Transport Research Laboratory
Creating the future of transport

PUBLISHED PROJECT REPORT PPR734

Low Level Cycle Signals on a separate pole to the main traffic signals

Track trial report

S D Ball, J Hopkin, K Millard, R Smith, V Chesterton, R Gardner, G Kandasamy, J Vestey, P Knight and I York



Prepared for: TfL

Project Ref: 11112436 WS4.LLCS.M19

Quality approved:

S Greenshields *Project Manager*

M Jones *Technical Referee*

Disclaimer

This report has been produced by the Transport Research Laboratory under a contract with TfL. Any views expressed in this report are not necessarily those of TfL.

The information contained herein is the property of TRL Limited and does not necessarily reflect the views or policies of the customer for whom this report was prepared. Whilst every effort has been made to ensure that the matter presented in this report is relevant, accurate and up-to-date, TRL Limited cannot accept any liability for any error or omission, or reliance on part or all of the content in another context.

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) and TCF (Totally Chlorine Free) registered.

Contents amendment record

This report has been issued as follows:

Version	Date	Description	Editor	Technical Referee
1	05/02/2015	Final	SB	MJ

Contents

Appendices

Figures

Tables

Glossary of abbreviations

ASL Advanced Stop Line

LLCS Low Level Cycle Signals

SRS Small Road System test track facility at TRL

TP Timing Point

Executive summary

This report summarises the results from the third sub-trial of a larger track trial investigating the reactions of road users to Low Level Cycle Signals (LLCS) under different junction configurations. The trials were conducted at a specially constructed typical "urban" four-arm junction built at TRL's test track.

In this trial the LLCS were positioned on a separate pole to the standard traffic signals, with the LLCS being at the second stop line and the main signals being at the first stop line. The two stop lines were 5 metres apart, resulting in a 5-metre cycle reservoir on each approach to the junction. To understand the relative effects of mounting the main signals and LLCS on separate poles, these trials were compared against the results of earlier trials where the LLCS signals were mounted on the same pole as the main signals. The junction layout was trialled both with and without an early release for cyclists ahead of the vehicle traffic. Trials were conducted for five different road user groups over ten days, with a total of 300 participants: cyclists (5 days); car drivers (3 days); motorcyclists (½ day); HGV drivers (½ day) and pedestrians (1 day). Key findings are listed at the end of each sub-section and are referenced here in square brackets.

The evidence from these trials without early release (cyclists, car drivers, motorcyclists, HGV drivers and pedestrians) supports the progression to on-street trialling of LLCS mounted on separate poles to the main signals. The evidence suggests that the system would be well understood [F1.a, F1.c] and would not adversely affect perceived safety [F8.a]. There was no evidence to indicate that the height and angle of the LLCS should be different from those tested in this trial [F3.d]. Compared with the trial where the LLCS were on the same pole as the main signals, more cyclists said they looked at the LLCS and fewer said they looked at the main signals when waiting at the junction [F4.b]. More car drivers and motorcyclists said they looked at the secondary signals and fewer motorcyclists said they looked at the main signals when waiting at the junction [F4.c, F4.d]. The relative location of the main signals and LLCS could offer a benefit to cyclists through improved compliance of motorists with stopping before the cycle reservoir [F5.c, F5.d]. The only caveats are that as a result of the new layout, a small proportion of cyclists initially stopped before the first stop line [F5.e], there was an increase in the average Entry Time of cars [F6.d] and there was also an increase in pedestrians crossing upstream of the crossing [F7.a]. Other caveats from previous reports were also still valid, namely that a small proportion of pedestrians misinterpreted the meaning of the signals to be for cyclists crossing the road [F1.b].

The evidence from these trials with an early release (cyclists and car drivers) supports the progression to on-street trialling of LLCS with an early release mounted on separate poles to the main signals. The findings were similar to the trials of LLCS with an early release on the same pole as the main signals; some differences were that more cyclists said they used LLCS [F12.a], more cyclists said they noticed the difference between the shorter and longer early releases [F10.d] and there were fewer observations where the car driver moved off on the early release [F14.a]. The caveats above from the trial without an early release apply, as well as those from previous reports, in particular that with an early release a small proportion of cyclists thought they had right of way when turning right across oncoming traffic [F14.e, F14.f].

1 Introduction

This report summarises the results from the third sub-trial of a larger track trial investigating the reactions of road users to Low Level Cycle Signals (LLCS) under different junction configurations. In this trial the LLCS were positioned on a separate pole to the standard traffic signals, with the LLCS being at the second stop line and the main signals being at the first stop line. This junction layout was trialled both with and without an 'early release' for cyclists ahead of the vehicle traffic.

This document is structured as follows:

- Section 2 summarises the methodology of the trial.
- Section 3 presents the findings to eight key research questions for when there was no early release.
- Section 4 presents the findings to seven key research questions for when there was an early release.
- Section 5 summarises the findings and considers how they relate to the study objectives.

A consistent colour scheme is used in the graphs in this report as shown in Table 1.

	Cyclists		Red / *Red Man*
	Car drivers		Red & Amber
	Motorcyclists		Green / *Green Man*
	HGV drivers		Amber
	Pedestrians		*Blackout*

Table 1 – Colour scheme for graphs

1.1 Scope and relation to other trials

The Low Level Cycle Signals that were trialled are shown in Figure 1. These signals were selected following an assessment of signals from six different suppliers.

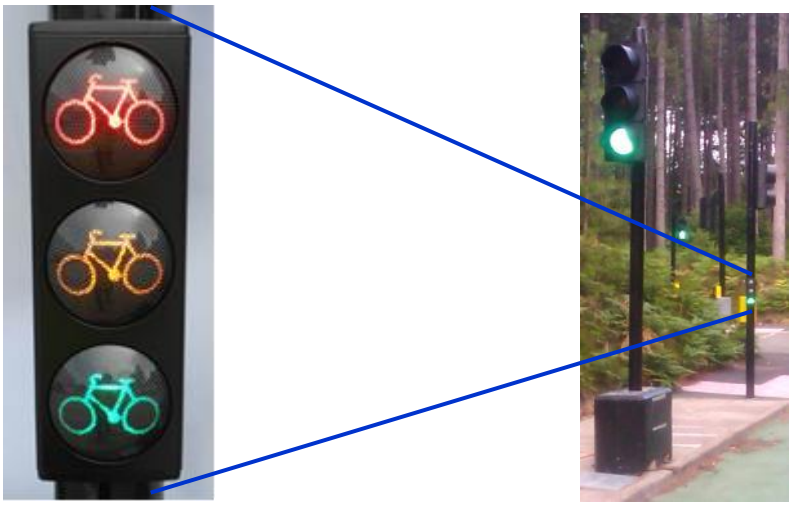

Figure 1 – Low Level Cycle Signals

The scope of this report is to present the findings from the third of four sub-trials, assessing the impact of the LLCS by comparing scenarios where the LLCS were on separate poles from the main signals, using earlier trials as a baseline.

1.1.1 LLCS on separate poles with no early release

The scope of Section 3 of this report is to present the findings from the trials of LLCS on separate poles with no early release. This trial assessed the impact of the location of the signals by testing scenarios where the LLCS were on a separate pole (trial code "M19a"), compared against the scenario in the first LLCS trial ("M14") in which the LLCS were on the same pole as the main signals. This was done for five road user groups.

Table 2 shows how the scope of this trial compares with the three other LLCS trials in the programme in which the LLCS: provided no early release and were either covered or uncovered ("M14"); had an early release ("M18"); and were accompanied by deeper cycle reservoirs ("M24"). In addition to the trials summarised in Table 2, two further trials are relevant: an earlier track trial, which assessed the impact of high level signals with a red cycle aspect (Ball et al. 2014); and a trial in which the LLCS with an early release are part of a 'standardised' junction design with a two-stage right turn (www.gov.uk 2013a).

Table 2 – Scope of Section 3 of this report (bold) and relation to other trials

Road layout	LLCS early release	**Cycle trial**	*Cycle groups trial*	**Car trial**	**Motorcycle trial**	**HGV trial**	**Pedestrian trial**	*Partially sighted pedestrian trial*
5m ASL, LLCS on same pole	*Covered*	*M14*		*M14*	*M14*	*M14*		
	Uncovered, no early release	**M14**		**M14**	**M14**	**M14**	**M14**	*M14*
	Early release (2,3,4,5 seconds)	*M18*		*M18*	*M18*			
5m "cycle reservoir", LLCS on separate pole	**Uncovered, no early release**	**M19a**	*M24*	**M19a**	**M19a**	**M19a**	**M19a**	
	Early release (2,3,4,5 seconds)	*M19b*		*M19b*				
7.5m "cycle reservoir", LLCS on separate pole	*Uncovered, no early release*		*M24*	*M24*				
	Early release (2,3,4,5 seconds)			*M24*				
10m "cycle reservoir", LLCS on separate pole	*Uncovered, no early release*		*M24*	*M24*				
	Early release (2,3,4,5 seconds)			*M24*				

1.1.2 LLCS on separate poles with an early release

The scope of Section 4 of this report is to present the findings from the trials of LLCS on separate poles with an early release. This trial assessed the combined impact of the location of the signals with an early release by testing scenarios where the LLCS were on

a separate pole with an early release ("M19b"), compared against the scenario in the second LLCS trial ("M18") in which the LLCS were on the same pole as the main signals and had an early release. This was done for two road user groups as shown in Table 3.

Table 3 – Scope of Section 4 of this report (bold) and relation to other trials

Road layout	LLCS early release	**Cycle trial**	*Cycle groups trial*	**Car trial**	*Motorcycle trial*	*HGV trial*	*Pedestrian trial*	*Partially sighted pedestrian trial*
5m ASL, LLCS on same pole	**Covered**	**M14**		**M14**	*M14*	*M14*		
	Uncovered, no early release	**M14**		**M14**	*M14*	*M14*	*M14*	*M14*
	Early release (2,3,4,5 seconds)	**M18**		**M18**	*M18*			
5m "cycle reservoir", LLCS on separate pole	**Uncovered, no early release**	**M19a**	*M24*	**M19a**	*M19a*	*M19a*	*M19a*	
	Early release (2,3,4,5 seconds)	**M19b**		**M19b**				
7.5m "cycle reservoir", LLCS on separate pole	*Uncovered, no early release*		*M24*	*M24*				
	Early release (2,3,4,5 seconds)			*M24*				
10m "cycle reservoir", LLCS on separate pole	*Uncovered, no early release*		*M24*	*M24*				
	Early release (2,3,4,5 seconds)			*M24*				

1.2 Background

1.2.1 Existing regulations and previous research

Background information is presented in the "M14" report for LLCS used as repeaters with no early release (Ball et al. 2015a). This covers: existing UK regulations for cycle signals; previous research into compliance of cyclists with signals; enforcement of signals and ASLs; and LLCS in other countries.

1.2.2 On-street trials in the UK

1.2.2.1 High level signals with a red cycle aspect

A track trial study was undertaken by TRL to assess the impacts of high level signals with a red cycle aspect (Ball et al. 2014). Following the track trial and DfT approval, on-street trials of high level signals with a red cycle aspect began at Bow Roundabout on Cycle Superhighway 2 in London in October 2013. In this trial there was no early release for cyclists.

1.2.2.2 High level signals with an early release green cycle aspect

In August 2013 the DfT gave approval for on-street trials of high level cycle signals with an early release in Cambridge. A further trial authorisation was granted to Manchester City Council in December 2013. (www.gov.uk 2013b).

In Cambridge, the cycle signals give an early release at one of the approaches to one junction and were installed as part of a scheme to improve the junction and replace obsolete signals.

In Manchester, the signals consist of a standard 3-aspect vehicle signal head with a 4th green cycle symbol aspect mounted underneath the full green aspect. The green cycle aspect operates in a similar way to a filter arrow, providing a few seconds dedicated green time for cyclists before the main traffic flow is released.

1.2.2.3 Low Level Cycle Signals with no early release

A track trial study was undertaken by TRL to assess the impacts of Low Level Cycle Signals used as repeaters of the main traffic signals (Ball et al. 2015a). Following the track trial and DfT approval, on-street trials of Low Level Cycle Signals with no early release began at Bow Roundabout on Cycle Superhighway 2 in London in January 2014. There are plans to extend this trial to a further 11 sites in London (www.gov.uk 2013a).

1.2.2.4 Low Level Cycle Signals with an early release

A track trial study was undertaken by TRL to assess the impacts of Low Level Cycle Signals with an early release (Ball et al. 2015b). As of March 2014, there were no on-street trials of LLCS with an early release in the UK.

1.2.3 Existing UK regulations for ASLs

Advanced Stop Lines (ASL) are a priority measure for cyclists at signal junctions. The marking is prescribed in diagrams 1001.2 and 1001.2A of the Traffic Signs Regulations and General Directions 2002, as amended (TSRGD 2002). The meaning is that "*vehicles other than cycles must stop at the first line when signalled to do so… forming a reservoir space for cyclists*" (DfT 2003). TSRGD prescribes that the two stop lines must be between 4 and 5 metres apart. This allows the full width of the approach to be available for cyclists waiting at the red light. TSRGD also requires either a gate or a lead-in lane to enable the cyclist to pass the first stop line and legally access the ASL reservoir. In 2013 the DfT granted authorisation to TfL to install ASL reservoirs up to 7.5 metres deep to cater for the growth in cycle traffic (assets.dft.gov.uk 2013).

1.2.4 Existing research into compliance of vehicles with ASLs

In 2005, TRL undertook a research study with over 5,000 observed cyclists on 12 sites in the Greater London area with advanced stop lines. It was found that 36% of all observations involved some form of encroachment by vehicles into the ASL reservoirs. Of those that did encroach into the ASL, about half stopped at least half way into the ASL (Allen et al. 2005). A similar study of ten sites in London found comparable results; on average motorcycles encroached into at least half the reservoir 60% of the time, compared with 14% of the time for car traffic (Atkins 2005).

2 Methodology

2.1 Trial site

The trials were conducted at a specially constructed typical "urban" four-arm junction built at TRL's 'Small Road System' (SRS) test facility, see Figure 2. The trial site comprised standard traffic signals and LLCS on each arm. The LLCS were installed at a height of 1.4 metres from the kerb to the centre of the amber aspect and at an angle of 15 degrees away from the kerb. The traffic signals were set on a fixed time loop, driven by a standard traffic signal controller.

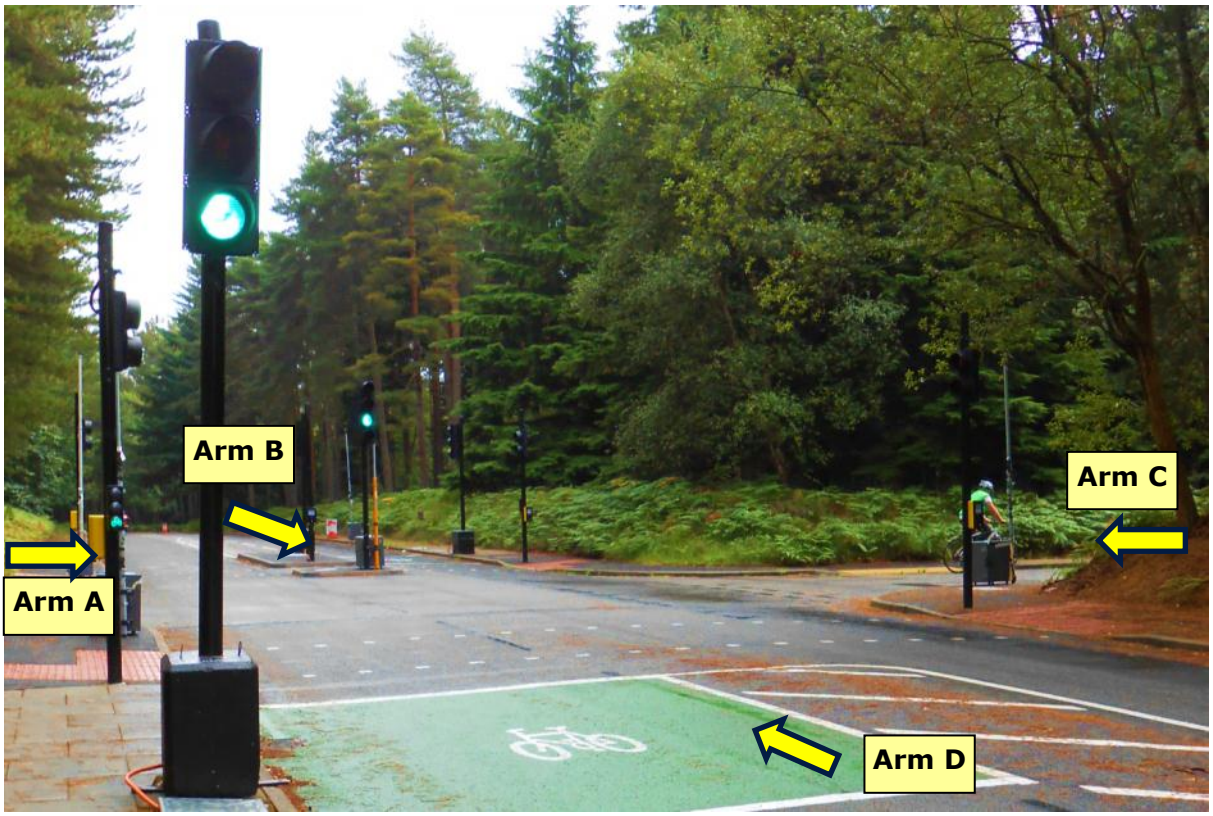

Figure 2 – Trial site

2.2 Design variables

Three categories of variables were considered when defining the trial scenarios:

- Design variables (physical design elements)
- Situational variables (specific turning movements by user groups)
- Participant variables (traffic and cycle flows and speeds)

Where possible, variables were chosen to include a baseline value so that observed relative changes could be attributed to the interventions being trialled. However, this could not always be achieved for every variable. Furthermore, it was not possible to test each variable in a single trial; therefore results from a number of different trials were combined.

2.2.1 Location of the LLCS and the main signals

The trial was carried out as part of a "control" and "treatment" experiment. The road layout of a junction arm is illustrated in Figure 3. In this trial, the LLCS were mounted on a separate pole to the main signal, 5 metres further back at the first stop line, with a 5-metre cycle reservoir on each approach to the junction. The terminology 'cycle reservoir' is used rather than 'Advanced Stop Line (ASL)', because in the Treatment scenario the main vehicle signals are associated with the first stop line and the LLCS are associated with the second stop line.

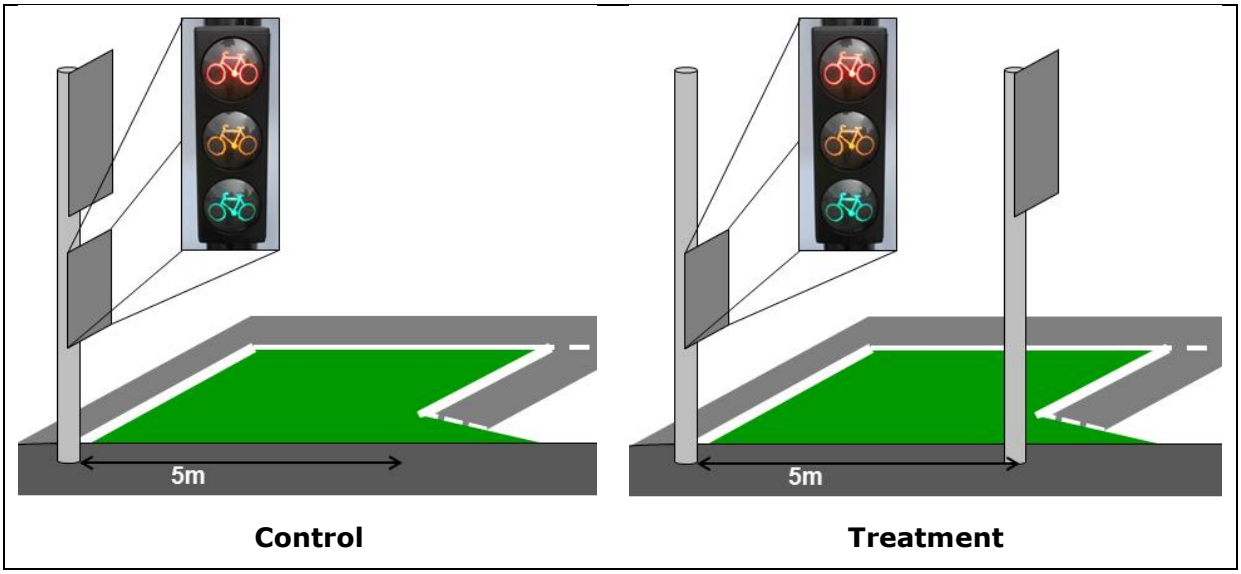

Figure 3 – "Control", LLCS on the same pole as the main signals (left) and "Treatment", LLCS on a separate pole to the main signals (right)

To understand the relative effect of the signals on behaviour, the results of this third trial (M19a) are compared with the "uncovered scenario" in the first trial ("M14") in which the LLCS were located on the same pole as the main signals. In both trials there was no early release. In the graphs in this report the results from the M19a Trial have a downward diagonal pattern, whereas results from the first trial have a solid fill. The findings for these trials are presented in Section 3.

When comparing the scenarios in the Treatment and Control, statistical tests[1] were undertaken to distinguish whether results were likely to be due to introduction of the design variable, or whether they were likely to have occurred by chance.

2.2.2 Alternative methodology

An alternative methodology was planned in the event that a substantial proportion of cyclists stopped before the first stop line, with three options as below:

1. Briefing half of the cyclists to explain the purpose of the layout, i.e. replicating an education / information campaign
2. Including a sign on the pole at the first stop line, e.g. "cyclists use reservoir"

[1] The Two Proportion Z-Test was used to assess the differences in proportions, and the T Test was used to assess differences in averages.

3. Installing an additional LLCS on the pole at the first stop line, which would be always green, i.e. permitting cyclists to enter the reservoir, but to then stop before the second (red) LLCS at the second stop line.

The stopping behaviour of the cyclists was monitored during the first day of the separate poles trial and none of these options were required owing to the small proportion of cyclists that stopped before the reservoir.

2.2.3 LLCS with an early release

In the third trial (M19a), all of the participants (cyclists, car drivers, motorcyclists, HGV drivers and pedestrians) experienced the LLCS without an early release. In the fourth trial (M19b), half of the cyclists experienced early releases of 2 and 4 seconds and the other half experienced early releases of 3 and 5 seconds. Similarly, half of the car drivers experienced 2 and 4 second early releases for cyclists and the other half experienced 3 and 5 second early releases for cyclists.

The results of the fourth trial were compared with the second trial ("M18") in which the LLCS were located on same poles with an early release. In the graphs in this report the results from the second trial have an upward diagonal pattern, whereas results from the fourth trial have a criss-cross pattern. The findings for these trials are presented in Section 4. Trial codes are used in this report as shown in Table 4.

Table 4 – "Control", LLCS on the same pole as the main signals and "Treatment", LLCS and the main signals on separate poles

Size of cycle reservoir	Section of report with findings	Control	Treatment
5m "cycle reservoir"	Section 3	No early release, same pole (M14 Trial)	No early release, separate poles (M19a Trial)
	Section 4	Early release (2,3,4,5 seconds), same pole (M18 Trial)	Early release (2,3,4,5 seconds), separate poles (M19b Trial)

2.2.4 Junction layout

A scale drawing of the junction is shown in Figure 4 and a description of the junction layout and placement of the LLCS and other signals is shown in Figure 5 and Table 5.

Table 5 – Summary of LLCS locations, junction layout and turning movements

Arm	Near-side LLCS	Off-side LLCS	Secondary traffic signal on far side of junction	Closely associated secondary traffic signal	Pedestrian signalised crossing	Right Turn Arrow	Colour of cycle reservoir	Turning movements
A	✓	✓	✓		✓		Not painted	Left, Right
B	✓	✓		✓	✓		Not painted	Left, Straight
C	✓		✓				Not painted	Left, Right
D	✓		✓		✓	✓	Green	Straight, Right
P	✓				✓		N/A	N/A

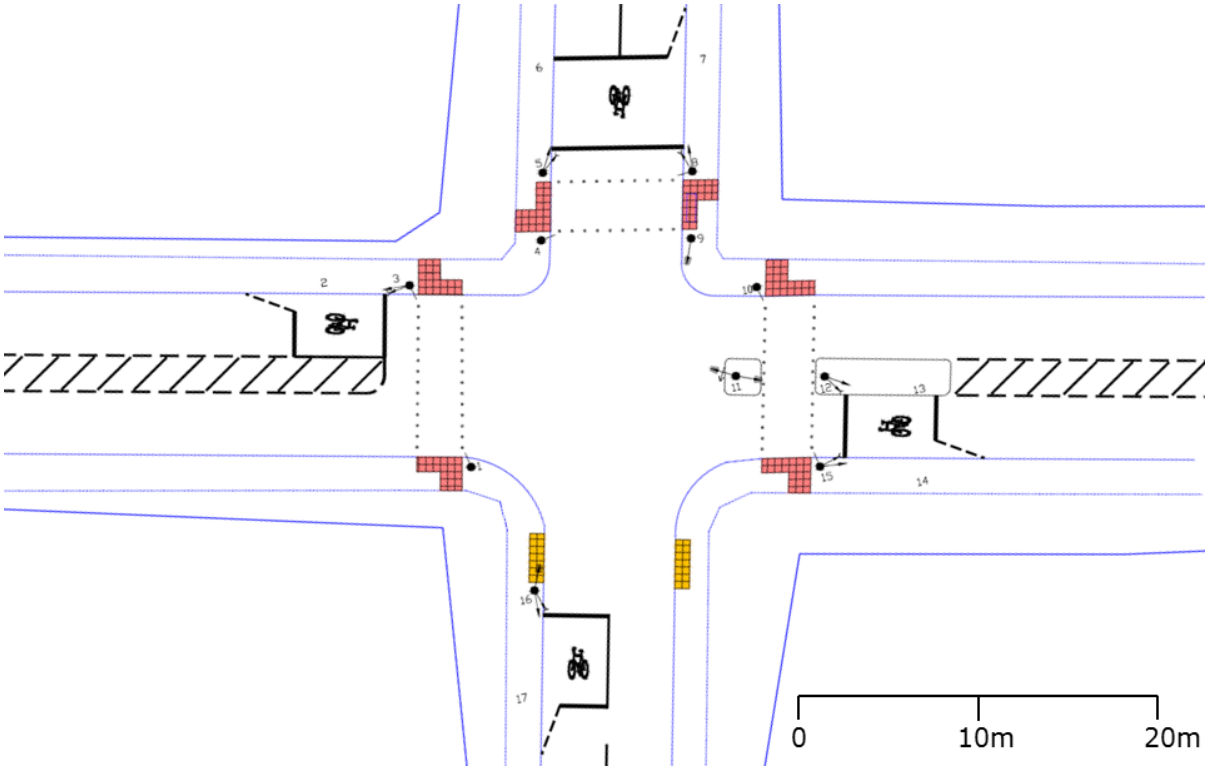

Figure 4 – Junction layout, scale drawing

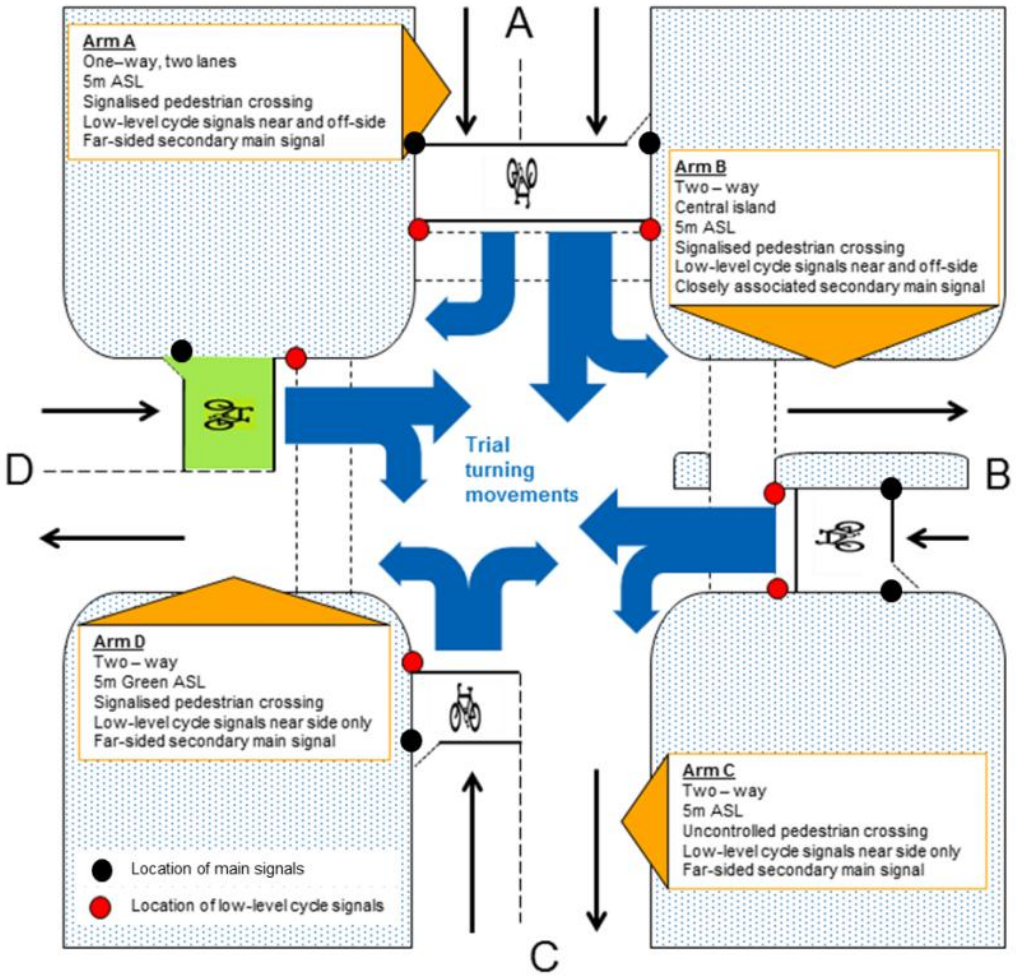

Figure 5 – Junction layout description

One of the approaches (Arm A) was a two-lane one-way street, whereas the other three approaches were one-lane two-way streets. LLCS were mounted on the left-hand side of the road on each approach, and in addition, for two of the arms (Arms A and B), there was also an 'off-side' LLCS on the right-hand side of the road at Arm A and in the centre of the road at Arm B. Each approach had a cycle reservoir, one of which was green (Arm D), the others remaining unpainted. Each junction arm had a dropped kerb with pedestrian crossing studs; three had pedestrian signals and one was uncontrolled (Arm C). Three of the approaches had a secondary traffic signal on the far side of the junction, whereas one approach had a closely associated secondary traffic signal on an island beyond the pedestrian crossing, but before the junction itself (Arm B). The signals ran on fixed times, in the sequence: Arm A; Arm C; Arm B & Arm D at the same time; Arm D with Indicative Green Arrow; pedestrian phase[2]. There was a slight incline from Arm D up to Arm B.

2.2.5 Stand-alone crossing layout

LLCS were also mounted on a Puffin crossing (P) away from the junction. This crossing had near-sided pedestrian units fitted, unlike the junction which was fitted with far-sided pedestrian signals. With the exception of the pedestrian trial, the traffic signals were always green.

2.3 Other variables

2.3.1 Participant types and trial days

Trials were conducted for five different road user groups over ten days, with a total of 300 participants: 148 cyclists (5 days); 88 car drivers (3 days); 13 motorcyclists (½ day); 15 HGV drivers (½ day) and 36 pedestrians (1 day). The number of days of trialling was determined by the target sample sizes of 40 independent observations for cyclists and 30 independent observations for other road users; see Appendix B for the sample size collected.

To enable TRL to fulfil its responsibilities for the safety of participants it was not possible to trial with participant cyclists and participant car drivers at the same time. Results have therefore been compared using data from the participant cyclists from the cycle trial and the participant car drivers from the car trial.

2.3.2 Controlled vehicles/cycles

In some cases there were other vehicles/cycles present at the junction, which were controlled by TRL staff. Table 6 lists the scenarios that were tested: the types of participants are listed in each column and where there were other controlled vehicles these are shown by a tick in each row.

[2] Pedestrian trial only

Table 6 – Controlled vehicles used in each of the trials

	Type of participant				
	Cycle trial	Car trial	Motorcycle trial	HGV trial	Pedestrian trial
No other vehicles	✓	✓	×	✓	×
With controlled cyclist	×	✓	✓	×	✓
With controlled car	✓	×	✓	×	×
With controlled cyclist and controlled car	×	×	×	×	×

In the cycle trial, participants encountered the junction both with and without a controlled car; similarly in the car trial, participants encountered the junction both with and without a controlled cyclist. In the motorcycle trial, participants experienced the junction both with a controlled car and with a controlled cyclist, but not at the same time; the HGV trial involved no other road users. The pedestrian trial had some controlled cyclists.

2.3.3 Turning movements

With Arm A being a one-way street, there were nine possible turning movements (three from Arm A and two from each of Arm B, C and D). It was decided however to exclude the straight-on movement from Arm A in order to make the experiment more balanced, see Table 5. Cars did not make the left turn from Arm A, because of restrictions imposed by the optimal 'reset routes'[3]. The HGV trial involved only straight-on movements because of the tight turning circles on the junction. The signals at Arm B and Arm D changed to green at the same time and so right-turning vehicles from Arm D had to turn across the path of traffic from Arm B.

2.3.4 Release times

Cyclists, car drivers, motorcyclists and HGV drivers were released at timed intervals so that they were always faced with a red signal when arriving at the junction. The cyclist always approached the junction ahead of the car, with the cyclist being released first and the car being released shortly after. In the motorcycle trial, the car was released five seconds after the motorcyclist. Participants were released from the start point one at a time.

2.4 Trial setup

2.4.1 Daily structure

The typical daily structure involved four groups of participants, two in the morning and two in the afternoon. Groups would undertake the trial in two or three 'sessions' of approximately 30 to 40 minutes. The schedule was designed so that participants would experience the signals on separate poles, possibly with an early release (see Section 2.2.3) and with and without controlled vehicles (see Section 2.3.2).

[3] See Section 2.4.2 for examples of 'reset routes'

From experience with previous trials it was expected that there would be a learning effect with the participants, i.e. where their behaviour may have modified as they became more familiar with the trial. In order to overcome this issue, the order of the sessions was chosen so that the participants encountered the combinations of variables in different orders.

2.4.2 *Runs within a session*

The different groups of road users experienced the LLCS a number of times over a period of between approximately 80 and 130 minutes. They traversed eight numbered routes, which continually looped them through the junction and back to a different start point. Routes 1-4 from the cycle trial are shown in Figure 6. Routes 5-8 are shown in the appendices of the report for the trial with no early release (Ball et al. 2015a).

In the HGV trial, each driver was accompanied in their cab by a facilitator, who instructed them when to approach the junction. In the pedestrian trial, participants walked a predetermined route to cross each of the four junction arms as well as the Puffin crossing.

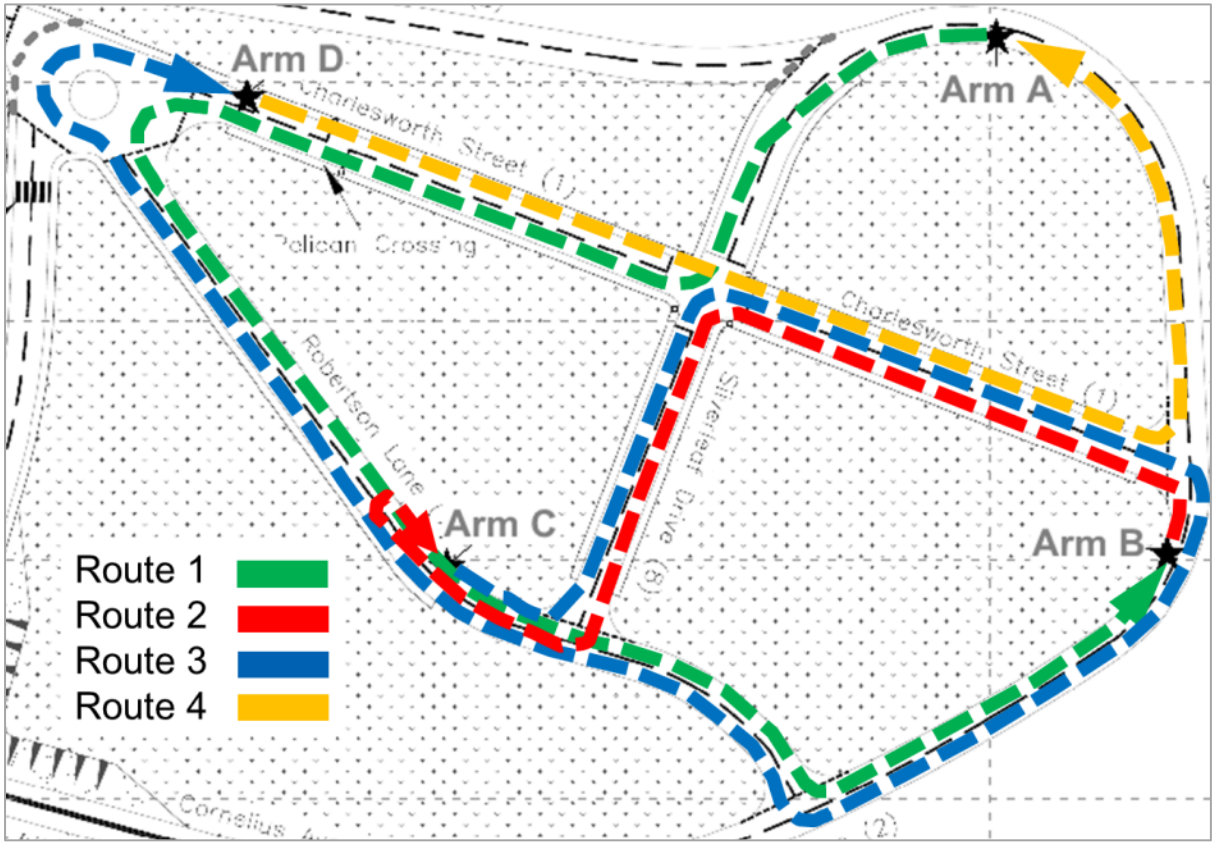

Figure 6 – Cycle trial: routes through the junction and to next starting point (Routes "1-4")

2.5 Study objectives and research questions

The overall objective of LLCS is:

i. to provide a dedicated signal for cyclists at traffic junctions that enables additional prioritisation to be given to cyclists and reduces potential conflict points between cyclists and other road users at junctions.

Further objectives include:

ii. to increase the compliance of cyclists with red signals;

iii. to improve compliance of drivers with the cycle reservoir;

iv. to provide a more comfortable viewing position for cyclists;

v. to encourage modal shift to cycling; and

vi. not to adversely affect safety or journey times of all road users.

In particular the LLCS were an enabler for the layout changes of moving the main signals to the first stop line. The primary reason for doing this was to improve compliance of motorists with the cycle reservoir.

The main study objective was to gather evaluation evidence on LLCS and the new junction layout in the context of an application to the DfT for an experimental order for an on-street trial. Several specific research questions were set, which instructed the design of the trial and the analysis as listed in Table 7.

Table 7 – List of research questions

Section 3 – LLCS on separate poles with no early release	**Section 4 – LLCS on separate poles with an early release**
1. Did people understand the LLCS and new layout?	9. Did people understand the LLCS with an early release and the new layout?
2. What did people think about the location of the signals?	10. Did people notice the early release and what did they think of it along with the new layout?
3. What attitudes did people have towards the LLCS and new layout?	11. What attitudes did people have towards the LLCS with an early release and new layout?
4. Did the LLCS and new layout affect what people looked at?	12. Did the LLCS with an early release and new layout affect what people looked at?
5. Did the LLCS and new layout affect compliance: i) whether cyclists stopped at a red light; ii) where people waited?	13. Did the LLCS with an early release and new layout affect compliance: i) whether cyclists stopped at a red light; ii) where people waited?
6. Did the LLCS and new layout affect how people moved off as the signals changed to green?	14. Did the LLCS with an early release and new layout affect how people moved off as the signals changed to green?
7. Did the LLCS and new layout affect how pedestrians crossed the road?	
8. Did the LLCS and new layout affect perceived safety?	15. Did the LLCS with an early release and new layout affect safety?

2.6 Measures collected to answer the research questions

Measures were collected to inform each of the research questions through a combination of a post-trial questionnaire, focus groups and video analysis.

2.6.1 Post-trial questionnaire

A paper questionnaire was given to each participant for self-completion after they had completed the track trial. The majority of the questions were common across each of the road user groups, although there were some questions tailored to the various road users.

Each questionnaire included classification questions on participants' demographic characteristics and also their level of experience with traffic signal junctions and cycle reservoirs. Participants were asked about their experiences from the trial in relation to: the signals; their stopping behaviour; and also their experiences when going through the signals for each of the junction approaches. Finally, their attitudes towards LLCS were investigated.

All but one participant who took part in the trial completed the questionnaire[4]; see Section 2.3.1 for the number of participants in each road user group. The responses to closed questions are presented in graphs with vertical bars, whereas responses to open questions have been classified and are presented in graphs with horizontal bars.

2.6.2 Focus groups

Groups of eight participants were invited to take part in a group discussion after they had completed the post-trial questionnaire. The discussion was used to probe participants' understanding and gain further insights into some of the reasons behind their behaviour during the trial. Thus the focus group participants were a sub-set of all the trial participants. A total of seven focus groups were conducted for the five road user groups in the trial without an early release (cyclists, car drivers, motorcyclists, HGV drivers and pedestrians) and the two road user groups in the trial with an early release (cyclists and car drivers).

2.6.3 Video analysis

The video analysis of the behaviour at the junction was aimed at extracting data to describe two types of road user behaviour: 'moving behaviour' and 'stopping behaviour'. A description of the locations of the cameras is included in the appendices of the report for the trial with no early release (Ball et al. 2015a).

2.6.3.1 Measures relating to the moving behaviour of the road users

The moving behaviour of the participants was described through timing points as they passed fixed locations, as well as relative to the signal changes, as shown in Figure 7.

The signal timing points were as follows (on each arm):

[4] One cyclist left early and took the questionnaire home, but didn't post it back; as such the sample size for the questionnaires in the cycle trial was 147 rather than 148.

- Timing points at fixed locations
  - TP1 – 15 metres before main stop line
  - TP2 – 'Cycle Reservoir Entrance' (5 metres before main stop line)
  - TP3 – 'Cycle Reservoir Exit' (i.e. the main stop line)
  - TP4 – 'Junction Entrance' (i.e. the first set of pedestrian crossing markings; 1.7 metres after the main stop line)
  - TP5 – 'Junction Exit' (i.e. the second set of pedestrian crossing markings on the exit arm)
- Other timing points
  - Time LLCS changed from Red to Red & Amber
  - Time traffic signals changed from Red to Red & Amber
  - Time the cycle/vehicle stopped moving
  - Time the cycle/vehicle started moving

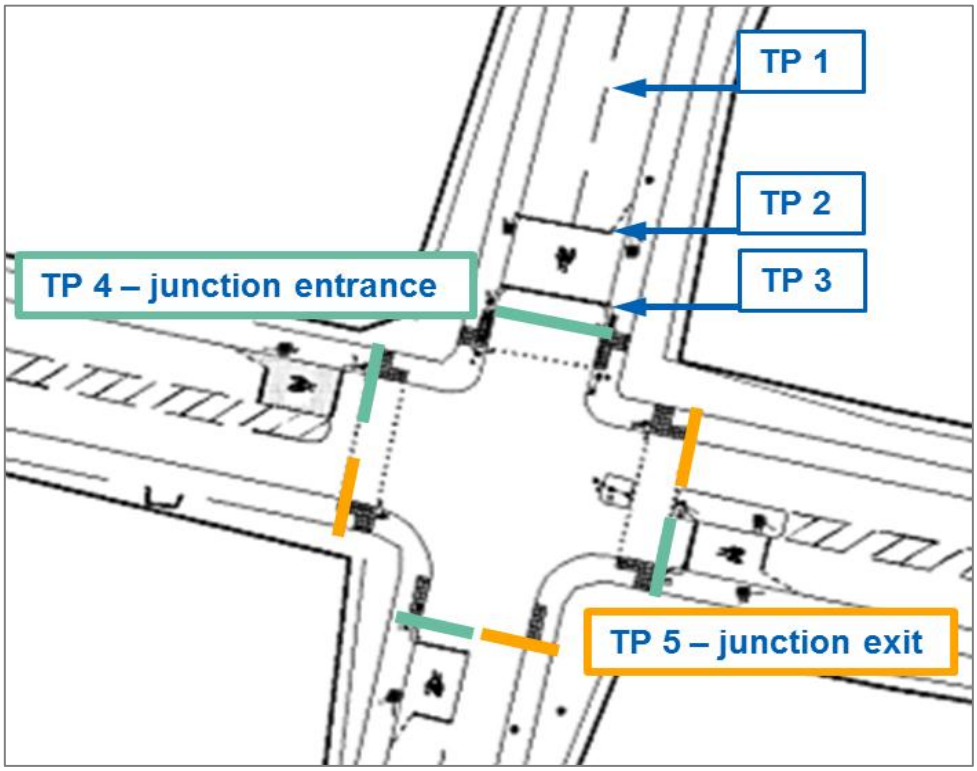

Figure 7 – Timing points at fixed locations

Three measures of the moving behaviour of road users were defined.

1. **'Reaction Time'** – described how quickly the participants reacted to the main signals changing to Red & Amber (time the wheels started moving minus time the main signals go to Red & Amber).
2. **'Entry Time'** – described how long it took to enter the junction relative to the main signals changing to Red & Amber; different to the Reaction Time, in that changes in stopping position are implicit within the Entry Time (time the wheels passed Junction Entrance (TP4) minus time the main signals go to Red & Amber).

3. **'Clearance Time'** – described how long it took the participant to clear the junction (Time the wheels passed Junction Exit (TP5) minus time the main signals go to Red & Amber).

For each of these three measures, the following comparisons were of interest:

1. Within a trial for a particular road user group.
2. Between this trial and the earlier trials for a particular road user.
3. Between the values for participants in the cycle trial and the values for the participants in the car, motorcycle and HGV trials.

2.6.3.2 Measures relating to the stopping behaviour of the road user

For the cycle trial the stopping behaviour of the cyclists was noted longitudinally and laterally with respect to the cycle reservoir. For this exercise those participants who did not stop were excluded.

For the car trial, motorcycle trial and HGV trial, the 'Within Cycle Reservoir' stopping zone was split into four smaller zones. In the car trial and HGV trial, data was not recorded on the lateral stopping position, although it was recorded for the motorcycle trial.

2.6.3.3 Measures relating to the crossing behaviour of pedestrians

In the pedestrian trial, data was captured on when participants arrived at the crossing, when they crossed and where they crossed.

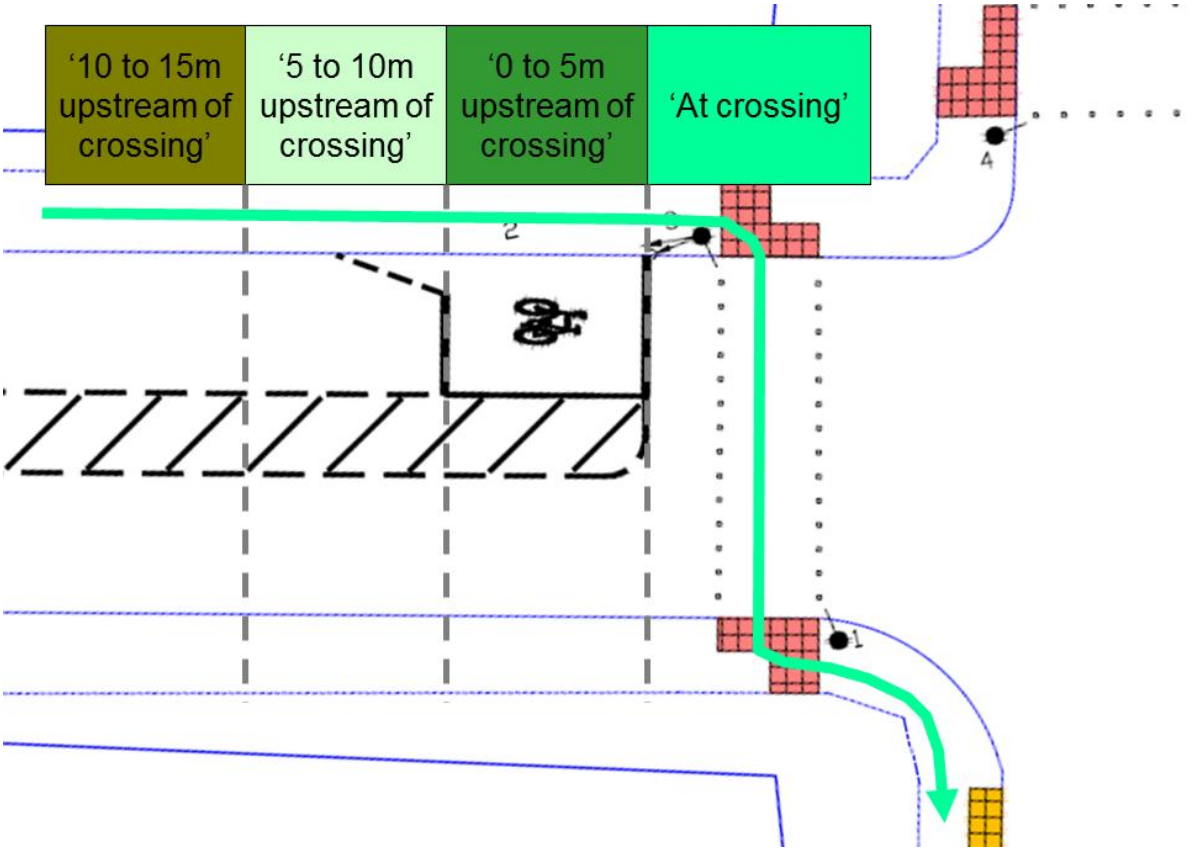

Figure 8 - Zones where pedestrians started to cross

2.7 Limitations

The situations presented to the participants were necessarily lacking some aspects of realism; some limitations of the experiment are listed below.

Compliance is difficult to study accurately on a test track, with participants often being more compliant than in the real world. Specifically in this experiment, the following factors may have had an effect of the compliance of participants:

- Participants were aware they were being studied.
- They were not under time pressures.

Other limitations of the study, which affected realism included:

- The results relate to a small four-arm junction. One of the factors that the right-turning behaviour of cyclists depends on is the distance between their starting position and the conflict point. This distance will be different for larger junctions and as such the results are not directly applicable to all junctions. Other junction characteristics, such as slope may also affect the behaviour of cyclists.
- The cars were controlled by TRL staff, who were instructed to move off as normal but be prepared to stop as the safety of the participants was paramount.
- Some participants commented on the lack of realism of the trial; in particular there were relatively low levels of traffic.
- For safety reasons, the trial was arranged so that the cyclists arrived at the junction before the drivers, i.e. cyclists never approached the junction from behind waiting vehicles. In particular this excluded the potential for conflicts with vehicles turning left across the path of cyclists behind them going straight on.
- This trial did not consider features such as bus stops, on-street parking, loading/drop-off zones or pedestrian crossings, all of which would influence behaviour.
- Participants had clear information about their route and continuously repeated manoeuvres through the same junction.

Previous experiments have been conducted under similar 'artificial' conditions, where behaviour is often found to differ from reality. However, the extent of immersion in the conditions simulated has been found to be sufficient for participants to realistically adapt their natural behaviour. Thus, it is possible to investigate the relative (although not absolute) effects of controlled design changes. Specifically, this trial enabled relative comparisons to be made between the LLCS being on the same pole as the main signal and on separate poles.

3 Findings – M19a Trial: LLCS on separate poles with no early release

3.1 Did people understand the LLCS and new layout?

Table 8 – Research questions on understanding

Road user	Theme	Research question	Video	Q'naire
All road users	Understanding	Did they understand the purpose of the LLCS? / To what extent did they confuse LLCS with Toucan crossings?	✗	✓
		Understanding of the cycle reservoir / junction layout	✗	✓

3.1.1 Understanding of the LLCS

Almost all participants (over 95% of cyclists and pedestrians, 100% of car drivers and motorcyclists, and 93% of HGV drivers) said they understood the LLCS to be traffic signals for cyclists or normal traffic signals. Most acknowledged that the LLCS were acting as repeaters of the main signals. The responses are acknowledged in Figure 9.

Three participants, an HGV driver, a cyclist (who cycled more than once a week), and a pedestrian initially thought the LLCS related to a cycle crossing.

> *"[It means] that bikes are waiting to cross so look out." (HGV driver M19a)*

> *"I assume they aid cyclists crossing at right angles to the traffic at the junction." (Cyclist M19a)*

> *"Safe for cyclists to cross." (Pedestrian M19a)*

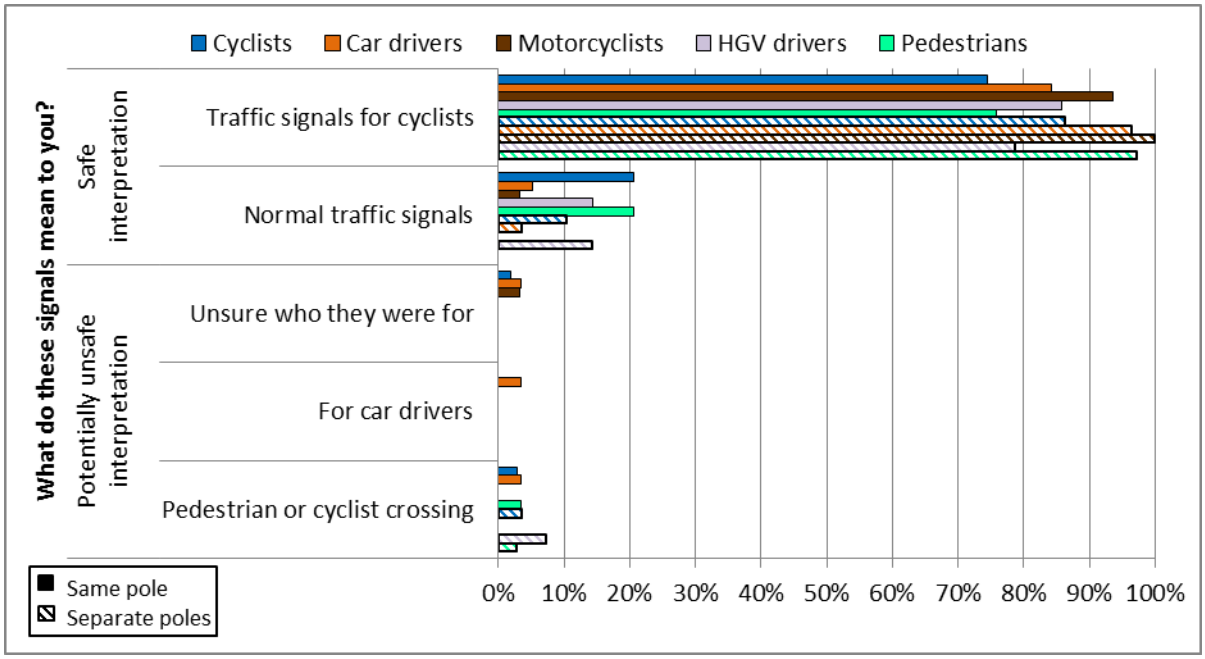

Figure 9 - Understanding of the LLCS (questionnaire)

This cyclist suggested that as the trial progressed they recognised that the LLCS were traffic signals for cyclists, commenting:

"Because of their direction it was a bit confusing that they applied to cyclists on the road rather than cyclists waiting to cross." (Cyclist)

In the focus groups, most participants said that the design was intuitive. Some suggested that initially they did not fully pay attention to them or follow their instruction. For example two focus group car driver participants initially thought that the lights were to assist cyclists to cross the traffic. The focus group participants all agreed that after a few runs they fully understood how to use the junction.

The HGV drivers in the focus group who noticed the LLCS (50%) said that after noticing them it was clear that they were not for them so they paid no more attention to them.

"You're looking at [the main] red light and that's it." (HGV driver FG M19a)

3.1.2 Understanding of the cycle reservoir

As discussed in Section 2.2.1, the terminology 'cycle reservoirs' is used rather than 'ASL' to describe the waiting area for cyclists between the first and second stop line.

In responding to the questionnaire, as in the M14 Trial, M19a participants showed a good understanding of the cycle reservoirs.

In the separate poles trial, all the cyclists understood that the area was for cyclists to stop in when waiting for the traffic signals to change, compared to 99% in the same pole trial.

"Only cyclists can stop in these areas and not cars. They [(cars)] stop behind the first white line." (Cyclist M19a)

"Cycles can enter at a red light. Other vehicles [can] only if they cannot stop in time but generally used by other vehicles." (Cyclist M19a)

In the separate poles trial, all car drivers, 92% of motorcyclists, 87% of HGV drivers and 97% of pedestrians understood that the cycle reservoirs were for cyclists only; these were similar proportions to the same pole trial.

One motorcyclist (8%) suggested that the reservoir represented a 'cycle priority box' and thought that they should not enter unless clear. This participant said that they always wait in cycle reservoirs when there are no cyclists around.

All HGV drivers showed that they understood that they should not enter the cycle reservoir, although two (13%) misunderstood the purpose of it. One participant thought both cyclists and motorcyclists could wait in the area and another thought the reservoir was part of a cyclist crossing point. One HGV driver disliked the layout as they suggested the cyclist would have to go through a red main signal in order to enter the cycle reservoir.

"A cyclist has to go through on red light to enter the green box or the cycle area." (HGV driver M19a)

In the separate poles trial, one pedestrian (3%) suggested that the cycle reservoir was a cyclist crossing, although there was also one pedestrian (3%) who said this in the same pole trial.

All participants understood the green cycle reservoir to be for cycles only. However two participants thought that vehicles could also wait in the unpainted cycle reservoirs, but should allow cyclists priority when present.

"[Green cycle reservoir] waiting area for cycles only. [Unpainted cycle reservoir] Waiting area for vehicles with priority for cycles." (Cyclist M19a)

"[Green cycle reservoir] keep clear cycle only. [Unpainted cycle reservoir] You can stop in this but if you can leave clear." (Car driver M19a)

During the trial, these car drivers sometimes stopped in the cycle reservoir when waiting at the junction.

The colour of the reservoir was not the main focus of the trials, although there were two other findings on: attitudes to the colour (Section 3.3.5); whether pedestrians were more or less likely to cross through the coloured reservoir (Section 3.7.1.2).

F1.a. Almost all participants (over 95% of cyclists and pedestrians, 100% of car drivers and motorcyclists, and 93% of HGV drivers) said they understood the LLCS to be traffic signals for cyclists or normal traffic signals.

F1.b. As in the previous trial, a small percentage (less than 5%) of pedestrians, cyclists and car drivers misinterpreted the LLCS as indicating when cyclists should cross the road, so they could have incorrectly judged that they had priority.

F1.c. All cyclists and all car drivers, 92% of motorcyclists and 87% of HGV drivers understood the meaning of the cycle reservoirs; these were similar proportions to the previous trial. The minority of motorcyclists, HGV drivers and pedestrians who misunderstood the purpose of the cycle reservoirs either thought that motorcycles could also use them or that they were a cyclist crossing.

3.2 What did people think about the location of the signals?

Table 9 – Research questions on the location of the signals

Road user	Theme	Research question	Video	Q'naire
All road users	Attitudes	What did they think about the location of the LLCS and main traffic signals?	✗	✓

This section relates to questions from the post-trial questionnaire where participants were asked specifically about the new layout. Thus there is no comparison with the earlier M14 Trial.

Participants were asked what they thought about the location of the LLCS in relation to the main traffic signals. The results are shown in Figure 10.

Participants using all modes generally felt that the signals were 'about right' in their location (about 80% of cyclists, about 70% of car drivers and HGV drivers, and about 60% of motorcyclists and pedestrians). Over 20% of car drivers, motorcyclists and pedestrians felt the LLCS would have been better located on the same pole as the main signals.

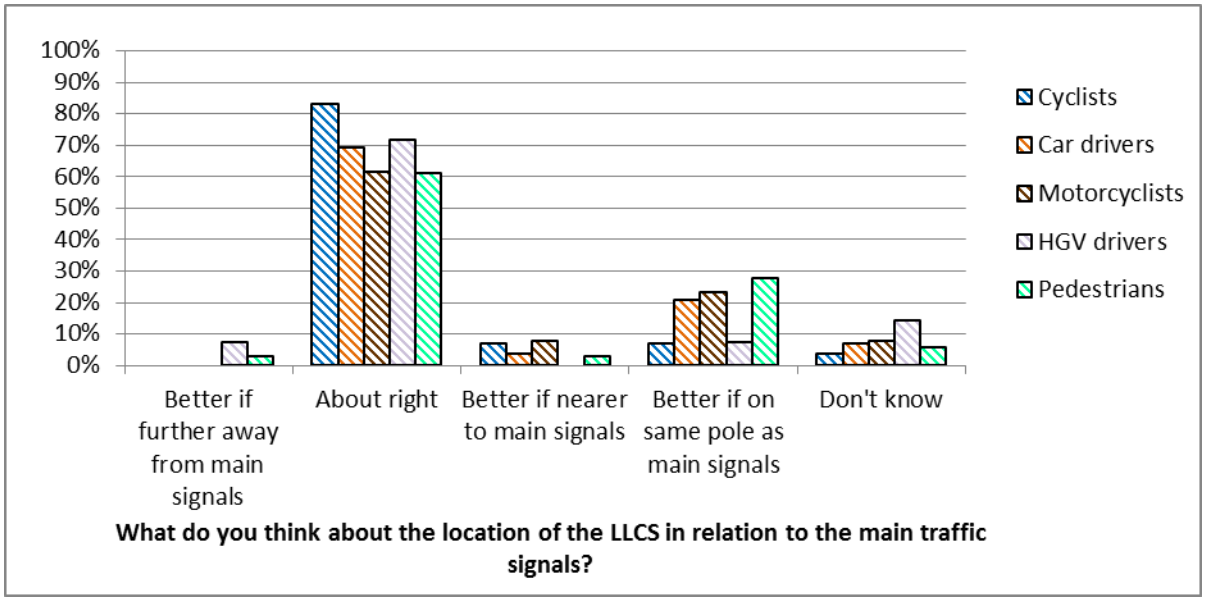

Figure 10 - Views on the location of the LLCS (questionnaire)

Participants were asked to explain their answers and these answers are discussed below; the answers were also classified and are shown in Appendix D.

3.2.1 Cyclists

Comments about the location of the LLCS were generally positive, with many cyclists saying they were easy to read and understand. In terms of understanding the use of separate poles, one cyclist suggested it made drivers stop before the cycle reservoir, whereas if both sets of signals were on the same pole, drivers may not notice the cycle reservoir and drive into it:

> *"By separating the car and bike lights it forces drivers to stop before the cycle box. If together I think drivers might miss seeing the box and go into it." (Cyclist M19a)*

Another suggested that having the main signals at the entrance to the cycle reservoir discourages motorists from stopping in the cycle reservoir, which implies that it would be safer:

> *"Having the [main] traffic signal pushed back is probably safer than a traditional ASL." (Cyclist M19a)*

Just over 15% of cyclists indicated that they were either unsure of the LLCS or did not use them when turning right. One participant suggested having an LLCS on the same pole as the secondary signal ahead.

> *"When turning right I didn't use them. [I] used [the] main lights instead as I was waiting on [the] other side of lane." (Cyclist M19a)*

> *"However the additional traffic signal far ahead has captured my attention. Could there be a low level cycle signal repeater on that pole?" (Cyclist M19a)*

One cyclist commented that if the LLCS were nearer to the main signals, motorists will realise that cyclists have their own lights.

3.2.2 Car drivers

Car drivers were positive in their comments about the location of the LLCS, with the majority saying that the LLCS were easy for drivers to see as well as cyclists. One driver commented that the cyclists should have an early release, whilst another said that the LLCS enabled them to anticipate when the cyclist would move off or stop.

Those drivers who said that the LLCS should be on the same pole as the main signals argued that this would make drivers more aware of cyclists and what they are doing:

> *"Drivers will be looking at their signals, having both on same pole will ensure that drivers are more aware of cyclists." (Car driver M19a)*

Similarly, another driver suggested that the LLCS were less likely to be missed if they are nearer the main signal.

One car driver did not think the LLCS were relevant to them so should not be made visible:

> *"I assume they are not relevant to me as a driver. So I think they should ideally not be visible to me. But that's hard." (Car driver M19a)*

A small number of car drivers in the focus group suggested that the position of the main signals aided their understanding of the junction in that it made their stopping position more clear. Most drivers said their stopping position was based on the stop line.

3.2.3 Motorcyclists

Most motorcyclists acknowledged that the LLCS were in a good position for cyclists. One specifically mentioned that they are not intended for other road users:

> *"Right position from other normal lights but should be used for cyclists, not intended for other road users behind to see (and therefore anticipate)." (Motorcyclist M19a)*

However a different participant also commented that the LLCS can be useful for motorcyclists as well, when the main traffic signals are difficult to see:

> *"Allows cyclists better vision of the lights. It can also be a useful spot for a motorcyclist as well as same lights are hard to see sometimes." (Motorcyclist M19a)*

One motorcyclist said that the LLCS should be nearer the main traffic signal, as on one of the approaches to the junction they noticed the main signals more readily than the LLCS.

Those motorcyclists who said the LLCS should be located on the same pole as the main traffic signals commented that this would make the motorists more aware of them and would make any difference between the LLCS and main signals clear. One participant suggested that an early release for cyclists may be beneficial:

> *"If the cycle lights were not synchronous with the main traffic signals, any difference would be clear. On this trial, they were always synchronised, but it may be better to give cyclists a 0.5-1 second head start." (Motorcyclist M19a)*

One motorcyclist thought the LLCS were for cyclists so did not pay any attention to them. There were no negative comments from motorcyclists.

3.2.4 HGV drivers

Responses from HGV drivers about the location of the LLCS included that they were a 'sensible distance from the main signals' and 'the position is about right for all road users and pedestrians to see'.

Similarly to one of the cyclists, one HGV driver suggested locating an LLCS on the secondary signal as well for cyclists turning right:

> *"As a cyclist they should be on the central reservation light as well in case cyclist is turning right." (HGV driver M19a)*

One HGV driver commented that in an early release situation, the LLCS should be placed further away from the main traffic signals.

> *"If cyclists are to be timed differently I would place their lights further away." (HGV driver M19a)*

Most HGV drivers who said they noticed the LLCS found it either 'very easy' or 'easy' to see the signals when stopped at a red light. One driver said it was very difficult and commented that the signals need to be more visible, although they did acknowledge that the signals are 'for cyclists, not the main traffic'.

In the focus group, all HGV drivers agreed that it is more important for them that the main signals are clear; they did not mind which poles the signals were on.

3.2.5 Pedestrians

Just over 60% of pedestrians thought that the location of the LLCS was about right with comments such as:

> *"[The] distance apart means when glancing at the signals, one can see them at the same time." (Pedestrian M19a)*

Just under 30% of pedestrians thought that the signals should have been together; these people suggested that having all of the signals on one pole would be easier for a pedestrian to follow:

> *"[If they were on the same pole] we would be able to see how the signals related to each other." (Pedestrian M19a)*

> *"It is more helpful if the traffic/pedestrian & cyclists signals are all integrated so everyone can see & hear when it is safe to cross." (Pedestrian M19a)*

F2.a. Most participants (about 80% of cyclists, about 70% of car drivers and HGV drivers, and about 60% of motorcyclists and pedestrians) thought the location of the LLCS signal poles was about right but over 20% of car drivers and motorcyclists and just under 30% of pedestrians felt that the LLCS would have been better located on the same pole as the main signals.

F2.b. Drivers who preferred the LLCS to be on the same pole as the main signals thought it would make them more aware of cyclists and what they were doing, than if they were on separate poles.

Further information in Appendix D

3.3 What attitudes did people have towards the LLCS and new layout?

Table 10 – Research questions on attitudes

Road user	Theme	Research question	Video	Q'naire
All road users	Attitudes	Who would benefit and what were the perceived benefits from LLCS and the new layout?	✗	✓
		Did people like the LLCS and the new layout?	✗	✓
		What did people think about the height and angle of the cycle signals?	✗	✓
		What did they think about the size and colour of the cycle reservoir?	✗	✓
		What improvements did people suggest for LLCS and the new layout?	✗	✓
		Would LLCS with the new layout make people more likely to cycle on busy roads?	✗	✓

3.3.1 Who would benefit and what were the perceived benefits from LLCS and the new layout?

In the M19a Trial, 90% of all participants thought that cyclists on the road would benefit from the LLCS; this was similar to the M14 Trial. More motorcyclists in the M19a Trial said that scooter riders and motorcyclists would also benefit (30% compared with 20% in the M14 Trial), primarily because the LLCS were easier for them to see than the main signals. The comments from the M19a Trial participants were classified as shown in Figure 11.

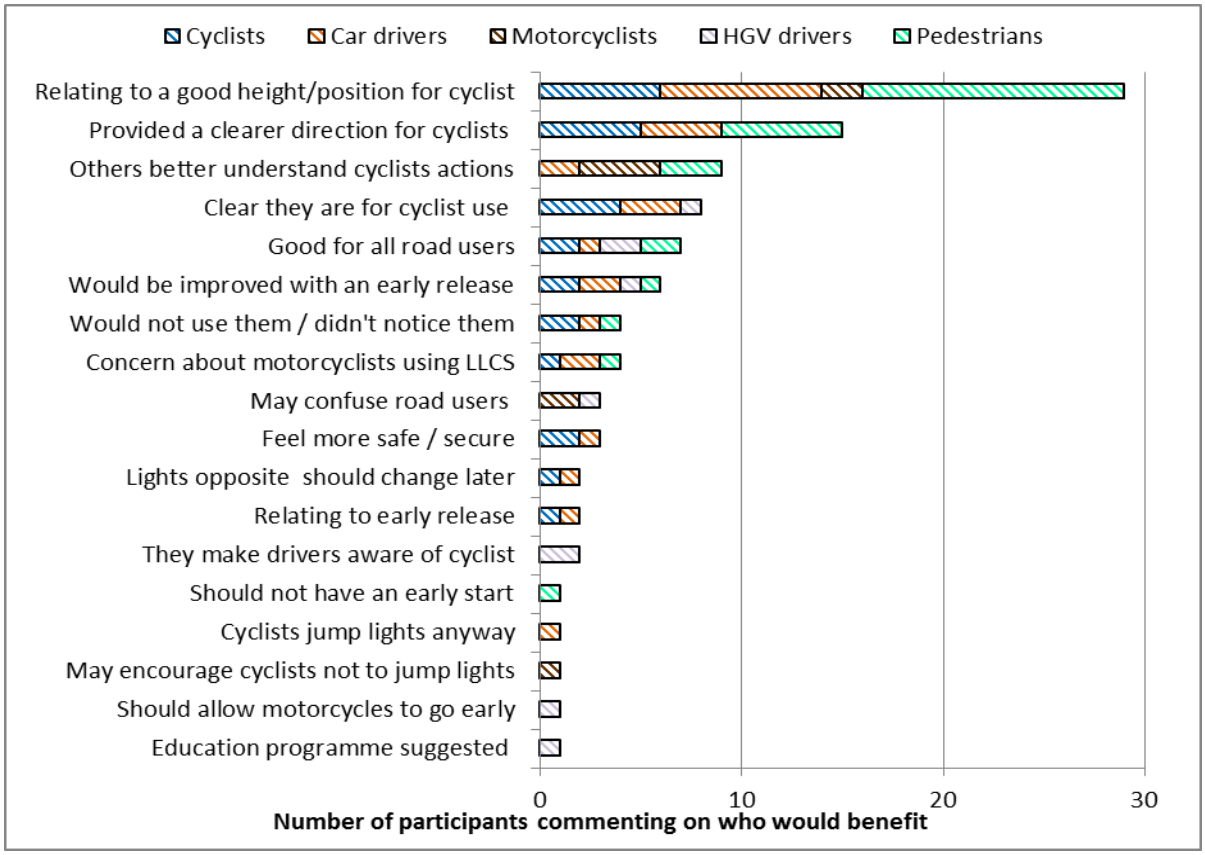

Figure 11 - Explanations when asked about who would benefit (questionnaire)

These comments were very similar to those from the M14 Trial, suggesting that the main benefits were associated with providing a good height and angle for the signals to be seen by cyclists and providing a clearer direction for cyclists.

3.3.2 Did people like the LLCS and the new layout?

A qualitative assessment was made to classify the comments about the LLCS in response to several questions (including the general comments at the end of the questionnaire) into three categories: in favour (positive), against (negative) and neutral; this last group also included people who made both positive and negative comments.

The majority of cyclists (89%), car drivers (68%) and motorcyclists (54%) were positive in their comments about the signals. Most HGV drivers were either positive (42%) or neutral (42%). Results are shown in Figure 12.

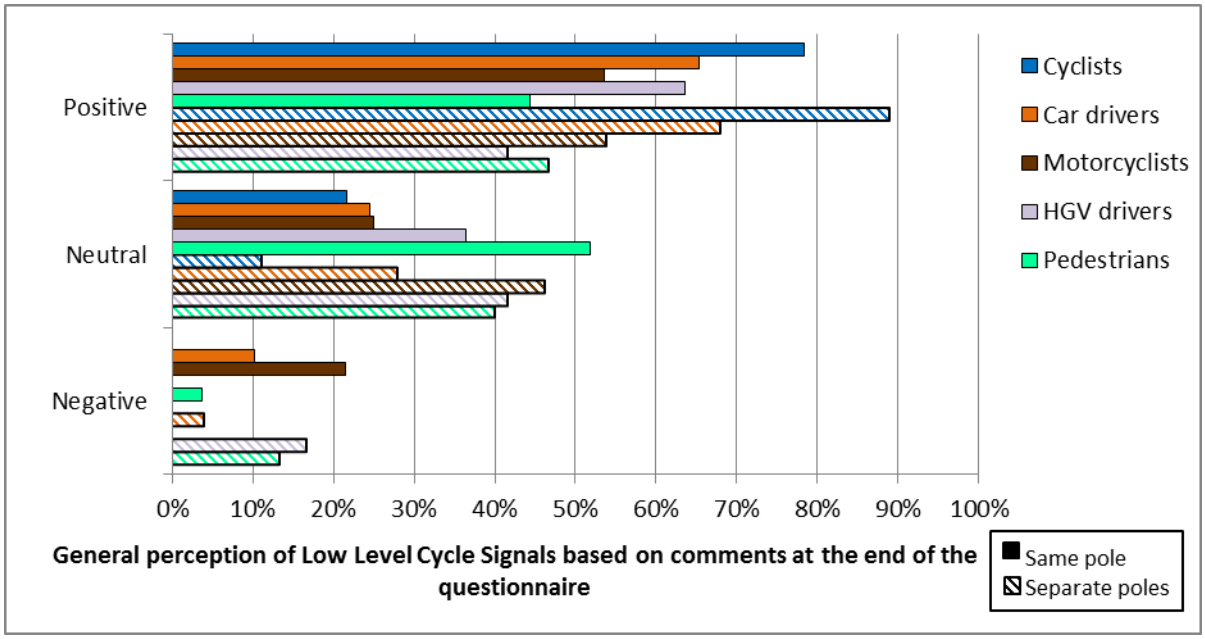

Figure 12 - Classification of attitudes (questionnaire)

3.3.3 What did people think about the height and angle of the cycle signals?

Participants were asked what they thought about the height and angle of the LLCS. Overall the responses were very similar in the M19a and M14 Trials, with the majority of participants stating that the height and angle of the LLCS was about right (over 55% and 65% respectively across all road user groups).

More pedestrians from the M19a Trial suggested that the height would be better if higher (17%) compared to 6% from the M14 Trial. Most said that higher signals would be clearer to them:

> *"I did not notice them for a while, if they were slightly higher I would. However they are good height for cyclists." (Pedestrian M19a)*

In the M19a Trial, the majority of the car drivers thought that the angle of the LLCS was about right (over 75% compared with 55% in the M14 Trial). However, more M19a cyclists thought the signals should be angled more towards the road (7% compared with none in the previous trial). As in previous trials, this is primarily related to turning right, when about 15% of cyclists found it difficult to see the LLCS comfortably when they were mounted on the near-side only. Two cyclists said it was uncomfortable looking so close when they are used to looking ahead or higher at main traffic signals. These participants suggested having the LLCS either nearer or on the same pole as the main traffic signals.

3.3.4 What did people think about the size of the cycle reservoir?

Participants were asked what they thought of the size of the area with the cycle symbol (the cycle reservoir). This was a new question and therefore there is no comparison with previous trials.

Almost all of the cyclists (97%) and over 70% of car drivers, motorcyclists, HGV drivers and pedestrians thought the cycle reservoir was about the right size. A small proportion of the participants (3% of cyclists and 7% of car drivers) said it would be better if the

cycle reservoir was larger and about 10% of the participants who were not cyclists thought it would be better if the cycle reservoir was smaller.

These findings will form the baseline for future trials in which different depths of reservoir will be tested.

3.3.5 What did people think about the colour of the reservoir?

In the focus groups, some participants said they thought that the green cycle reservoir was more prominent than the unpainted ones, with some car drivers saying they could see them from further away from the junction and some cyclists saying they felt safer in the green cycle reservoir:

> *"Felt more protected by the [reservoir with] green shading." (Cyclists FG M19a)*

A suggestion was also made that the cycle reservoirs should all be green as this makes them stand out more, ensuring that motorists do not enter them whilst waiting at the signals.

3.3.6 What improvements did people suggest for LLCS and the new layout?

The most commonly mentioned suggestions by cyclists were to make the signals brighter or more obvious and to give cyclists an earlier release than motor vehicles behind; this was also the case in the M14 Trial. Pedestrians also suggested providing more information about the signals.

> *"I think some explanation of the cycle signals is maybe needed especially if this differs to general traffic control." (Pedestrian M19a)*

3.3.7 Would LLCS with the new layout make people more likely to cycle on busy roads?

As in the M14 trial, a third of cyclists said the infrastructure would make them more likely to cycle in busy traffic, however it was not possible to ascertain what this was attributed to. Focus group participants suggested that more infrastructure, particularly segregated cycle lanes between junctions, would be required for them to cycle in busy traffic:

> *"Step in right direction [but] more needed…[don't implement] this in isolation" (Car drivers FG M19a)*

F3.a. 90% of all participants thought cyclists on the road would benefit from the LLCS and 30% of motorcyclists felt that scooter riders and motorcyclists would also benefit as the LLCS are easier for them to see when waiting at the junction.

F3.b. Improved visibility and a clearer direction for cyclists were perceived to be the key benefits. The LLCS were perceived to be useful to other road users, because they helped them better understand cyclists' actions.

F3.c. The majority of cyclists (89%), car drivers (68%) and motorcyclists (54%) were positive in their comments about the signals. Most HGV drivers were either positive (42%) or neutral (42%).

F3.d. Over 65% of participants in each road user group thought the height of the signals (1.4 metres) was about right and over 55% thought the angle of the LLCS (15 degrees) was about right.

F3.e. Almost all of the cyclists (97%) and over 70% of car drivers, motorcyclists, HGV drivers and pedestrians thought the size of the cycle reservoir was about right.

F3.f. The most common suggestions for improvements were to make the signals brighter and provide an early release for cyclists, and to provide more information on the LLCS for all users. This was particularly mentioned by pedestrians.

Further information in Appendix D

3.4 Did the LLCS and new layout affect what people looked at?

Table 11 – Research questions on information used when approaching and waiting at the junction

Road user	Theme	Research question	Video	Q'naire
Cyclists	Trial experiences	What did the cyclists look at when deciding when to enter the junction? What was the most important factor in their decision?	✗	✓
Car drivers, motorcyclists and HGV drivers	Trial experiences	What did the other road users look at when deciding when to enter the junction? What was the most important factor in their decision?	✗	✓
Pedestrians	Trial experiences	What did the pedestrians look at when deciding cross the road? What was the most important factor in their decision?	✗	✓
		To what extent did pedestrians use the information? - When they knew it was for road-cyclists? - When they misunderstood it?	✗	✓

In the post-trial questionnaire, participants were asked about the cues which they looked at when approaching the junction and when deciding to enter the junction or cross the road. Thus these results are about perceptions of what participants looked at rather than observations of what they actually looked at during the trial.

3.4.1 Cyclists, car drivers, motorcyclists and HGV drivers

3.4.1.1 Did they look at the LLCS?

Figure 13 shows the proportion of participants who said they looked at the LLCS; this shows the results for both the near-side LLCS (all arms) and the off-side LLCS (only Arm A and Arm B). Graphs for other cues similar to Figure 13 are included in Appendix D; these findings are summarised for each road user group in turn below.

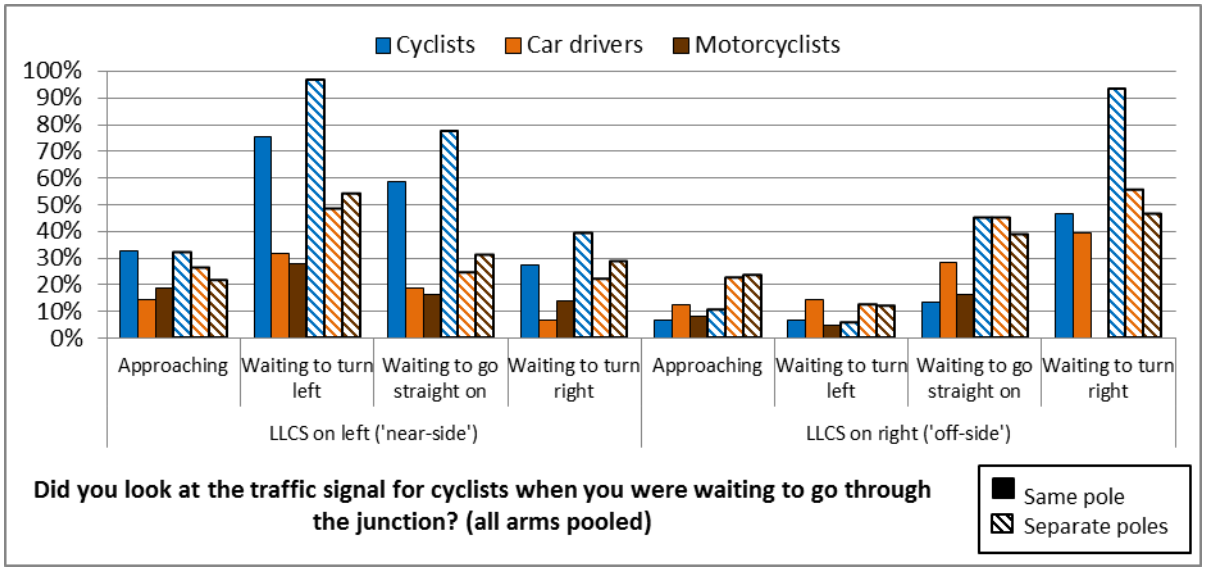

Figure 13 - Proportion of participants who said they looked at the near-side LLCS or the off-side LLCS (questionnaire)

In the M19a Trial, the LLCS on the left were generally reported to be looked at more when turning left and going straight on than in the M14 Trial, and the LLCS on the right were looked at more when turning right and going straight on. This was the case for all types of participant.

Similar to the M14 Trial, in the M19a Trial the main signals were typically used instead of the LLCS on the approach to the junction by all participant groups.

Cyclists

Compared with the M14 Trial, significantly more cyclists in the M19a Trial reported looking at:

- The near-side LLCS when turning left (97% compared with 75% in M14).
- The secondary signal ahead when turning left (56% compared with 34%), which is likely to be a result of the cyclists having the primary signal behind them and checking the secondary signal to understand when the car behind had a green signal.
- Both sets of LLCS when going straight on (near-side LLCS, 78% looked at compared with 59% and off-side LLCS, 45% looked at compared with 13%).
- The position and speed of on-coming traffic at Arm B where there were oncoming vehicles (72% compared with 47%).
- The off-side LLCS when turning right (93% compared with 47%).

- The near-side LLCS when there were no off-side LLCS (55% compared with about 30%).

Compared with the M14 Trial, significantly fewer cyclists in the M19a Trial reported looking at the near-side main signals when turning left (37% compared with 61%).

In the focus group, cyclists said they used the LLCS and the additional signals on the other side of the junction. As they got used to the infrastructure they said that they trusted the LLCS more and used the additional signals less.

> *"It's another source of information, once in the habit of using them." (Cyclist M19a)*

Car drivers

Compared with the M14 Trial, significantly more car drivers in the M19a Trial reported looking at:

- The near-side LLCS when turning left (48% compared with 32%) and turning right (22% compared with 7%).
- The off-side LLCS when going straight on (45% compared with 29%) and turning right (55% compared with 39%).
- The secondary signals when going straight on (83% compared with 61%) and turning right (79% compared with 63%).
- Both sets of LLCS when turning right (near-side LLCS, 22% looked at compared with 7% and off-side LLCS, 55% looked at compared with 39%).

The most looked at signal when going straight on and turning right was the secondary signal; this is different from the M14 Trial where the off-side main signal was most used. Two car drivers said they looked at the secondary signal because the main signals at the junction were obscured from their view.

Motorcyclists and HGV drivers

Compared with the M14 Trial, significantly more motorcyclists in the M19a Trial reported looking at:

- The near-side LLCS when turning left (54% compared with 28%) and turning right (28% compared with 14%).
- The off-side LLCS when approaching (23% compared with 8%) and turning right (46% compared with 0%).

Compared with the M14 Trial, significantly fewer motorcyclists in the M19a Trial reported looking at:

- The near-side main signals when turning left (62% compared with 87%) and turning right (26% compared with 47%). One motorcyclist suggested that it was difficult to see the near-side main signal from the first stop line, which could explain why more motorcyclists looked at the LLCS.

Results for going straight on were similar between the M14 and the M19a Trial.

HGV drivers generally looked less at the LLCS in the M19a Trial than in the M14 Trial.

These findings suggest that having the main signals and LLCS on separate poles caused participants to look more at the LLCS and the secondary signal; the effect is most marked for cyclists because of the position of the primary signals which meant they could not easily be seen from the first stop line.

3.4.1.2 What was the most important piece of information

The LLCS were stated to be the most important of the cues used when entering the junction by between 50% and 70% of cyclist participants in this trial; this was unlike the M14 Trial, where the main signals were more often regarded as the most important. Figure 14 summarises the results.

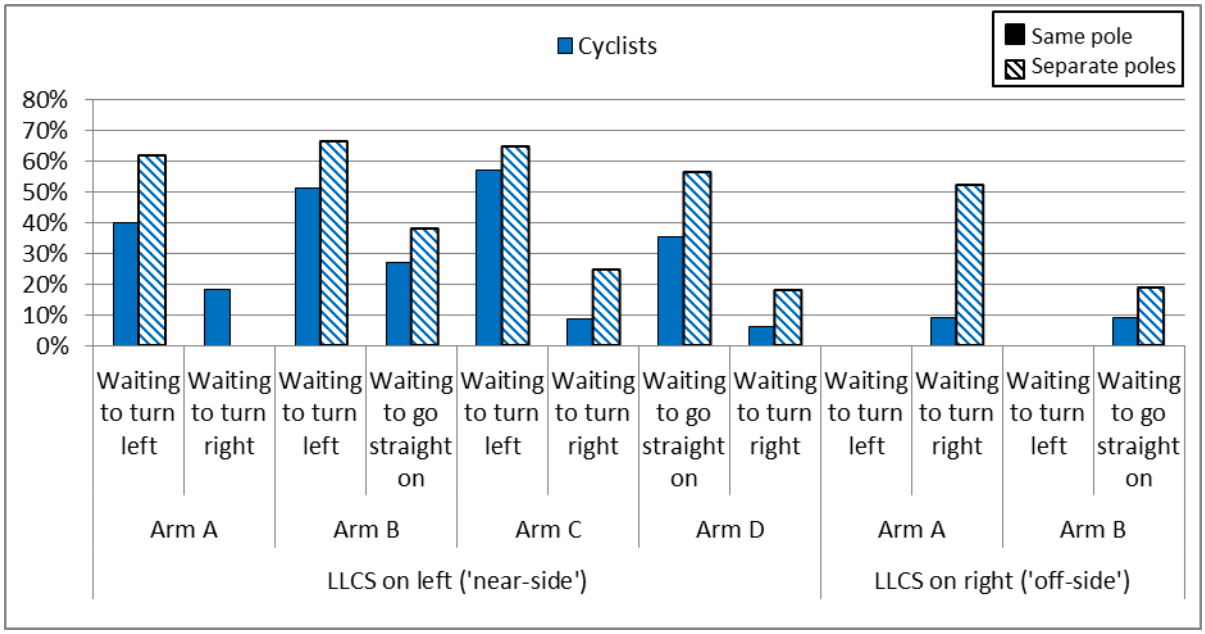

Figure 14 - Proportion of cyclists who said the near-side LLCS or the off-side LLCS were the most important piece of information

When compared with the M14 Trial, fewer car drivers in the M19a Trial reported that the main signals were the most important piece of information when waiting at the junction. Between 20% and 30% of car drivers thought that the near-side main signals were most important when turning left compared with around 60% in the previous trial. There was also a decrease in the proportion of car drivers who thought the off-side signals were most important when turning right (35% compared with 56%).

3.4.2 Pedestrians

On the controlled crossings most pedestrians said that the pedestrian signals and the presence of traffic were the main factors in deciding when to cross in both the M14 and the M19a Trial. Between 80% and 90% of participants stated that they used the pedestrian signals and a similar proportion said that they considered what the traffic was doing. These results are shown in Figure 15.

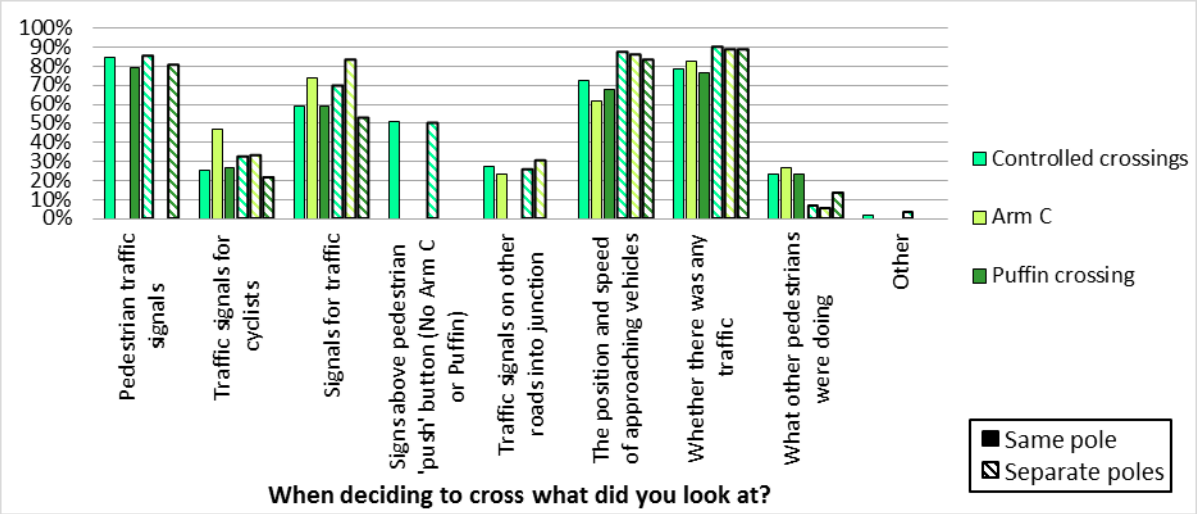

Figure 15 - What pedestrians said they looked at when deciding when to cross (questionnaire)

When asked what was most important when deciding to cross, about a third stated that it was the pedestrian signals and a similar proportion said they considered what the traffic was doing. About 15% of the pedestrians who crossed before they reached the crossing said the LLCS were the most important factor in both the M14 and M19a Trial and about 10% of pedestrians who crossed at the designated crossing said the LLCS were the most important.

Two pedestrians stated that they could not see the LLCS from the pavement:

> *"The cycle signal wasn't easy to spot and it was too low for pedestrians to see clearly." (Pedestrian M19a)*

> *"The signal is not positioned to make it easy for pedestrians to see from the safe area of the pavement at the crossing." (Pedestrian M19a)*

Some pedestrians in the focus group were concerned that because they could not see the LLCS they might walk into the road when the main signals are on red but the LLCS are on green.

F4.a. LLCS were the most important piece of information for cyclists entering the junction.

F4.b. Significantly more cyclists, car drivers and motorcyclists said they looked at the LLCS in the trial where the signals were located on separate poles than did the participants in the trial where the signals were on the same poles.

F4.c. Significantly more car drivers said they looked at the secondary signals when waiting to go straight on or turn right (83% and 79% compared with 61% and 63% in the same pole trial). Some suggested that they looked at the secondary signal instead of the main signals, because the main signals were obscured from their view.

F4.d. Compared with the M14 Trial, significantly fewer motorcyclists in the M19a Trial reported looking at the near-side main signals when turning left (62% compared with 87%) and turning right (26% compared with 47%). One motorcyclist suggested that it was difficult to see the near-side main signal from the first stop line.

F4.e. When compared with the M14 Trial, fewer car drivers in the M19a Trial reported that the main signals were the most important piece of information when waiting at the junction.

Between 20% and 30% of car drivers thought that the near-side main signals were most important when turning left compared with around 60% in the previous trial.

F4.f. Pedestrians said they looked at the pedestrian signals and the main traffic signals more than the LLCS, which overall were not considered to be as important.

F4.g. Two pedestrians said they could not see the LLCS from the pavement. This led to a concern that they might try to cross when the main signal was red but the LLCS was green.

3.5 Did the LLCS and new layout affect compliance: i) whether cyclists stopped at a red light; ii) where people waited?

Table 12 – Research questions on red light compliance and stopping position

Road user	Theme	Research question	Video	Q'naire
Cyclists	Compliance with red light	To what extent did the LLCS affect compliance with red lights?	✓	✗
	Longitudinal stopping position	To what extent did the LLCS and new layout affect the proportion of cyclists stopping before the first stop line?	✓	✓
		To what extent did the LLCS and new layout affect the compliance of cyclists stopping past the second stop line?	✓	✓
	Lateral stopping position	To what extent did the LLCS and new layout affect the lateral stopping position?	✓	✓
Car drivers, motorcyclists and HGV drivers	Longitudinal stopping position	To what extent did the LLCS affect whether other road users encroached into the ASL and how did this vary by when there were some or no cyclists?	✓	✓

In the cycle trial, two types of compliance were studied: Section 3.5.1 assesses to what extent cyclists went through the junction whilst a red signal was still showing; Section 3.5.2 assesses the stopping position of cyclists relative to the first and second stop line. For other road users, the stopping position relative to the first stop line was analysed, i.e. their compliance with the cycle reservoir.

3.5.1 Compliance with red signals

Cyclists, car drivers and motorcyclists were released at times chosen so that they approached the junction whilst the red signals were displayed.

Table 13 shows the number of observations where a participant cyclist went through the junction while the signal was still on red, split by the junction layout scenarios. A non-compliant observation was defined as where they entered the junction on a red signal[5] and then proceeded through the junction without stopping. This shows that there was no difference in the compliance of cyclists with the red signal between the 'same pole' trial and the 'separate poles' trial.

[5] i.e. passed "Timing Point 4 (TP4)", 1.7 metres after the main stop line, before the signals changed from red

Table 13 - Cycle trial: number of observations where the cyclists were non-compliant with a red signal (video data)

Trial	Junction layout scenario	Early release scenario	Non-compliant observations	Total observations	Percentage non-compliant
M14	N/A	LLCS covered	14	838	1.7%
	Same pole	LLCS uncovered (0 secs)	1	910	0.1%
M19a	Separate poles	0 secs	0	637	0%

3.5.2 Longitudinal stopping position

The position that participants stopped at the traffic lights was captured from videos, as discussed in Section 2.6.3. This included the lateral position (i.e. 'Left Zone', 'Middle Zone' or 'Right Zone') and the longitudinal position (i.e. the position along the road).

3.5.2.1 Cyclists

Findings from the video analysis

As discussed in Section 2.4.1, participants took part in either two or three 'sessions' of approximately 30 to 40 minutes. Figure 16 shows the proportion of observations where the cyclist stopped before the reservoir, split by their first session and later sessions.

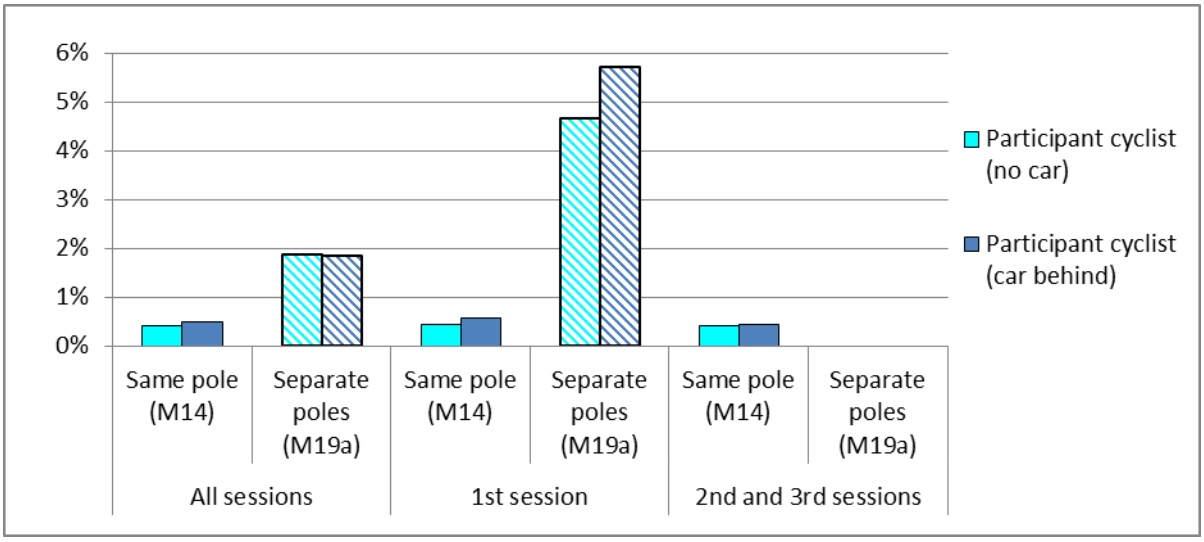

Figure 16 – Cycle trial: proportion of observations where the cyclist stopped before the cycle reservoir, by location of signals and session (video data)

There was a small increase in the proportion of observations where the cyclist waited before the cycle reservoir in the trial with the signals on separate poles (2%), compared to the trial with the signals on the same pole (0.5%). However, in their first session in about 5% of observations the cyclist waited before the reservoir, whereas during their second and third sessions there were no observations of cyclists waiting before the reservoir. This shows that the behaviour of some cyclists changed as they became familiar with the layout.

Table 14 presents the results for the longitudinal stopping position of cyclists, classified into four zones: 'Before reservoir', 'Within reservoir', '0-1m after reservoir' and 'More

than 1m after reservoir'. This is presented here only for the second and third sessions, excluding the first session.

Table 14 – Cycle trial: longitudinal stopping position relative to the cycle reservoir, by location of signals and session (video data)

Session	Participant group	Trial	Before reservoir	Within reservoir	0-1m after reservoir	More than 1m after reservoir	Sample size
2nd and 3rd sessions	Participant cyclist (no car)	Same pole (M14)	0.4%	91.2%	8.4%	0.0%	239
		Separate poles (M19a)	0.0%	96.9%	3.1%	0.0%	161
	Participant cyclist (car behind)	Same pole (M14)	0.5%	94.6%	5.0%	0.0%	221
		Separate poles (M19a)	0.0%	96.4%	3.2%	0.5%	220

Excluding the first session, in the separate poles trial in the scenario with no car, there was a significant reduction in the proportion of cyclists waiting with their front wheel beyond the second stop line, from 8.4% to 3.1%[6]. In the scenario with a car behind there was no statistically significant difference in this measure between the separate poles trial (5.0%) and the same pole trial (3.8%).

Findings from the questionnaire and focus groups

When participants were asked in the post-trial questionnaire whether they noticed the cycle reservoirs when they first approached the junction, almost all participants said they did. Three cyclists said they did not notice the LLCS on their first run, and their comments suggest that initially they did not enter the cycle reservoir. However, once they did notice the cycle reservoir they used it every time.

> *"After I noticed it I used it all the time." (Cyclist M19a)*

> *"Once I had noticed it, it seemed the best and safest place to stop" (Cyclist M19a)*

Some of the cyclists taking part in the focus group also suggested that they had initially overlooked the cycle reservoirs and LLCS as they primarily focused on understanding their route. A few cyclists suggested that the cycle reservoir was not immediately obvious to them and they needed to trial the route a number of times before entering the cycle reservoir. After navigating the route for the second or third time, all participants confirmed that they did see the additional road markings and entered the cycle reservoir.

> *"Second time around I noticed the box, you don't see it on the approach." (Cyclists FG M19a)*

These findings support the findings of the video data and suggest that it was not noticing rather than not understanding the layout that led to cyclists not using the cycle reservoirs on their first run.

[6] P<0.05

3.5.2.2 Car drivers, motorcyclists and HGV drivers

Findings from the video analysis

A similar analysis was conducted for the motorists, although as discussed in Section 2.6.3 the 'within reservoir' zone was split into four: '0 to 1.25m into reservoir'; '1.25 to 2.5m into reservoir'; '2.5 to 3.75m into reservoir'; '3.75 to 5m into reservoir'. Figure 17 shows the proportion of observations where the motorist stopped within the reservoir; i.e. the front bumper of the vehicle (or front wheel of the motorcycle) was past the first stop line.

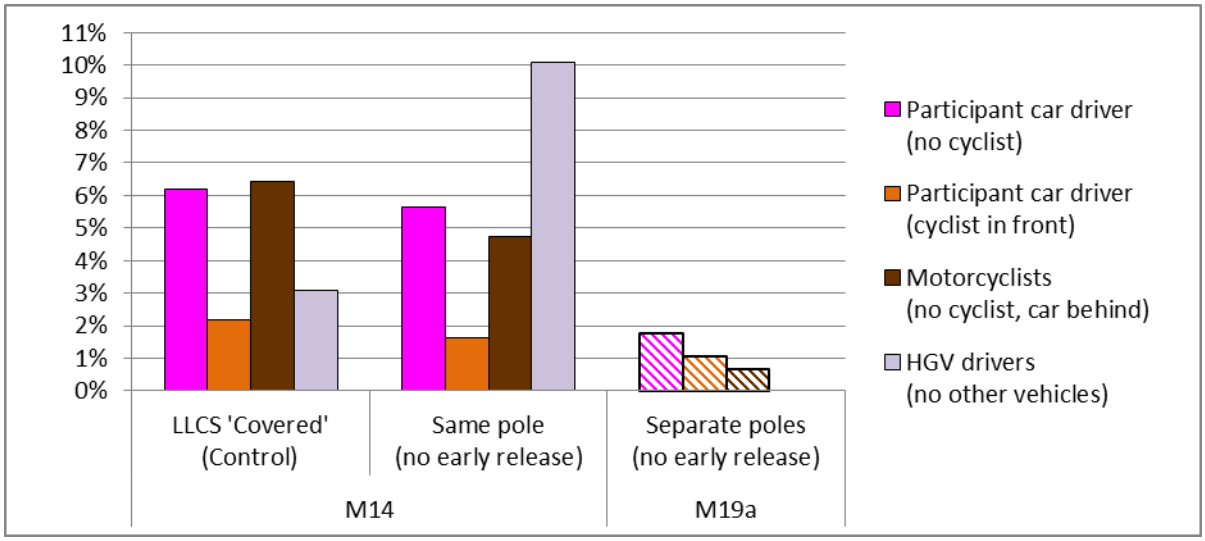

Figure 17 – Car trial, motorcycle trial and HGV trial: proportion of observations where the participant stopped within the cycle reservoir, by location of signals (video data)

As discussed in Section 2.7, compliance is difficult to study accurately on a test track, with participants often being more compliant than in the real world. In all the trials the observed compliance with the reservoir was substantially higher than values that have been observed on-street in other studies[7]. As such, the absolute values of compliance would not be expected to be reproduced in the real world, but it is likely the direction of the change would.

The trials with the separate poles were associated with an improvement in compliance of motorists stopping before the stop line. Specifically in the scenarios with no controlled cyclists in front, the proportion stopping within the reservoir decreased from: 5.6% to 1.8% in the car trial; 4.7% to 0.7% in the motorcycle trial; and 10.1% to 0% in the HGV trial, all of which were statistically significant decreases[8]. In the car trial and the scenarios with a cyclist in front, no significant differences in compliance were detected between the separate poles and the same pole trial. However, in the trials with the signals on the same pole the compliance with the reservoir was already very high and as such there was limited possibility for improvement.

[7] See Section 1.2.4

[8] $P<0.05$

Appendix C contains a similar graph to Figure 17, but for observations where the motorist stopped more than 1.25 metres past the reservoir entrance. This showed that there was a small statistically significant decrease in the proportion of cars that stopped with their bumper more than 1.25m into the reservoir; this was from 1.5% to 0% in the trial with no cyclist and from 1.1% to 0% in the trial with a cyclist in front. Although only a small change, this was an indicative effect that suggests the location of the main signals deterred the car drivers from stopping far into the reservoir. There was a similar indicative trend for the motorcycle trial, although this was not statistically significant due to the lower sample size in this trial. In the HGV trial there were no observations in any trials where they stopped more than 1.25m into the reservoir.

Findings from the questionnaire and focus groups

In the questionnaire, those car drivers who said the LLCS affected where they stopped explained that the LLCS reminded them of the presence of cyclists and that they stopped outside the cycle box.

> *"It was an extra signal to remind me of cyclists." (Car driver M19a)*

> *"I always stopped outside the area marked for cyclists." (Car driver M19a)*

In the focus groups, some car drivers said that the positioning of the signals was not an important part of their decision not to enter the cycle reservoir, whereas some suggested that they would be more likely to enter the cycle box if the main signals had been in line with the cyclist stop line.

As discussed in Section 3.4.1, there were some decreases in the proportion of motorists who said they looked at the main traffic signals and some increases in the proportion who said they looked at the secondary signals and LLCS. One motorcyclist commented that it was less easy to see the near-side main signal from the stop line when waiting to turn left from Arm C:

> *"Less easy to see the main signal front left at stop line." (Motorcyclist M19a)*

There was anecdotal evidence to suggest that those who still used the main traffic signals would need to stop further back from the stop line in order to still be able to see them, as illustrated in Figure 18.

Figure 18 – View from inside a car (from passenger seat) on approaching the signals

3.5.3 Lateral stopping position

3.5.3.1 Cyclists

When cyclists were turning left or going straight on there was in increase in the proportions waiting in the left zone of their lane when the LLCS were on a separate pole. Similarly, when cyclists were turning right, there was in increase in the proportions waiting in the right zone of their lane. See Appendix C for further information.

F5.a. There was no difference in the compliance of cyclists with the red signal between the same pole trial and the separate poles trial.

F5.b. In all trials the observed compliance with the cycle reservoir was substantially higher than values that have been observed on-street in other studies; the absolute values of compliance would not be expected to be reproduced in the real world, but it is likely the direction of the change would.

F5.c. The trials with the separate poles were associated with an improvement in compliance of motorists stopping before the stop line. Specifically in the scenarios with no controlled cyclists in front, the proportion stopping within the reservoir decreased from: 5.6% to 1.8% in the car trial; 4.7% to 0.7% in the motorcycle trial; and 10.1% to 0% in the HGV trial, all of which were statistically significant decreases.

F5.d. There was a small statistically significant decrease in the proportion of cars that stopped with their bumper more than 1.25m into the reservoir; this was from 1.5% to 0% in the trial with no cyclist and from 1.1% to 0% in the trial with a cyclist in front. Although only a small change, this was an indicative effect that suggests the location of the main signals deterred the car drivers from stopping far into the reservoir.

F5.e. In the questionnaires and focus groups, some cyclists explained that they didn't notice the reservoir on their first few passes through the junction and stopped before the reservoir, but once they realised it was there they all stopped in it.

F5.f. In the separate poles trial in the scenario with no car, there was a significant reduction in the proportion of cyclists waiting with their front wheel beyond the second stop line, from 8.4% to 3.1%, excluding the first session.

F5.g. On some approaches, the separate pole was associated with a shift to the left in cyclists' stopping position when they were turning left or going straight on, bringing them closer to the LLCS.

Further information in Appendices C and D

3.6 Did the LLCS and new layout affect how people moved off as the signals changed to green?

Table 15 – Research questions on moving behaviour

Road user	Theme	Research question	Video	Q'naire
Cyclists	Reaction to the LLCS	'Reaction Time' – To what extent did cyclists react to the LLCS?	✓	✗
	Time to enter the junction	'Entry Time' – To what extent did cyclists enter the junction ahead of cars?	✓	✗
	Right-turning cyclists	To what extent did right-turners from Arm D turn ahead of oncoming cars?	✓	✓
Car drivers, motorcyclists and HGV drivers	Reaction to the LLCS	'Reaction Time' – To what extent did other road users start moving forwards early? How did this vary by when there were some or no cyclists?	✓	✓
	Delay to enter the junction	'Entry Time' – To what extent were other road users delayed from the green light to reaching the junction entrance?	✓	✗

The times when participants started to move ('Reaction Time'), entered the junction ('Entry Time'), and cleared the junction ('Clearance Time') were recorded as explained in Section 2.6.3. In this section results are presented for the Reaction Time and Entry Time. In the cycle trial, participants encountered the junction both with and without a controlled car; similarly in the car trial, participants encountered the junction both with and without a controlled cyclist. In both the cycle trial and car trial, the cyclist always approached the junction ahead of the car. In the motorcycle trial participants encountered the junction either with a car behind them or a cyclist in front of them.

3.6.1 Reaction Time

Figure 19 shows the average Reaction Time of the participants to the main signals in both the cycle trial and the car trial. The green line indicates when the signals turned to green, i.e. two seconds after the signals turned to red and amber.

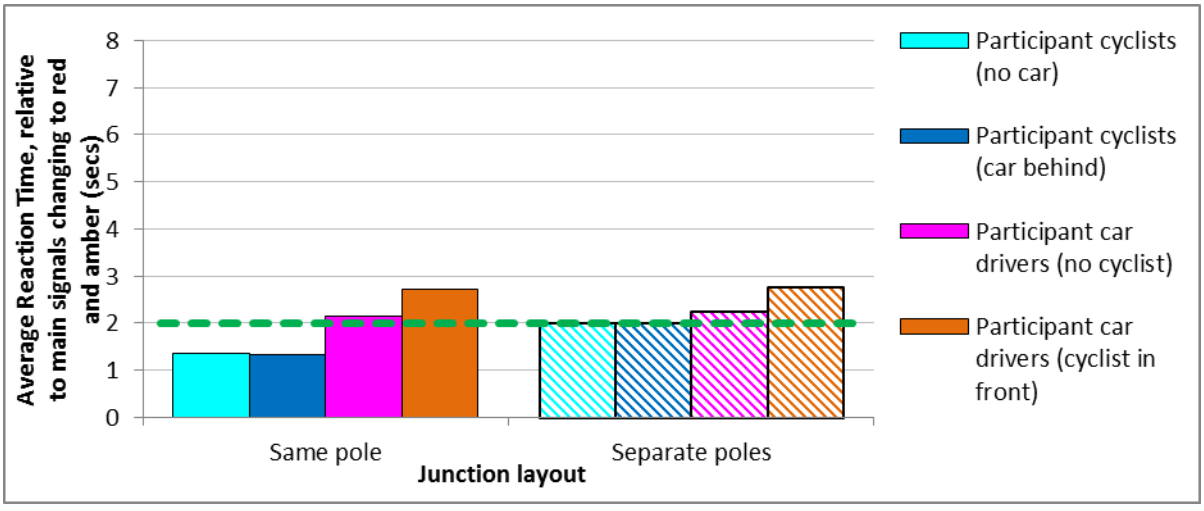

Figure 19 – Cycle trial and car trial: average Reaction Time of cyclists and car drivers, relative to the main signals changing to red and amber, by location of signals (video data)

There was a small statistically significant increase in the average Reaction Time of the cyclists; this was from 1.3 seconds in the same pole trial to 2.0 seconds in the separate poles trial in both the scenario with and without a controlled car behind them. This may suggest that the cyclists were less rushed in the trial with the signals mounted on the separate poles:

> *"The delay in the car starting meant I did not feel hassled to move quicker" (Cyclist M19a)*

One cyclist also mentioned feeling less rushed due to the cycle reservoir:

> *"With the amount of space provided in the cycle area it gave plenty of time to turn the corner comfortably with the car behind" (Cyclist M19a)*

A few others suggest that they didn't feel rushed because the controlled car drivers were 'well behaved', and that this was not representative of the real world.

There were no significant differences in the average Reaction Time of the car drivers between the same pole and separate poles trials, although on both trials the average Reaction Time was lower in the scenario with the controlled cyclist in front.

3.6.2 Entry Time

Figure 20 shows the average Entry Time of the participants to the main signals in both the cycle trial and the car trial.

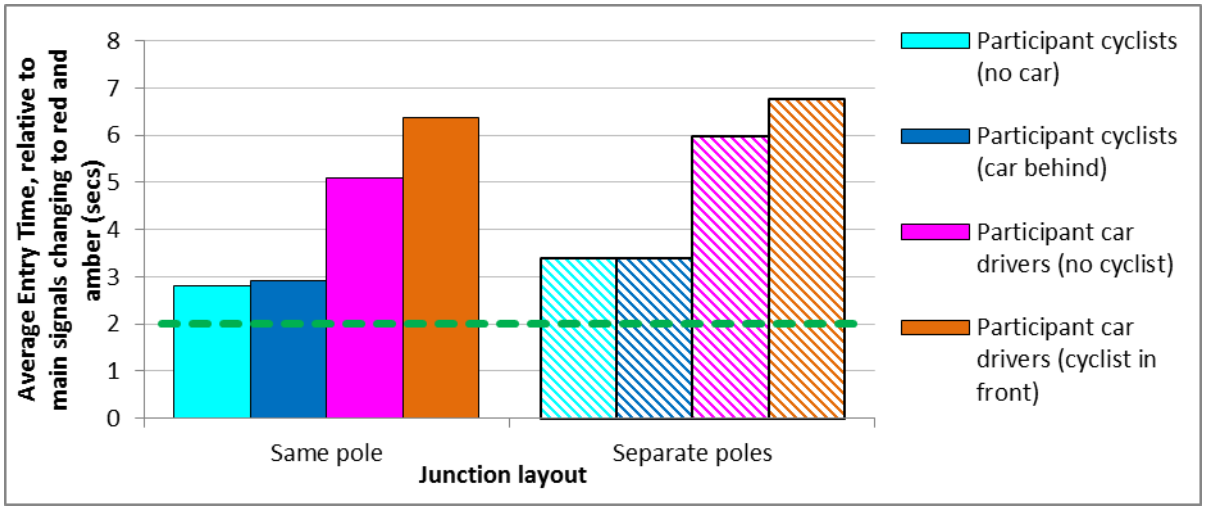

Figure 20 – Cycle trial and car trial: average Entry Time of cyclists and car drivers, relative to the main signals changing to red and amber, by location of signals (video data)

In the cycle trials, similar to the Reaction Time there was a statistically significant increase in the average Entry Time of the cyclist; this was from 2.8 seconds in the same pole trial to 3.4 seconds in the separate poles trial in the scenario with no car and from 2.9 seconds to 3.4 seconds in the scenario with a controlled car behind.

In the car trials, there was also a statistically significant increase in the average Entry Time of the cars; this was from 5.1 seconds in the same pole trial to 6.0 seconds in the separate poles trial in the scenario with no cyclist and from 6.4 seconds to 6.8 seconds in the scenario with a controlled cyclist in front.

Given that there was no change in the average Reaction Time of car drivers between the same pole and separate poles trials, the increase in average Entry Time may therefore be explained by the stopping position of the car. As discussed in Section 3.5.2.2, there was a small increase in the proportion of motorists stopping before the reservoir, but there was also anecdotal evidence that some motorists stopped further back from the stop line. In particular those who still used the main traffic signals rather than the secondary signals or LLCS were likely to stop further back from the stop line. It seems that this change in stopping position due to the main signals being moved to the first stop line results in an additional delay to the motorist in entering the junction of around 0.5 seconds when there is a cyclist in front and around 1.0 seconds when there is no cyclist in front.

In the same pole trial, the average Entry Time of the cars was greater in the scenario with a cyclist in front, because in some cases the car caught up with the cyclist and so was delayed entering the junction. The delay due to stopping further back was additional to the delay when the car caught up with the cyclist, which explains why the additional delay due to stopping further back is smaller in the scenario with a cyclist in front compared to the scenario with no cyclist.

3.6.3 Right-turning behaviour of cyclists

In the trials with no early release, both with signals on the same pole and separate poles, there were no observations where the cyclist turned right in front of the oncoming car. This is explored further in the scenario with an early release in Section 4.6.3.

F6.a. There was a small statistically significant increase in the average Reaction Time of the cyclists; this was from 1.3 seconds in the same pole trial to 2.0 seconds in the separate poles trial in both the scenario with and without a controlled car behind them. This may suggest that the cyclists were less rushed in the trial with the signals mounted on the separate poles.

F6.b. There was also a statistically significant increase in the average Entry Time of the cyclist; this was from 2.8 seconds in the same pole trial to 3.4 seconds in the separate poles trial in the scenario with no car and from 2.9 seconds to 3.4 seconds in the scenario with a controlled car behind.

F6.c. There were no significant differences in the average Reaction Time of the car drivers between the same pole and separate poles trials.

F6.d. There was a statistically significant increase in the average Entry Time of the cars; this was from 5.1 seconds in the same pole trial to 6.0 seconds in the separate poles trial in the scenario with no cyclist and from 6.4 seconds to 6.8 seconds in the scenario with a controlled cyclist in front. This was likely explained by some car drivers stopping further back from the stop line in order to be able to see the main signals.

F6.e. In the trials with no early release, both with signals on the same pole and separate poles, there were no observations where the cyclist turned right in front of the oncoming car.

3.7 Did the LLCS and new layout affect how pedestrians crossed the road?

Table 16 – Research questions on pedestrian behaviour

Road user	Theme	Research question	Video	Q'naire
Pedestrians	Compliance with crossing location	To what extent did the LLCS affect where pedestrians started crossing? / What effect did the LLCS and new layout have on whether pedestrians walk into the ASL when walking up to the signals?	✓	✓
	Compliance with Red Man	To what extent did it affect compliance with the Red Man?	✓	✓

In the pedestrian trial, participants were released in pairs 15 metres 'upstream' of the crossing, so that they saw the LLCS on approach. They were also released up to the Puffin crossing from the 'downstream' side, so that they saw the low level near-side pedestrian signals on one approach.

3.7.1 Where participants started crossing – compliance with crossing studs

3.7.1.1 Findings from the video analysis

As shown in Figure 8 in Section 2.6.3.3, data was captured on where pedestrians started and finished crossing in four zones: '10 to 15m upstream of crossing'; '5 to 10m upstream of crossing; '0 to 5m upstream of crossing' and 'At crossing'.

Figure 21 and Figure 22 show the six different crossings that pedestrians experienced. At the Puffin crossing there was no cycle reservoir, but for the crossings at the signal junction the '0 to 5m upstream of crossing' zone corresponded with the cycle reservoir.

Arm A (2-lane, controlled)

Arm B (1-lane, controlled, with island)

Arm C (1-lane, uncontrolled)

Arm D (1-lane, controlled, painted reservoir)

Figure 21 – Pedestrian trial, crossings at the junction: photos of crossings experienced by pedestrians

Puffin (LLCS side)

Puffin (pedestrian signal side)

Figure 22 – Pedestrian trial, Puffin crossing: photos of crossings experienced by pedestrians

Figure 23 shows where the pedestrians stepped into the road for the four approaches at the signal junction.

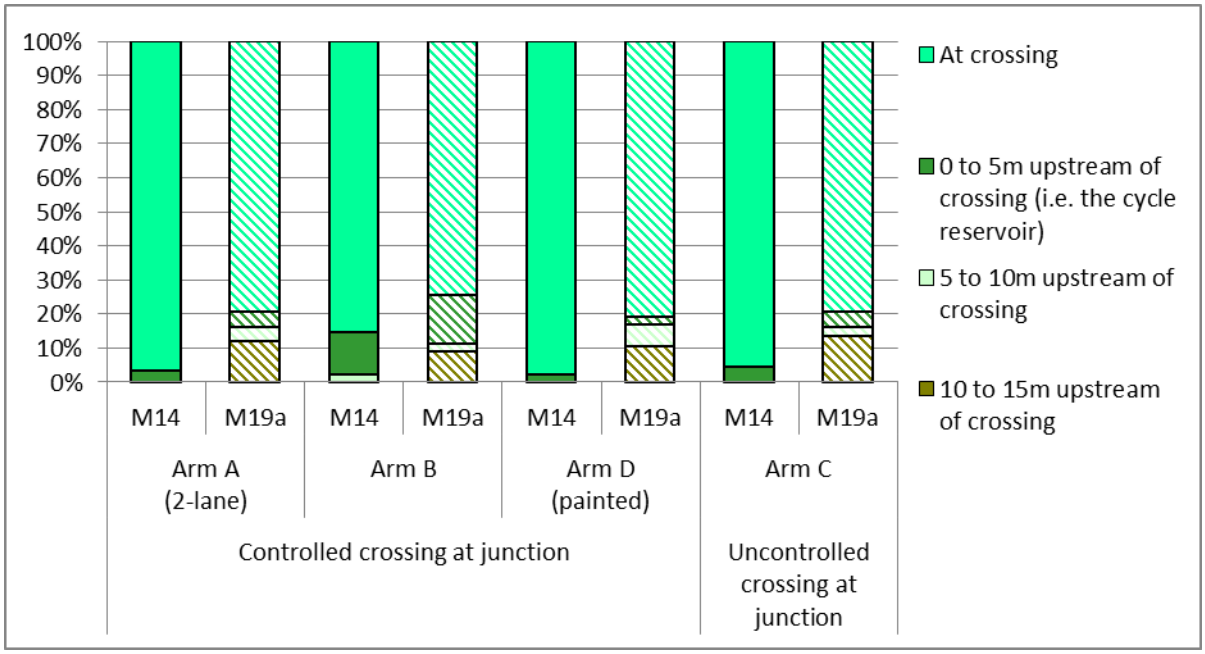

Figure 23 – Pedestrian trial, crossings at the junction: zone where pedestrians started to cross, by location of signals and crossing type (video data)

For the separate poles trial compared against the same pole trial, there were statistically significant increases in the proportion of observations where the pedestrian crossed before they reached the crossing. This was the case at all four arms of the junction: 3% to 21% on Arm A; 15% to 26% on Arm B; 2% to 19% on Arm D (the controlled crossings); and 4% to 21% on Arm C (the uncontrolled crossings). This proportion was highest on Arm B, which was the crossing with an island.

The Puffin crossing essentially served as a 'Control' experiment for the crossings at the junction, because the signals were still mounted on the same pole at this location. There was a small increase in the proportion of observations where the pedestrian crossed before they reached the signals, but this increase was not statistically significant.

Sample biases were investigated to determine whether this finding was a result of the location of the poles or due to differences in the sample in the two trials. There was no substantial difference in the age of the sample nor in their reported tendency to cross away from the crossing in real world conditions.

Figure 24 - An example of pedestrians crossing through the cycle reservoir

The analysis on where pedestrians started crossing was broken down by whether there was a cyclist present as the pedestrian passed the point 5m before the crossing. This

shows that the findings for the location where pedestrians started to cross were similar whether a cyclist was present or not. See Appendix C for further information.

3.7.1.2 Findings from the questionnaire and focus groups

In the M19a Trial significantly[9] more pedestrians said they crossed though the cycle reservoir and significantly[10] fewer said they crossed at the crossing point every time, compared with the M14 Trial; 28% of M19a pedestrians said they used the dedicated crossing (between the dotted lines) every time compared with 47% in the M14 Trial.

Most of the comments about why M14 and M19a pedestrians crossed away from the designated crossing point are similar, showing that in both trials pedestrians generally understood the road layout and that they chose to cross through the cycle reservoir but did so safely, such as when there were no cycles in the area:

> *"If the road is clear and entering the cycle zone is the quickest route then I would walk in the area." (Pedestrian M14)*

> *"I would walk in … [to the cycle reservoir] to cut the corner if there was no one waiting there or approaching and if the light was red." (Pedestrian M19a)*

However three M19a pedestrians (8%) did make comments which suggested that they did not intend to cross in the cycle reservoir and the junction layout contributed to their mistaken crossing position. *T*his finding *may be* the result of moving the main *signals further away from the junction, i.e. this may have led the pedestrians to believe that the area in which they could cross was larger than in the previous trial.*

> *"[I crossed in the cycle reservoir because I was] looking both ways, not down." (Pedestrian M19a)*

> *"[I always crossed in the cycle reservoir because the] road construction led one into using this part of the road." (Pedestrian M19a)*

Two focus group participants provided further explanations, saying that at Arm B they mistakenly crossed through the cycle reservoir from the central island:

> *"[You are aiming for] the raised island… [and afterwards] you do see the dotted bit for the pedestrian but because that is [not that obvious I crossed at the wrong point]." (Pedestrian M19a)*

> *"I genuinely thought I had crossed… [on the crossing]." (Pedestrian M19a)*

Focus group participants thought that the green tarmac would make it less likely that they would mistakenly walk into the cycle reservoir. One participant went on to say that a green cycle lane leading into the cycle reservoir would make it even more obvious.

3.7.2 When participants started crossing – compliance with Red Man

Findings from the video analysis show that for most crossing types, about a third of pedestrians waited for the Green Man, whereas about two-thirds crossed soon after they arrived, i.e. with the Red Man showing. See Appendix C for a more detailed analysis.

---

[9] $p<0.1$

[10] $p<0.1$

In the focus group the pedestrians suggested that the LLCS had little bearing on their decision when to cross.

F7.a. For the separate poles trial compared against the same pole trial, there were statistically significant increases in the proportion of observations where the pedestrian crossed before they reached the crossing. This was the case at all four arms of the junction:
Arm A: 3% to 21% (Controlled – one way road)
Arm B: 15% to 26% (Controlled with island)
Arm D: 2% to 19% (controlled – no island)
Arm C: 4% to 21% (uncontrolled crossing).

F7.b. The findings for the location where pedestrians started to cross were similar whether a cyclist was present or not.

F7.c. Of those pedestrians who crossed through the cycle reservoir, most understood the purpose of the cycle reservoir, although a small minority (8% of all participants) said they did not notice them when crossing and mistakenly crossed in the reservoir and said the junction layout and 'road construction' contributed to this.

F7.d. The focus group participants indicated that the LLCS had little effect on their decision when to cross (compliance with the Red Man).

Further information in Appendices C and D

3.8 Did the LLCS and new layout affect perceived safety?

Table 17 – Research questions on safety

Road user	Theme	Research question	Video	Q'naire
All road users	Trial experiences	Did people experience difficulties?	✗	✓
		What was the effect on the perceived safety?	✗	✓

3.8.1 How easy/safe did people perceive the junction to be?

3.8.1.1 Cyclists

When asked *"how easy is it for 'your mode' to use this type of junction compared with an ordinary junction with traffic signals?",* results were similar to the previous trial (M14) with about 90% of cyclists saying that the trial junction was either 'easier' or 'much easier' to use than an ordinary junction.

Comparing the safety of the trial junction with an ordinary junction, participants in the separate poles trial (M19a) gave similar answers to those in the same pole trial (M14). Results are shown in Figure 25. The majority of cyclists (about 90%) said the junction

was either 'safer' or 'much safer'. Significantly[11] more said it was 'much safer' in the separate poles trial (52%) compared with the same poles trial (26%).

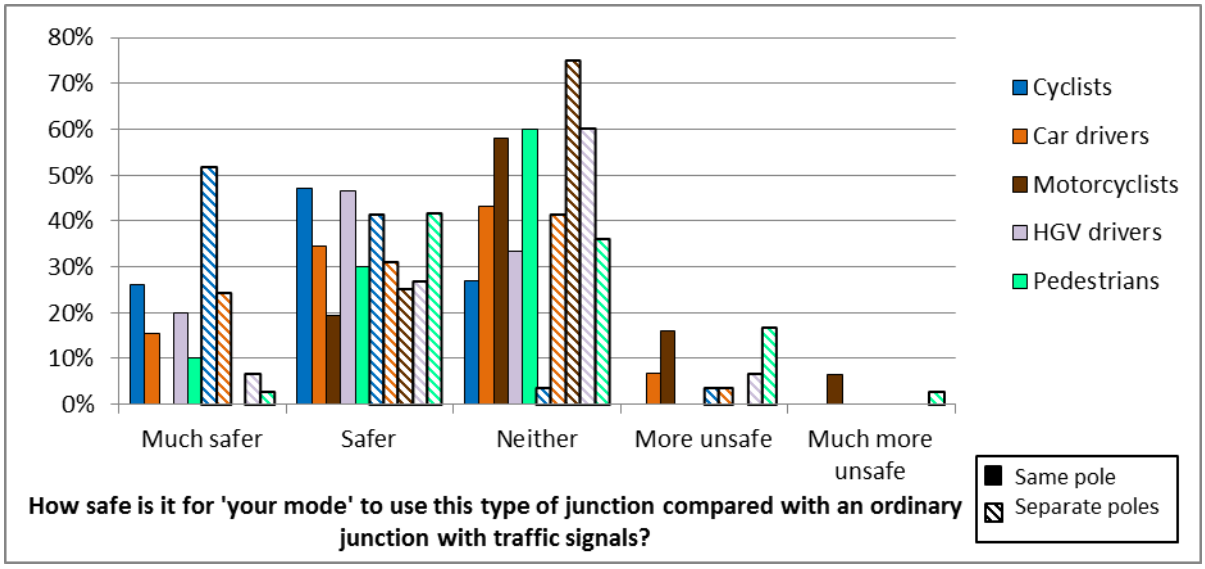

Figure 25 - Proportion of participants who thought the junction was safer or more unsafe compared with an ordinary junction (questionnaire)

In explaining their answers to this question about safety, the most common types of comment were positive comments related to cyclists being separated from traffic, more visible, and getting a head start at the lights. As in the previous trial (M14), some cyclists thought that the cycle signals would improve car driver and HGV driver awareness of cyclists.

Of those cyclists who commented on the LLCS in this trial (about 20%), all but one said that they felt 'safer' or 'much safer' when using this type of junction compared with an ordinary one. The most common comments in relation to safety were that cyclists are more likely to be able to see the traffic signals when LLCS are present, and abide by them.

> *"I feel it improves safety as it reduces the chance of a cyclist not being able to see the lights." (Cyclist M19a)*

> *"[This junction is] probably safer as you're less likely to go when you're not supposed to." (Cyclist M19a)*

The cyclist who thought the junction felt more unsafe than an ordinary junction was concerned that cyclists might be less aware of approaching traffic as a result of using the LLCS:

> *"If you are not so aware of approaching traffic they may try and cut across you." (Cyclist M19a)*

3.8.1.2 Car drivers, motorcyclists and HGV drivers

Overall, car drivers' perceptions were very similar in the M14 Trial and the M19a Trial. Just over half the car drivers (about 55%) said this type of junction was either 'safer' or

[11] $p<0.01$

'much safer' and 'easier' or 'much easier'. Only 10% of those who referred to the LLCS suggested that they made the junction feel 'safer' or 'much safer'. The majority of others thought that the junction felt 'neither safer nor more unsafe' and 'neither easier nor more difficult' to use than an ordinary junction.

Three quarters of the M19a motorcyclist participants perceived this type of junction to be 'neither' (safer nor more unsafe) than an ordinary junction. The other 25% thought that this type of junction was 'safer'. About 50% felt that this junction was 'neither easier nor more difficult to use'. This is about the same as in the M14 Trial.

Compared with the M14 Trial, more HGV drivers in the M19a Trial said this type of junction felt 'neither safer nor more unsafe' than an ordinary junction (60% compared with 33%). The same proportion felt the junction was 'neither easier nor more difficult' to use than an ordinary junction. Fewer M19a HGV drivers than in the M14 Trial said that this junction felt 'safer' (27% down from 47%).

A small minority (one car driver and one HGV driver) thought that the trial junction was 'more unsafe' than an ordinary junction because drivers either would not see the LLCS or they would mistakenly think the LLCS to be the same as traffic lights for motor vehicles.

3.8.1.3 Pedestrians

Six out of the 36 pedestrians (17%) thought that the trial junction in the separate poles trial was 'more difficult' to use compared with only one pedestrian (3%) in the same pole trial. This was a significant[12] increase. Pedestrians suggested that the LLCS were not easy to see when waiting to cross and that having more signals to look at makes it harder to know when to cross.

> *"They now have to wait for two lots of signals which increases the waiting time at crossings for pedestrians." (Pedestrian M19a)*

> *"Signals need to be all in same place e.g. Cyclists on post of traffic lights otherwise too many places as pedestrians to look at to assess to cross." (Pedestrian M19a)*

Significantly[13] more pedestrians indicated in the post-trial questionnaire that they thought this junction was 'more unsafe' or 'much more unsafe' (20% thought this compared with none of the pedestrians in the M14 Trial). These participants expressed concerns about cyclist-pedestrian collisions if the LLCS and pedestrian lights were not co-ordinated or pedestrians did not notice them. Other pedestrians were concerned that drivers may mistake the LLCS for their own signal.

> *"If the cycle signals are different to traffic signals but pedestrians have not noticed them, there could be a collision." (Pedestrian M19a)*

> *"Possibly more unsafe, as cyclists may set off quicker, catching out any pedestrians who are slower. It may cause collision." (Pedestrian M19a)*

[12] $p<0.1$

[13] $p<0.05$

Two pedestrians in the M19a Trial suggested that there is a lot of information for pedestrians to take in and the LLCS were not positioned well for pedestrians, making it unclear for pedestrians when it is safe to cross.

> *"The pedestrians need to look at the cycle signal to see what it says; green/red/amber before knowing if it is safe to cross the road and the signal is not positioned to make it easy for pedestrians to see from the safe area of the pavement at the crossing." (Pedestrian M19a)*

As discussed in Section 3.4.2, it was found that pedestrians tended to use as many visual clues as possible when deciding when to cross the road. As such, when moving the main signals to the first stop line, it seems that they felt this was one less clue they could use.

3.8.1.4 Findings from the focus groups

Most focus group cyclists suggested that they thought the LLCS were useful because they were easier to see, but that they did not provide a safety improvement. Almost all cyclists in the focus group agreed that the cycle reservoir made them feel safer as it gave them space to pull away without having motor traffic in close proximity.

> *"Good to get the wobble of the cyclists out the way before the cars come." (Cyclists FG M19a)*

These focus group cyclists suggested that they had not really noticed any effect in having the main signals at the back of the cycle reservoir; this may be because of the lack of traffic and the fact that the car drivers drove very considerately.

All of the focus group car drivers agreed that the combined layout of the cycle box and LLCS were a safer design for both drivers and cyclists. However, a small number of motorists in the car, motorcycle and HGV focus groups were concerned that this design would encourage cyclists to undertake vehicles to enter the box.

Four pedestrians in the focus group felt that the LLCS could make the junction slightly more unsafe for pedestrians. All of the pedestrian focus group participants (9 in total) were concerned about using the junction with an early release if they did not know about the early release. Some thought the early release could cause problems for safety as they would not be expecting cyclists to go when the cars were stopped:

> *"We cross when the traffic is halted, so if the traffic is stopped and then bikes started going [I] would not be expecting [that]." (Pedestrian FG M19a)*

> *"I might make a decision to cross… because the cars are stopped and suddenly, one microsecond later that cycle light has gone green and the cyclists are kicking off." (Pedestrian FG M19a)*

F8.a. The majority of cyclists (about 93%) perceived the junction to be 'safer' or 'much safer' than an ordinary junction.

F8.b. The majority of car drivers (about 95%) perceived the junction to be either 'safer', 'much safer' or no different and 'easier, 'much easier', or no different from an ordinary junction; however only 10% specifically mentioned the LLCS in terms of safety. In the focus group it was agreed that it was the combination of the cycle reservoir and the LLCS that made it feel safer.

F8.c. The majority of motorcyclists (75% and 54%) and HGV drivers (60%) perceived there to be no difference between the safety and ease of using the trial junction and an ordinary junction.

F8.d. Compared with the trial where the LLCS and main signals were on the same pole, significantly more pedestrians (20%) felt the junction was 'more unsafe' or 'much more unsafe', because of concerns that the LLCS were not positioned well for pedestrians, making it unclear when it is safe to cross.

Further information in Appendix D

4 Findings – M19b Trial: LLCS on separate poles with an early release

In Section 4, the specific research questions for each sub-section are similar to the equivalent sub-section in Section 3, although consider the combined effect of LLCS on separate poles to the main signals with an early release. The tables of research questions have therefore not been included at the start of each sub-section unless there were additional research questions.

4.1 Did people understand the LLCS with an early release and the new layout?

Similarly to the M18 Trial, the majority of cyclists showed an understanding of how to use the LLCS with an early release.

As in previous trials, the majority of participants understood that the LLCS were for cyclists on the road (91% of cyclists and 100% of car drivers). Those who did not say the LLCS were traffic signals for cyclists said they were 'normal traffic signals' which is also a safe interpretation.

One cyclist (who has never cycled regularly) said that they were not sure whether the cycle reservoir was meant for cyclists to stop in or was part of a Toucan crossing and therefore this participant said that they did not wait in the cycle reservoir during the trial:

> *"I was not sure if this was for cyclists to stop in or cyclists crossing." (Cyclist M19b)*

Another cyclist (who does not currently cycle) indicated that they were unsure whether they could stop in the cycle reservoir, so also avoided it.

> *"I was not sure that I had to be in this area so I avoided it." (Cyclist M19b)*

About 10% of cyclists suggested they were initially confused by the early release (compared with 2% in the M18 Trial), suggesting that they were not sure whether they could cycle through a main red signal when moving off[14].

> *"[It] took me a few times before I felt confident in pulling away, particularly when I was turning right through a red main light." (Cyclist M19b)*

> *"Unsure. I felt I still wanted to adhere to the main red signal. When cycle signal was green and main red I felt uncertain over driver reaction behind me." (Cyclist M19b)*

> *"A little confusing if you are using main traffic light too." (Cyclist M19b)*

[14] Cyclists could see that the secondary signals were red and some felt as though they were cycling through a red signal as a result.

F9.a. All cyclists and car drivers made a safe interpretation of the LLCS with an early release, saying they were either traffic signals for cyclists or normal traffic signals.

F9.b. Two cyclists, who said they did not currently cycle frequently, were confused by the purpose of the cycle reservoir and therefore did not use it.

F9.c. About 10% of cyclists were initially confused by the layout and the early release, commenting that they were not sure whether they could go through the main red signal. However, almost all participants indicated that they understood the signals and layout after a few passes through the junction.

4.2 Did people notice the early release and what did they think of it along with the new layout?

Table 18 – Research questions on the early release

Road user	Theme	Research question	Video	Q'naire
All road users	Trial experiences	Did they notice the early release?	✗	✓
		Did they notice the difference between shorter and longer early releases?	✗	✓
	Attitudes	What did they think about the early release?	✗	✓

The results in the M19b Trial were very similar to the M18 Trial, with 96% of cyclists and 98% of car drivers saying they noticed the early release for cyclists in this trial.

4.2.1 Views on the early release

Overall, the response was positive with over 80% of each road user group giving positive comments. Just under 15% of cyclists and 5% of car drivers gave negative comments when asked what they thought about the early release. These results are very similar to the previous 'early release' trial (M18).

The most common response from cyclists was that the LLCS gave cyclists a head start on the traffic behind, allowing them to build up speed, whilst car drivers generally agreed that the LLCS allowed them to anticipate the changing of the main signals (as in the M18 Trial). Two car drivers thought the early release meant cyclists had priority and five participants (cyclists and car drivers) thought the early release should have been longer.

There were some safety related comments, with a number of cyclists (eight) and car drivers (two) concerned that motorists would move off on a cycle green signal. This was an increase compared with the M18 Trial. Results are summarised in Figure 26[15].

[15] 112 cyclists and 57 car drivers provided comments.

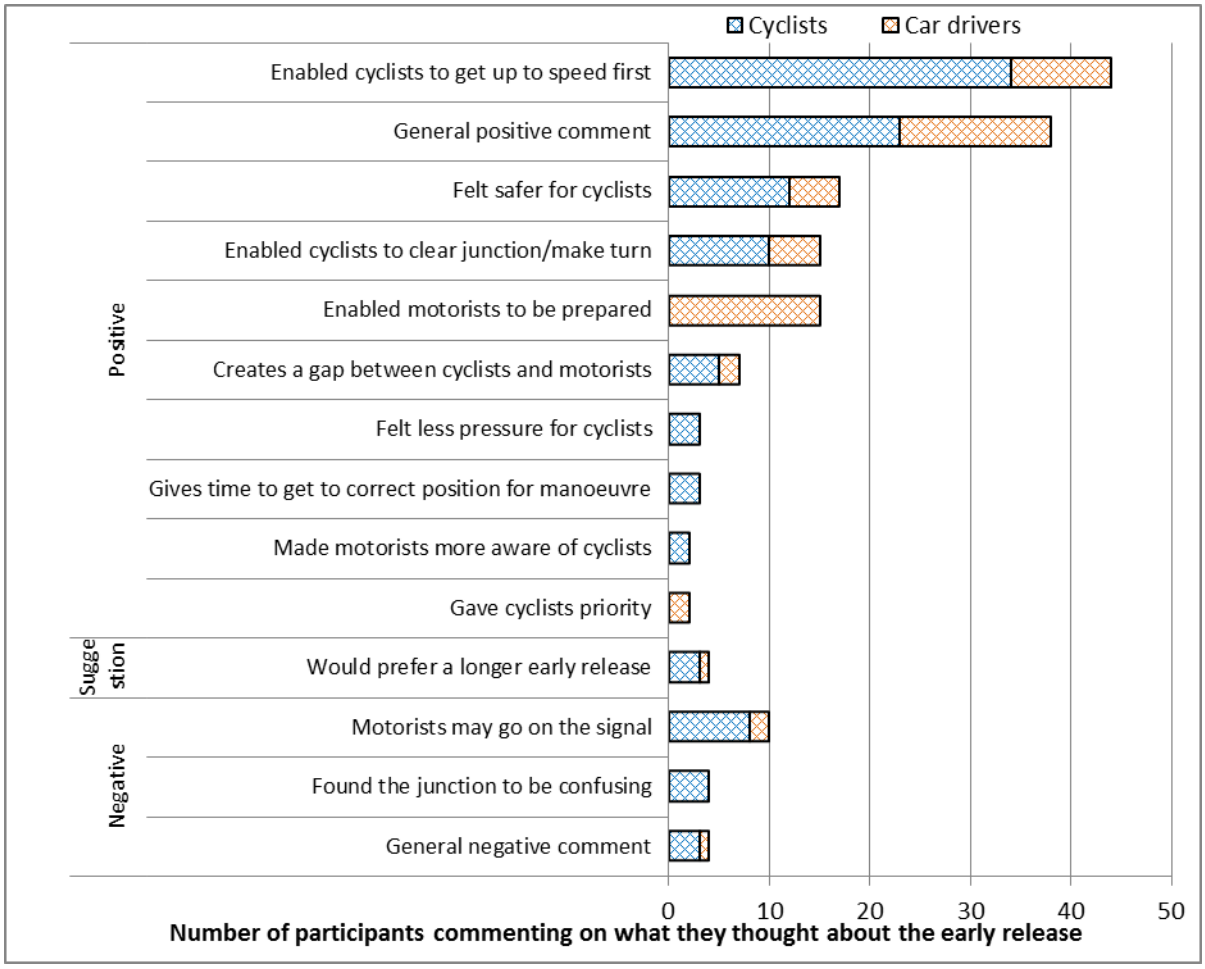

Figure 26 - Comments about the early release (questionnaire)[16]

4.2.1.1 Positive comments

Examples of the comments made in each of the 'positive' categories are listed below.

- Enabled cyclists to get up to speed first

  "Good. Gave cyclists time to pick up speed in front of car traffic." (Cyclist M19b)

- Felt safer for cyclists

  "I think this is a good idea, it allows the cyclist a light start over motorists which is safer especially if turning right or left." (Cyclist M19b)

- Enabled cyclists to clear the junction/ make a turn

  "It gave the cyclists a chance to make their turns ahead of cars allowing clearer vision for both cyclist and driver." (Car driver M19b)

- Enabled motorists to be prepared

  "Good idea it prepares you for a green on main signal." (Car driver M19b)

- Creates a gap between cyclists and motorists

[16] Excludes comments made by only one participant

"Good as it gives bikes separation from cars at junctions." (Cyclist M19b)

- Felt less pressure for cyclists

  "I thought it was a good idea as it takes the pressure off the cyclist, as I don't cycle often at all, knowing cars are waiting for me would put pressure on." (Cyclist M19b)

- Gives time to get into the correct position for a manoeuvre

  "Novel & allows a cyclist time to safely manoeuvre across & reposition." (Cyclist M19b)

- Made motorists more aware of cyclists

  "Good idea to get moving before traffic, so other vehicles can notice you." (Cyclist M19b)

- Gave cyclists priority

  "This [the early release] is what made me believe cycles have priority and have own traffic lights." (Car driver M19b)

4.2.1.2 Suggestions

Some suggested a longer early release; for example:

"Good idea, although time difference should be slightly longer." (Cyclist M19b)

4.2.1.3 Negative comments

Examples of the comments made in each of the 'negative' categories are listed below.

- Motorists may go on the signal

  "I'm not so sure of the idea. I felt as a driver you may go at the same time. You go when they go. I can see accidents here as it was on your eye level." (Car driver M19b)

- Found the junction to be confusing

  "Unsure. I felt I still wanted to adhere to the main red signal. When cycle signal was green and main red I felt uncertain over driver reaction behind me." (Cyclist M19b)

4.2.2 Noticing the early release

Significantly[17] more cyclists noticed that the early release was different between some sessions (36% up from 24%) than in the M18 Trial. Slightly fewer car drivers noticed the difference in the duration of the early release in the M19b Trial than in the M18 Trial (37% compared with 52%).

[17] $p<0.1$

4.2.3 Effect of the early release

About 20% of cyclists said that the difference between the longer and shorter early release affected the way they went through the junction. Of those who commented, most said that they felt safer and more at ease with the longer early release. One car driver out of the eight who said they were affected, said the shorter early release gave them less time to prepare for the main signals changing to green.

A number of participants (cyclists and car drivers) in the M19b Trial referred to the separate poles making it more obvious that there was a difference between timing of the LLCS and the main signals (the early release). Several said that it was a good idea to keep the LLCS separate as they thought car drivers were less likely to move off on a cycle early release green than if the signals were on the same pole when they might get confused.

> *"They need to be separated so that you do not get confused but near enough so that you can see what is happening overall." (Cyclist M19b)*
>
> *"Separate from main signal so doesn't interfere or confuse." (Car driver M19b)*
>
> *"They were quite clearly a separate function." (Car driver M19b)*
>
> *"Need to be in line with [the] cyclist stop [line], not vehicle stop line, so think [this] is correct. If [the LLCS were] below main signals [they] would not be lined up correctly and might be confused for a main signal repeater for vehicles." (Car driver M19b)*

4.2.4 Views on the separate poles

The majority of M19b Trial participants (68% of cyclists and 80% of car drivers) thought that the layout of the LLCS at the junction was 'about right'. This is a similar result to the M19a Trial. Those participants who responded 'about right' suggested that having the LLCS and the main signals on the same pole may be confusing, with drivers potentially moving off on the wrong signal.

Two cyclists said that the LLCS were too far away and they did not notice them at first. These participants commented that they initially thought the LLCS were pedestrian lights. The responses of these participants throughout the post-trial questionnaire suggest that they did understand that the LLCS were signals for cyclists on the road.

F10.a. Similar to the previous trial (M18), 96% of cyclists and 98% of car drivers noticed the early release.

F10.b. Over 80% in each road user group were positive about the early release with the most common reasons being 'enabled cyclists to get up to speed first' and 'enabled cyclists to clear the junction'.

F10.c. About 15% of cyclists and 5% of car drivers were negative about the early release with the most common reasons being 'Concern that motorists may go on the signal' and 'Found the junction to be confusing'. However results from the M18 Trial (same pole) suggest that motorists would not go on an early release.

F10.d. There was a statistically significant increase in the proportion of cyclists who said they noticed the difference between the shorter and longer early releases (37% compared with 25% in the trial where the signals were on the same pole).

F10.e. About 20% of cyclists said that the difference affected the way they went through the junction, with those who commented feeling safer and more at ease with a longer early release. Both cyclists and car drivers said that having the signals on separate poles made the early release more obvious.

F10.f. Similar to the trial with no early release, 68% of cyclists and 80% of car drivers thought that the layout of the LLCS was 'about right'.

Further information in Appendix E

4.3 What attitudes did people have towards the LLCS and new layout?

Results from the M19b Trial were similar to previous trials with about 80% of cyclists and car drivers stating that the LLCS were at about the right height. The remaining 20% generally said the LLCS would be better if they were higher.

When asked about the angle of the LLCS in the M19b Trial, just over 65% of cyclists and about 90% of car drivers thought this was about right. This is very similar to the M18 Trial and slightly more than the M19a Trial (about 60% of cyclists and 75% of car drivers answered 'about right'). Those cyclists who did not think the angle was 'about right', primarily thought that the LLCS should point more towards the road.

F11.a. 80% of cyclists and car drivers felt the LLCS were at about the right height whilst 65% of cyclists and 90% of car drivers thought the angle was 'about right'. This was similar to the separate poles trial with no early release.

Further information in Appendix E

4.4 Did the LLCS with an early release and new layout affect what people looked at?

4.4.1 Did people look at the LLCS?

4.4.1.1 Cyclists

Cyclists said they looked most at the LLCS. Significantly[18] more said they looked at the LLCS in the M19b Trial compared to the M19a Trial. Results were also very similar to the M18 Trial which suggests that this is related to the early release and not to the signals being located on separate poles.

Cyclists looked at the secondary signals significantly[19] less in the M19b Trial than in the M19a Trial for all manoeuvres (turning left, going straight ahead and turning right) and when approaching the junction; however once again results were similar to the M18 Trial suggesting the early release was a more important influence than putting the LLCS on separate poles. Results are summarised in Figure 27.

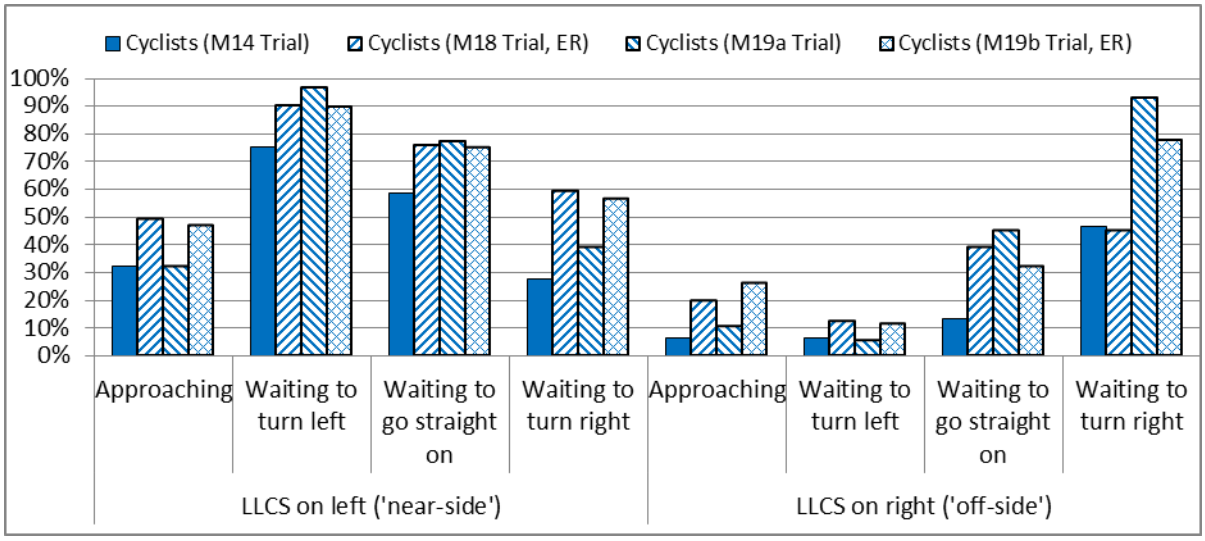

Figure 27 - Cycle trial: Proportion of cyclists who said they looked at the near-side or off-side LLCS (questionnaire)[20]

Significantly[21] more cyclists said they looked at the off-side LLCS when turning right when comparing the two 'early release' trials (78% in the M19a Trial compared with 52% in the M18 Trial). However, when comparing the two 'separate pole trials', significantly[22] fewer cyclists used them when there was an early release (78% in the M19b Trial compared with 93% in the M19a Trial). Therefore it is difficult to determine whether this result is related to the separate poles.

[18] LLCS on left: $p<0.01$, LLCS on right: $p<0.05$.

[19] Approaching: $p<0.1$; waiting to turn left: $p<0.001$; waiting to go straight on: $p<0.01$; waiting to turn right: $p<0.001$.

[20] (ER)= with early release

[21] $p<0.001$

[22] $p<0.1$

Cyclists reported looked significantly[23] less at the near-side main signals than did those in the M18 Trial; this is likely to be the result of the main signals being located behind the cycle reservoir where the cyclists usually waited.

4.4.1.2 Car drivers

Significantly[24] more car drivers in the M19b Trial reported that they looked at the near-side LLCS when stopped at the junction compared with those in the M19a Trial. However the results were similar to the M18 Trial, suggesting that this is due to the early release rather than putting the LLCS on separate poles. Results are summarised in Figure 28.

Compared with the M18 Trial, significantly[25] fewer car drivers in the M19b Trial said they looked at the near-side main signals and significantly[26] more said they looked at the secondary signals. This was similar to the findings in the M19a Trial, as discussed in Section 3.4.1.1. This may be due to the main signals being located further back from the junction and being more difficult to see from the first stop line, as discussed in Section 3.5.2.2.

The secondary signals were reported to be the most looked at cue when waiting to go straight on and to turn right. This differs from the previous trials when the off-side main signals were important when turning right.

A number of car drivers said they looked at the LLCS to understand what the cyclists were doing and to anticipate the main signals.

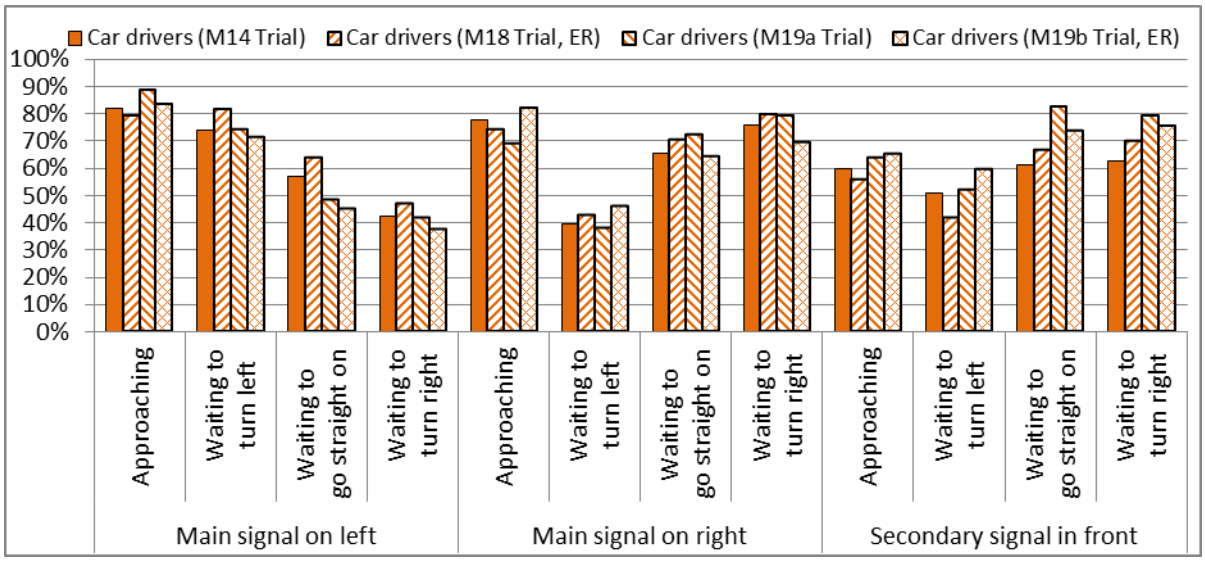

Figure 28 - Car trial: Proportion of car drivers who said they looked at the near-side main signals; off-side main signals and secondary signals (questionnaire)

[23] p<0.01 for turning left, going straight on, and for turning right.

[24] Waiting to turn left: p<0.01; waiting to go straight on: p<0.01; waiting to turn right: p<0.001.

[25] Waiting to turn left: p<0.1; waiting to go straight on: p<0.01; waiting to turn right: p<0.1.

[26] Approaching: p<0.05; waiting to turn left: p<0.01

4.4.2 Most important piece of information

In the M19b Trial, the LLCS were identified as the most important of the cues for at least half of cyclists, between 50% and 85% (depending on the manoeuvre) as shown in Figure 29. This was slightly higher than in the M18 Trial. Significantly[27] more cyclists said the LLCS were the most important piece of information in the M19b Trial compared with the M19a Trial, and also significantly[28] fewer rated the secondary signals as most important. Therefore we can conclude that the early release is the primary reason why cyclists looked at the LLCS, although having the LLCS on a separate pole to the main signals also had an additional but lesser effect.

The most important cues reported by the car drivers were the main signals and the secondary signals; however slightly more said the LLCS were the most important piece of information in the M19b Trial compared with the M19a Trial – presumably as a result of the early release.

There was a significant[29] increase in the proportion of car drivers who said the secondary signals were most important when comparing the M19b Trial and the M18 Trial; results were similar in the two 'separate pole' trials. In the M19b Trial, fewer car drivers said they thought the main signals were the most important cue than in the M18 Trial. This is likely to be associated with the position of the main signals being further back from the junction (behind the cycle reservoir).

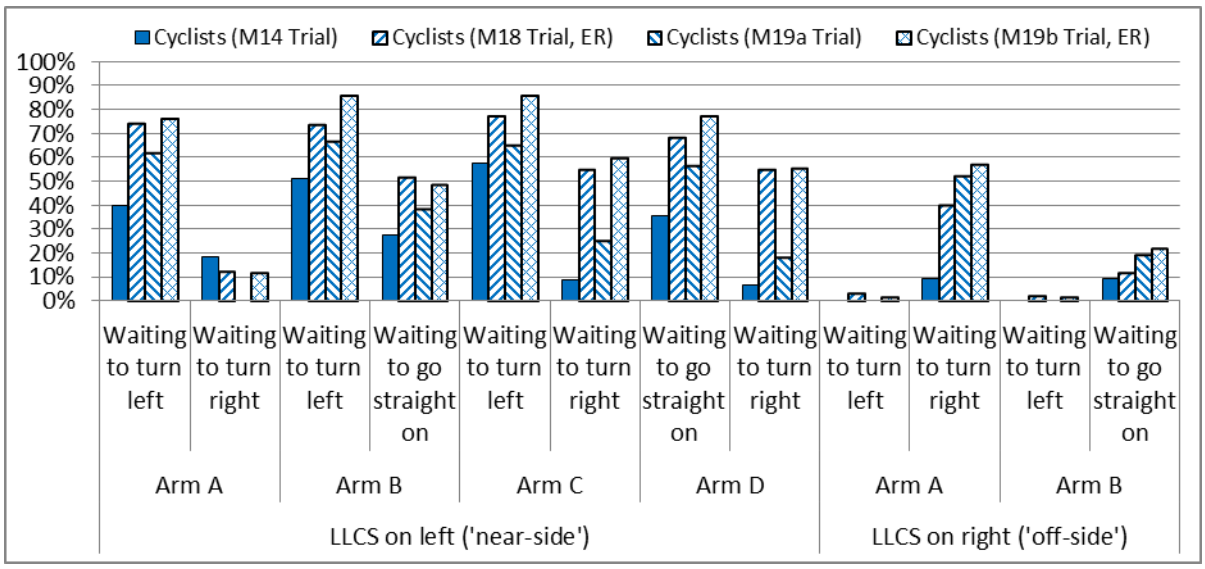

Figure 29 - Cycle trial: Proportion of cyclists who said they thought the LLCS were the most important piece of information (questionnaire)[30]

[27] Arm A, right turn: $p<0.1$; Arm B, left turn: $p<0.05$; Arm C, left turn: $p<0.05$; Arm C, right turn: $p<0.01$; Arm D, straight on: $p<0.05$; Arm D, right turn: $p<0.01$.

[28] Arm A, left turn: $p<0.01$; Arm A right turn: $p<0.01$; Arm B, left turn: $p<0.01$; Arm C, left turn: $p<0.001$; Arm C, right turn: $p<0.01$; Arm D, straight on: $p<0.01$.

[29] The five manoeuvres with significant results were: right turn at Arm A (35% compared with 4%); left turn at Arm B (22% compared with 0%); going straight on at Arm B (39% compared with 6%); left turn at Arm C (24% compared with 3%); and going straight on at Arm D (52% compared with 15%).

[30] (ER)= with early release

F12.a. The LLCS were the most important piece of information for between 50% and 85% of cyclists (depending on the manoeuvre). This was a result of the early release, although having the LLCS on a separate pole to the main signals also had an additional effect but to a lesser extent.

F12.b. Car drivers said they looked more at the near-side LLCS and less at the near-side main signals during the trials where an early release was experienced. They said they looked at the secondary signals more when the LLCS were on separate poles.

F12.c. The main and secondary signals were the most important piece of information to car drivers, with less than 25% saying the LLCS were the most important when the LLCS were located on separate poles.

Further information in Appendix E

4.5 Did the LLCS with an early release and new layout affect compliance: i) whether cyclists stopped at a red light; ii) where people waited?

Section 3.5 summarised the findings for compliance in the trials with no early release. The equivalent analysis is presented in this section for the trials with an early release.

4.5.1 Compliance with red signals

There were no consistent trends in the proportion of cyclists who went through the junction on a red signal in the different early release scenarios.

Of the few focus group participants (M19b) who stated that they do sometimes 'jump the lights', they suggested the facility would not alter their behaviour and if deemed safe they would continue to do so. It was also the opinion of the other participants that the facility would not change the mind-set of cyclists jumping lights.

4.5.2 Longitudinal stopping position

4.5.2.1 Cyclists

Findings from the video analysis

As discussed in Section 3.5.2.1, the behaviour of some cyclists changed as they became familiar with the layout. Table 19 shows the longitudinal stopping position of the cyclists for all the cycle trials. This is presented here only for the second and third sessions, excluding the first session.

Table 19 – Cycle trial: longitudinal stopping position relative to the cycle reservoir, by location of signals, early release and session (video data)

Session	Participant group	Junction layout	Early release	Before reservoir	Within reservoir	0-1m after reservoir	More than 1m after reservoir	Sample size
2nd and 3rd sessions	Participant cyclist (no car)	Same pole	No early release (M14)	0.4%	91.2%	8.4%	0.0%	239
			With early release (M18)	0.1%	91.6%	7.9%	0.4%	844
		Separate poles	No early release (M19a)	0.0%	96.9%	3.1%	0.0%	161
			With early release (M19b)	4.7%	92.4%	3.0%	0.0%	880
	Participant cyclist (car behind)	Same pole	No early release (M14)	0.5%	94.6%	5.0%	0.0%	221
			With early release (M18)	0.0%	92.8%	7.0%	0.1%	853
		Separate poles	No early release (M19a)	0.0%	96.4%	3.2%	0.5%	220
			With early release (M19b)	3.9%	91.7%	4.4%	0.1%	959

For the early release trials, excluding the first session, there was an increase in the proportion of observations where the cyclist stopped before the cycle reservoir in the separate poles trial (M19b), compared against the same pole trial (M18); this was from 0.1% to 4.7% in the scenario with no car and from 0% to 3.9% in the scenario with the car behind.

This result is likely due to differences in the sample between the two trials, rather than being as a result of the introduction of an early release. As discussed in Section 4.1, there were two cyclists who did not understand the reservoir and said that they did not stop in it at any point during the trial.

Findings from the questionnaire and focus groups

A number of cyclists in the M19b Trial commented on their stopping position during the trial. Although 60% of cyclists, when asked said that the LLCS did not affect where they stopped, those who commented said that they positioned themselves so that they could see the LLCS clearly. Common comments were that they stopped closer to the kerb or slightly further back in the cycle reservoir.

In the focus group, most cyclists also suggested that whilst waiting in the cycle reservoir, their location would vary depending on their desired destination. Some said that they would be more likely to wait on the side of the cycle reservoir that they were intending to travel. However, others said that they would wait on the near-side of the reservoir until the lights had changed and then would potentially move across the cycle reservoir if turning right.

4.5.2.2 Car drivers

In the separate poles trial with an early release there was a high level of compliance with the cycle reservoir with only 1.5% of non-compliant observations in both the scenarios with and without a controlled cyclist. This was a similar level of compliance to the separate poles trial with no early release (see Section 3.5.2.2) and also to the same pole trial with an early release. Due to the high level of compliance in the previous trials it was not possible to detect whether there was any additional effect due to the early release.

F13.a. There were no consistent trends in the proportion of cyclists who went through the junction on a red signal in the different early release scenarios between the same pole trial and the separate poles trial.

F13.b. Excluding the first session, there was an increase in the proportion of observations where the cyclist stopped before the cycle reservoir in the separate poles trial (M19b), compared against the same pole trial (M18); this was from 0.1% to 4.7% in the scenario with no car and from 0% to 3.9% in the scenario with the car behind. This was likely due to the sample rather than an effect of the early release: two cyclists said they didn't understand the reservoir and so didn't stop inside it.

F13.c. There was a very high level of compliance (98.5%) with the reservoir by car drivers, which was a similar level of compliance to previous trials.

4.6 Did the LLCS with an early release and new layout affect how people moved off as the signals changed to green?

4.6.1 Reaction Time

4.6.1.1 Findings from the video analysis

Figure 30 shows the proportion of observations where the car driver started moving before the main signals changed to red and amber.

In the separate poles trial compared against the same pole trial, for the scenario where there was a cyclist in front, there was a statistically significant decrease in the proportion of observations where the car started moving before the signals changed to red and amber; this was from 3.1% to 0.4% pooled across all early release scenarios. For the scenario with no cyclist, this proportion was 1.5% in the same pole trial and 1.1% in the separate poles trial, which was not a statistically significant difference.

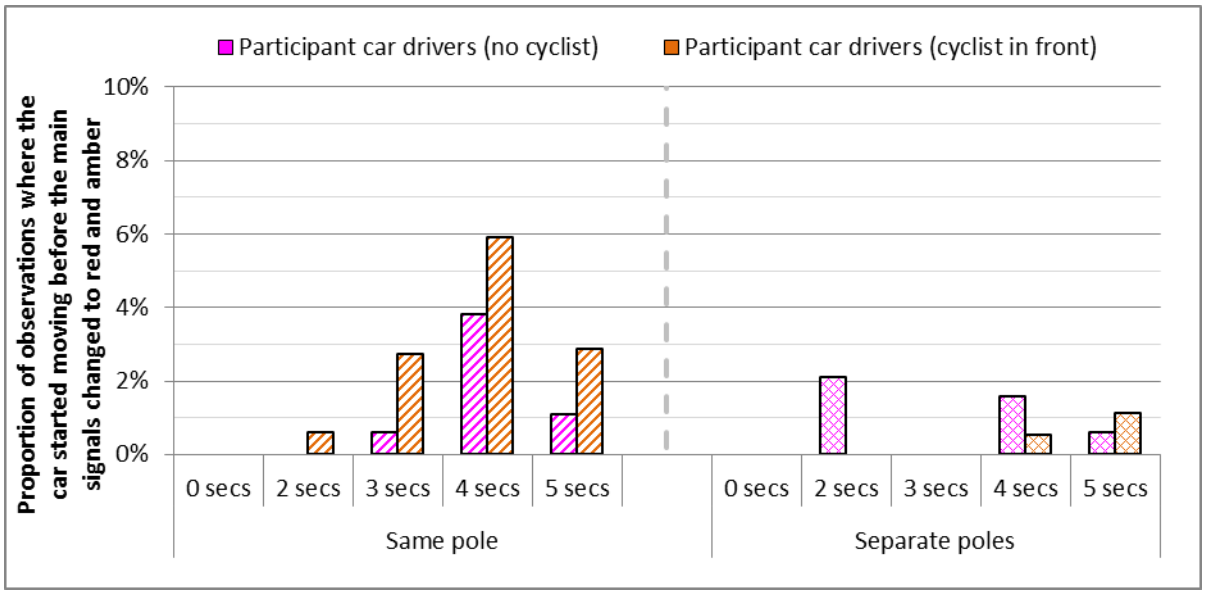

Figure 30 – Car trial: proportion of observations where the car started moving before the main signals changed to red and amber, by location of signals and early release (video data)

Figure 31 shows the average Reaction Time of the participants to the main signals in both the cycle trial and the car trial. The green line indicates when the signals turned to green (the LLCS for the cycle trial and the main signals for car trial). This shows that the average Reaction Times for cyclists were close to the time when the signals turned to green for each early release scenario. The average Reaction Times for the car drivers were around half a second slower in the separate poles trial compared to the same pole trial.

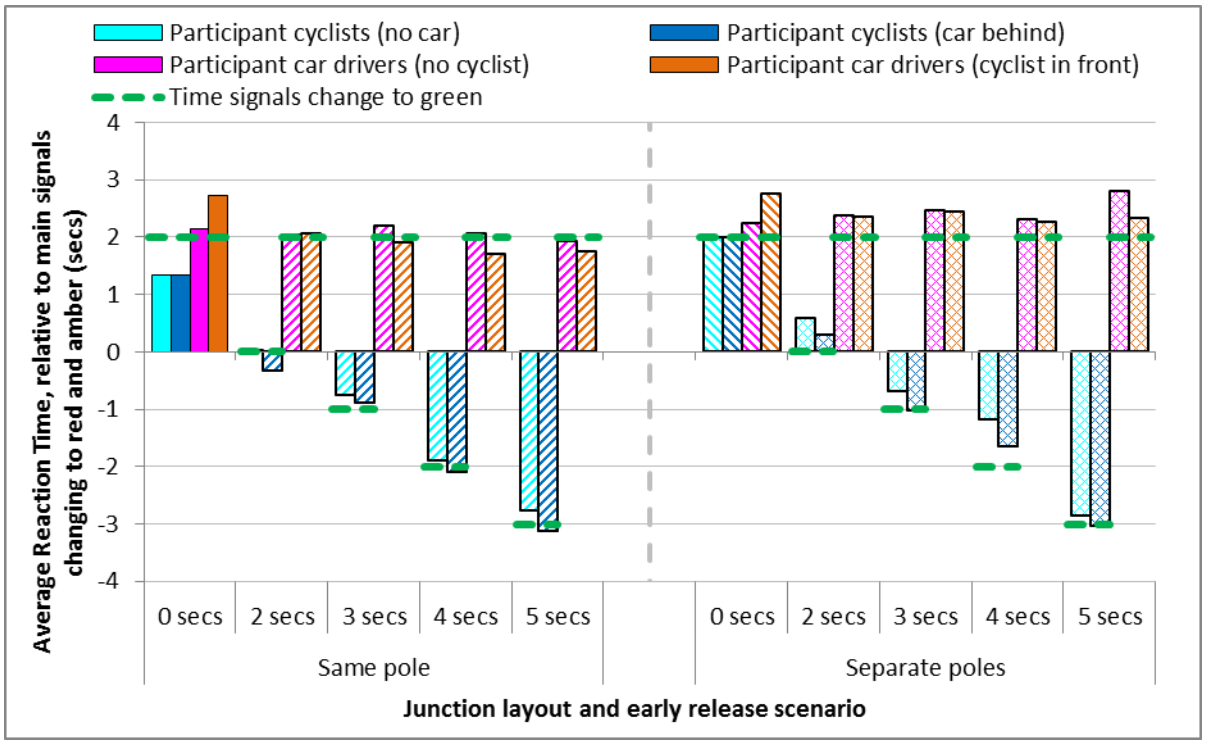

Figure 31 – Cycle trial and car trial: average Reaction Time of cyclists and car drivers, relative to the main signals changing to red and amber, by location of signals and early release (video data)

4.6.1.2 Findings from the questionnaire and focus groups

Cyclists

In the focus group, some cyclists suggested that because using the LLCS was a new concept for cyclists, a number continued to wait until the main lights were also green.

> *"[I] wasn't confident to go on the low level lights, [so] waited for the main lights to change too." (Cyclist FG M19b)*

Car drivers

In the questionnaire, car drivers were asked whether during normal driving they thought they would ever start moving into the junction when the LLCS were green and the main signal was red. Results are shown in Figure 32.

In the separate poles trial with an early release, 8% of car drivers said they would go on the early release and 14% of car drivers said 'it depends'. The results were similar in the same pole trial with an early release, although slightly more participants in this trial

responded 'yes' or 'it depends' (less than 5% said 'yes' and 10% said 'it depends' in the previous trial).

When comparing the M19a and M19b Trials (with and without an early release) there was more of a difference between the two, with none of the M19a participants suggesting they would start moving when the LLCS were green and the main signal was red and about 5% saying 'it depends'. This is likely to be due to participants in the early release trial being able to experience the hypothetical situation for themselves, possibly affecting their response.

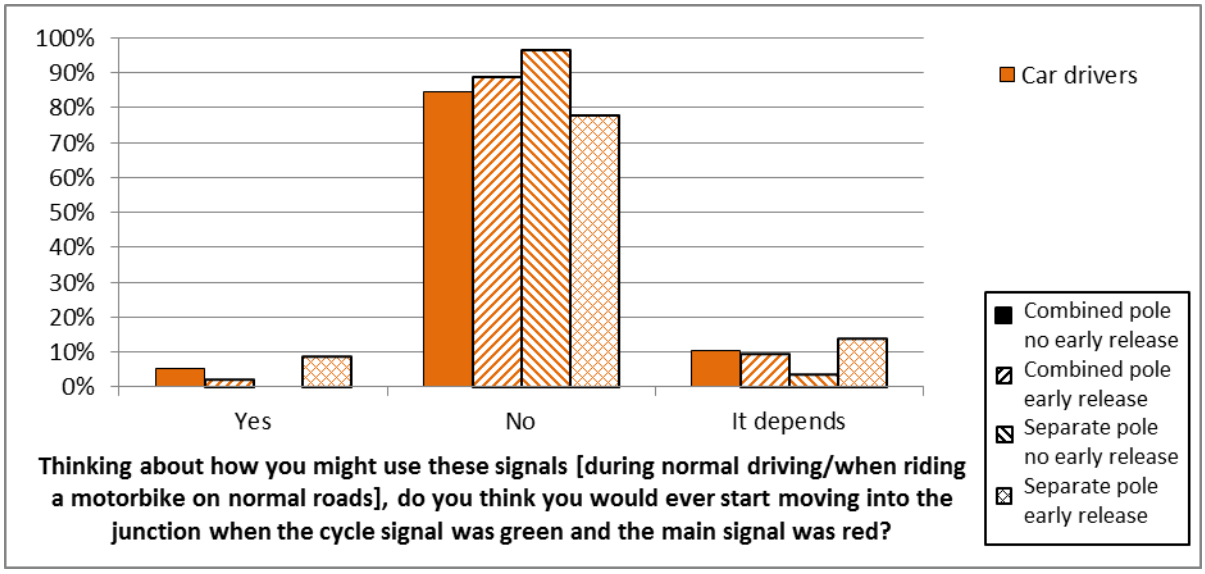

Figure 32 – Proportion of participants who said they would go on a cyclist early release in normal driving conditions, by location of signals and early release (questionnaire)

All those who said they would start moving early commented that this would be unintentional as a result of not paying full attention or being distracted by the early release for cyclists. These comments were similar to those provided in the 'same pole', early release trial (M18).

> *"It is in your eye line and when you see the cyclist go in front you may go too." (Car driver M19b)*
>
> *"I did it once today and when more relaxed i.e. [the] second run with cyclists. [This] could be a problem if [I was] tired or not fully concentrating." (Car driver M19b)*
>
> *"I accidently did it once during the trial as a lapse of concentration." (Car driver M19b)*

Of those who said 'it depends', three car drivers said they may go when the LLCS was green if there were no cyclists about:

> *"If [there were] no cyclist[s] about it should be safe to move off." (Car driver M19b)*
>
> *"I might be tempted to if the cycle box was empty and I knew the time before main signals go green." (Car driver M19b)*

The other five drivers suggested that they may move forward into the junction if they were anticipating the main signal turning green, or accidentally if they were not paying full attention.

4.6.2 Entry Time

Figure 33 shows the average Entry Time of the participants relative to the main signals in both the cycle trial and the car trial. The green line indicates when the signals turned to green (the LLCS for the cycle trial and the main signals for car trial). In this graph, observations have been excluded where the participant entered the junction while both the main signals and LLCS were on red.

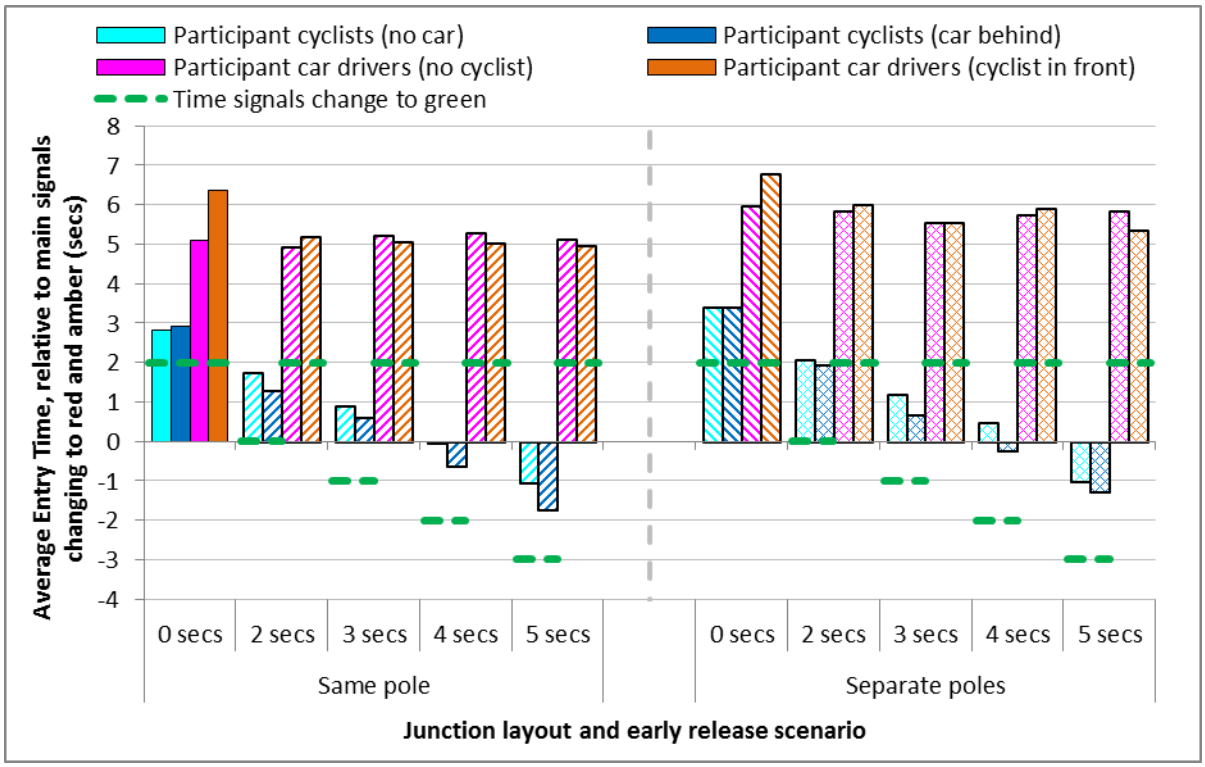

Figure 33 – Cycle trial and car trial: average Entry Time of cyclists and cars, relative to the start of the main signals, by location of signals and early release (video data)

Similar to the finding in the separate poles trial with no early release, the average Entry Times of the cars were about one second higher than in the separate poles trial compared to the same pole trial in each early release scenario. This may again be explained by the cars stopping further back in order to see the main signals as discussed in Section 3.5.2.2. Essentially, moving the main signals to the first stop line gave the cyclist an additional one-second gap on average to enter the junction ahead of the car.

An alternative measure of the time advantage that cyclists have is shown below. Figure 34 shows the average time that the controlled cyclist entered the junction before the car entered the junction. This measure is affected by any variations in the Entry Time of the controlled cyclists. Pooling the averages across all early release scenarios suggests that moving the main signals to the first stop line gives an additional time advantage to the cyclist of 0.2 seconds.

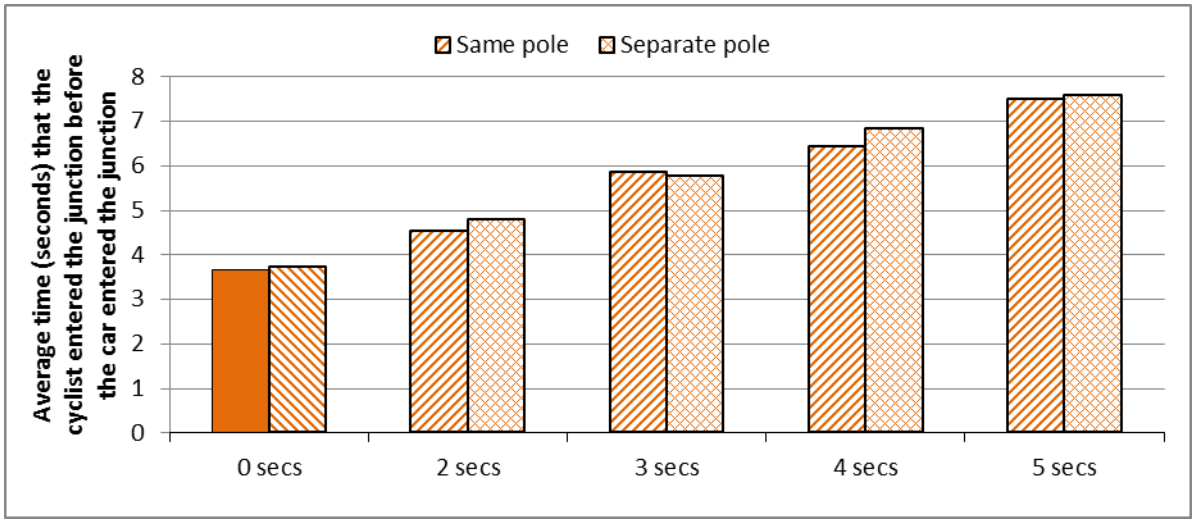

Figure 34 – Car trial: average time (seconds) that the controlled cyclist entered the junction before the car entered the junction, by location of signals and early release (video data)

Table 20 summarises the data in Figure 34 and also includes an average estimate of how far a cyclist would travel past the Junction Entrance[31] if turning left or going straight on. This estimate assumes a speed of 5.4m/s[32]; this is perhaps a high estimate, because cyclists may not be up to full speed by this point and also this would be likely lower if turning.

Table 20 – Car trial: estimate of distance (metres) cyclists would travel past the junction entrance by the time the car enters the junction

Early release	Location of signals	Average time (secs) that the cyclist entered the junction before the car entered the junction	Estimate of distance (metres) cyclists would travel past the junction entrance by the time the car enters the junction
0 secs	Same pole (M14)	3.67	19.8
	Separate poles (M19a)	3.73	20.1
2 secs	Same pole (M18)	4.53	24.5
	Separate poles (M19b)	4.79	25.9
3 secs	Same pole (M18)	5.83	31.5
	Separate poles (M19b)	5.75	31.1
4 secs	Same pole (M18)	6.42	34.7
	Separate poles (M19b)	6.82	36.8
5 secs	Same pole (M18)	7.48	40.4
	Separate poles (M19b)	7.57	40.9

[31] The 'Junction Entrance' is defined here as 'Timing Point 4', as shown in Figure 7 in Section 2.6.3.1.

[32] "The average speed of cyclists on a level surface is around 12 mph [=5.4m/s]", source: DfT guidance LTN2/08, §8.2.2

4.6.3 Right-turning behaviour of cyclists

4.6.3.1 Findings from the video analysis

Positioning the LLCS on a separate pole from the main signals did not affect the proportion of observations where the cyclist turned right in front of the oncoming car, compared to the 'same poles' trial.

Figure 35 - Example of a cyclist turning right in front of the oncoming vehicle

Similar to the findings in the trial with the LLCS on the same pole as the main signals (M18), in the 'separate poles' trial (M19b), a longer early release resulted in a larger proportion of observations where the cyclist turned right in front of the oncoming car; this was 24%, 52%, 46% and 71% for the 2, 3, 4 and 5 second early release scenarios, respectively.

Comparing the separate poles trial against the same poles trial, of those observations where the cyclist turned in front of the oncoming car, there was no difference in the number or severity of conflicts, nor in the time taken for the cyclists to pass the conflict point. There was a decrease in the average gap between the cyclists and cars, although this was likely due to the variability in the car driver behaviour and not due to the location of the signals.

4.6.3.2 Findings from the questionnaire and focus groups

When asked in the post-trial questionnaire whether they considered turning in front of the car, there were similar responses in the separate poles trial compared to the same poles trial; this suggests that the location of the poles did not significantly affect whether cyclists chose to turn in front of the car.

For those who did turn in front of the car, similar reasons were given to the same poles trial, with about a third saying that the car was far enough back to give the cyclists enough time to cross in front. About a fifth referred specifically to the early release, whereas about a fifth said that either they thought they had right of way or that they were not sure who had right of way at the junction.

F14.a. The separate poles resulted in a statistically significant decrease in cars moving before the starting amber, from 3.1% (same pole trials) to 0.3%, pooled across all early releases.

F14.b. Similar to the same pole trial with early release, in the separate poles trial with an early release, 8% of car drivers said that on normal roads they would go on an early release and 14% responded 'it depends' (compared with less than 5% and 10% respectively).

F14.c. The average Reaction Times for the car drivers were around half a second slower in the separate poles trial compared to the same pole trial.

F14.d. Moving the main signals to the first stop line gave the cyclist an additional one-second time advantage on average to enter the junction ahead of the car. This was similar for the different durations of the early release.

F14.e. Positioning the LLCS on a separate pole from the main signals did not affect the proportion of observations where the cyclist turned right in front of the oncoming car, compared to the 'same poles' trial.

F14.f. Similar to the findings in the trial with the LLCS on the same pole as the main signals, in the 'separate poles' trial a longer early release resulted in a larger proportion of observations where the cyclist turned right in front of the oncoming car; this was 24%, 52%, 46% and 71% for the 2, 3, 4 and 5 second early release scenarios, respectively.

Further information in Appendix C and Appendix E

4.7 Did the LLCS with an early release and new layout affect perceived safety?

4.7.1 How much time did people feel they had?

About 40% of cyclists said they felt they had plenty of time to get through the junction safely ahead of the car, similarly to the M18 Trial which also gave an early release. Slightly more cyclists felt they had 'just enough time' with the early release, than those in the M19a Trial without an early release. This finding is very similar to the previous trials, suggesting that cyclists feel they have more time to get through the junction when there is an early release. A number of cyclists commented that they would have preferred a longer early release.

4.7.2 How easy/safe did people perceive the junction to be?

4.7.2.1 Findings from the questionnaire

In the M19b Trial, similarly to the previous trials, 90% of cyclists felt that the junction used in the trial was either 'much easier' or 'easier' to use than an ordinary junction with traffic signals.

The same proportion of cyclists also thought that the junction felt 'much safer' or 'safer' to use. Of those cyclists in the M19b Trial who mentioned the LLCS in their comments, 63% specified the early start as the reason for the junction feeling safer. Three cyclists (10%) said that the junction felt 'more unsafe'. Those who said they felt it was more unsafe to use were concerned that cyclists would rely more on the LLCS and look less around the junction for themselves to check it was safe to proceed, and that motorists would not be aware of the early release.

When asked about the safety of the junction in the M19b trial, 3% of cyclists specifically mentioned the separate poles and of these, comments included: "a more secure area"; "clear signals"; "the signals were well laid out and designed"; "move the light onto the main pole".

The majority of car drivers in the M19b Trial felt that the trial junction was 'easier' or 'much easier' (63%) and 'safer' or 'much safer' (about 70%) to use. This was similar in the previous trials. Car drivers suggested that having the LLCS on separate poles made it clearer that they were for cyclists only.

There were 10% of car drivers in this trial who thought that the junction was more difficult compared with 2% in the previous early release trial (M18). This was a significant increase. One car driver suggested that the early release made it more difficult as it gives the potential for car drivers to move when the cycle signal is green but the main signal is still red. This driver also felt that the junction was 'more unsafe' to use as a result.

Others suggested that they had to be more cautious and aware as there were more signs and distractions for car drivers. There was some suggestion that the early release would be frustrating for motorists and could cause problems for motorists if there were large volumes of cyclists.

> *"It may create a lot of frustration for motorists (synchronisation is very important) different timings not good" (Car driver M19b)*
>
> *"There could be chaos at junctions if lots of cyclist were into the box when the lights changed, waiting for them to get going and turn. [It] would mean not many drivers would get through each time." (Car driver M19b)*

When asked about the safety of the junction in the M19b trial, 3% of car drivers specifically mentioned the separate poles and of these comments included that it "reinforces the zone" and that cars "must not enter the cyclist area".

4.7.2.2 Findings from the focus groups

Cyclists in the M19b focus group explained that they felt safer due to the extra time and space provided by the LLCS. This was based on the overall impression rather than a single element of the junction layout.

Reasons given by car drivers for this layout feeling safer, included the early start and positioning of the signals give more order to each road user's movements:

> *"…signals for all road users … gives added confidence." (Car driver, FG)*

As discussed in Section 2.3.4, cyclists always approached the junction on a red signal and ahead of cars; as such, the conflict when cyclists approach as the lights change to green along the inside of a car was not tested as part of this trial. Nevertheless some M19b car drivers in the focus group pointed out that in a real-world situation they might be less aware of cyclists approaching on the inside when the lights go green for them, as they would expect all cyclists to have already gone in the early release phase.

> *"[when I was pulling off I] wasn't looking at whether …[cyclists] were coming up on the left or right of me [I was only concerned with cyclists in the cycle reservoir] (Car driver, FG)*

F15.a. The majority of cyclists (about 90%) felt that the trial junction was 'easier' or 'much easier' and 'safer' or 'much safer' to use than an ordinary junction.

F15.b. 3% of cyclists felt that the junction was more difficult to use. There was concern from two cyclists that cyclists would begin to rely more on the LLCS and less on road sense.

F15.c. Of those cyclists who mentioned the LLCS, 63% specified the early release as the reason for the junction feeling safer (similar to the M18 Trial).

F15.d. The majority of car drivers (between 60% and 70% of car drivers) felt that the trial junction was 'easier' or 'much easier' and 'safer' or 'much safer' to use than an ordinary junction.

F15.e. There were 10% of car drivers who said the junction felt more difficult to use and one car driver (2%) said the junction felt more unsafe.

F15.f. Of those car drivers who mentioned the LLCS, about 40% said it was the early release that made them feel safer. One car driver said they felt less safe as there was the potential for car drivers to be distracted by the LLCS and move into the junction early.

F15.g. When asked about the safety of the junction in the M19b trial, 3% of cyclists and 3% of car drivers specifically mentioned the separate poles; most of these comments were positive to say that the layout of signals was clear and helped to reinforce the cycle reservoir.

Further information in Appendix E

5 Conclusions

5.1 Findings against each research question

Previous trials involved the LLCS and main signals being mounted on the same pole, both with no early release (trial code: 'M14') and with an early release (trial code: 'M18).

- Section 3 contains the findings from the trial with the signals on separate poles with no early release (trial code: 'M19a'), compared against the previous trial with no early release ('M14').
- Section 4 contains the findings from the trial with the signals on separate poles with an early release (trial code: 'M19b'), compared against the previous trial with an early release ('M18').

The key findings are summarised at the end of each sub-section in Sections 3 and 4. Each finding has an ID (e.g. "F1.a"), where the number relates to a corresponding research question in Table 7; these findings are referenced in this section below. These key findings are also summarised in a table in Appendix A.

5.2 How the findings relate to the study objectives

The main study objective was to gather evaluation evidence on LLCS mounted on separate poles to the main signals in the context of an application to the DfT for an experimental order for an on-street trial. This is assessed below for the new layout with and without an early release.

5.2.1 LLCS on separate poles without an early release (M19a)

The evidence from these trials (cyclists, car drivers, motorcyclists, HGV drivers and pedestrians) supports the progression to on-street trialling of LLCS mounted on separate poles to the main signals. The evidence suggests that the system would be well understood [F1.a, F1.c] and would not adversely affect perceived safety [F8.a]. There was no evidence to indicate that the height and angle of the LLCS should be different from those tested in this trial [F3.d]. Compared with the trial where the LLCS were on the same pole as the main signals, more cyclists said they looked at the LLCS and fewer said they looked at the main signals when waiting at the junction [F4.b]. More car drivers and motorcyclists said they looked at the secondary signals and fewer motorcyclists said they looked at the main signals when waiting at the junction [F4.c, F4.d]. The relative location of the main signals and LLCS could offer a benefit to cyclists through improved compliance of motorists with stopping before the cycle reservoir [F5.c, F5.d].

The only caveats are that as a result of the new layout, a small proportion of cyclists initially stopped before the first stop line [F5.e], there was an increase in the average Entry Time of cars [F6.d] and there was also an increase in pedestrians crossing upstream of the crossing [F7.a]. Other caveats from previous reports were also still valid, namely that a small proportion of pedestrians misinterpreted the meaning of the signals to be for cyclists crossing the road [F1.b].

5.2.2 LLCS on separate poles with an early release (M19b)

The evidence from these trials (cyclists and car drivers) supports the progression to on-street trialling of LLCS with an early release mounted on separate poles to the main signals. The findings were similar to the trials of LLCS with an early release on the same pole as the main signals; some differences were that more cyclists said they used LLCS [F12.a], more cyclists said they noticed the difference between the shorter and longer early releases [F10.d] and there were fewer observations where the car driver moved off on the early release [F14.a].

The caveats in Section 5.2.1 from the trial without an early release apply, as well as those from previous reports, in particular that with an early release a small proportion of cyclists thought they had right of way when turning right across oncoming traffic [F14.e, F14.f].

5.3 Considerations for an on-street trial

This section discusses areas for consideration when designing on-street trials of LLCS mounted on separate poles to the main signals. It should be re-iterated that these findings are based on a situation when there was only one participant stopped at the junction approach with a 5m cycle reservoir. Later trials will investigate the effect of the LLCS when there are groups of cyclists and different cycle reservoir depths ("M24").

5.3.1 LLCS on separate poles with no early release

5.3.1.1 Cyclists stopping before the first stop line

The separate poles trial had the main traffic signals at the first stop line and the LLCS at the second stop line.

There was a small increase in the proportion of observations where the cyclist initially waited before the cycle reservoir in the trial with the signals on separate poles. However, all of these observations were in the participants' first of three sessions. In the questionnaires and focus groups, some cyclists explained that they did not notice the reservoir on their first few passes through the junction and stopped before the reservoir, but once they realised it was there they all stopped in it. This suggests that it was not noticing rather than not understanding the layout that led to cyclists not using the cycle reservoirs on their first pass through the junction. There is no adverse risk associated with cyclists not understanding the layout immediately, rather just that they don't gain the benefit of the separate poles.

As discussed in Section 2.2.2, an alternative methodology with three options was planned in the event that a substantial proportion of cyclists stopped before the first stop line. The stopping behaviour of the cyclists was monitored during the first day of the separate poles trial and none of these options were required owing to the small proportion of cyclists who stopped before the reservoir. From a behavioural point of view, the track trials suggest that none of these options are required in an on-street trial. Also in the event that a small proportion of cyclists do stop before the reservoir, there is no safety risk, the only impact would be that they do not benefit from the cycle reservoir.

From a legislative point of view it is technically illegal for cyclists to pass the first stop line when the main signals are red. A further track trial has been undertaken in which

the LLCS with an early release are part of a 'standardised' junction design with a two-stage right turn (www.gov.uk 2013a); this includes a junction layout with an additional LLCS on the pole at the first stop line which is always on green to legally permit cyclists to pass the first stop line. This trial will assess to what extent this would pose a safety risk if it was to be used in an on-street trial; i.e. the possibility that cyclists might see the green LLCS at the first stop line, but not see the red LLCS at the second stop line and proceed through the junction on red.

5.3.1.2 Motorists stopping before the first stop line

The trials with the separate poles were associated with an improvement in compliance of motorists stopping before the stop line. In all trials the observed compliance with the reservoir was substantially higher than values that have been observed on-street in other studies; the absolute values of compliance would not be expected to be reproduced in the real world, but it is likely the direction of the change would. There was also anecdotal evidence that some motorists stopped further back from the stop line, in particular those who used the main traffic signals rather than the secondary signals or LLCS.

In the car trials, there was also a statistically significant increase in the average Entry Time of the cars; this was from 5.1 seconds in the same pole trial to 6.0 seconds in the separate poles trial in the scenario with no cyclist and from 6.4 seconds to 6.8 seconds in the scenario with a controlled cyclist in front. Given that there was no change in the average Reaction Time of car drivers between the same pole and separate poles trials, the increase in average Entry Time may be explained by the stopping position of the car.

It seems that the change in stopping position due to the main signals being moved to the first stop line resulted in an additional delay to the motorist in entering the junction of around 0.5 seconds when there was a cyclist in front and around 1.0 seconds when there was no cyclist in front. In the same poles trial in the scenario with a cyclist in front, in some cases the car caught up with the cyclist and so was delayed entering the junction; the delay due to stopping further back was additional to this, which explains why this additional delay is smaller in the scenario with a cyclist in front compared to the scenario with no cyclist.

5.3.1.3 Pedestrians crossing upstream of the crossing

For the separate poles trial compared against the same pole trial, there were statistically significant increases in the proportion of observations where the pedestrian crossed before they reached the crossing. This was the case at all four arms of the junction. In an on-street trial this element of pedestrian behaviour should be monitored.

5.3.1.4 Considerations raised in previous track trials

The following considerations remain valid from the trial where the LLCS were mounted on the same pole as the main signals with no early release (Ball et al. 2015a):

- *Misinterpretation of the LLCS to be a crossing for cyclists* – as in the previous trials, a small percentage (less than 5%) of participants (in this case, pedestrians, cyclists and HGV drivers) misinterpreted the LLCS as indicating where cyclists should cross the road, so they could have incorrectly judged that they had priority.

- The same consideration remains valid: *"There may be concerns if LLCS are to be installed on sites where there is an uncontrolled pedestrian crossing at the junction or there is a Toucan crossing. In these instances greater care would need to be taken in the design specific to each implementation. Public information and awareness campaigns associated with the introduction of LLCS on-street would also help to reduce potential misunderstandings of their purpose." (M14 Trial)*

5.3.2 LLCS on separate poles with an early release

5.3.2.1 Pedestrian crossing behaviour if there was an early release

In the trial with no early release, some pedestrians in the focus group said that because they could not see the LLCS, they were concerned that if there was an early release they might walk into the road when the main signals are on red but the LLCS are on green (F4.g). This might lead to conflicts between cyclists and pedestrians. In an on-street trial this element of pedestrian and cyclist behaviour should be monitored.

5.3.2.2 Considerations raised in previous track trials

The following considerations remain valid from the trial where the LLCS were mounted on the same pole as the main signals with an early release (Ball et al. 2015b):

- *Confusion caused by the early release* – About 10% of cyclists were initially confused and said they took a while to understand how to use the early release.
  - The same consideration remains valid: *"This is not a major concern, because it is a relatively small proportion and if a cyclist didn't understand the early release at first, it is likely they would wait until the main signals changed, which would not present a safety risk." (M18 Trial)*
- *Whether motorists go on the cycle signal early release* – There was evidence to suggest that fewer car drivers started moving on the early release compared to the trial where the LLCS were mounted on the same pole as the main signals. However, when asked about this as a hypothetical situation, more car drivers said they may move off unintentionally through lack of concentration.
  - The same consideration remains valid: *"In such instances, the cyclists would be moving into the junction falsely assuming that motorists are waiting for their later release, which may potentially introduce a conflict where cyclists would expect none to exist." (M18 Trial)*
- *Right-turning behaviour* – Similar to the findings in the trial with the LLCS on the same pole as the main signals, in the separate poles trial a longer early release resulted in a larger proportion of observations where the cyclist turned right in front of the oncoming car; this was 24%, 52%, 46% and 71% for the 2, 3, 4 and 5 second early release scenarios, respectively.
  - The same consideration remains valid: *"The results for right-turning cyclists in each of the early release scenarios are not directly transferable to the real world. When deciding on the length of early release if deployed on-street, it is recommended that as many of these other variables are taken into account, in particular the distances cyclists have to travel to*

pass the conflict point, relative to the time they have available. Other variables that can't be controlled should be monitored where appropriate, such as the actual entry times and stopping positions of cars. In an on-street trial it is recommended to monitor the extent to which cyclists turning right in front of oncoming cars leads to conflicts. The main concern is the small proportion of cyclists who mistakenly thought they had right of way; raising awareness through public information could help to address this issue." (M18 Trial)

- *Difficulties seeing the LLCS when turning right* – When turning right 17% of cyclists in the M19a Trial and 9% in the M19b Trial described the LLCS as difficult to see, because they were not able to see the junction and the signal at the same time.
    - The same consideration remains valid: "*This may explain why some cyclists suggested making the angle of the LLCS point more towards the road. However, it is recommended that the angle of the LLCS is not pointed more towards the road, because this would likely increase the risk of confusion with Toucan crossings… There is sufficient evidence to suggest that an additional off-side LLCS is considered useful by cyclists when turning right, but is not required when turning left or going straight on. As such, an additional off-side LLCS is not required where there is no right turn or a low flow of right-turning cyclists." (M18 Trial)*

References

(Allen et al. 2005)
Allen, D., Bygrave, S., & Harper, H. (2005) *Behaviour at Cycle Advanced Stop Lines* – (PPR240). Crowthorne: Transport Research Laboratory.

(Atkins 2005)
Advanced Stop Line Variations Research Study Research Findings. Atkins

(Ball et al. 2014)
Ball, S. D., Hopkin, J., Reeves, C., Gardner, R., Knight, P., & and York I (2014) *High level signals with a red cycle aspect, Track trial report* - (PPR715). Crowthorne: Transport Research Laboratory.

(Ball et al. 2015a)
Ball, S. D., Hopkin, J., Chesterton, V., Emmerson, P., Gardner, R., Kandasamy, G., Militzer, M., Knight, P., & York, I. (2015) *Low Level Cycle Signals used as repeaters of the main traffic signals, Track trial report* - (PPR732). Crowthorne: Transport Research Laboratory.

(Ball et al. 2015b)
Ball, S. D., Hopkin, J., Chesterton, V., Gardner, R., Smith, R., Kandasamy, G., Knight, P., & York, I. (2015) *Low Level Cycle Signals with an early release, Track trial report* - (PPR733). Crowthorne: Transport Research Laboratory.

(DfT 2003)
Traffic signs manual, Chapter 5, road markings. DfT

(TSRGD 2002)
Traffic Signs Regulations and General Directions

(assets.dft.gov.uk 2013)
Road Traffic Regulation Act 1984 – Sections 64 and 65, Special Directions. GT50/139/0092. DfT. http://assets.dft.gov.uk/trafficauths/case-3826.pdf

(www.gov.uk 2013a)
Press release. *Low-level lights are set to give cyclists improved, clearer signals*. Published 13/12/2013.
https://www.gov.uk/government/news/government-approves-low-level-lights-to-boost-cyclists-safety

(www.gov.uk 2013b)
Speech by Robert Goodwill MP. *Cycling networks fit for growth*. Published 06/12/2013.
https://www.gov.uk/government/speeches/cycling-networks-fit-for-growth