 2nd Half Of Crossing	3	2 or 6	All
6	On Entrance	On Entrance	On 2nd Half Of Crossing	2	3 or 5	All

The results for cars exiting the roundabout when cyclists were crossing the exit arm in the circulatory cycle lane and pedestrians were crossing the exit arm on the pedestrian crossing are summarised in **Figure 119**. In this and subsequent figures, if two users entered an interaction zone within one second of each other, then no priority was assigned (recorded as "same"). Otherwise the participant entering first is assumed to have taken priority (recorded as "Before"), and the other participant was assumed to have given way (recorded as "After").

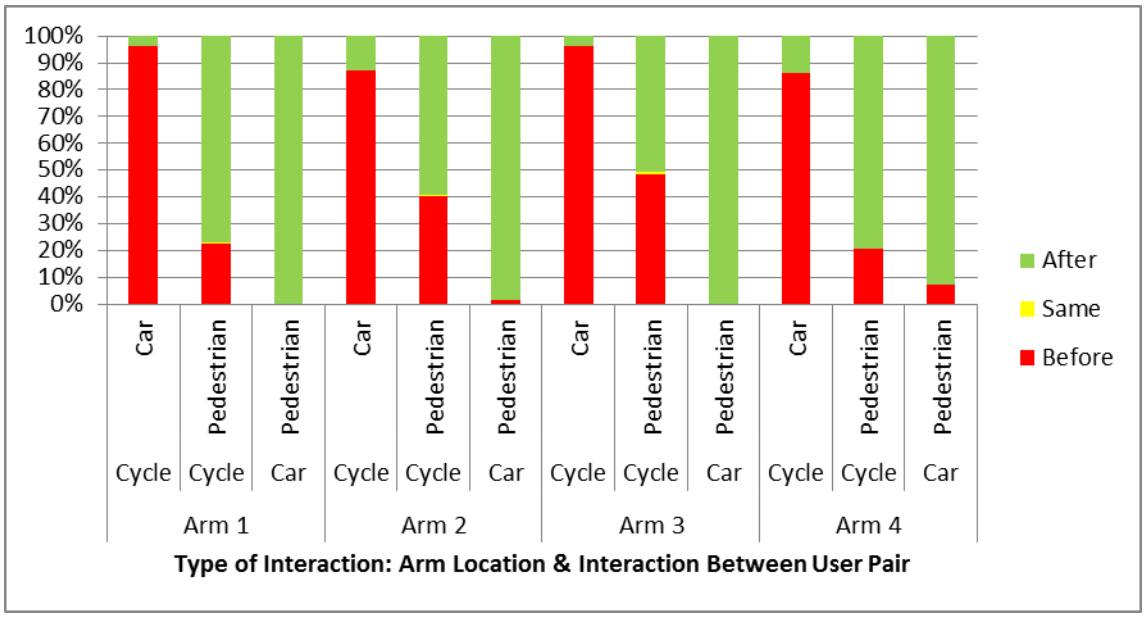

Figure 119: Who went first: Interaction 1

When an interaction occurred:

- The cyclist crossed the exit arm first (in front of the car) in at least 86% of occasions.
- Car drivers nearly always (97% of cases) gave way to the pedestrians.

Pedestrians and cyclists did not directly interact, so the results only indicate that pedestrians tended to start walking on the pedestrian crossing slightly before cycles reached the exit.

Interaction 2 was the same as Interaction 1, except that it occurred across the first roundabout arm that cyclists crossed over, as opposed to the second roundabout arm. The results for this interaction are summarised in **Figure 120**.

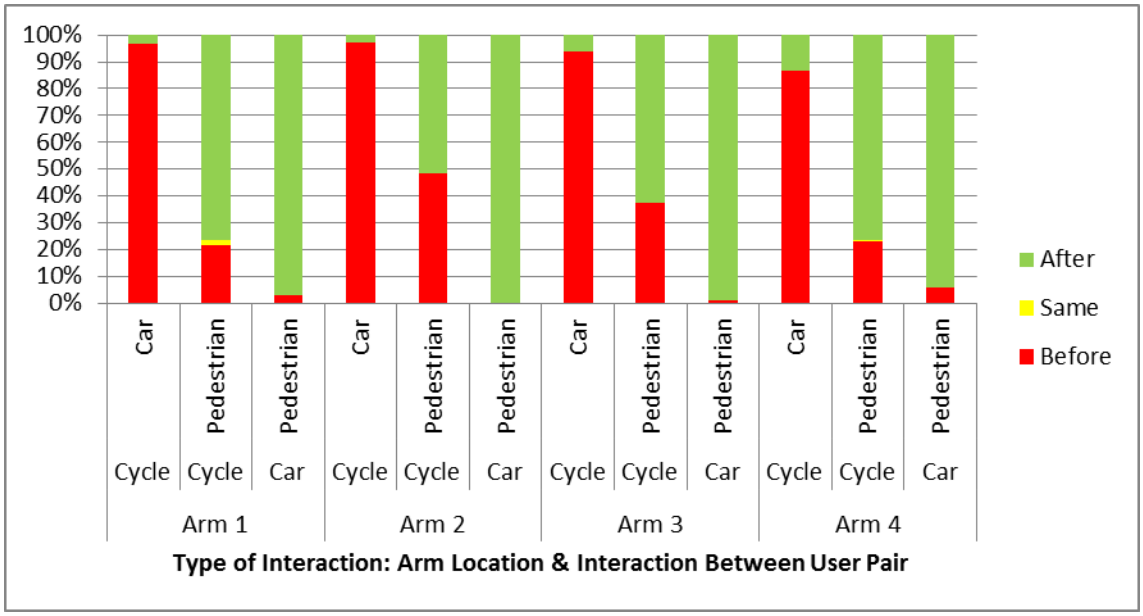

Figure 120: Who went first: Interaction 2

It is not surprising that most percentages for Interaction 2 are similar to those for Interaction 1. In fact, when a direct interaction occurred, the percentages were no more than three percentage points different from each other: except for the give way behaviour between cyclists and car drivers on Arm 2.

- On Arm 2, 10% more cars went in front of the cyclists. This was the only arm where car drivers could separately cross the circulatory flow and the pedestrian crossing. Also, Interaction 2 occurred on the first arm crossed by the cyclists rather than the second arm, so they would be expected to be travelling slower.

The results for cars exiting the roundabout at the same time as cyclists, and whilst pedestrians crossed the arm on the pedestrian crossing are summarised in **Figure 121**.

When an interaction occurred:

- Both the cyclists and car drivers went after the pedestrians on Arms 1, 2 and 3, suggesting that they gave way: at least 97% of car drivers and 94% of cyclists.
- On Arm 4 only 90% of car drivers and 25% of cyclists went after the pedestrians, suggesting that they did not give way as often.

Arm 4 was the only one with no pedestrian crossing markings on the separate cycle lane leading onto and off of the roundabout. Therefore, cyclists had priority when exiting.

- Car drivers went after cyclists when exiting on Arms 1 and 4 in at least 88% of cases.

On these arms the cyclists exited the roundabout on separate cycle lanes, so the priority was possibly a result of car drivers initially showing caution until the cyclists committed to exiting the roundabout.

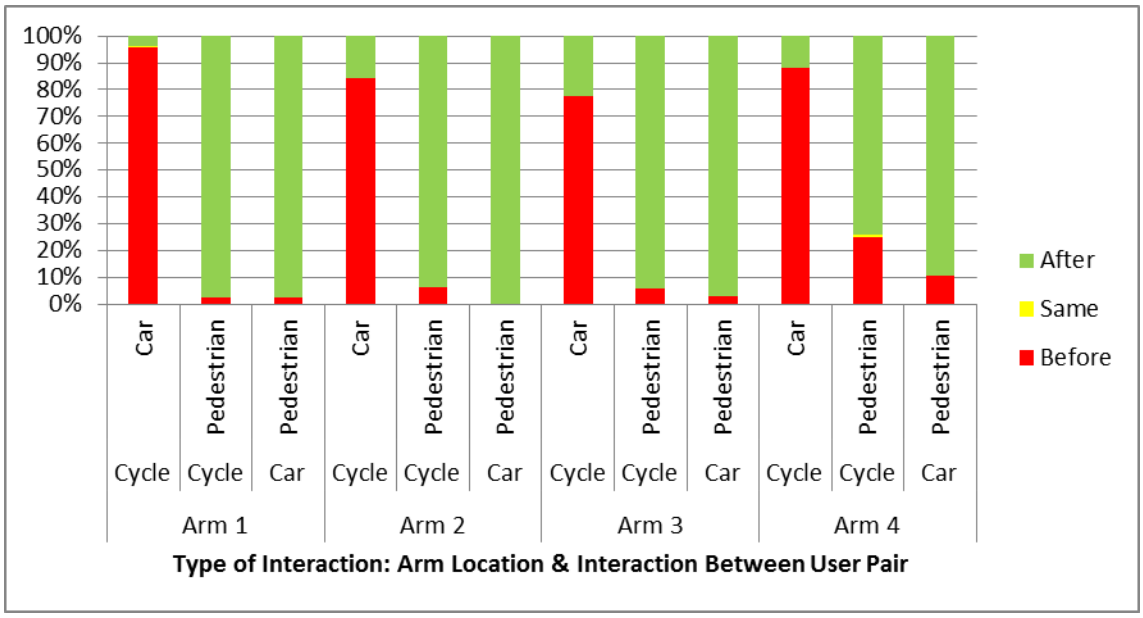

Figure 121: Who went first: Interaction 3

- Car drivers also generally went after cyclists when exiting on Arms 2 and 3 in 78% to 84% of cases.

There were no separate cycle lanes on the exit of these roundabout arms, and it appears slightly greater percentages of cyclists did give way to car drivers under these conditions.

The results for cars entering the roundabout when cyclists were crossing the arm in the circulatory cycle lane and pedestrians were crossing the arm on the pedestrian crossing are in **Figure 122**.

When an interaction occurred:

- The cyclist crossed the car's entrance arm first in front of the car on 39% to 63% of occasions.
- The lowest percentages occurred on Arm 2, on which car drivers could cross over the pedestrian crossing lane and the orbital cycle lane separately: the percentages on the other arms ranged from 48% to 63%.

Overall, car drivers were more likely to go in front of the cyclists crossing their exit arm when entering the roundabout then when exiting it. Car drivers stated willingness to give way was approximately the same for both these manoeuvres. Consequently, this could be a result of more familiarity with the decision, or that the situation was easier to judge on the approach to the roundabout, which resulted in smaller gaps being accepted.

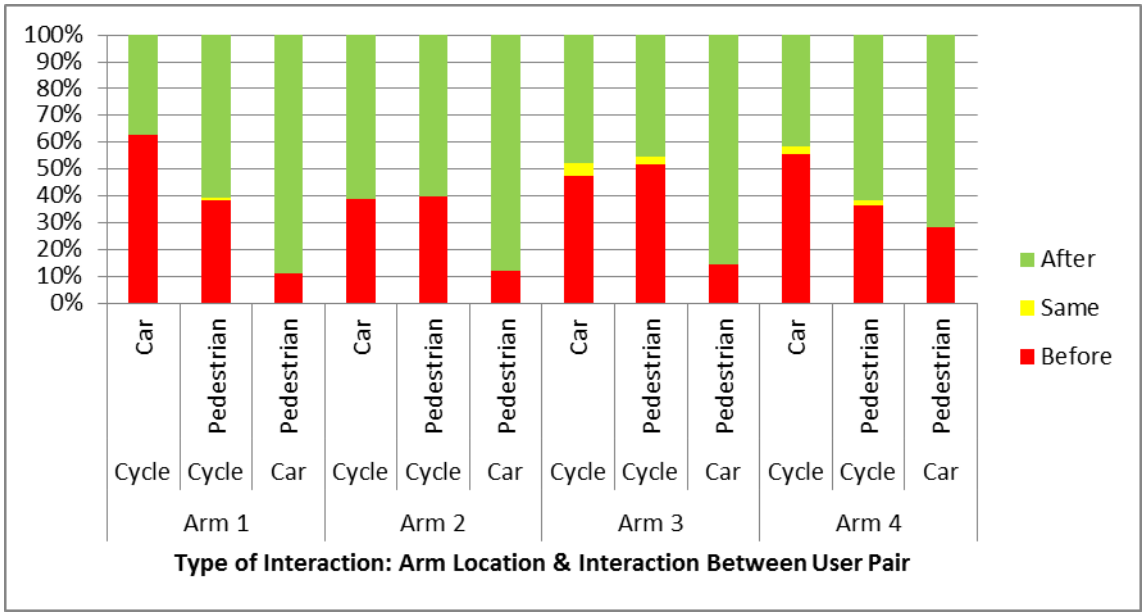

Figure 122: Who went first: Interaction 4

Pedestrians and cyclists did not directly interact, so this only indicates that pedestrians tended to start walking on the pedestrian crossing slightly before cycles reached the exit.

- Car drivers nearly always (86% of cases) gave way to the pedestrians on Arms 1, 2 and 3. However, only 72% gave way on Arm 4.

Interaction 5 was the same as interaction 3, except that it occurred across the first roundabout arm that cyclists crossed over, as opposed to the second roundabout arm. The results for this interaction are summarised in **Figure 123**.

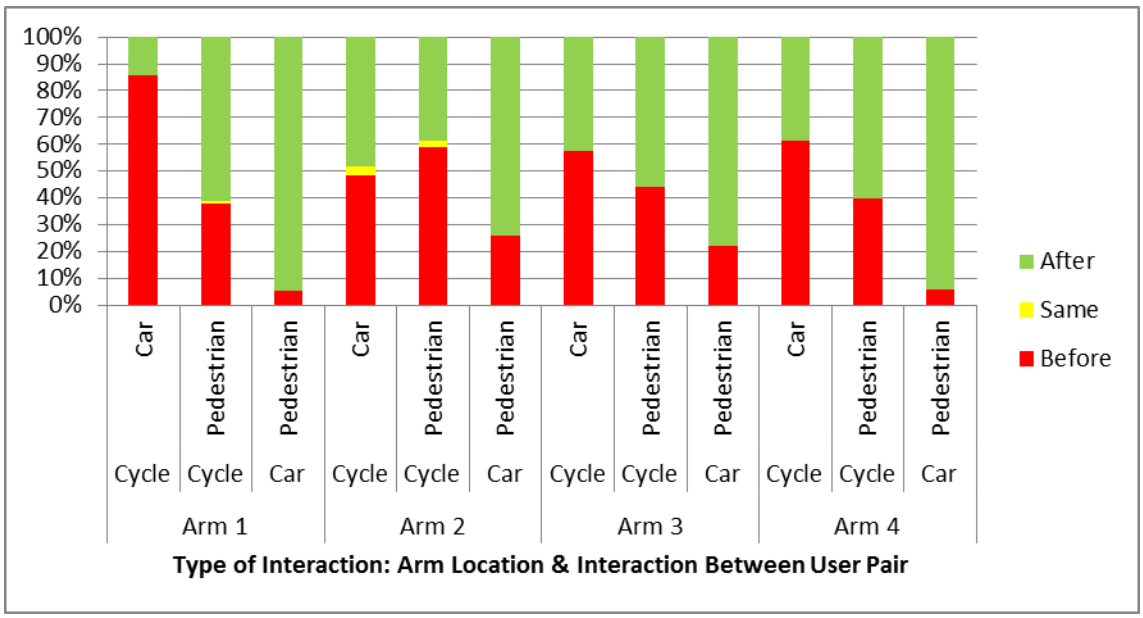

Figure 123: Who went first: Interaction 5

When an interaction occurred:

- The cyclist crossed the car's entrance arm first in front of the car in 48% to 86% of occasions.
- The percentage point increase (compared to Interaction 4) on Arms 2, 3 and 4 was between 6 and 10% and could be due to car drivers being more cautious as cyclists were only just establishing themselves on the roundabout after entering from the previous (anticlockwise) roundabout arm.
- In addition, the percentage point increase for Arm 1 was 23%, and this coincided with the shortest length of orbital cycle lane between the cyclists' entrance arm and the location of the interaction, see Figure 1.

Pedestrians and cyclists did not directly interact, so the results only indicate that pedestrians generally tended to start walking on the pedestrian crossing slightly before cycles reached the exit.

- Car drivers nearly always (at least 94% of cases) gave way to the pedestrians on Arms 1 and 4.
- Fewer (74% to 78%) gave way on Arms 2 and 3.

Interaction 6 occurred when cars entered the roundabout at the same time as the cyclists, and whilst pedestrians were crossing the arm on the pedestrian crossing. The results are summarised in **Figure 124**.

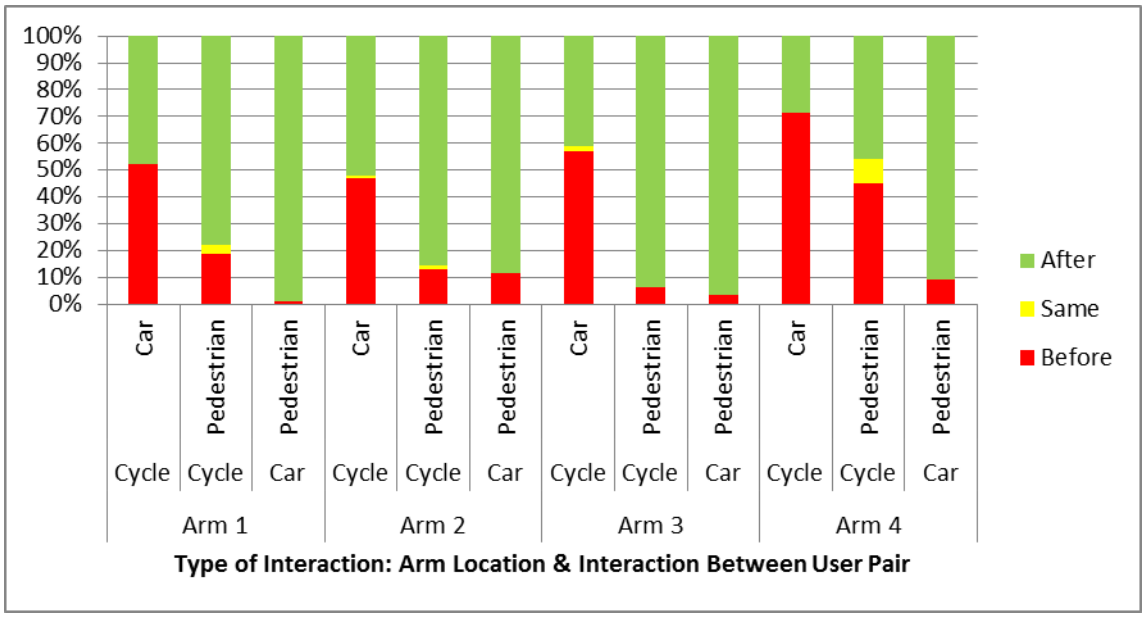

Figure 124: Who went first: Interaction 6

When an interaction occurred:

- Cyclists entered the roundabout before the cars on 47% to 57% of occasions (i.e. approximately half of the time) on Arms 1, 2 and 3.
- On Arm 4, 71% of cyclists entered the roundabout before the cars; this was the easiest/fastest entrance onto the roundabout for cyclists.

Pedestrians and cyclists did directly interact:

- Between 78 to 94% of cyclists gave way to the pedestrians on Arms 1, 2 and 3.
- In contrast, only 46% of cyclists gave way to pedestrians on Arm 4, the only arm with no pedestrian crossing markings on the separate cycle lane leading onto and off of the roundabout.

Also:

- Car drivers nearly always (at least 88% of cases) gave way to the pedestrians on all arms.

3.3.2 Effects on pedestrian journey time

Pedestrians started on one of four arms and crossed the arm in a clockwise direction. They could meet car drivers and cyclists in one of the six interaction situations, see **Figure 118**. The interaction was said to have occurred if the pedestrian was in the vicinity of the appropriate Interaction Zone (see **Figure 81**) at the same time (i.e. within 3 seconds) as a car driver and a cyclist. The timing points used to define being in the vicinity are as shown in Figure 125 for Arm 4:

- Timing point 2 for interactions when vehicle exit the roundabout
- Timing point 3 for interactions when vehicle enter the roundabout

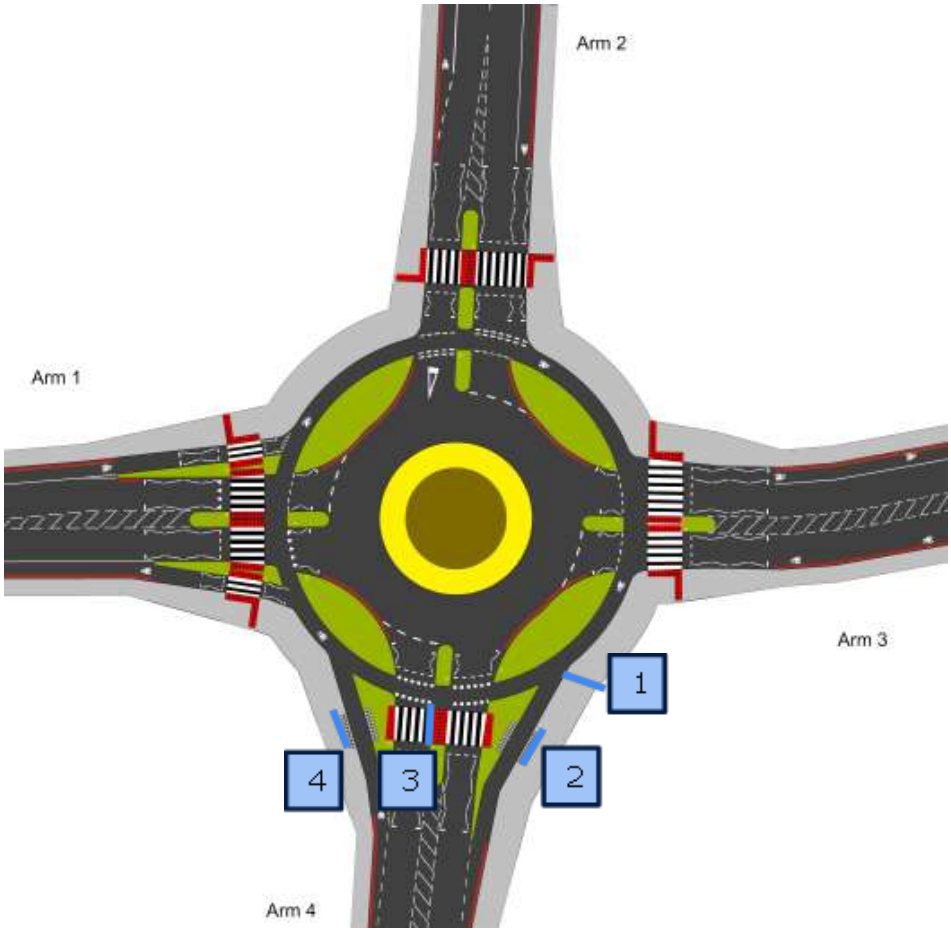

Figure 125: Journey timing points for pedestrians

The average times for pedestrians to cross the roundabout arms were measured: taken between Points 1 and 4 for Arm 4. Such timing points were defined for all arms of the roundabout. The average times for pedestrians to cross the roundabout are summarised in **Figure 126**.

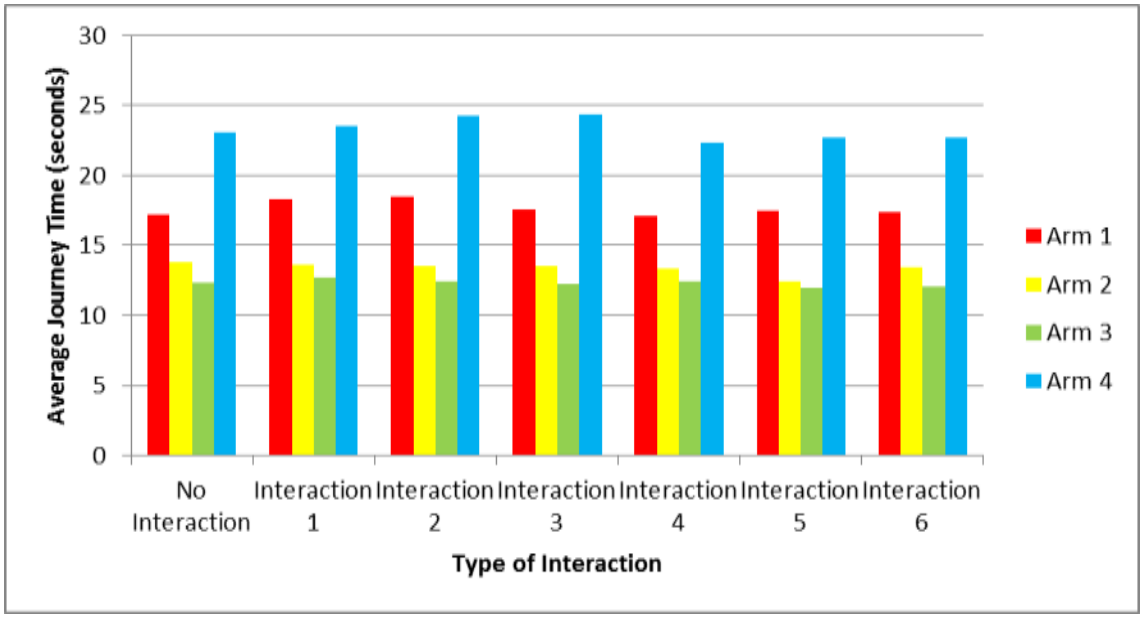

Figure 126: Pedestrian Journey Times

Pedestrians were almost always given priority by both cyclists and car drivers. Therefore, their journey times were unaffected by any of the interactions. The only variations occurred owing to the varying widths of the crossings, leading to different journey lengths for the different arms.

3.3.3 Effects on cyclist journey time

Cyclists started on one of four arms and either turned left, right, or continued straight on at the roundabout. They could meet car drivers and pedestrians in one of the six interaction situations, see **Figure 118**. The interaction was said to have occurred if the cyclist was in the vicinity of the appropriate Interaction Zone (see **Figure 81**) at the same time (i.e. within 3 seconds) as a car driver and a pedestrian. The timing points used to define being in the vicinity were as shown in Figure 9 for Arm 4:

- Timing point 2 for interactions when entering the roundabout
- Timing point A for interactions with circulating and interacting with cars exiting the roundabout
- Timing point B for interactions with circulating and interacting with cars entering the roundabout
- Timing point 5 for interactions when exiting the roundabout

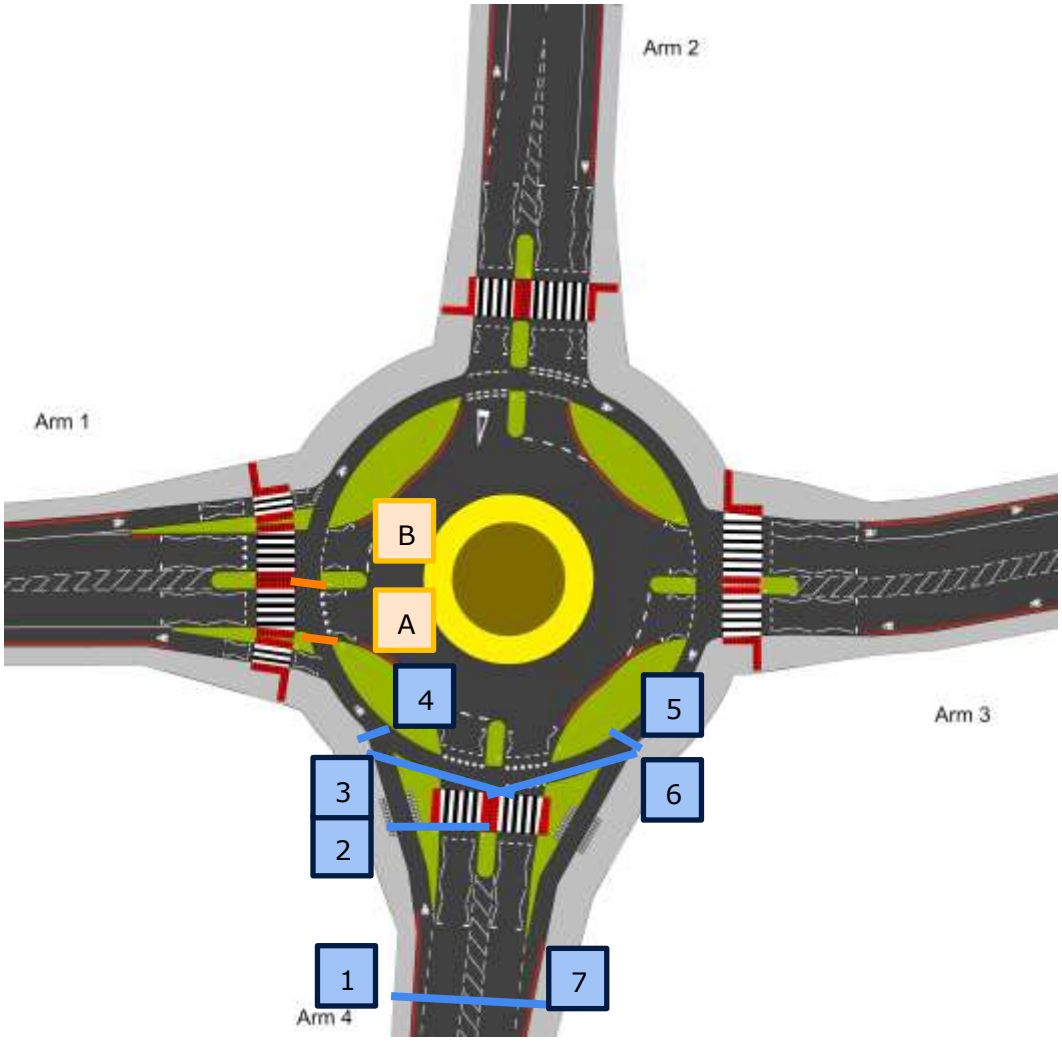

Figure 127: Journey timing points for cyclists

The average time for cyclists to enter the roundabout, circulate around the roundabout and leave it, were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 4; where Point 1 was fixed for the trials on the roundabout's arm. The time to circulate over Arm 1 was taken between Points A and B. The time to exit from over Arm 4 was taken between Points 5 and 7. Such timing points were defined for all arms of the roundabout.

The average times for cyclists to enter, exit and circulate the roundabout are summarised in **Figure 128**.

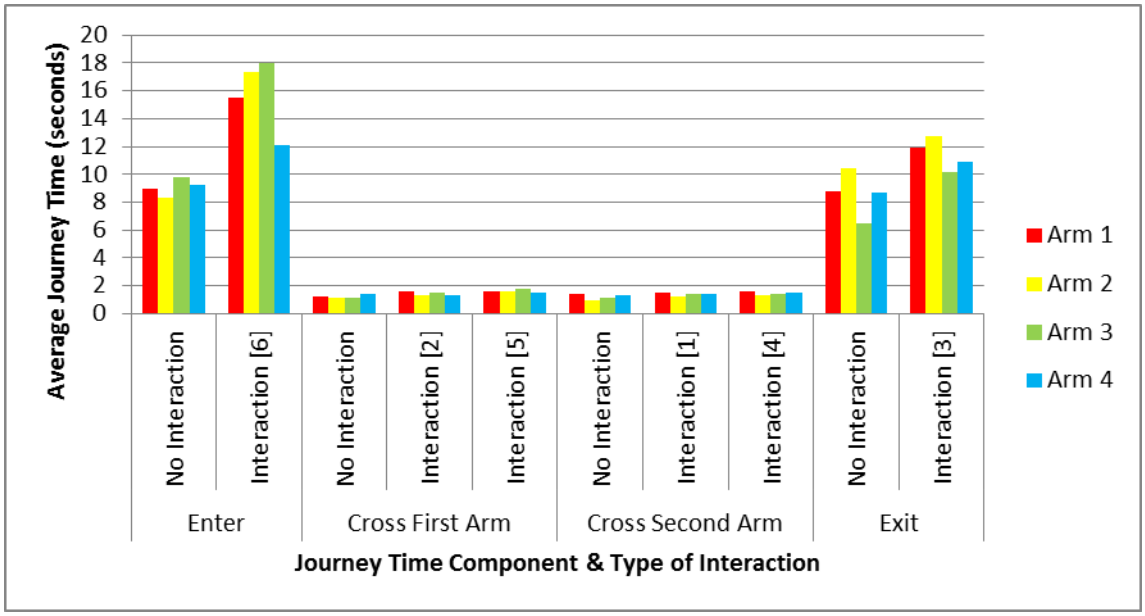

Figure 128: Cyclist Journey Times

An interaction whilst the cyclists passed the entrance, or exit, of the roundabout arms had little effect on their journey time:

- They increased by less than 0.4 seconds on average.
- However, some of these increases were statistically significant, and this could imply that cyclists slowed down slightly (i.e. showed caution) when an interaction occurred.
- In contrast, an interaction whilst the cyclists entered the roundabout had a highly significant effect on journey times into the roundabout, increasing them by 2.9 seconds on Arm 4, 6.6 seconds on Arm 1, and 8 to 9 seconds on Arms 2 and 3.

These increased journey times are in line with the variations in roundabout arm geometry and the priority given to cyclists. The least effect was on Arm 4 on which the cyclists entered the roundabout on a separate cycle lane and often did not give way to pedestrians as there was no pedestrian crossing on the cycle lane. The next smallest effect was on Arm 1 on which the cyclists entered the roundabout on a separate cycle lane, but were more likely to give priority to pedestrians. Finally, on Arms 2 and 3, they entered in parallel with the car drivers and generally gave way to pedestrians on the pedestrian crossing.

An interaction whilst the cyclists exited the roundabout also had a significant effect on journey times; increasing them by between 2.2 seconds and 3.7 seconds. Car drivers generally gave way to them when they both exited together, so causing them little delay. However, they gave way to pedestrians on Arms 1, 2 and 3 causing them some delay. They were less likely to give way to pedestrians on Arm 4, which together with probably showing caution resulted in the smallest (2.2 second) delay when leaving the roundabout.

3.3.4 Effects on car journey time

Car drivers started on one of four arms and either turned left, right, or continued straight on at the roundabout. They could meet cyclists and pedestrians in one of the six interaction situations, see **Figure 118**. The interaction was said to have occurred if the

cyclist was in the vicinity of the appropriate Interaction Zone (see **Figure 81**) at the same time (i.e. within 3 seconds) as a car driver and a pedestrian. The timing points used to define being in the vicinity were as shown in Figure 9 for Arm 4:

- Timing point 2 for interactions when entering the roundabout
- Timing point 5 for interactions when exiting the roundabout

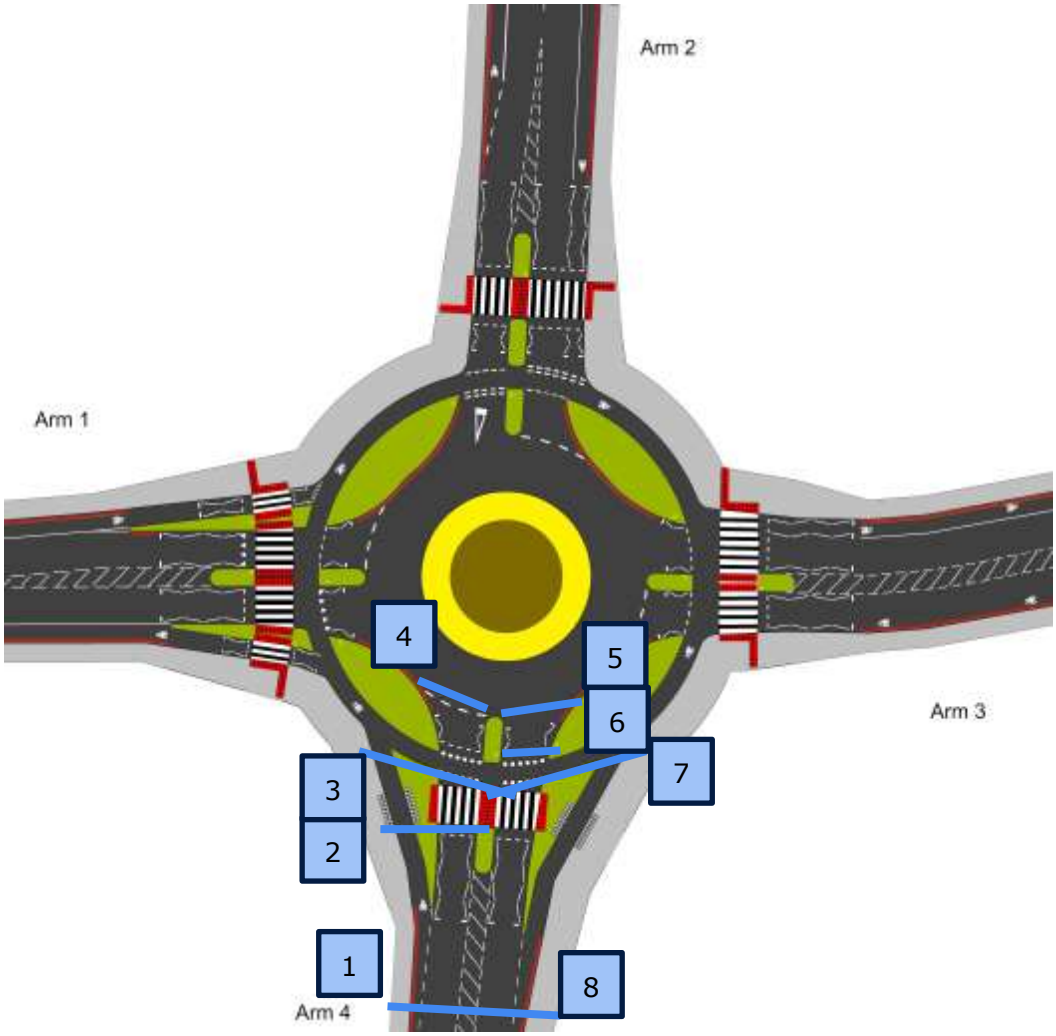

Figure 129: Journey timing points for cars

The average time for car drivers to enter and exit the roundabout were measured. The time to enter the roundabout from Arm 4 was taken between Points 1 and 4; where Point 1 was fixed for the trials on the roundabout's arm. The time to exit from over Arm 4 was taken between Points 5 and 8. Such timing points were defined for all arms of the roundabout.

The journey times of the first vehicles to arrive at the interaction zone were significantly different to those of the second vehicles. This could have been a result of the second vehicle arriving whilst the first vehicle was already being delayed. Alternatively, it may have been a result of the second vehicle waiting to cross a timing point behind the first vehicle, particularly when exiting the roundabout. The results for the two car drivers are therefore presented separately. The average journey time of the first car driver is shown in **Figure 130**.

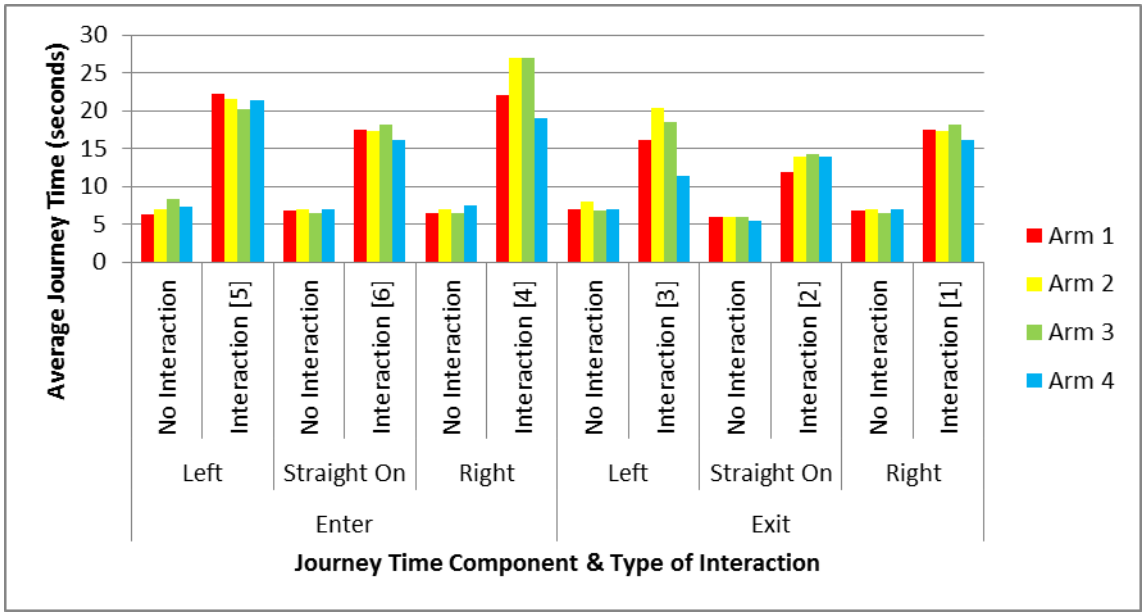

Figure 130: First Car Journey Times

- An interaction whilst the car drivers entered the roundabout had a large and significant effect on journey times into the roundabout increasing them by between 10.3 to 20.5 seconds on all arms: increases of between 130 and 310%

This also supports the assumption that when a participant goes after another participant, they have in fact given way to them.

These increased journey times are in line with the types of interaction occurring, the variations in roundabout arm geometry and the associated priorities given to the different types of participants.

- When car drivers entered with the cyclists (Interaction 6) the delay was mainly from pedestrians on the crossing (9.1 to 11.7 seconds).
- Geometry possibly had a limited effect under these circumstances: the smallest delay occurred on Arm 4 where cyclists entered a separate cycle lane, and the largest delay was on Arm 2 where the cyclists remained on the main carriageway with the cars.
- In Interactions 4 and 5 the cyclists were in the orbital cycle lane and crossed over the arm on which the cars were entering. This increased delay compared with giving way to pedestrians only by the order of 4 to 5 seconds.
- Smaller delays were experienced whilst exiting, compared to entering, the roundabout if both pedestrians and cyclists were crossing the arm: Interactions 1 and 2 compared to Interactions 4 and 5. Geometry appeared to have no consistent effect on this delay.

Geometry appeared to affect driver delay when cyclists exited the roundabout with them (Interaction 3).

- The lowest delay was on Arm 4 where cyclists exited the roundabout in a separate cycle lane a distance before the main exit.
- The next smallest delay was on Arm 1, where cyclists also used a separate cycle lane which was closer to the main exit than on Arm 4.

- Next was Arm 3 where cyclists entered a separate cycle lane, which was next to the car's exit point.
- The largest delay was on Arm 2 where both cyclists and car drivers exited together.

The average journey times of the second car drivers is shown in **Figure 131**, and are slightly smaller than those for the first car driver to arrive at the interaction point. These may have also been affected by the different circumstances presented to these drivers.

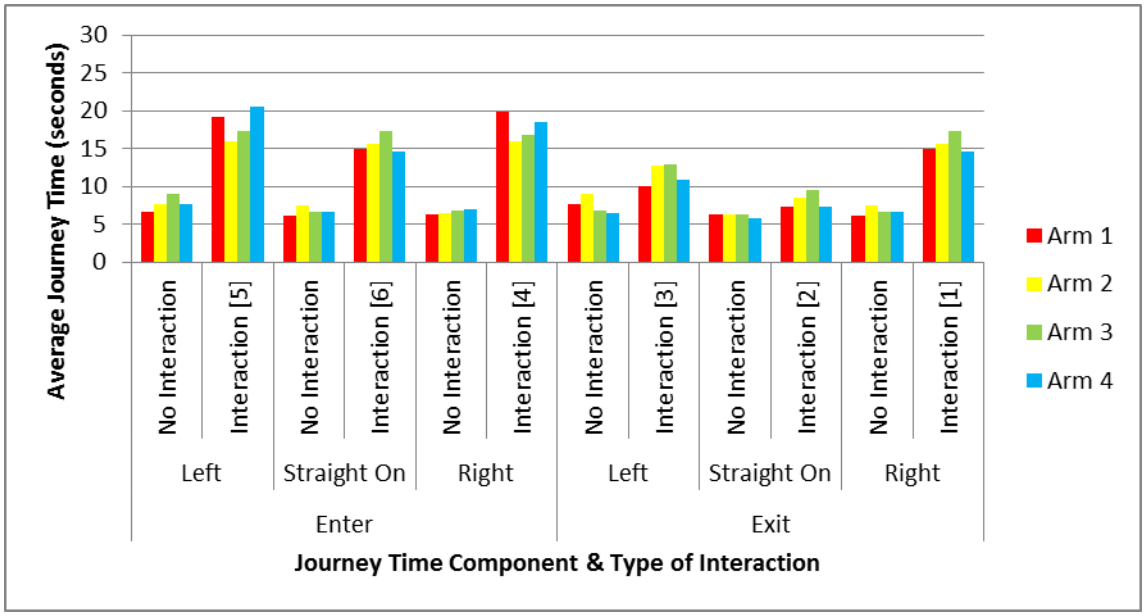

Figure 131: Second Car Journey Times

3.4 Participant on-track responses

During the trials, participants were asked to respond to simple questions at the end of each individual journey around the roundabout.

The questions they were asked were the following:

- 'On a scale of 1 to 10 where 10 is Very Easy, how easy it was to negotiate the roundabout?' i.e. 'How easy it was to cycle/drive/walk from one arm to another?'
- 'On a scale of 1 to 10 where 10 is Very Safe, how safe did you feel?'

3.4.1 Cyclists responses

Figure 132 and **Figure 133** show the ease of use and safety responses respectively to these questions, showing a count of all responses from all cyclists.

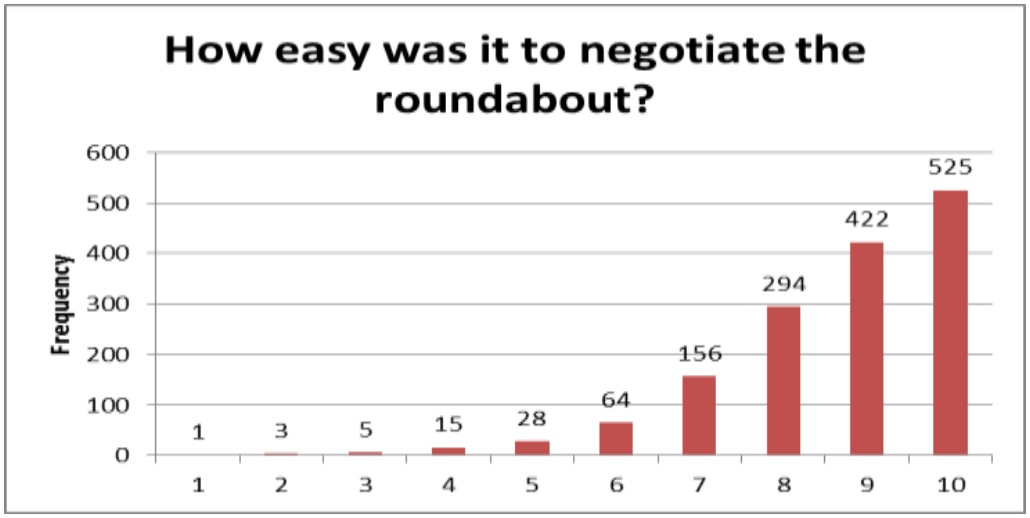

Figure 132: Cyclists' scores for ease of use using the roundabout

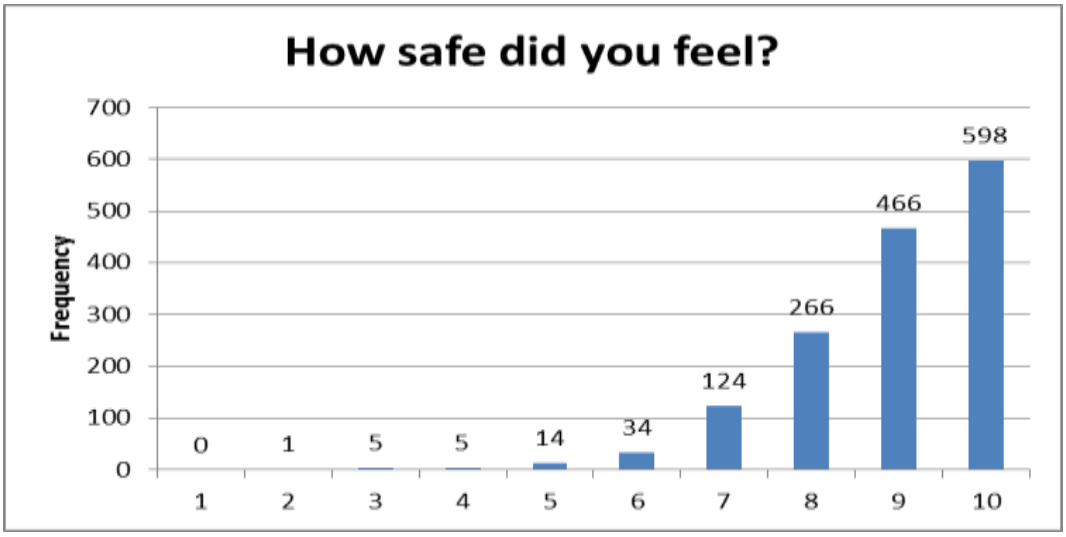

Figure 133: Cyclists' scores for safety of use using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (97%) and safe (98%). This is not overly surprising as cyclists were not placed in any difficult situations. It does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 85% of the safety scores were within ±1 of the ease of negotiating scores. For this reason, only results from the ease of use scores are discussed in the remainder of this report, as the results for safety are the same.

Figure 134 shows the ease of use by turning direction, aggregated over all four arms.

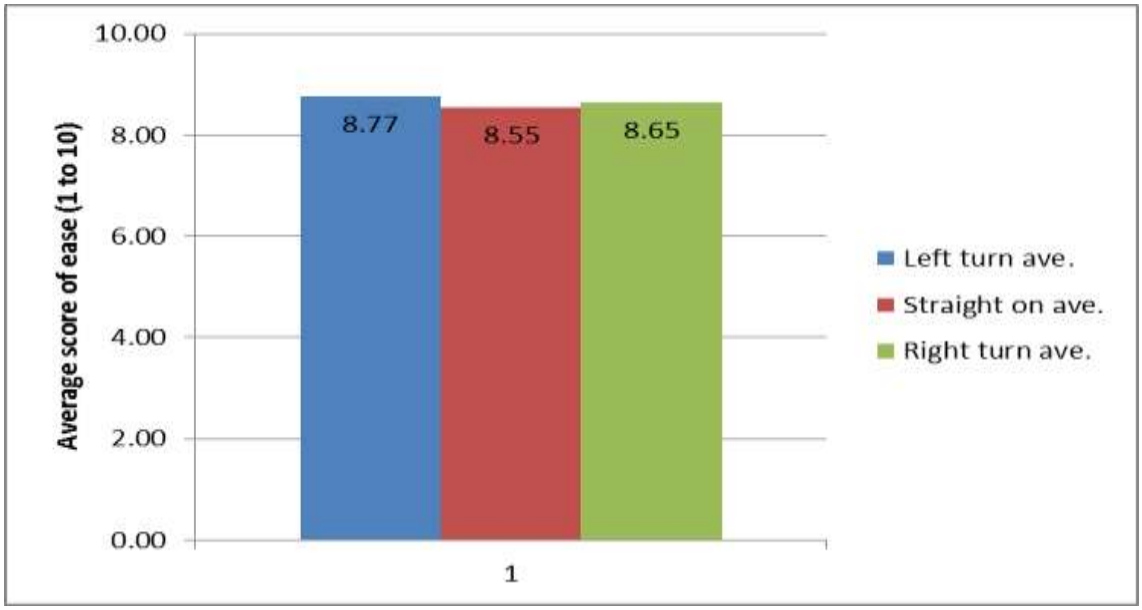

Figure 134 Cyclists' scores of ease of negotiating the roundabout by movement

This implies that (on average) cyclists found it as easy to turn in any direction at the roundabout: that is, the scores are very similar (within 0.22) and all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in **Figure 135**.

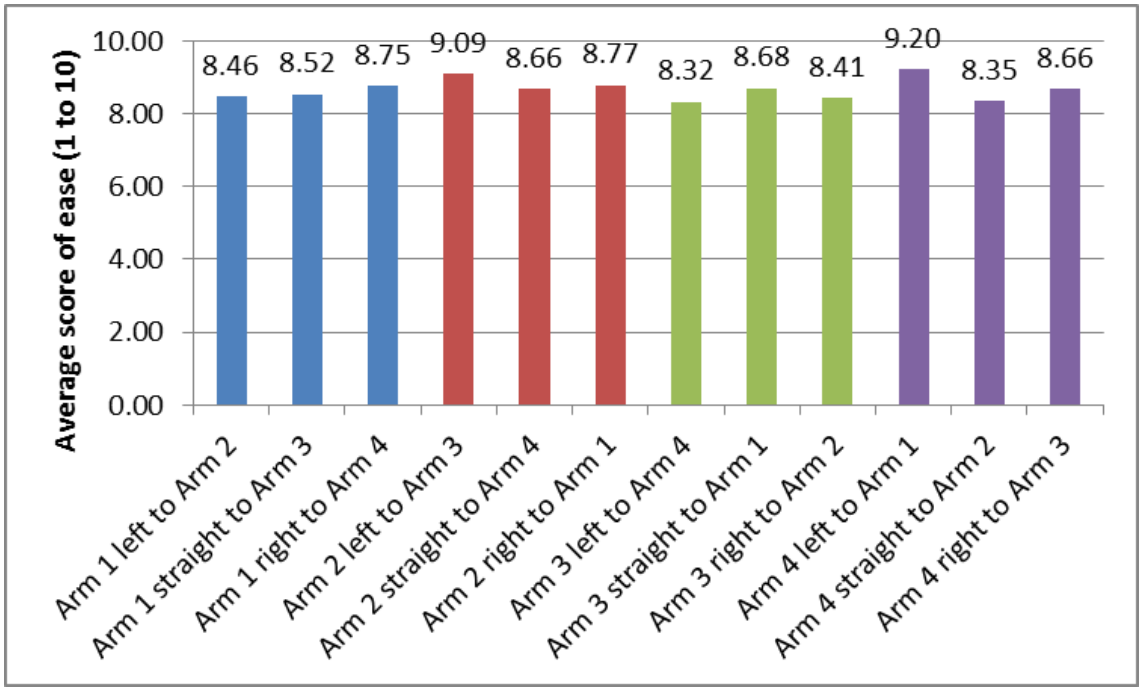

Figure 135: Cyclists' scores of ease of negotiating the roundabout by arm and movement

This shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that there was little difference between Arms 1, 2 and 3 with the average ease of use score only varying by 0.3 or less. The scores for Arm 4 were more variable than those on the other arms. Overall, there is an indication that turning out of Arm 3 was judged as slightly harder, on average, than the other arms.

3.4.2 Drivers responses

Figure 136 and **Figure 137** show the ease of use and safety responses respectively to these questions, showing a count of all responses from all drivers.

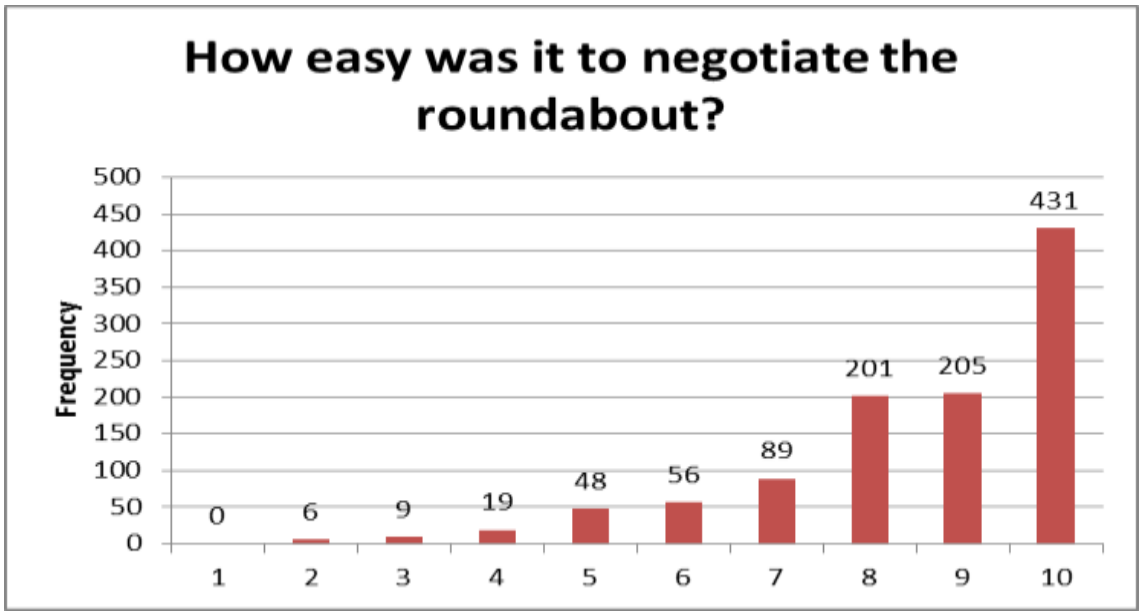

Figure 136: Drivers' scores of safety and ease of use using the roundabout

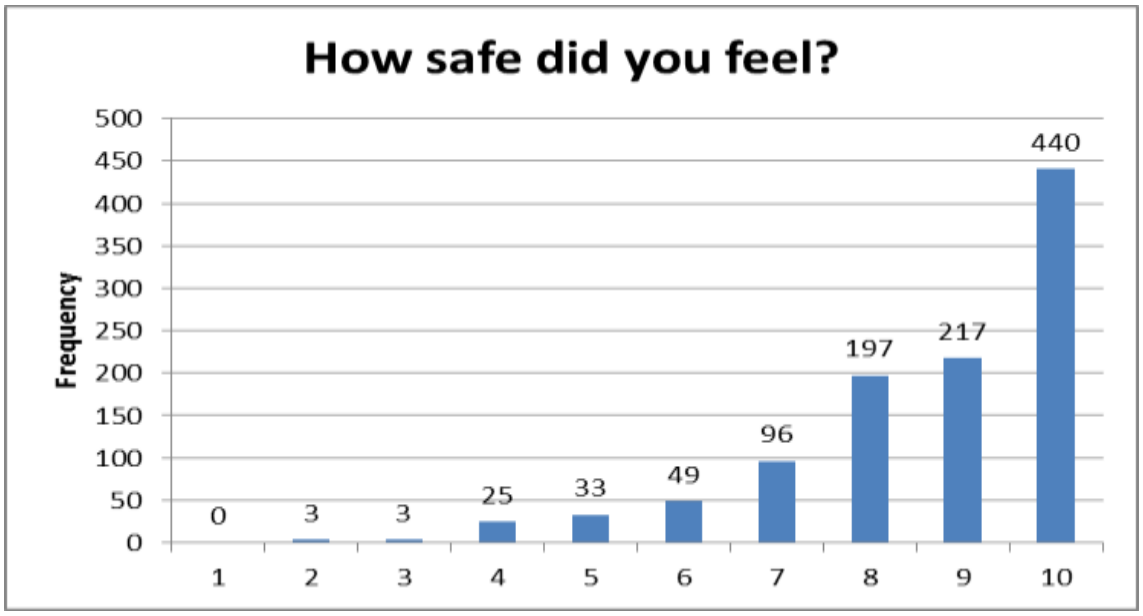

Figure 137: Drivers' scores of safety and ease of use using the roundabout

The above score distributions were given across all turning movements, and for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (92%) and safe (94%). As with the cyclists, this is not overly surprising as drivers were not placed in any difficult situations. This indicates that they did not find any major issues with using the roundabout infrastructure from any of the arms.

The results do show, subjectively, that driver found the trial situations marginally less easy and safe than the cyclists and pedestrians did. (Both cyclists and pedestrians scored 97% easy and 98% safe in the on-track responses).

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 85% of the safety scores were within ±1 of the ease of negotiating scores.

Figure 138 shows the ease of use by turning direction, aggregated over all four arms.

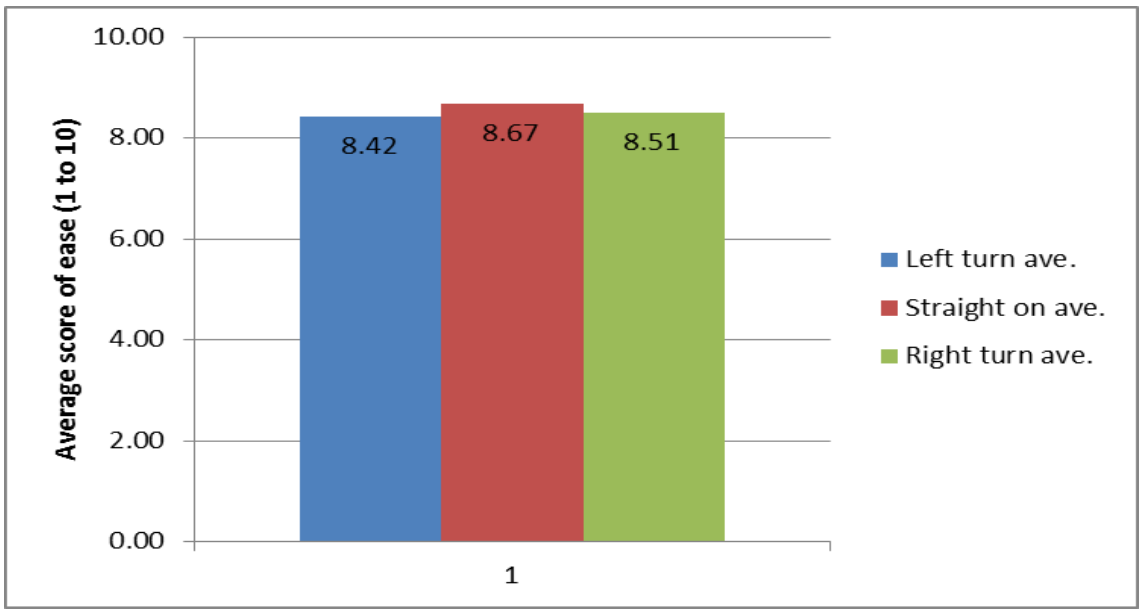

Figure 138: Drivers' scores of ease of negotiating the roundabout by movement

The above implies that (on average) drivers found it as easy to turn in any direction at the roundabout: that is, the scores are very similar (within 0.25) and all movements were generally easy to make. The full disaggregation of the scores by roundabout arm and turning direction are summarised in **Figure 139**.

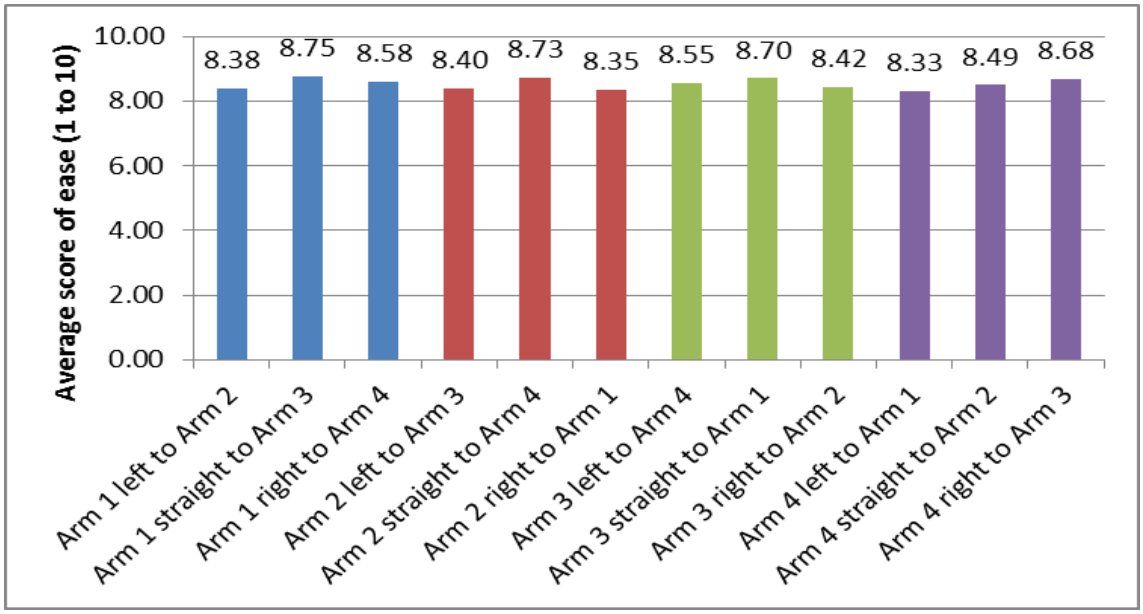

Figure 139: Drivers' scores of ease of negotiating the roundabout by arm and movement

This shows the specific scores for how easy it was to negotiate each possible route using the roundabout. The scores indicate that there was little difference between all four Arms with the average ease of use score only varying by 0.4 at most.

3.4.3 Pedestrian responses

Figure 140 and **Figure 62** show the ease of use and safety responses respectively to these questions, showing a count of all responses from all pedestrians.

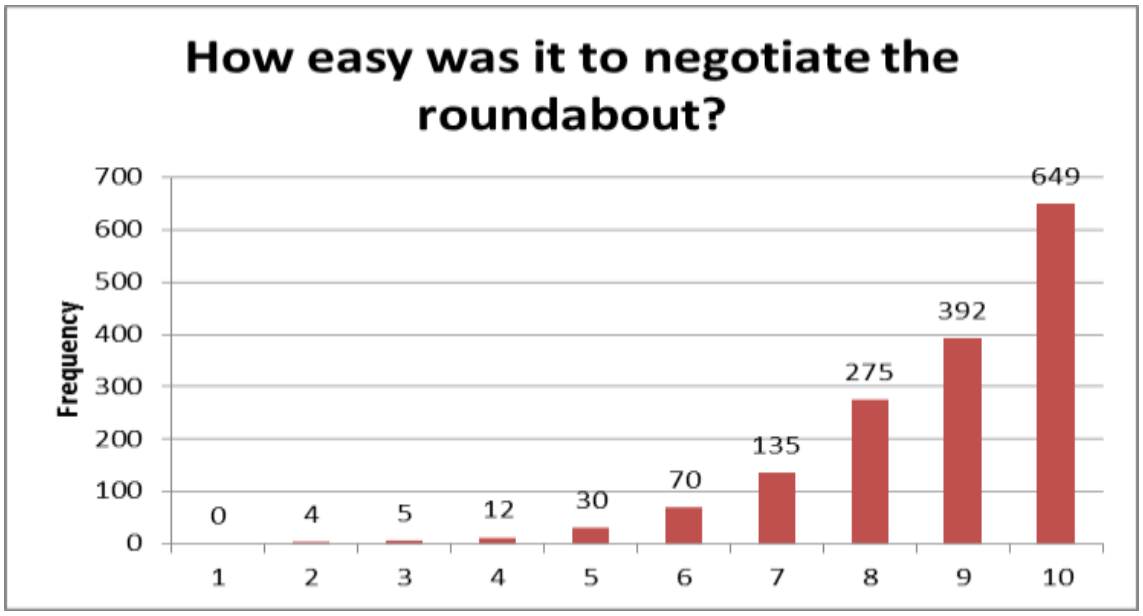

Figure 140: Pedestrians' scores for ease of use using the roundabout

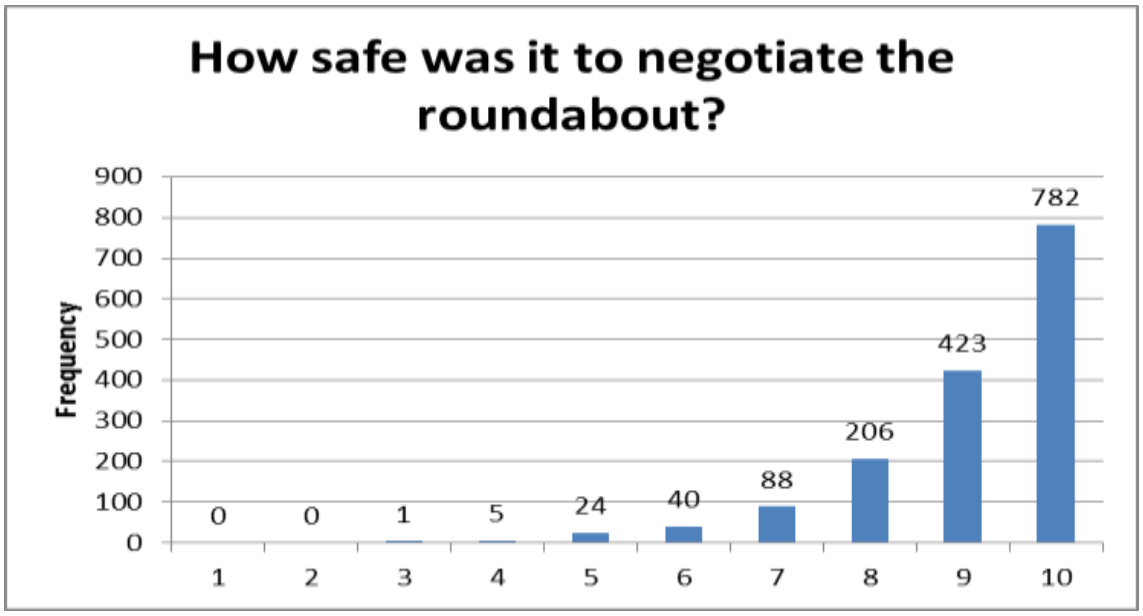

Figure 141: Pedestrians' scores for safety of use using the roundabout

The above score distributions were given for using all the roundabout's arms. Overall, these imply that the majority of runs were found to be both easy (97%) and safe (98%). This is not overly surprising as pedestrians were not placed in any difficult situations.

However, it does indicate that they did not find any major issues with using the roundabout infrastructure from any of the arms. It should be noted that because of the trial methodology, pedestrian only moved around the roundabout in a clockwise direction.

It was also found that the safety scores were highly related to the ease of negotiating the roundabout: 88% of the safety scores were within ±1 of the ease of negotiating scores.

Figure 142 shows the ease of use by crossing. This implies that (on average) pedestrians found it easy to cross all the Arms of the roundabout. Crossing Arm 1 was found to be marginally the easiest and crossing Arm 3 marginally the most difficult.

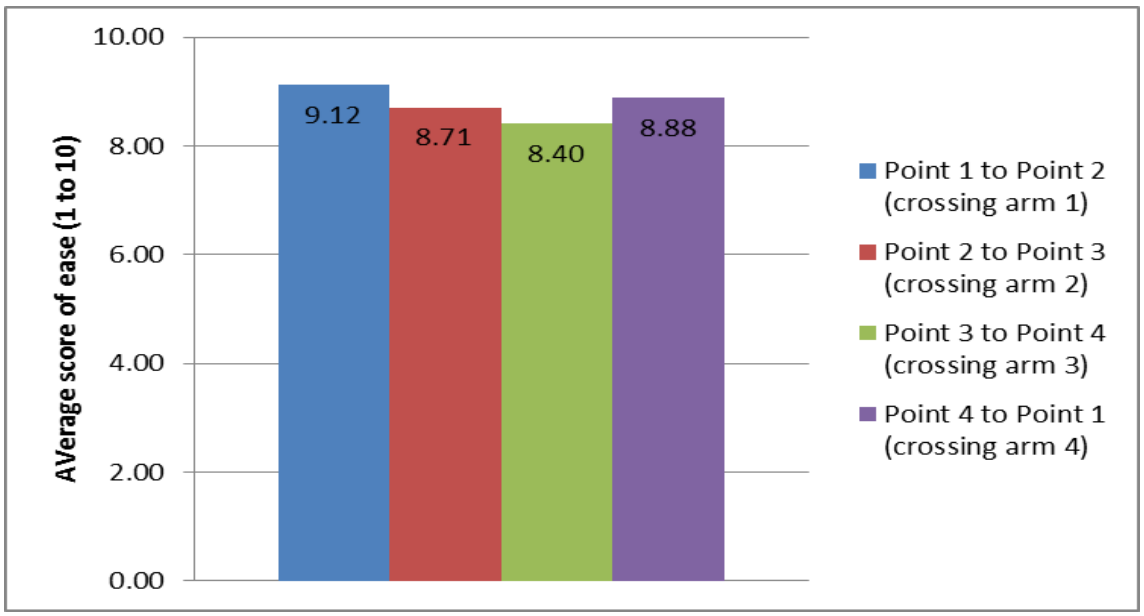

Figure 142: Pedestrians' scores of ease of negotiating the roundabout

This also shows that, again by a small margin, pedestrians found to easier to cross car and cycle lanes separately (Arms 1 and 4) than together (Arms 2 and 3).

B.9 M28c Large vehicle Capacity Findings Report

Findings report: Dutch Roundabout Impact of Long Vehicles (M28C) trials

1 Introduction

1.1 General introduction to the Dutch-style Roundabout (DRB)

As part of the Cycle Facility Trials project, which TRL is undertaking for TfL, TRL has been tasked with investigating the implications of implementing a design which separates cars from cyclists in the circulating part of the roundabout in an attempt to improve cyclists' safety when using the roundabout.

The 'Dutch-style Roundabout' is based on a design of roundabout that is widely used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in Figure 1.

In the version trialled at TRL, Zebra crossings are placed across each arm.

Four different designs of entry and exit layout were tested by having different layouts at each of the four arms of the roundabout. These were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

While the initial build of the roundabout used in trials M5 and M6 used standard Dutch markings on the roundabout, an important aspect of this build of the roundabout is that it used mainly UK style markings. The changes included the following:

- Application of zigzag markings on either side of the Zebra crossings
- Different marking delineating the orbital cycle lane (single or double dashed lines rather than elephants feet/sharks teeth), although elephants feet were left on Arm 4 and sharks teeth left on the Arm 1 exit
- A "give way" marking was used on Arm 2 exit to reinforce the cycle priority

- The Dutch markings indicate the outside of the circulating car lane by a dashed line; UK practice only lines the entry-lanes, not the exit lanes.

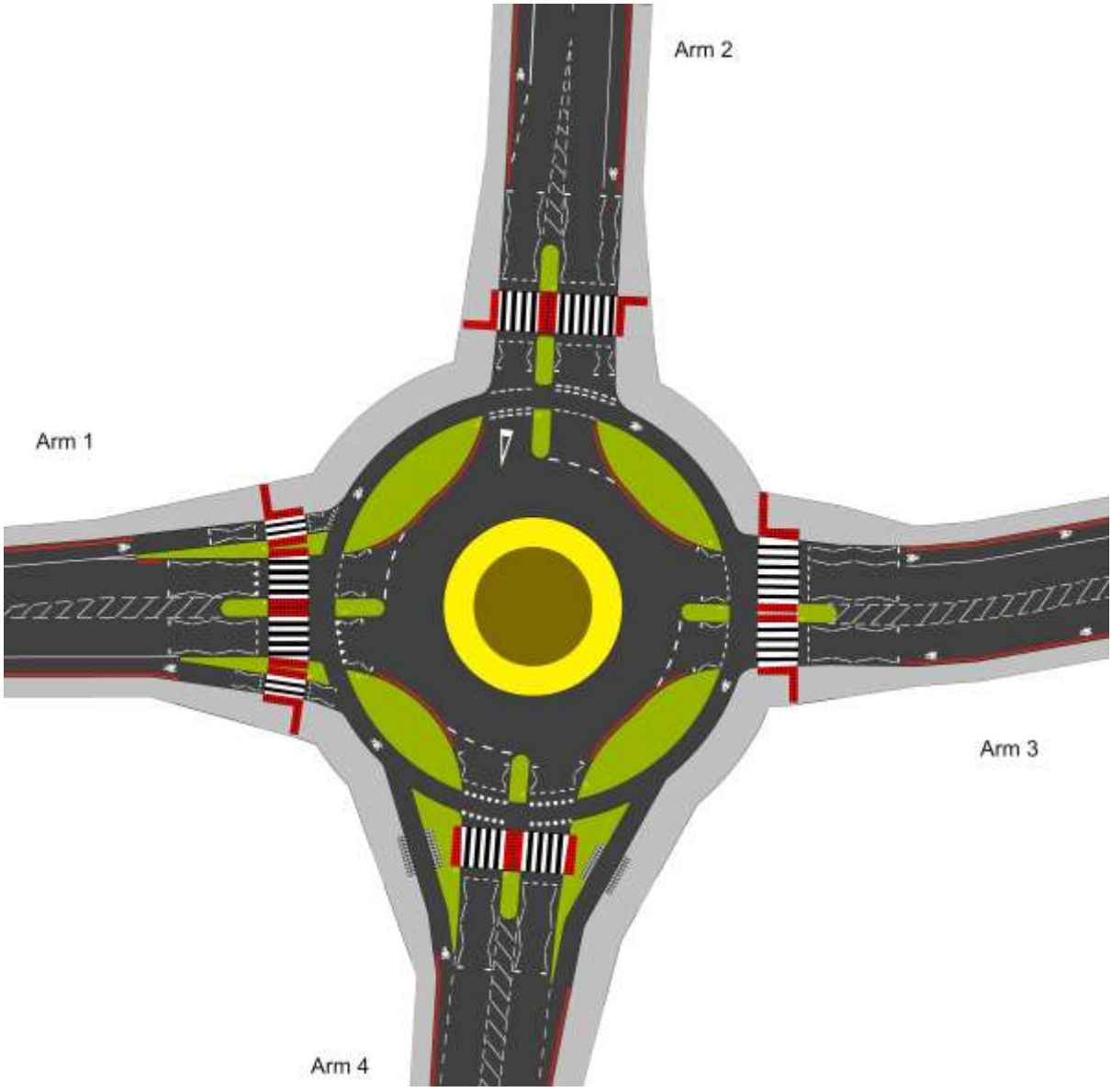

Figure 143: Layout of the Dutch-style Roundabout with UK road markings

In addition, cycle symbols were painted on the cycle lane to clarify the cycle lanes.

1.2 Introduction to the M28c trials

The M28 trials were concerned with understanding the capacity[7] implications of using the Dutch-style roundabout design on UK roads. There were three sub-trials, namely:

- M28a which investigated the fundamental vehicle capacity of the roundabout

[7] *Capacity* refers to the maximum flow rate of vehicles that are able to use the roundabout before it becomes congested. See the M28a report for more details on the capacity of roundabouts.

- M28b which investigated the effect of cyclists using the orbital cycle lane on the vehicle capacity of the roundabout
- M28c (this trial) which investigated the effect that long vehicles using the roundabout have on other vehicles using the roundabout

This report only reports on the findings from the M28c trials, M28a and M28b are reported on in separate deliverables.

The rationale behind the M28c trials was the observation that the combination of a single lane roundabout with the tight turning radii of the continental style geometry of the roundabout could lead to the circulating lane being blocked by large vehicle waiting for cyclists on the orbital cycle lane when exiting the roundabout. The problem can be clearly seen in **Figure 144**.

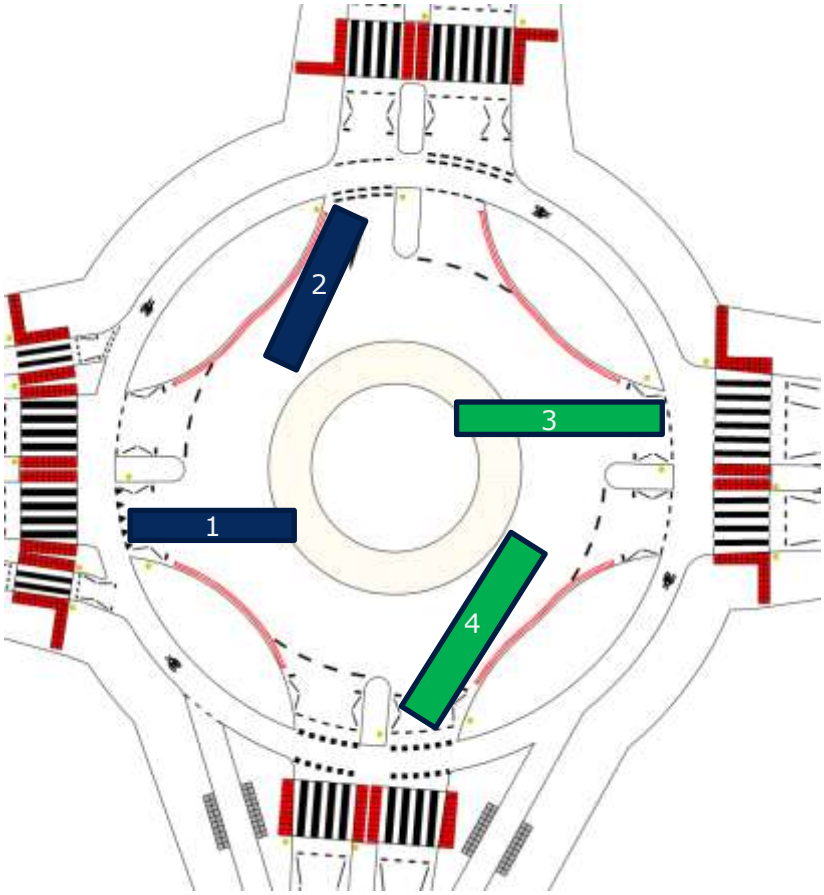

Figure 144: Long vehicle blocking circulating lanes

This shows two 12m long vehicles, (1 and 2, dark blue) stopped at the circulating cycle lane. Vehicle 1 is shown exiting directly in line with the exit lane – a worst case but unlikely scenario. Vehicle 2 is shown exiting at a more realistic angle. They both completely block the circulating vehicle lane, although it is possible for vehicles to pass behind the angled 12m vehicle using the apron. Longer 15m vehicles (the length of new luxury coaches, 3 and 4 in green) are even worse. Or course the actual effect will depend on the angle at which the long vehicles exit the roundabout, and also how far behind the stop line they actually stop.

2 Methodology

The objective of the trial was to understand if drivers are able to, and are prepared to, circulate round the roundabout if encountering a long vehicle stopped at the exit to the roundabout. Each of the long vehicles was driven by a participant over the roundabout and the driver was asked to exit at a particular arm. On exiting, they were delayed by one or two bicycles (ridden by trial staff) using the orbital cycle lane, causing the vehicle behind to either stop, or pass behind the large vehicle on the circulating lane. The reaction of the following driver (whether they stop, or are they prepared to squeeze behind the back of the large vehicle) was recorded.

Two scenarios were investigated.

Scenario 1

The long vehicle was driven straight over the roundabout, taking the second exit. A car, driven by a participant, coming from the left fell in behind the long vehicle. The large vehicle was stopped at the exit by circulating cycles, forcing the following vehicle to either stop or go round the back of the vehicle. To add realism, this car was followed by other cars, thus providing pressure from following cars to keep moving. This is called a "side" interaction, and is illustrated below.

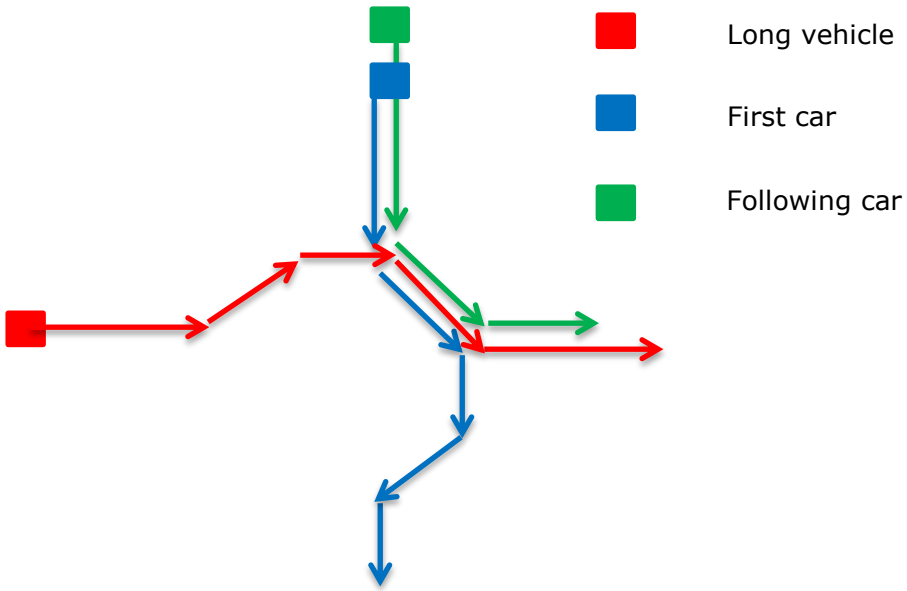

Figure 145: Trial scenario 1

Scenario 2

The long vehicle was driven straight over the roundabout, taking the second exit, followed by a car turning right (taking the third exit). The long vehicle was stopped at the exit by circulating cycles, forcing the following vehicle to either stop or go round the back of the vehicle. To add realism, this car was followed by other cars, thus providing pressure from following cars to keep moving. This is called an "in-line" interaction, and is illustrated below.

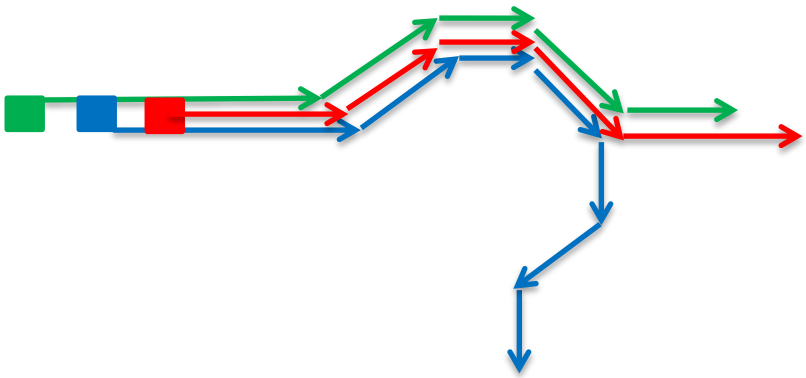

Figure 146: Trial scenario 2

The trials were arranged so that the long vehicles drove between arms 1 and 3 and arms 3 and 1 alternatively, the vehicle doing a U-turn at the end of each run. To maximise the amount of testing achieved in the limited time available, two vehicles were set off at the same time, one each from arms 1 and 3.

The trials were run in four sessions, two in the morning and two in the afternoon. Each scenario was trialled in each session for each long vehicle. Because of the limited time available for this trial, the number of participants which could be accommodated was only enough to provide indicative results on the effect of long vehicles. To obtain more rigorous results will require additional research.

At the end of each run, the driver in the first car was asked how easy they felt the drive was on a scale of 0 (impossible) to 3 (easy).

Video analysis was used to establish:

- Was the first car able to pass behind the long vehicle while it was stopped?
- Did the car have to use the apron to get round the long vehicle, and if so how much of the apron was used?
- What was the time taken for the first car to execute movements?

Finally the long vehicle drivers were asked to comment on the trial.

3 Summary of Findings

Five different large vehicles were trialled, namely:

- A long wheelbase Transit-style van (all sessions)
- An 18t lorry (afternoon sessions only)
- A single decker bus (12m long) (all sessions)
- A luxury coach (15m long) (all sessions)
- An articulated vehicle (morning sessions only)

All long vehicles were driven by drivers with experience of that vehicle type.

A total of 16 car drivers took part in the trials, 8 in the morning session and 8 in the afternoon session. All participants encountered each type of long vehicles as both a first and second driver.

Experienced trained cyclists were used to delay the long vehicle while exiting the roundabout.

3.1 Video Analysis Findings

The main video analysis looked at how cars reacted when encountering a long vehicle stopped at the roundabout exit. The results are shown in **Table 6**. This shows that, apart from the van, all cars were at least slowed by the long vehicle. The figures for the coach are anomalous and seem to show that the coach has less effect than the shorter 12m bus and 18t lorry. This is largely due to the fact that there were only few successful interactions involving the coach because of difficulties with timing the trial runs. The coach driver also tended to stop very close to the cycle lane. If we exclude the coach, it is clear that all the longer vehicles (bus, HGV and lorry) caused over ¾ of cars to stop and wait for them. Only a minority of drivers chose to use the apron.

Table 6: Reaction when encountering stopped long vehicle

Vehicle	Stopped	Slowed, used apron	Slowed, no apron	No Delay
12m Bus	81%	4%	15%	0%
HGV	88%	0%	13%	0%
15m Coach	17%	17%	67%	0%
Long Van	40%	10%	46%	4%
18t Lorry	94%	6%	0%	0%

The results also show that, in some cases, there is a significant difference in delay caused by whether the interaction was "in-line" (following vehicle encountered the long vehicle directly from behind) or from the side (the following vehicle encountered the long vehicle from the left side). The difference is illustrated in **Figure 151**, and the results are shown in **Table 7**. This shows the cases of the largest difference (for the long van) and the smallest difference (the bus).

Table 7: Difference between "in-line" and "side" interaction

Vehicle	Stopped	Slowed, used apron	Slowed, no apron	No Delay
12m Bus				
In-line encounter	75%	8%	17%	0%
Side encounter	86%	0%	14%	0%
Long Van				
In-line encounter	25%	6%	56%	13%
Side encounter	47%	12%	41%	0%

As noted before, these figures must be seen as indicative only owing to the small sample size used in the trial. However the figures are clear enough to make is certain that long vehicles will have a significant effect on the roundabout capacity, with the four largest vehicle delaying every following vehicle to some extent.

Despite the fact that some long vehicles significantly blocked the roundabout, the vast majority of motorists (>90%) rated the movement as "easy" or "moderate".

3.2 Empirical evidence

Figure 147 to **Figure 150** show the various long vehicles stopped at the roundabout exit waiting for cyclists to pass. This clearly shows that the longer vehicles tended to block the car lane while waiting for passing cyclists. It is also clear that most long vehicles stopped well before the cycle lane, further blocking the vehicle lane. The reason for this is to give the drivers a clearer view of the cycle, as discussed later.

Figure 147: Bus at roundabout exit

In the left hand image of **Figure 148** the driver can clearly be seen craning his head forwards to try to see if there are any more cyclists approaching from the left. Lack of visibility is further discussed in section 3.3.

Figure 148: HGV at roundabout exit

Figure 149 shows that the blocking effect of the long wheelbase van is almost negligible, while for the 18t lorry there is space for car to pass if it clips the apron.

Figure 149: Van and 18t lorry at roundabout exit

Figure 150 shows that cars must use the apron to pass the 15m coach.

Figure 150: 15m coach at roundabout exit

Figure 151 shows that it is somewhat easier for a car approaching from the rear to pass behind the coach using the apron than one approaching from the left hand roundabout entry. This implies that the effect of long vehicles on capacity will depend to some extent on the distribution of traffic between entry arms.

Figure 151: Following vehicle approaches from left and rear

3.3 Feedback from long-vehicle drivers

All drivers of the longer vehicles, (bus, coach, HGV and 18 tonne lorry) expressed severe reservations about the visibility of cyclists using the cycle lane:

"Vision is restricted on the nearside, unable to see if other cyclists are following [the first]"

"Massive blind spot on left. 1st cyclist seen if 2nd waits 2 seconds extra as you pull away he then appears."

"Cannot see cyclists on near side when stopped at exit, particularly if there is more than 1. Tend to see the approaching cyclists before stopping, but cycle lane then in blind spot and have no idea about following cyclists."

The problem is illustrated in **Figure 152** below. A vehicle (dark blue) is shown stopped at the cycle lane at a roundabout exit. Cycles use the cycle lane as shown by the dark red arrow. The vehicle driver has a near-side view in his rear-view mirror as illustrated by the yellow area, and a view out of the side window as illustrated by the green area. The entire red area is in his blind spot, which include most of the cycle lane. The actual coverage will of course vary with the types of mirror used, size of side windows and the angle at which the vehicle approached the exit.

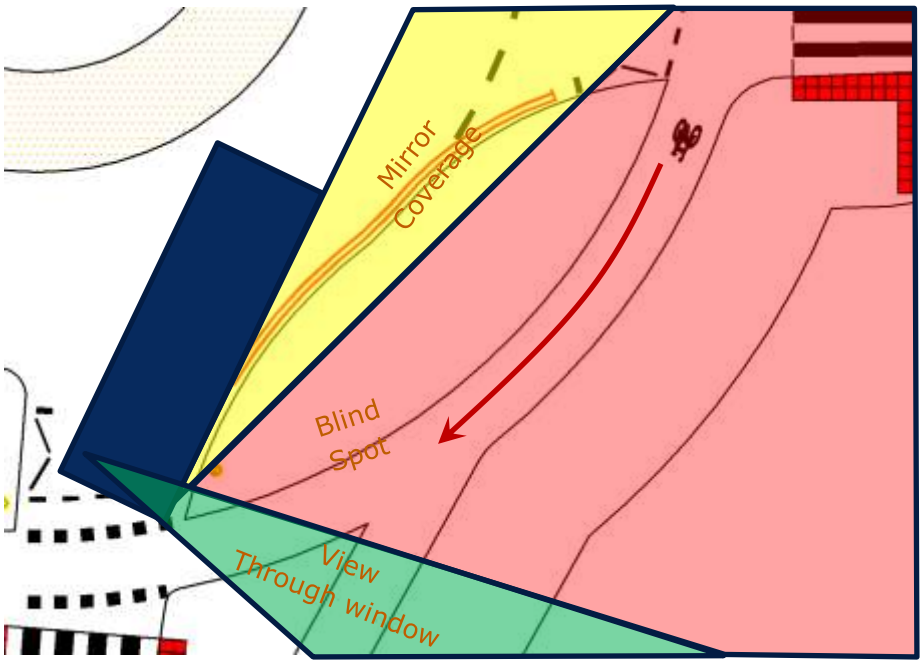

Figure 152: Long vehicle driver blind spot

The problem is potentially worst for HGVs which may also have a blind spot just below the rear view mirror because of the high sides of the vehicle. The side windows on busses and coaches tend to be somewhat lower, giving them a better view immediately alongside the vehicle. The relative side views from the coach, bus and HGV are shown in Figure 153, which also shows the height of a cyclist compared to the side windows of the HGV.

Figure 153: Side view from various vehicles

This is a potentially serious safety concern with this design of roundabout.

In the trial, the HGV driver attempted to maximise his view of the cycle lane when approaching the exit by cutting across the apron so that when he stopped at the cycle lane he was as straight as possible. He also tended to stop well before the stop line. This is shown in the left hand image of Figure 154. Both of these actions minimised the possibility of other vehicle to pass behind him by using the apron. When using the roundabout in a normal way, there was enough space on the apron to allow vehicle to pass behind him, as shown in the right hand image.

Figure 154: HGV attempting to maximise view of cycle lane

The combination of poor visual coverage of the cycle lane and attempts by drivers to maximise what they can see therefore leads to a potential increase in the likelihood of long vehicles blocking the roundabout at exit lanes. The fact that nearly all drivers who encountered a long vehicle experienced some delay, many coming to a halt behind the vehicle, means that it is certain that these vehicles will affect the capacity of the roundabout. The extent to which this will occur could not be evaluated in this trial.

The high level of concern expressed by some drivers of longs vehicles about the visibility of cyclists on the cycle lane should be investigated further.

B.10 Technical note on road markings for cycle priority at roundabouts

This note considers the findings on participants understanding of the road markings used on the Dutch roundabout trials. The note was written after the first trials (M5, M6, M21 and M22) had been completed. As the findings after all trials had been completed were not materially different, the note has not been updated.

Technical note on road markings for cycle priority at roundabouts

1 Introduction

As part of the Cycle Facility Trials project, TRL has been asked to comment on the most effective road markings to use to indicate that cyclists have priority on the circulating part of the Dutch-style roundabout.

At the time of writing, the analysis of all the trials has not yet been completed, so this note will use the results from the M6a/M6b trials (cycle-car interaction trials with Dutch markings) and the equivalent M21/M22 trials (cycle-car interaction trials with UK markings).

2 Roundabout Design

The 'Dutch-style Roundabout' is based on a design of roundabout that is used in The Netherlands. It uses continental geometry (short turning radii to reduce speeds and a single circulating vehicle lane) and has a kerb-segregated cycle lane at carriageway height, orbiting around the outside of the roundabout, with priority for cyclists across the entry and exit lanes.

In the version trialled at TRL, Zebra crossings are placed across each arm. The trial layout varies slightly at each arm, involving varying distances and angles of separation between the cycle lane and vehicle lane, and the extent to which cyclists are guided into the circulating orbital cycle lane. This approach permits different design elements to be tested and compared within the same trial (see below for more detail).

The design drawings were developed with TfL and further background information is provided in the planning sheet previously discussed with TfL (WS2.DRBb.M5). The layout is shown in **Figure 155** (Dutch markings) and **Figure 157** (UK markings).

The different designs of the entry and exit layouts tested were:

- Arm 1: Cyclists approach in a segregated cycle lane which connects with the segregated orbital lane. Cyclists also exit the orbital cycle lane using a segregated cycle lane.
- Arm 2: Cyclists approach in a mandatory cycle lane with a fairly sharp left turn into the orbital cycle lane encouraged by an island which is shaped to direct the cyclists into the segregated orbital lane. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn directly into the main carriageway.
- Arm 3: Cyclists approach on the carriageway with a fairly sharp left turn into the orbital cycle lane. The island separating the cycle lane from the main carriageway is neutral in terms of directing cyclists into the orbital segregation. When exiting, cyclists leave the orbital cycle lane taking a fairly sharp left turn into a mandatory cycle lane.
- Arm 4: Cyclist approaches roundabout in a normal vehicle lane, with a segregated lane leading to the orbital lane turning off to the left. Cyclists leave the orbital lane in a segregated cycle lane which eventually merges with the main carriageway.

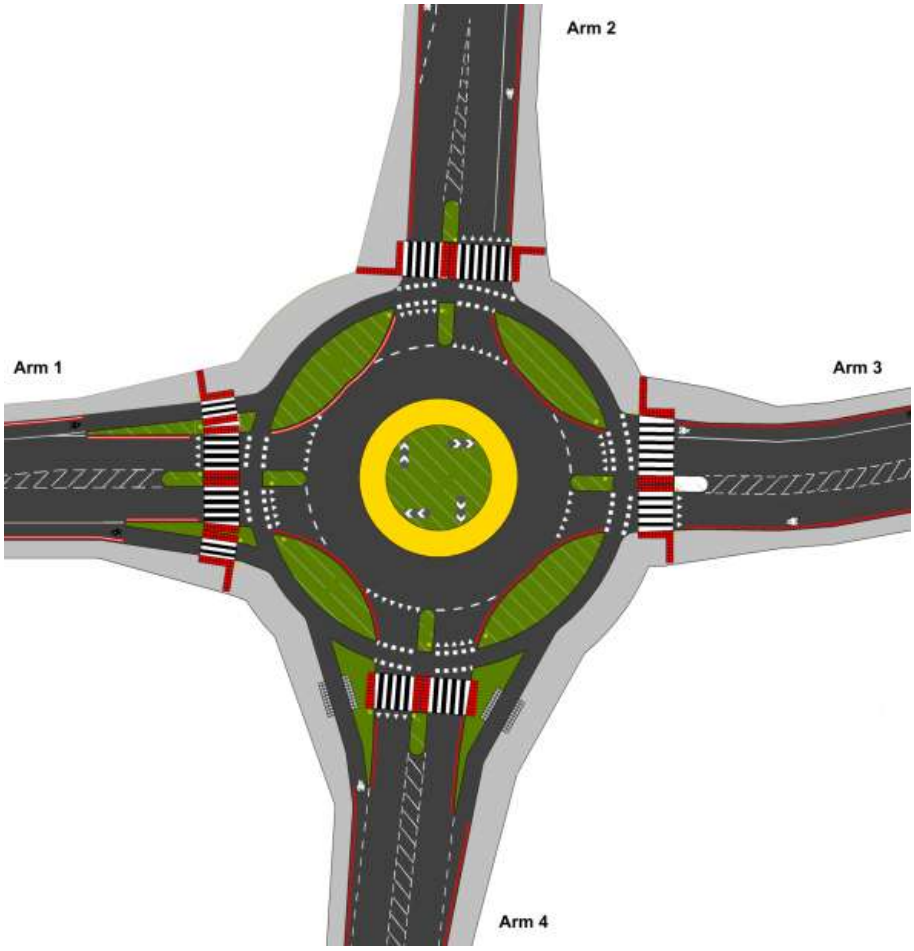

Figure 155: Roundabout with Dutch-style markings

Figure 155 shows the layout of the roundabout with Dutch-style road markings. The main points of the markings are highlighted in **Figure 156**.

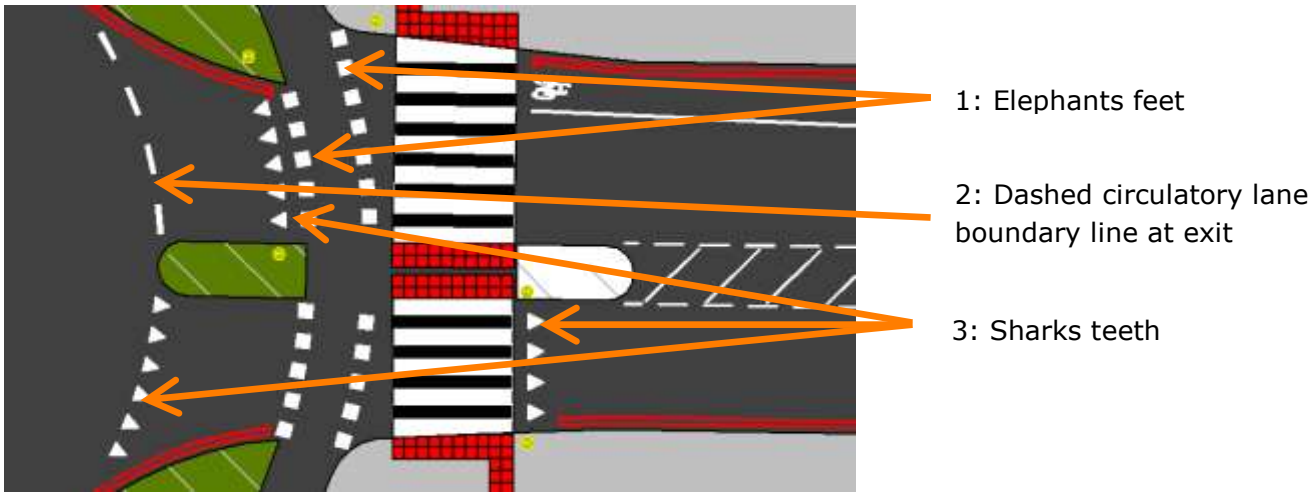

Figure 156: Detail of Dutch markings - Arm 3

This shows the following markings:

1. "Elephants feet" (white squares) demarcating the edges of the cycle lane
2. Dashed white lane marking, demarcating the edge of the circulatory car lane at the exit point

3. "Sharks teeth" white triangles used to indicate that the vehicle approaching must give way to others, in this case cycles (top arrow, on exit lane), pedestrians (middle arrow), and cars circulating the roundabout (lower arrow)

None of the above markings are used as standard in the UK.

Figure 157 shows the same roundabout, but now using a variety of mainly UK markings (some adapted to fit into the available road space).

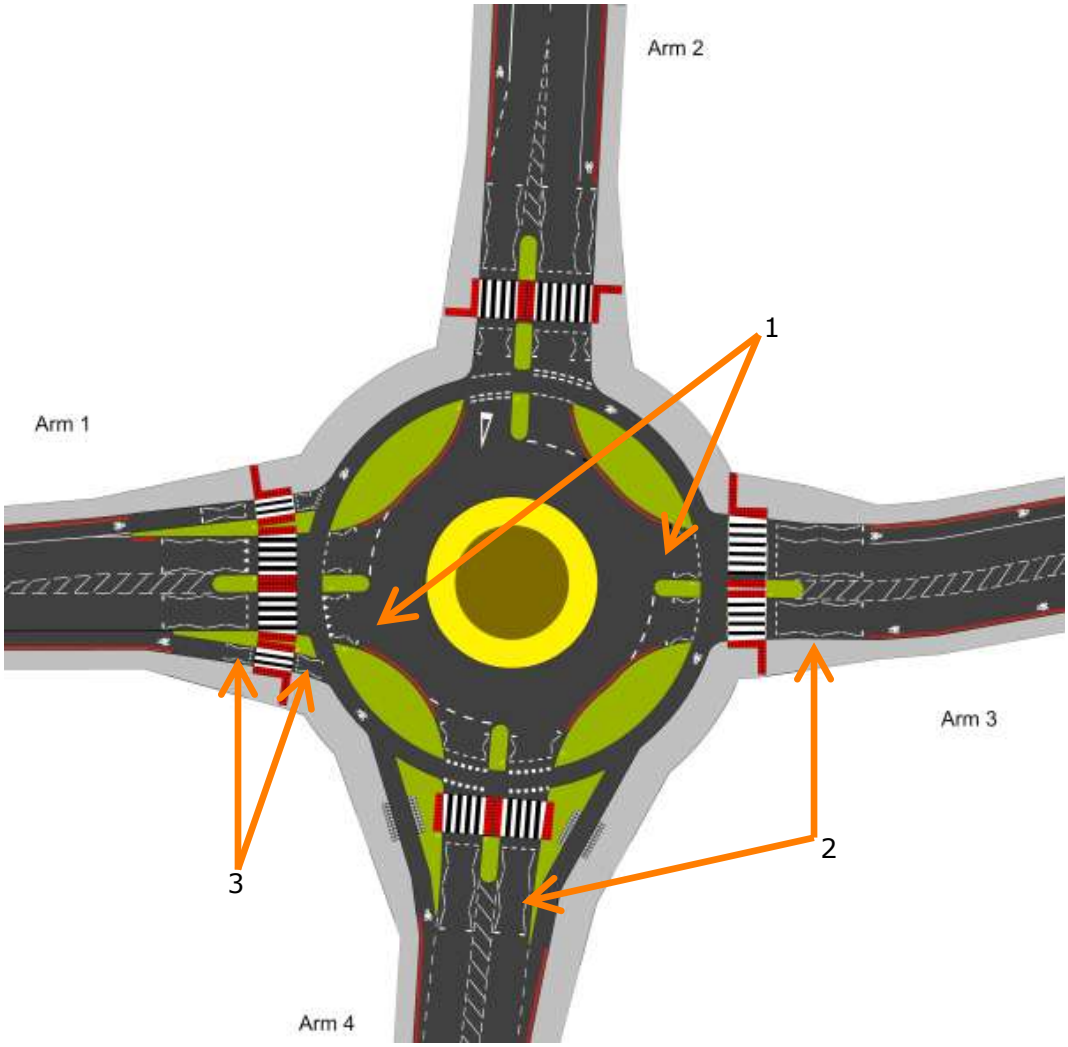

Figure 157: Roundabout with UK-style markings

It can be seen that the outer edge of the circulatory vehicle lane is no longer marked at the exit lane (e.g. 1 in **Figure 157**) compared to the Dutch markings (point 2 in **Figure 156**), as per standard UK practice. As there is no UK standard which can be applied to this geometry of roundabout, each of the arms was treated slightly differently, as described below, with some common elements.

On all four arms, zig-zag markings were applied to the car lane (2 in **Figure 157**) on the approaches to the pedestrian crossings and cycle lanes. They were also applied to the cycle lanes (3 in **Figure 157**) where these had a zebra crossing (Arms 1, 2 and 3).

Figure 158 shows the markings on Arm 1. Here the "Sharks teeth" (1) were used to indicate to car drivers that cycles and pedestrians have priority, both on the entrance to and exit from the roundabout. Dashed lines (2) are used to indicate the edges of the circulatory car lane, cycle lane and pedestrian crossing.

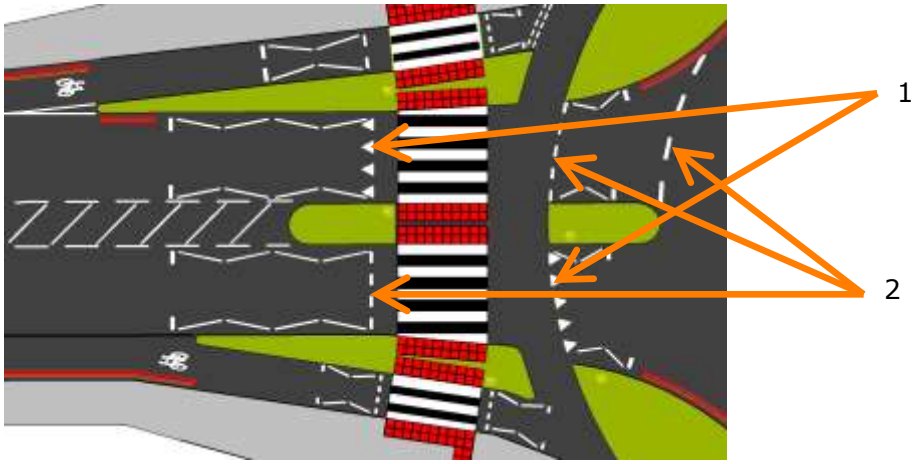

Figure 158: Arm 1 UK markings

The markings used on Arm 2 are shown in **Figure 159**. This shows the use of double give way lines (1) to demarcate the edge of the cycle lane at which cars must yield priority. On the exit lane this is reinforced with the use of a yield marker (2). Note also that the zebra crossing has been moved 5m away from the cycle lane on this arm only, giving a space for a vehicle to stop between the pedestrian crossing and the cycle lane.

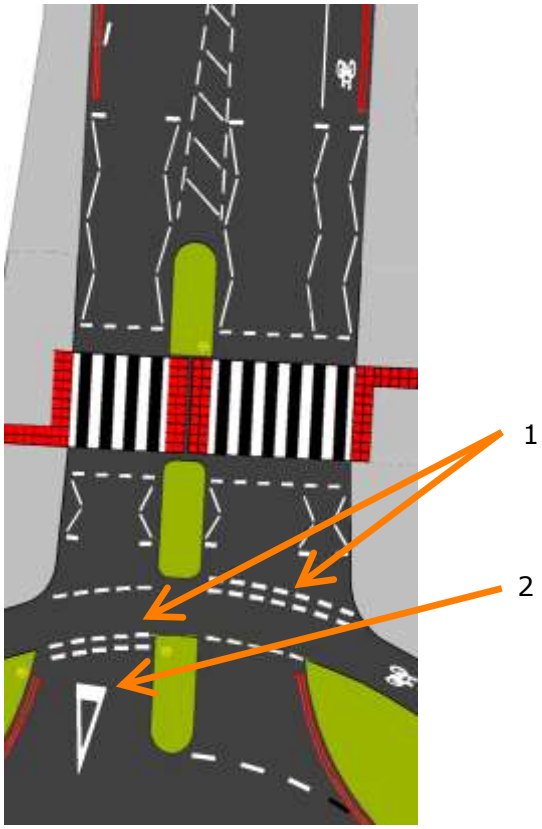

Figure 159: Arm 2 UK markings

Figure 160 shows the markings on Arm 3. In this case, a single dashed give way line (1) indicates the inner edge of the cycle lane on both the entrance and exit lanes. No other markings are used to indicate priority.

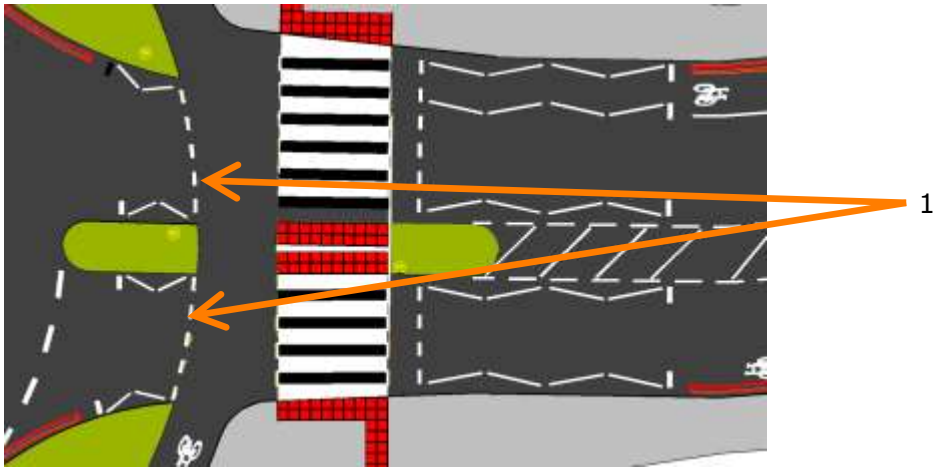

Figure 160: Arm 3 UK markings

Figure 161 shows the markings on Arm 4. These are the same as Arm 3 with the addition of "Elephants feet" to demarcate both edges of the cycle lane (1).

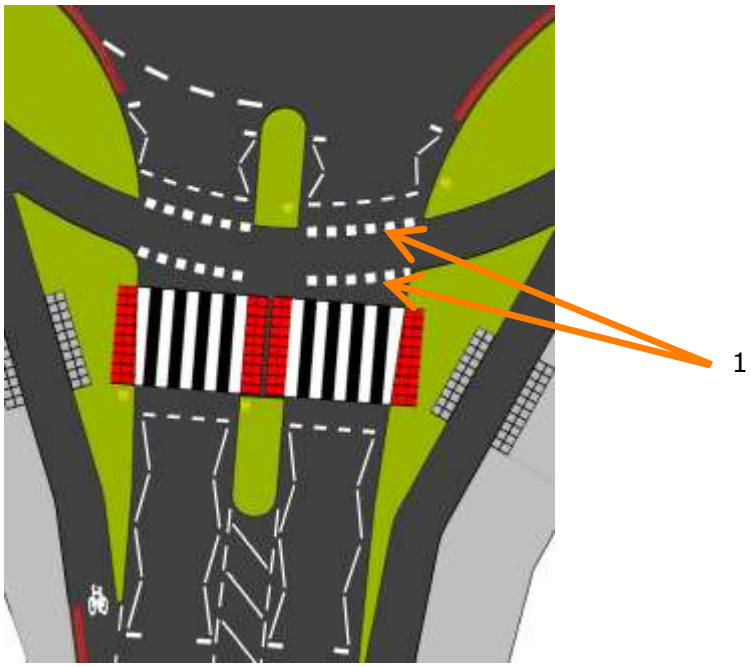

Figure 161: Arm 4 UK markings

3 Methodology

The M6a trial provided feedback on what cyclists' understood and how they used the Dutch-style roundabout while controlled car drivers interacted with them. The M6b trial provided the equivalent feedback with participant car drivers and controlled cyclists. In both trials the roundabout was laid out using Dutch-style road markings. The M21 and M22 trials were essentially identical to the M6a and M6b trials, but with a variety of UK markings used on the roundabout as described above.

For the purposes of this technical note, the results from M6 were compared with the equivalent results from M21/M22 to seek to understand which markings were most easily understood by the trial participants. This was done by comparing the understanding of each of the UK markings options to the original Dutch markings, and

comparing the various UK markings to each other to find which one was the best understood.

The analysis has relied chiefly on the analytical analysis of the questionnaire results as these are the most rigorous.

4 Results

4.1 Understanding of the Dutch markings

The principal safety concern is the understanding of the sharks teeth used on the Dutch markings. The correct interpretation of this is that it is a "give way" marking, indicating that driver must yield priority to the crossing users, be they cyclists, pedestrians, or indeed other cars (**Figure 162**).

Figure 162: Sharks teeth at cycle path (left), pedestrian crossing (centre) and roundabout edge on entry lane (right)

Most of the drivers (86%) and cyclists (78%) said they noticed the unusual road markings at the entrance to the roundabout, but were less likely to say they noticed them on leaving the roundabout (68% and 64% respectively). It is understandable that cyclists were less likely to see the markings, because the markings were not directly encountered when they exited the roundabout. The reduction amongst car drivers is not as easy to explain, but might be a result of information loading.

When asked in open questions to explain the meaning of the sharks teeth markings before the crossing on leaving the roundabout, almost a quarter of cyclists and drivers said they did not know. Correct explanations (give way) were provided by 12% of drivers and 24% of cyclists. The other main explanations tended to be about being cautious, slowing down, or marking the pedestrian crossing. A categorisation of the responses is shown graphically in **Figure 163**.

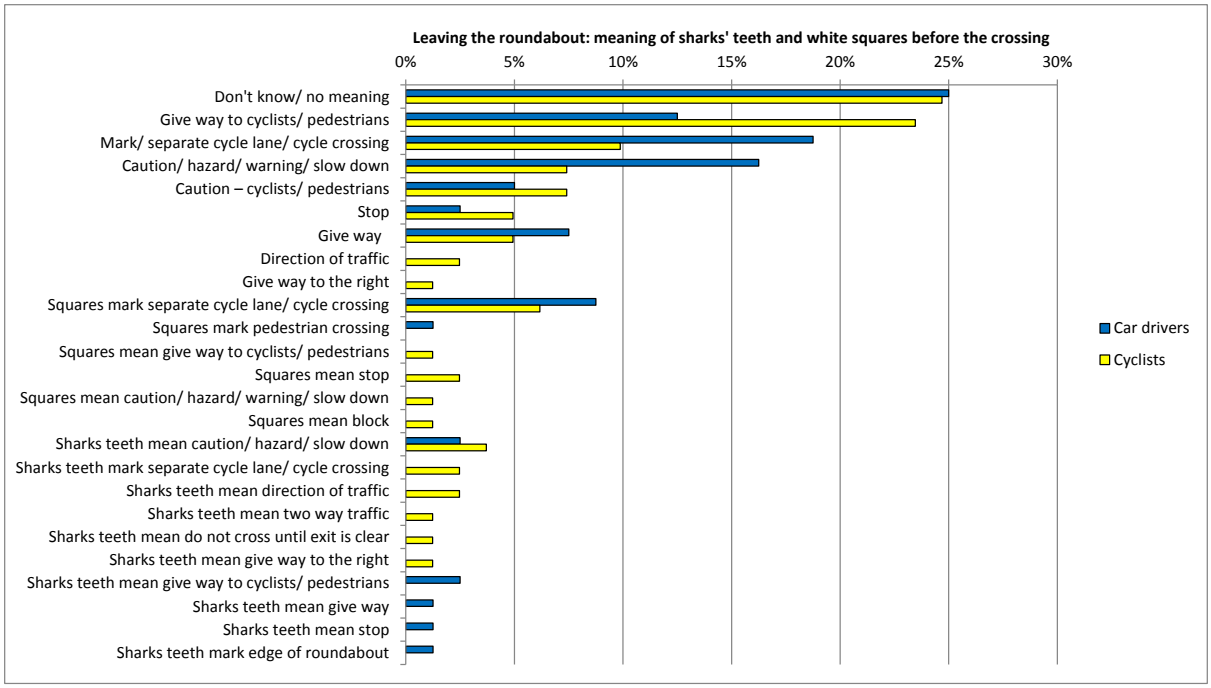

Figure 163: Understanding the sharks teeth

About half of the participants thought that the white squares (elephants feet, visible in **Figure 162**) either side of the cycle crossing were indeed marking the cycle crossing; about 12% of drivers and 15% of cyclists said they did not know. Of the others, cyclists tended to think that they meant give way to cyclists, while drivers tended to think they meant give way to pedestrians or were marking a pedestrian route or crossing. The comments indicated a degree of misunderstanding among participants, with some indicating that it was not clear from the markings which road users should have priority. **Figure 164** shows the range of interpretations given to the elephants feet markings by both drivers and cyclists.

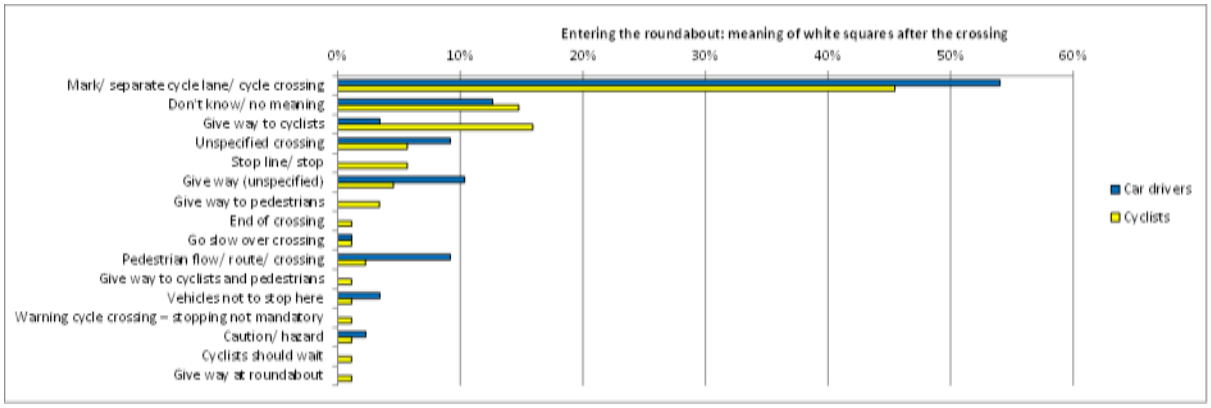

Figure 164: Understanding of elephants feet

Looking at whether drivers would be prepared to give way to cyclists, we can look at both the results from the entry and exit lanes.

On entry, the normal rules of roundabout priority should apply, so it should be clear to all drivers that they must give way to cyclists coming from the right. However, as the cyclists are segregated from the rest of the traffic as they approach the side road it is possible that drivers will treat the situation as if it were off-carriageway path crossing a

side road, where cyclists normally give way in the UK. Nonetheless, it is clear from **Figure 165** that they indeed prepared to give way by a statistically significant large majority on all arms, and an even higher majority (**Figure 166**) would give way to cyclists already crossing using the cycle lane. The results for the different arms are very similar.

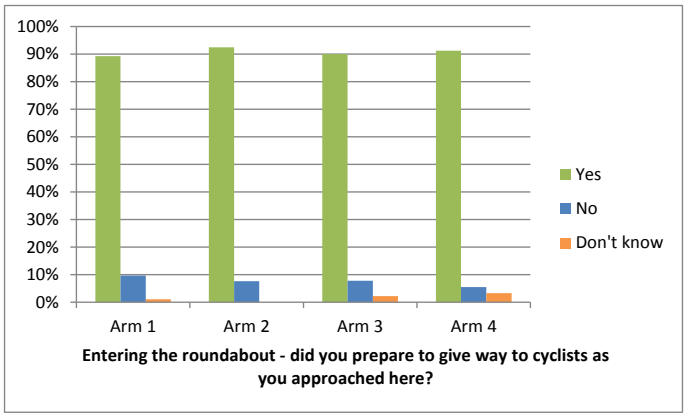

Figure 165: Preparedness to give way on entry

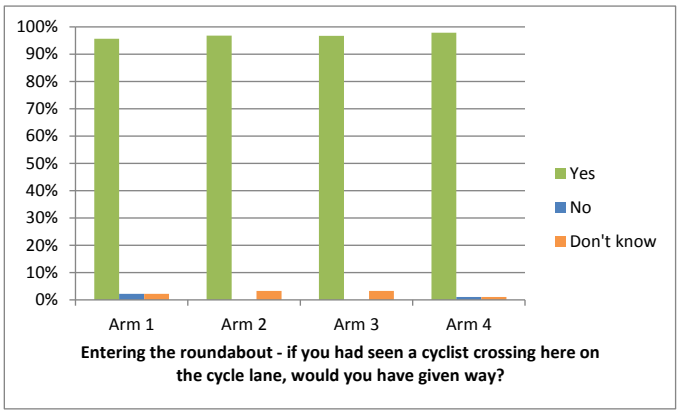

Figure 166: Willingness to give way to cyclists on entry

Turning to the exits, it is sensible to assume that priority will not be as clear as the entry arm – cyclists will now be coming from the left and will not as obviously be "on" the roundabout. It is therefore interesting to note that a slightly higher percentage of drivers were prepared to give way to cyclists as they exited the roundabout (**Figure 167**). This may indicate a natural cautiousness in an unusual and unknown environment.

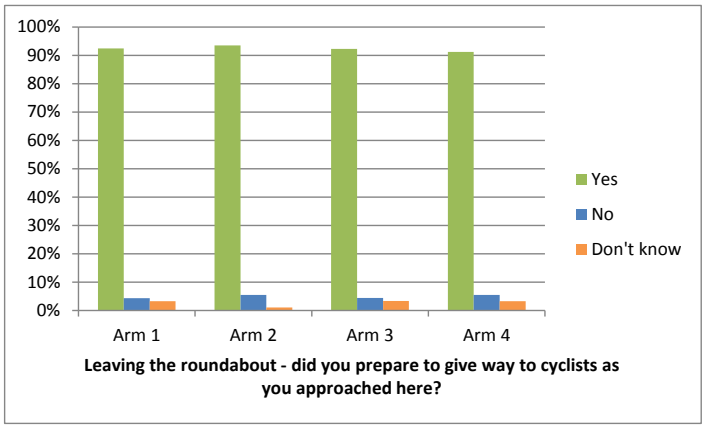

Figure 167: Preparedness to give way on exit

As shown in **Figure 168**, a higher percentage of drivers were willing to give way to cyclists already using the cycle lane. The result is very similar to that for the entry lane, although slightly fewer drivers were willing to give way on arm 2.

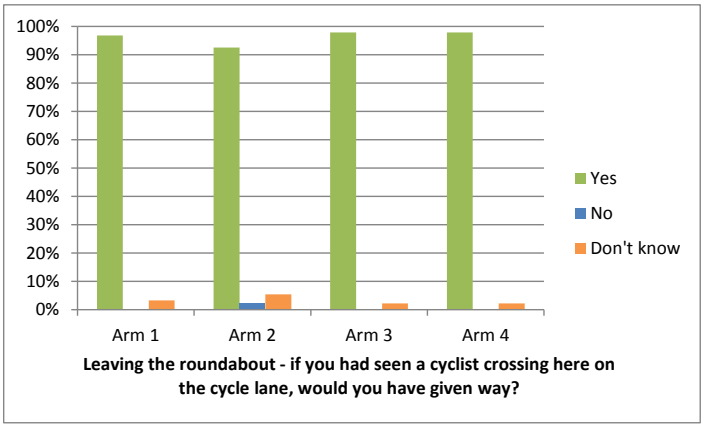

Figure 168: Willingness to give way on exit

4.2 Understanding the UK markings

4.2.1 Recap of markings used

As shown in **Figure 158** and **Figure 169**, the markings used on Arm 1 are a mixture of UK markings with Dutch-style sharks teeth indicating cycle priority over cars exiting the roundabout, and pedestrian priority over cars approaching the roundabout. As the cycle path and zebra crossing are directly alongside each other, they effectively have joint priority over cars.

Figure 169: Arm 1 Exit

The markings used on Arm 2 shown in **Figure 159** and Figure 170 include a standard double dashed give way line on both the entry and exit lanes, denoting that cyclists and pedestrians have priority in both directions. On the exit lane this is reinforced with a give way marking painted on the road just before the give way lines.

Figure 170: Arm 2 Exit

The markings used on Arm 3 shown in **Figure 160** and **Figure 171** (left) include a standard single dashed give way line on both the entry and exit lanes, denoting that cyclists and pedestrians have priority in both directions.

Arm 4 (**Figure 162** and **Figure 171** (right)) is the same as Arm 3, but with the addition of elephants feet markings showing the edges of the cycle lane.

Figure 171: Arm 3 and 4 Exits

The analysis of UK markings did not include evaluating the understanding of the markings as they were largely UK markings.

As for the Dutch markings, participants were asked if they prepared to give way to cyclists on both entry and exit, and whether they were willing to give way to cyclists using the roundabout.

Figure 172 shows that the majority of driver prepared to give way to cyclists on entry to the roundabout. The percentages are slightly lower than for the Dutch markings, particularly for arms 1 and 2. The difference for arm 2 may be due to the zebra crossing being moved further from the cycle lane, making it less visible to drivers.

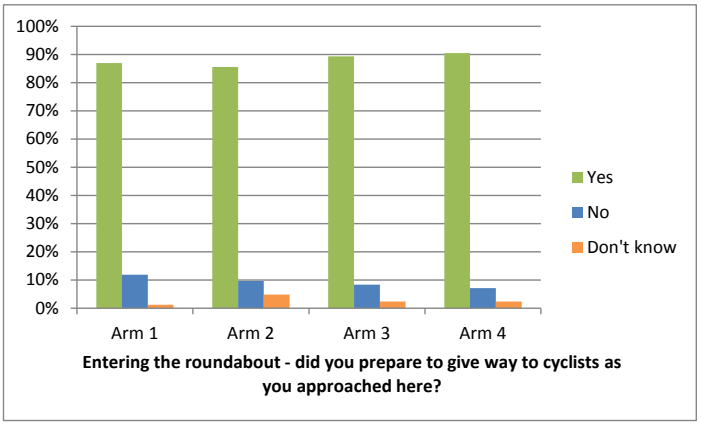

Figure 172: Preparedness to give way on entry

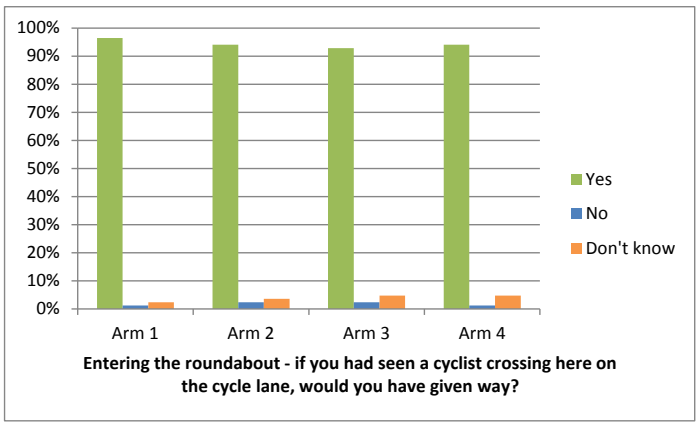

Figure 173: Willingness to give way on entry

Figure 173 shows that drivers were willing to give way to cyclists on the cycle lane by a large majority. These results are slightly lower than for the equivalent with Dutch markings.

Figure 174 and **Figure 175** show the equivalent results for the exit lanes. Again the results are similar to the Dutch markings, although there is more variation between the arms. For both preparedness and willingness, Arm 2 had the best performance. Arm 3 had the lowest performance for both preparedness and willingness.

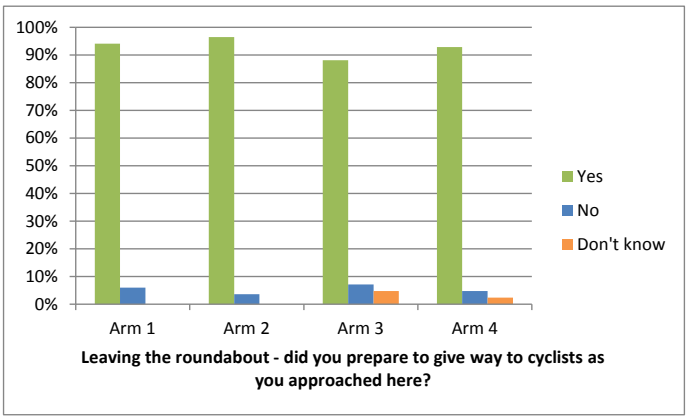

Figure 174: Preparedness to give way on exit

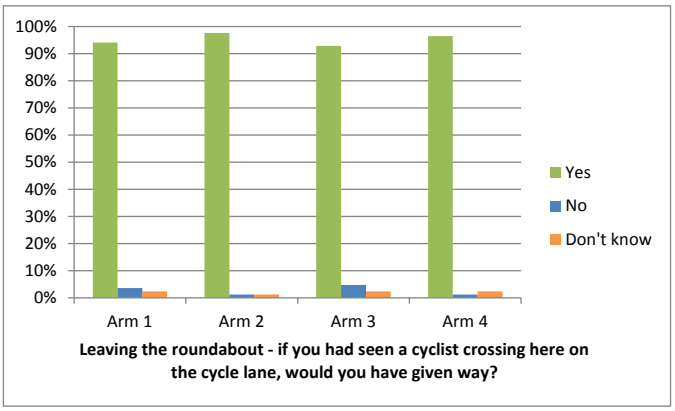

Figure 175: Willingness to give way on exit

4.3 Discussion

Using the evidence from the M6/M21/M22 trials, it is clear that that, for all markings, a large majority of drivers understood that they were expected to give way, and were willing to do so, or, where uncertain, gave responses that demonstrated caution. It would appear that overall the Dutch markings give slightly better performance than the UK markings when averaged across all arms; however the differences are small and statistically insignificant and could be due to the different groups of participants, or increased natural caution through unfamiliarity, rather than an inherent superiority of one set of markings over another.

Comparing the different arms with UK marking may be more informative. In this case the same participants were using all four arms, so small differences are more likely to be significant.

On entry, there was little difference between the arms, and these differences are as likely to be due to layout differences as differences in markings. The layout differences are confounding factors which make it impossible to reliably differentiate the effects of different markings from those caused by different layouts.

On exit, Arm 2 gave the best performance in both preparedness and willingness to give way. This is not surprising as this has a very clear and generally well understood "give way" marking painted on the exit arm just before the "give way" line. This difference is emphasised by the fact that Arm 2 performed worst on the willingness to give way on exit with Dutch markings. Slightly more surprising is that Arm 1 with the "sharks teeth" marks performed better than Arm 3 with "give way" dashed lines on preparedness to give way. This seems to indicate that the "sharks teeth" may be clearer to drivers than standard UK "give way" lines.

From the limited evidence available at this stage, it would seem that on entry standard UK markings are sufficient. On exit, the implementation of a standard UK "give way mark" may provide some benefit. The Dutch "sharks teeth" may provide some benefit over standard UK "give way" dashed lines.

It must be emphasised that these results are taken from a limited data set, and the differences seen are small and not statistically significant. Two points are worth considering:

1. The trial suggests that there are no disadvantages to the Dutch markings either in terms of understanding, so may be worth considering because they offer some practical benefits over UK signs and lines in this application (compact, no signs needed)
2. The Dutch roundabout by itself presents drivers with an unfamiliar situation in which the priorities are the other way round to those they've come to expect where segregated cyclists cross a side road turning. So it is possible that the use of an unfamiliar marking could actually be helpful in drawing attention to an unfamiliar situation.

Lastly, no participants in the trials were instructed on the meaning of signs and markings before or during the trials, so the beneficial effect of a public information campaign before introducing new layouts, signs and markings cannot be estimated.

B.11 Review of Literature on cyclist visibility from HGVs on roundabouts

This appendix contains a report written for TRL by Alex Sully Consulting regarding literature on cyclists in blind spots on roundabouts.

Desk top review of literature relating to collision between cyclist and large vehicles at roundabouts with circulatory cycle tracks

Background

Alex Sully Consulting has been commissioned by TRL to undertake a desk-top study to determine whether there are any published papers which address the issue of collisions between large vehicles and with cyclists that have priority on circulatory cycle tracks on roundabouts.

The documents reviewed are listed in Appendix A. Where appropriate, useful information has been drawn out and comments made about cyclists and roundabouts in general. In total 16 sources of information from mainland European Countries were consulted including 4 papers held on the ELTIS website. In addition, twelve reports prepared by TRL for a variety of clients were also reviewed.

Findings

The study was unable to find any reports that deal directly with this type of collision. Only two, *The Circumstances of blind spot crashes and short and long-term measures* SWOV R-2008-11A 2008 and *Fact Sheet – Blind spot crashes* SWOV 2012 make mention of the issue The former concludes that the increase in these collisions may be due to an increase in the number two-way cycle tracks, i.e. off of the carriageway, and the increasing number of roundabouts. No conclusions or recommendations are drawn which address this specific problem.

Although no mention has been made of this point, it is assumed that the problem only arises when a large vehicle approaches, or is stopped at, the crossing point for cyclists on a circulatory cycle track. Lorries stopped at the give way line at the entry to the circulating traffic lanes will block the crossing and the drivers will only be looking for vehicles (including cyclists) approaching from their off-side within the carriageway. It is also considered that a large vehicle exiting the roundabout and approaching the crossing point may have blind spots due to the alignment of the cab relative to the crossing alignment.

It was noticeable that a number of the reports mentioned the matter of blind spot mirrors and the fact that despite their presence, blind spots still remained. Furthermore, the mirrors themselves are capable of blocking the vision of the drivers of large vehicles.

Note: Although it is believed that cycle tracks that give priority for cyclists on cycle tracks around roundabouts could be lawfully created, the author is unaware of any examples in the UK.

Conclusions

Currently there is no published research that addresses this problem and offers recommendations on how to tackle it.

Recommendation

Further trials be undertaken to establish the degree to which cyclists on circulatory roundabouts are potentially put at risk by blind spots for drivers of large vehicles both on entry and exit.

Appendix A: Documents Consulted and Extracts

1 The Circumstances of blind spot crashes and short and long-term measures SWOV R-2008-11A 2008

In Dutch with English summary – extracts:

“The Netherlands still counts an average of 15 fatalities per year despite these measures.” i.e. collisions between lorries and cyclists.

“A second type of blind spot crash

Other than the 'classic' blind spot crash (lorry turning right and cyclist going straight on) described above, this study brought to light a second type of blind spot crash. These are crashes in which a lorry crosses a bicycle path (cyclists having right of way) at right angles and fails to notice a cyclist. This type of crash happens at intersections with a main road and at entering a roundabout. Crashes at these locations have become more frequent during the last few years, possibly caused by the increasing number of bicycle paths with two-way traffic and the increasing number of roundabouts. Especially cyclists who come from the right deserve attention because they are positioned in the blind spot at the right front of the lorry. A second point of attention in this type of blind spot crashes is the obstruction of the driver's view by the presence of (blind spot) mirrors on the lorry's side brackets. These limit the view, to the left as well as to the right, of both the bicycle path and the main road.”

“Solutions

Set of four concrete measures

Given the cyclists' right of way, the responsibility of avoiding a crash primarily lies with the lorry driver. However, cyclists must acknowledge their responsibility by making use of their right of way in an appropriate manner.

The following set of concrete measures offers four angles to reduce the number of blind spot crashes:

1. Separation of cyclists and lorries at locations where lorries can turn right. This separation can be realized by forcing lorries to halt at a generous distance from the halt line or the give way road marking, which places cyclists in full view in front of them. To support this motoring performance for lorry drivers, the halt lines or the give way road markings for motorized traffic are moved further backwards, at a larger distance from the intersection or roundabout.
2. A code of conduct for cyclists must be drawn up. This code will state that cyclists position themselves immediately in front of their own halt line or give way road marking and will be the first road users to depart when the light turns green or when the road is clear. The halt line or give way road marking for cyclists is closer to the intersection than that for motorized traffic. Cyclists coming from the rear must remain behind a lorry and do not position themselves beside the vehicle.
3. The introduction of measures 1 and 2 does not entirely prevent errors being committed. A check needs to be included to prevent a crash. At the location where the lorry turns off and crosses the cyclist's way, the driver needs to ascertain that the road is clear. At this point he must carry out an extra check for which he needs to make use of the front view mirror (Class VI 'front mirror' in Directive 2003/97/EC) or

the front camera. This extra check needs to be made part of the driver training and the refresher courses for lorry drivers.

4. All lorries must be equipped with the new front view system. Since 2007 the front view system has been compulsory for new lorries. We recommend also making this system compulsory for lorries that were built before 2007.

Strategic solution for all types of crashes between lorries and vulnerable road users

A strategic measure to prevent blind spot crashes – and, more generally, crashes between lorries and vulnerable road users – is the elimination of possible conflicts: lorries and vulnerable road users are not at the same location (at the same time). This requires a complete, structural separation of heavy and light traffic. In the long term this can be realized by only admitting heavy freight traffic to a main road network which gives access to, for instance, distribution centres. Only light freight traffic will be allowed to use the secondary road network. The main feature that distinguishes light freight vehicles from heavy ones is the absence of the blind spot: both front and side windows provide a direct view of vulnerable road users. The SWOV publication Advancing Sustainable Safety discusses this vision in detail.

Supporting measures

Supporting measures are advisable for both the set of four concrete measures and the strategic solution. The most important, ranked by stakeholder, are:

- road authorities: routing of heavy traffic in cities and the combined distribution of goods in cities;
- lorry manufacturers: development of a special type of distribution lorries with low front and side windows;
- transport companies: the introduction of safety culture and the determining of safe routes in consultation with governments and road authorities;
- lorry drivers: taking the (compulsory) refresher courses and the responsibility for well-adjusted mirrors;
- cyclists: red light discipline and acquiring the code of conduct.

Possibly effective products on the market

Using the knowledge about the circumstances of blind spot crashes, a number of products have been judged that are intended to prevent black spot crashes. One of the six products that were assessed seems an important candidate for further investigation. This is the warning system which detects cyclists with the use of, for instance, radar, and transmits a signal to the driver in his cab. However, this system needs to be adapted in such a way that the driver does not get excess information, but is only warned when it is necessary. Cyclists only need to be detected at those locations where the lorry crosses their way: the place where the driver must carry out the extra check.

Recommendations

SWOV recommends putting the set of four measures into execution at short notice in order to reduce the number of blind spot crashes. The supporting measures can be of assistance during the implementation.

A complete, structural separation of heavy and light traffic is the best solution to prevent conflicts between lorries and cyclists. This is one of the views of Advancing Sustainable Safety. Elaboration of this view is recommended.

SWOV also recommends further investigation of a system that detects cyclists. It concerns a warning system that for instances uses radar to inform the driver about the presence of cyclists. To limit the frequency of information signals, the possibility must be investigated of only warning the driver at the moment he needs to carry out the extra check."

2 SWOV fact Sheet – Blind spot crashes 2012

This fact sheet makes reference to all kinds of crashes involving lorries and cyclists i.e. at signals, turning right etc. It explains at that that time the number of fatalities has remained below 10 (the period 2007 – 2011 inclusive).

It also comments on cyclists at roundabouts with separate cycle tracks thus: "A separate category of blind spot crashes concerns lorries that approach a priority road and cross a priority cycle path, especially if the cycle path has two-way traffic (Figure 3B). The lorry driver often fails to notice cyclists coming from the right because he apparently does not expect them. Both these types of blind spot crashes also happen on roundabouts where cyclists have right of way (Figure 3C)."

The figure referred to is shown below:

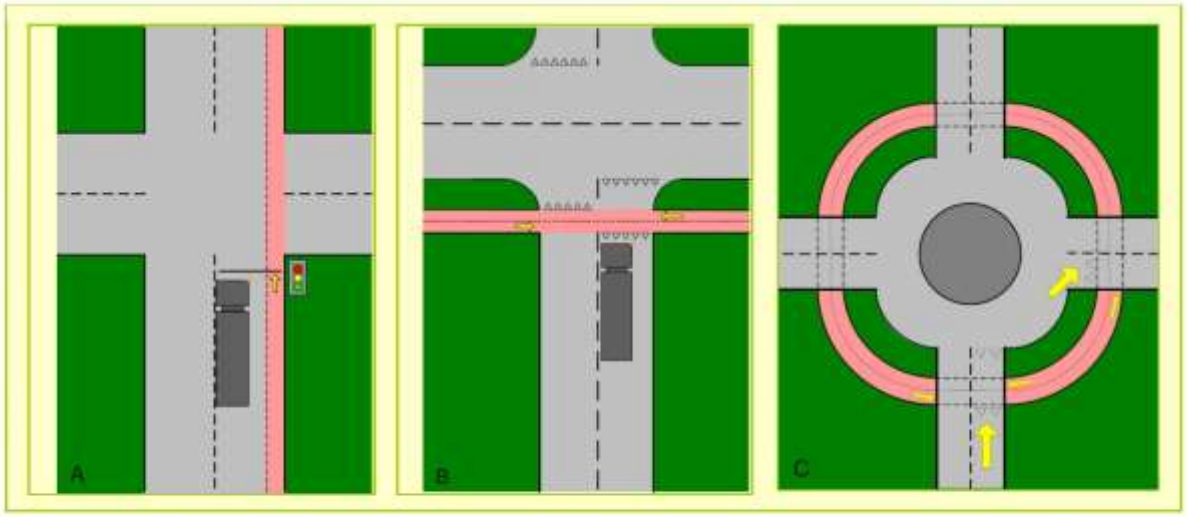

Figure 3. *Three frequent situations in which conflicts arise between lorries and cyclists. A. At a junction (with traffic lights) the lorry accelerates from stationary and turns right; the cyclist goes straight ahead. B. The lorry approaches a priority road with a separate cycle track (two-way traffic).C. Entering and leaving a roundabout where cyclists have priority. When a lorry enters the roundabout, the situation corresponds with situation B, or with situation A when the lorry leaves the roundabout.*

"Most crashes involving lorries turning right concern vehicles with a high windscreen. In 98% of such crashes (in 2006 and 2007) the windscreen was higher than 1.50 to 1.60 metres, while 70% of the lorries driving at those locations during this period were found to have a high windscreen. Therefore lorries with a high windscreen are relatively often involved in blind spot crashes (Schoon, Doumen & De Bruin, 2008)."

The report summarises the reason why crashes occur as follows: "The problem is caused by the fact that although the lorry driver generally is aware that the cyclist has the right of way, he often sees the cyclist too late or not at all. The cyclist on his part is insufficiently aware of the limited view of the lorry driver. A survey among crash casualties involving lorries turning right revealed that cyclists were frequently unaware that the lorry wanted to turn right

(Schoon, Doumen & De Bruin, 2008). In addition, cyclists often take the right of way without first making sure that they are actually given it."

A range of measures is discussed to address the problem and these include:

- Infrastructure – separating lorries and cyclists by the use of delivery centres or by shifting the times that freight vehicles can access city centres. In the short term it is suggested that the give way line be set further back. This does not, however, address the question of large vehicles that straddle the crossing point whilst waiting to join the roundabout.
- Increase the driver's field of vision
- Employ technology to warn drivers of the presence of cyclists
- Use public information and educational methods to alert each mode to the needs and likely behaviour of the other.

The report concludes that there needs to be more research into this issue.

3 SWOV Research Activities issue 47 2011

This newsletter has an article on *Cycling fatalities in blind spot crashes*. It references reports mention within this note. It also points out that the majority of crashes involve trucks whose base of the windscreen is high.

4 SWOV Fact Sheet – Road safety hazards of public transport

This report has been included because of the similarities in terms of size and (in some cases) driver position between buses and lorries

"... as yet there is comparatively little information about the background of the involvement of large, non-standard vehicles, such as buses and trams, in crashes in urban traffic".

"Knowledge of bus crashes is mainly based on a study by Davidse et al. (2003). This study identified

The most frequent types of crash:

- Crashes on bus lanes;
- Crashes involving blind spots;
- Buses causing rear-end collisions while braking;
- Single vehicle crashes with injury for occupants;
- Crashes as a consequence of bus driver distraction."

None of the proposed measures to prevent such crashes refer to cyclists or cycle lanes. Reference is made to

- "Training defensive driving behaviour, such as adjusting the driving speed to the actual circumstances (during driving courses and refresher courses);
- Installing mirrors with wider field of vision (side mirrors);
- Standardizing the location of the bus lanes in the infrastructure;"

5 *Are roundabouts with separate cycle tracks also safe for cyclists?* SWOV Report R-2004 – 14 2004

Sub title of report: *Which priority rule is safe for cyclists on individual urban roundabouts?*

Whilst concluding that cyclists are safer when they are required to give way on separate cycle tracks, no mention is made in the summary of the nature of the accident types studied nor is there reference to collisions with lorries and the issue of blind spots.

A challenge to this report made by Fietsersbond (Dutch cyclists organisation) on the grounds that "SWOV wrongly fails to make a distinction between cyclists and scooter riders. Because scooters were moved from bicycle paths to the main carriageway in 1999, the conclusions based on old data no longer apply in practice."[8]

6 Crossing accidents with cyclists Schepers, J.P., Voorham, J. 2010

This report is in Dutch and includes mention of roundabouts. However, in the comment on the Fiets Beraad website it states "This study investigated over 500 intersections in 7 towns. Despite this size the number of accidents was barely enough to allow reliable pronouncements."

7 The problem of lorries turning right SWOV Report R-2006-2 2006

This report has no reference within the English summary to cyclists on roundabouts. It concludes: The most important results of the crash analyses are:

- The general pattern of crashes is that a lorry turning right does not give right of way to a cyclist continuing straight ahead; the cyclist takes right of way, whether conscious of there being a lorry present or not.
- It mainly concerns lorries turning right after having stopped (e.g. for traffic lights).
- The most common point of contact in a lorry-bicycle crash is on the front corner on the right-hand side of the lorry.

Its recommendations are:

- Preventing lorries and cyclists entering the junction area simultaneously by installing a separate green light;

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8 http://www.fietsberaad.nl/library/repository/bestanden/SWOV%20roundabout%20without%20cyclist%20priority%20safer%20for%20cyclist.doc

- Installing traffic mirrors at junctions;
- Electronic detection of cyclists;
- Information for vulnerable road users;
- Larger front and side windscreens for lorries;
- Forbidding heavy traffic in city centres.

8 Safety on urban through-road intersections; Comparison of crash rates SWOV R-2003-36

This report expresses intersection safety in proportion to crash rates. It makes no mention of cyclists at roundabouts in the English summary. This, however, is the report that the Fietsersbond claims contradicts R-2004 – 14 thus: "The SWOV report into junctions (R-2003-36) concludes literally: "The risk on roundabouts with cyclist priority is not higher or lower than on roundabouts without cyclist priority." No conditions are hereby made. The Fietsersbond claims that different studies lead to different results."

9 *Crossing facilities for cyclists and pedestrians* – SWOV Fact Sheet 2005

This document was consulted in the hope that it might include cycle track crossings at roundabouts. No mention was made but interestingly it did conclude that "The results were different for the moped crashes: cycle paths had the largest moped crash rate, and lanes and mopeds on the carriageway had the same crash rates". This may have given rise to the challenges to the report above.

Mention is made that (at that time) "There are as yet no so detailed requirements for cyclists" whereas there is a specific design for pedestrian crossings. It does however, go on to say that "Crossing facilities at crossroads that are only for cyclists should be raised."

This report also concluded that "More cyclist crashes occur at locations where cycle lanes cross side streets than where there are no cyclist facilities. Raised cyclist crossing facilities at crossroads have a positive safety effect; 33% less cyclist crashes in Sweden."

10 ELTIS

This knowledge sharing website was consulted but failed to provide any meaningful material. It did, however, highlight the fact that roundabouts are generally less safe for cyclists than other forms of junction. One report concluded that cycle lanes in roundabouts should not be used.

11 European Cyclists Federation

This organisation publishes a fact sheet on the blind spot issue. It does not refer to collisions at roundabouts but does provide a useful guide to the layout of mirrors on trucks and the effect of European directives on large vehicles.

12 TRL reports

Findings report: Dutch Roundabout Driver/Cyclist/Pedestrian Interaction (M27) trials

This document mentions the problem of motorists being concerned about seeing cyclists in blind spots three times: in connection with exiting the roundabout (once); and turning left (twice)

Construction logistics and cyclist safety – Summary Report PPR640 and full report PPR639 2013

These reports address the issue of cyclists' interactions with construction traffic and makes no mention of cyclists at roundabouts with circulatory cycle tracks. However, since it does give information about blind spots, it appears (figure 3-3 of summary report) that with certain vehicles, a cyclist approaching from the nearside could be partially hidden from the view of the driver. This would be an issues for cycle tracks which allow two-way flow around a roundabout. Figure 32 of full report demonstrates that, for certain vehicles, the nearside mirrors cause an obstruction to the view through the nearside window. The vehicles studied were all rigid with no articulated vehicles studied. This may be important in terms of how the cabs of articulated lorries are positioned at the give way line for any circulatory cycle track.

A study of the implementation of Directive 2007/38/EC on the retrofitting of blind spot mirrors to HGVs PPR588 2011

This report follows TRL being appointed to undertake a review of the effectiveness of the retro-fit Directive. It mentions blind spot collisions but not those occurring in connection with circulatory cycle tracks at roundabouts.

The report refers to studies that show that fatalities resulting from accidents involving lorries and pedestrians and two-wheeled vehicles had fallen over the period 1993 – 2000 and were predicted to fall further as the result of fitting blind spot mirrors.

There is a suggestion that accidents could result from blind spot mirrors blocking vision. Suggestion that 57% of fatl accidents involving a pedal cyclist were blind spot related.

Reference is made to blind spot truck accidents in the Netherland but not the circumstances i.e. there is no mention of accidents at roundabouts with circulatory lanes.

Infrastructure and Cyclist Safety (findings) PPR580 2011

This document reports on the findings of a literature review to consider the role of infrastructure in relation to the safety of cyclists. Mo mention is made of accidents at roundabouts with circulatory lanes. I does, however make the following comment "cyclist injuries involving heavy goods vehicles (HGVs) at junctions were often found to take place at low speed. This suggests that relative positioning and visibility of the cyclist may be a key factor in these incidents."

On-road trial of roadside mirrors in London CPR986 2011

This report focuses on roadside mirrors at signal controlled junctions and makes no mention of their use at roundabouts with circulatory cycle tracks.

Collisions involving cyclists on Britain's roads: establishing the causes PPR445 2009

This report makes no mention of their use at roundabouts with circulatory cycle tracks. It does, however, state "most collisions (with large goods vehicles) occurred during manoeuvres, in particular left turns and at roundabouts".

Analysis of police collision files for pedal cyclist fatalities in London, 2001 - 2006

Although this report makes no mention of accidents on roundabouts with circulatory cycle tracks, it does mention that of the fatalities investigated "The most common (23 [of 92]) of these was when the pedal cyclist fatality was struck by a large vehicle changing lane to the left or turning left." Only 2 of the 92 collisions investigated took place at a roundabout. Although 11 were recorded as 'cyclist' crossing the road there was no correlation between this and roundabouts.

International comparison of roundabout design guidelines PPR206 2007

This is a review of standards and guidelines commissioned by the Highways Agency to compare then current standards with those of other countries. It does look at accident issues but makes no comment about blind spot collisions.

It makes an interesting comment to the effect that roundabouts are used for safety reasons in many mainland European countries as opposed to capacity in the UK. It also notes that in Sweden and Finland cyclists are sometimes given priority on circulatory cycle tracks and that experienced cyclists will remain on the carriageway even though an off-carriageway cycle track exists. Presumably the latter is only likely to be the case where using cycle tracks is not mandatory (i.e. when signed as such).

"Conflict observation in Finland showed that motorists turning right onto the roundabout frequently failed to cyclists approaching from the right". No mention of blind spot collisions is made here.

Although not referred to in specific terms it is worth noting that controlled (signalled toucan crossings) are generally set back a minimum of 20m from the inscribed circle. This is different to the usual cycle track location in mainland Europe which is 5m or so back with the pedestrian crossing point close behind.

Cyclists at 'continental' style roundabouts: reports on four trial sites – TRL581 2003

The number of cyclists observed during the trials made it difficult to draw firm conclusions. This report primarily addresses on-carriageway behaviour and makes no mention of blind spot collisions on circulatory cycle tracks. It does recommend the introduction of toucan crossings on the arms of roundabouts and conversion of the existing footways to cycle tracks plus additional facilities to enable cyclists to use them.

Cyclists at roundabouts — the effects of 'Continental' design on predicted safety and capacity TRL285 1997

This report primarily addresses on-carriageway behaviour and makes no mention of blind spot collisions on circulatory cycle tracks. I does make the comment that "… pedal cyclist accident involvement rates are lower at roundabouts where the flows of cyclists are higher: drivers expect to see cyclists and subconsciously adjust their visual search strategy."

"A study of 201 roundabouts in the Netherlands (Schoon and Van Minnen, 1994) found that roundabouts with a separate cycle track had fewer cycle accidents (0.03 cycle accidents per year) than those with no cycle facilities (0.1 cycle accidents per year). However, in almost all cases, cyclists on the separate cycle track must give way to motor vehicles. Segregated cycle tracks are recommended at sites with at least 8,000 motor vehicles per day and a large number of cyclists."

A 'before and after' study by the Danish Roads Directorate (1993) of 82 roundabouts built since 1985, examined roundabouts with a separate cycle track, a cycle lane, and no cycle facilities. In apparent contrast to the other European studies, the results showed no indication of higher risks for cyclists at roundabouts without cycle facilities."

Roundabouts in continental Europe designed with cycle facilities or 'cycle-thinking' TRL302 1998

This report describes a study tour of some roundabouts in Continental Europe where there are cycle facilities or where the roundabouts were designed with cyclists in mind. It makes no mention of blind spot collisions on circulatory cycle tracks. It does find that "Dutch research shows some residual cycle accidents where vehicles have not given way and these roundabouts with cyclist priority are considered significantly less safe than roundabouts where cyclists on a separate track or lane give way."