Transport Research Laboratory
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Low Level Cycle Signals with different cycle reservoir depths

Track trial report

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Disclaimer

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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 fourth 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 accompanied by three different cycle reservoir depths of 5m, 7.5m and 10m. 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.

Trials were conducted for two different road user groups over fifteen days, with a total of 1,290 participants: 1,117 cyclists (9 days) and 173 car drivers (6 days). In the cycle trial two group sizes were tested: a 'small group' of eight cyclists and a 'large group' of 16 cyclists. In the car trial, the data from a previous study was re-used as the baseline scenario of a 5m cycle reservoir, which involved 88 participant car drivers (3 days).

The main study objective was to gather evaluation evidence on different sizes of cycle reservoir for groups of cyclists and individual car drivers, specifically when combined with LLCS being mounted on separate poles to the main signals. The standard depth of ASLs is currently 4 to 5 metres, although orders have been granted for a small number of sites to have ASLs that are 7.5m deep and DfT's consultation update to the TSRGD (May 2014) includes 7.5m ASLs. Key findings are listed at the end of each sub-section and are referenced here in square brackets.

The average occupancy of the different reservoirs was found to be as follows:

- The average occupancy of the 5m reservoir was 8.0 cyclists when trialled with large groups (16 cyclists) and 6.5 cyclists when trialled with small groups (eight cyclists) [F6.a, F6.b].
- The average occupancy of the 7.5m reservoir was 13.0 cyclists when trialled with large groups (16 cyclists) [F6.b].
- The 10m reservoir was sufficiently large enough to hold at least 16 cyclists in almost all instances when trialled with large groups (16 cyclists) [F6.b].

These findings suggest that the following reservoir depths may be considered for a junction with a one-lane approach:

- A cycle reservoir between 5m and 7.5m deep when the required storage space is 8 to 13 cyclists.
- A cycle reservoir greater than 7.5m deep when the required storage space is 13 or more cyclists.
- A rule of thumb seems to be 1.7 cyclists per metre of reservoir depth for a one-lane approach.

Around half of the cyclists said that there were times when it was difficult or impossible to see the LLCS when waiting at the junction [F4.b]. This was greater with the larger groups (40%). The most common reason being that the LLCS was obscured by other cyclists [F4.c]. Of the cyclists who said it was difficult to see the LLCS and it affected how they went through the junction, over 40% said that they followed the cyclists in front, whereas a quarter said that they tried to reposition themselves so that they could see the LLCS [F4.d]. When asked specifically about the height of the LLCS, the most common response was "about right" (58%). Again the larger the group the more cyclists thought that the LLCS should be mounted higher (43-49% in the largest group) [F3.b]. These findings suggest that the height of the LLCS is about right, although could be mounted higher where large groups of cyclists are likely to be present.

Similar to the previous trials, the longer early releases encouraged a higher proportion of cyclists to turn right ahead of the oncoming car. For the small group of eight cyclists, the average number of cyclists who turned right ahead of the oncoming car ranged from 1.3 with the 2-second early release up to 5.6 with the 5-second early release. For the large group of 16 cyclists, this ranged from 1.6 with the 2-second early release up to 8.6 with the 5-second early release [F8.b].

It was also found that in the scenarios with the deeper cycle reservoirs there was a higher average number of cyclists who turned right ahead of the oncoming car [F8.c]. This might be explained by the car on the opposing approach being set back further from the junction, resulting in a larger gap in which more cyclists could turn.

The findings indicate that most of the cyclists who undertook the right turn movement in front of the oncoming car made a judgement to undertake this movement safely based on the junction layout, amount of early release and time required to clear the junction. However, there is evidence to suggest that some cyclists made this judgement based on the behaviour of the other cyclists in front, whereas a minority expected the car to wait for them [F8.e, F8.f].

Car drivers understood the different sized reservoirs equally well [F10.a] and the majority of car drivers thought that the size of the cycle reservoir they experienced was 'about right' [F11.a]. Common comments were that the size of the reservoir should be based on the location and volume of cyclists using the junction and that there is a need to strike a balance between space for cyclists and motor vehicles [F11.b]. The trials with the deeper cycle reservoirs were associated with a small decrease in compliance [F14.a], although the majority of encroachment was only up to 1.25m past the first stop line [F14.b]. Over half of the car drivers stopped more than 2.5m before the first stop line for the 7.5m and 10m reservoir depths, suggesting that a substantial proportion of car drivers stopped quite far back from the stop line, possibly in order to see the main signals that were located on the separate poles at the first stop line [F14.c].

When the reservoirs were 7.5m or 10m, the car drivers were more likely to start moving on the LLCS early release, compared to the 5m reservoir [F15.a]. Thus, the average Reaction Times for the car drivers were typically around half a second faster in the trials with the deeper reservoirs, compared to the trial with the 5m reservoir [F15.b].

The average Entry Time was highest in the scenario with no early release and a cyclist in front, suggesting that the car driver often had to wait for the cyclist before entering the junction.

For the scenarios with no early release and no cyclist present, the average Entry Time increased by about 0.2 seconds for each additional 2.5m of reservoir [F15.d]. For the trials with an early release, the 7.5m reservoir resulted in a small increase of about 0.1 seconds to the average Entry Time, whereas the 10m reservoir resulted in an increase of about 0.6 seconds, compared against the 5m reservoir [F15.e].

1 Introduction

This report summarises the results from the fourth 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 accompanied by three different cycle reservoir depths of 5m, 7.5m and 10m. 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 nine key research questions for the cycle trial.
- Section 4 presents the findings to six key research questions for the car trial.
- 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.

(light blue)	Small groups of cyclists (8)	(red)	Red
(dark blue)	Large groups of cyclists (16)	(red/amber)	Red & Amber
(orange)	Car drivers	(green)	Green

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.

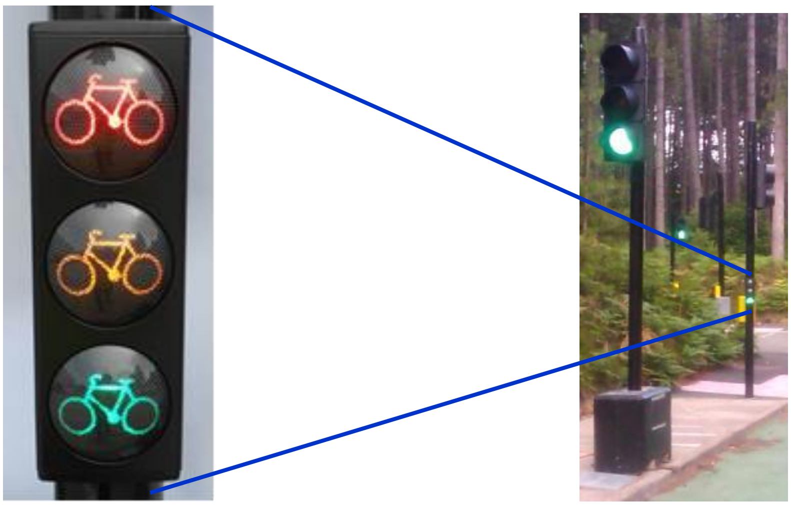


Figure 1 – Low Level Cycle Signals

The scope of this report (trial code 'M24') is to present the findings from the fourth of four sub-trials, assessing the impact of the LLCS by comparing scenarios where the LLCS were on separate poles from the main signals, with different depths of cycle reservoir, using earlier trials as a baseline.

Table 2 shows how the scope of this trial compared with the three other LLCS trials in the programme in which the LLCS either: provided no early release and were either covered or uncovered ('M14'); had an early release ('M18'); or were mounted on separate poles to main signals ('M19'). 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 this report (bold) and relation to other trials (italics)

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; previous research into compliance of vehicles with ASLs; and LLCS in other countries.

1.2.1.1 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). The consultation update to the TSRGD also includes 7.5m ASLs (DfT 2014).

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.

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

A track trial study was undertaken by TRL to assess the impacts of Low Level Cycle Signals on a separate pole to the main traffic signals (Ball et al. 2015c). As of March 2014, there were no on-street trials in the UK of LLCS mounted in this way.

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.

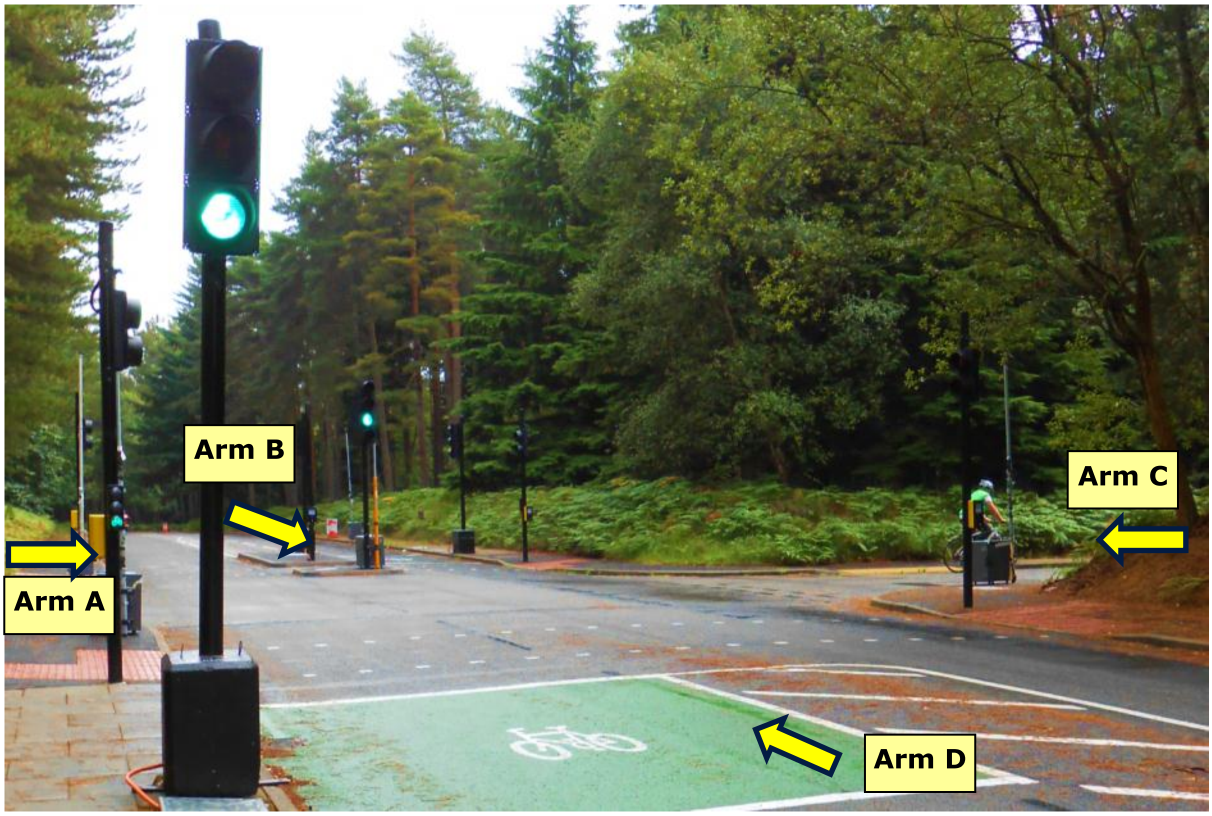


Figure 2 – Trial site

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 Size of the cycle reservoir

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, three cycle reservoir depths were trialled of 5m, 7.5m and 10m as shown in Figure 3.

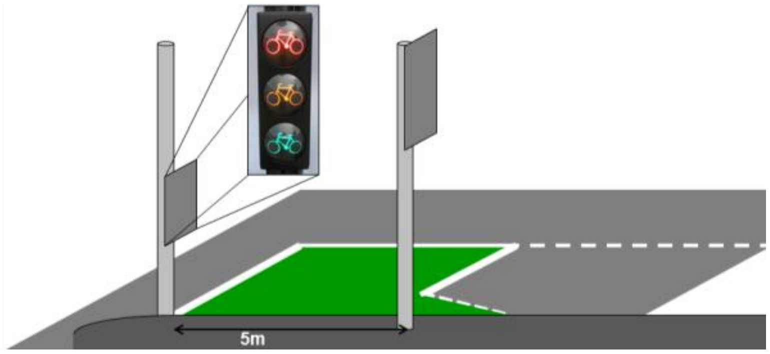
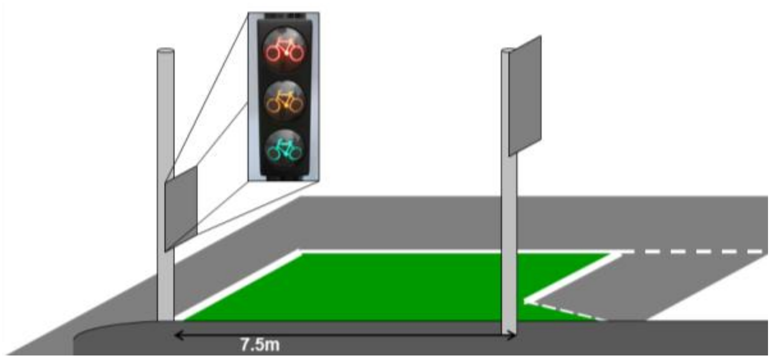
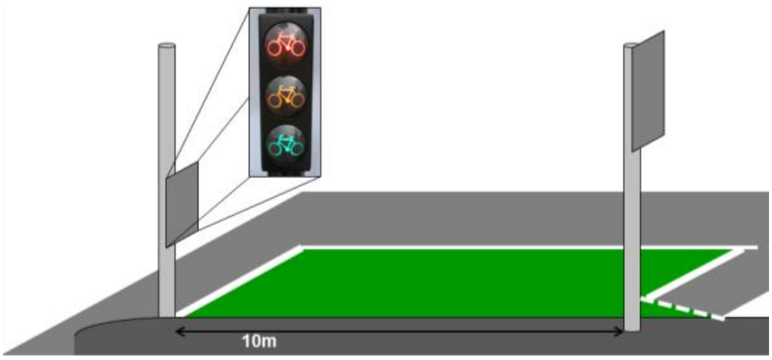
5m reservoir	
7.5m reservoir	
10m reservoir	

Figure 3 – "Control", 5m cycle reservoir and "treatment", 7.5m reservoir and 10m reservoir

2.2.2 Location of the LLCS and the main signals

For each of the cycle reservoir depths, the main traffic signals were mounted on a pole at the first stop line and the LLCS were mounted on a separate pole at the second stop line. The terminology 'cycle reservoir' is used rather than 'Advanced Stop Line (ASL)', because the main traffic signals are located at the first stop line rather than the second, cyclists', stop line as would be the case for a normal ASL.

2.2.3 LLCS with an early release

Trials were conducted both with and without an 'early release' for the LLCS. Similar to the previous trials, early releases of 2, 3, 4 and 5 seconds were all trialled.

2.2.4 Junction layout

A description of the junction layout and placement of the LLCS and other signals is shown in Figure 4 and Table 3 and a scale drawing of the junction is shown in Figure 5.

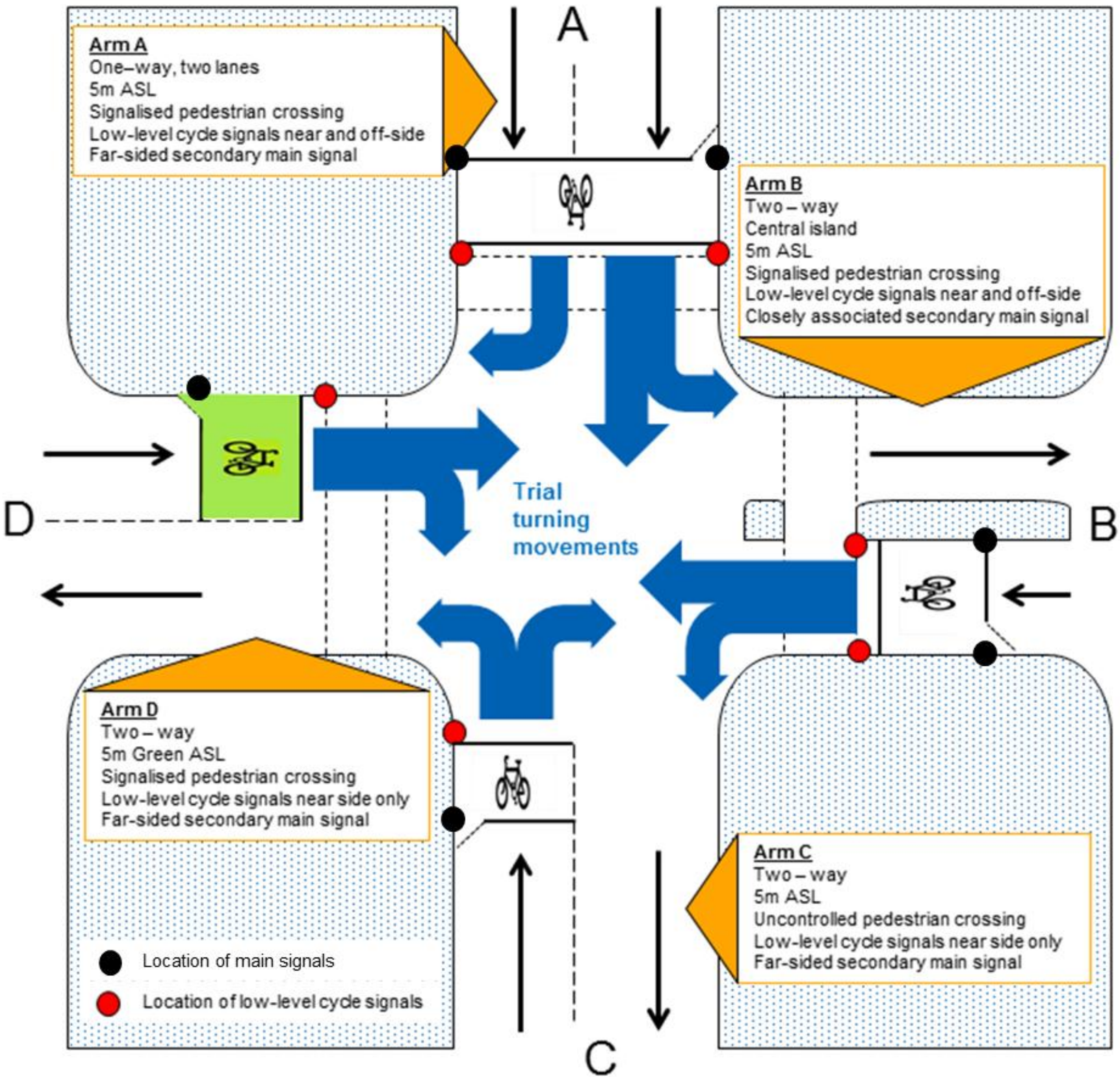


Figure 4 – Junction layout description

Table 3 – 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

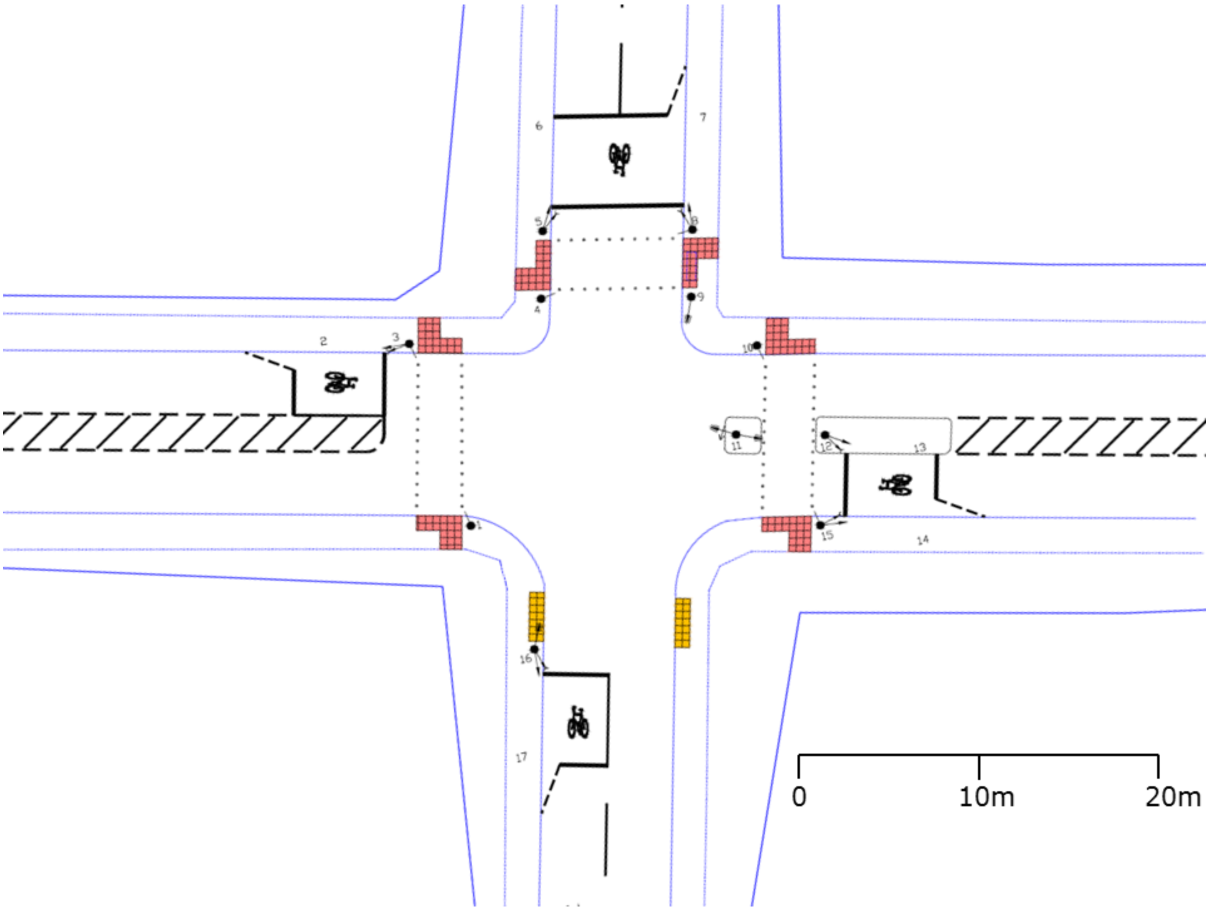


Figure 5 – Junction layout, scale drawing

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. There was a slight incline from Arm D up to Arm B.

2.3 Other variables

2.3.1 Participant types and trial days

Trials were conducted for two different road user groups over fifteen days, with a total of 1,290 participants: 1,117 cyclists (9 days) and 173 car drivers (6 days). The number of days of trialling was determined by the target sample sizes of 30 independent observations; see Appendix B for the sample size collected. As discussed in Section 1.1, for the car trial, the results from the 'M19' trial were re-used as the baseline scenario of a 5m cycle reservoir, which involved 88 participant car drivers (3 days).

In the cycle trial two group sizes were tested: a 'small group' of eight cyclists and a 'large group' of 16 cyclists.

The graphs in this report use patterns to distinguish between the different trial scenarios as shown in Table 4.

Table 4 – "Control": LLCS on separate poles with 5m cycle reservoir and "Treatment": LLCS on separate poles with 7.5m and 10m cycle reservoirs

Section of report with findings	5m cycle reservoir	7.5m cycle reservoir	10m cycle reservoir
Section 3	Small group of cyclists, with and without early release Large group of cyclists, with and without early release	Small group of cyclists, with and without early release Large group of cyclists, with and without early release	Small group of cyclists, with and without early release Large group of cyclists, with and without early release
Section 4	Car driver, no early release Car driver, with early release	Car driver, no early release Car driver, with early release	Car driver, no early release Car driver, with early release

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 5 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.

Table 5 – Controlled vehicles used in each of the trials

	Cycle trial	Car trial
No other vehicles	✗	✓
With controlled cyclist	✗	✓
With controlled car	✓	✗

In the cycle trial participants encountered the junction with a controlled car, see Figure 6. In the car trial participants encountered the junction both with and without a controlled cyclist.

Figure 6 - Cycle trial: groups of cyclists going straight on with controlled cars behind

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). In the cycle trial straight on movements were included from Arm A, Arm B and Arm D, because this is typically the most common movement where there are high cycle flows, e.g. on London's Cycle Super Highways. A right turn was also included from Arm D across the path of an oncoming car from Arm B. In the car trial, seven turning movements were included, excluding left turn and straight on movements from Arm A.

2.3.4 Release times

Participants were released at timed intervals so that they were always faced with a red signal when arriving at the junction. The cyclists always approached the junction ahead of the car, with the cyclists being released first and the car being released shortly after.

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. Participants would undertake the trial in three 'sessions' of approximately 30 to 40 minutes.

In the cycle trial, participants were assigned to be in either a small or large group and remained in the same group for the whole day. The schedule was designed so that cyclists would experience the junction with no early release in one session, with a short duration early release in another session and a long duration early release in another session.

In the car trial, on some days there was no early release (similar to the 'M14' and 'M19a' trials) and on some days there was an early release (similar to the 'M18' and 'M19b' trials). The schedule was designed so that car drivers would experience the junction with a controlled cyclist in some sessions and with no other vehicles in other sessions.

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 numbered routes, which continually looped them through the junction and back to a different start point. The routes from the cycle trial are shown in Figure 7. Routes from the car trial are shown in Appendix B.

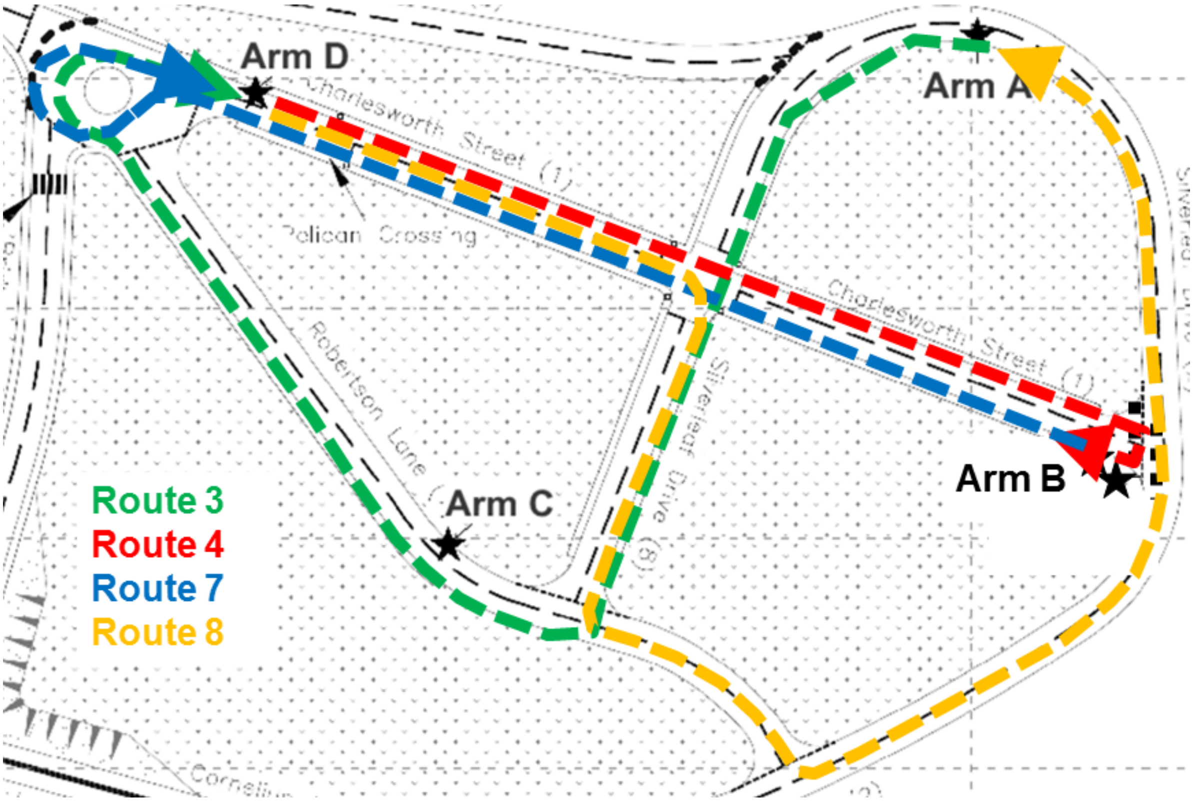


Figure 7 – Cycle trial: routes through the junction and to next starting point

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 different sizes of cycle reservoir for groups of cyclists and individual car drivers, specifically when combined with LLCS being mounted on separate poles to the main signals. As discussed, in Section 1.2.1.1, the standard depth of ASLs is currently 4 to 5 metres, although orders have been granted for a small number of sites to have ASLs that are 7.5m deep and the consultation update to the TSRGD includes 7.5m ASLs. Several specific research questions were set, which instructed the design of the trial and the analysis as listed in Table 6.

Table 6 – List of research questions

Section 3 – Groups of cyclists and LLCS with different cycle reservoir depths	Section 4 – Car drivers and LLCS with different cycle reservoir depths
1. Did cyclists understand the LLCS and cycle reservoirs?	10. Did car drivers understand the LLCS and cycle reservoirs?
2. What attitudes did cyclists have towards the cycle reservoirs?	11. What attitudes did car drivers have towards the cycle reservoirs?
3. What attitudes did cyclists have towards the LLCS?	12. What attitudes did car drivers have towards the LLCS?
4. What information did cyclists use at the junction?	13. What information did car drivers use at the junction?
5. Did the LLCS and cycle reservoirs affect whether cyclists stopped at a red light?	
6. How did the different cycle reservoir depths affect where cyclists waited?	14. How did the different cycle reservoir depths affect where car drivers waited?
7. Did the LLCS and cycle reservoirs affect how cyclists moved off as the signals changed to green?	15. Did the LLCS and cycle reservoirs affect how car drivers moved off as the signals changed to green?
8. Did the LLCS and cycle reservoirs affect whether right-turning cyclists turned in front of oncoming cars?	
9. What did the cyclists think about the effect on safety of the LLCS and cycle reservoirs?	

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 participants who took part in the trial completed a questionnaire; see Section 2.3.1 for the number of participants in each road user group. In the cycle trial some participants had taken part in a previous LLCS trial; rather than the full questionnaire these completed a short questionnaire with only classification questions. Because of the large number of participants, some cyclists only completed a 'medium' questionnaire, which didn't include questions on which visual cues they used at the junction.

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 five focus groups were conducted for the two road user groups, with three for the cyclists (5m, 7.5m and 10m reservoirs) and two for the car drivers (7.5m and 10m reservoirs).

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 8.

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

- 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

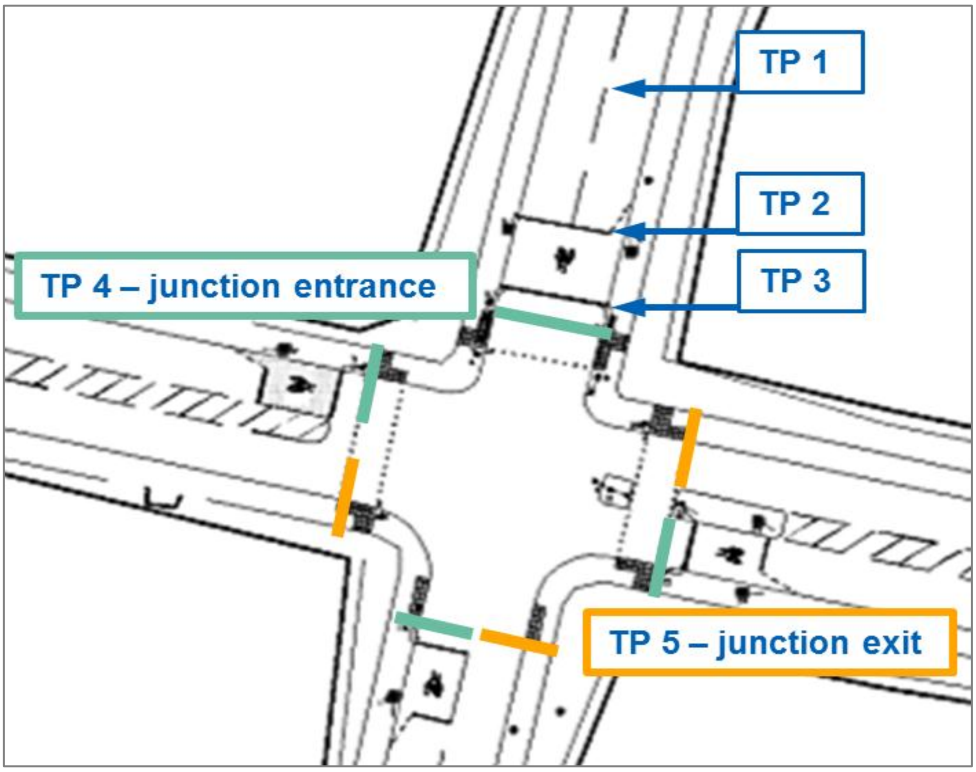


Figure 8 – Timing points at fixed locations

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.

In the cycle trial, timing points were taken for both the first and last cyclist in the group.

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 defined using the stopping zones in Figure 9, where the position of the cyclists' front wheel was noted longitudinally and laterally with respect to the cycle reservoir. For this exercise those participants who did not stop were excluded.

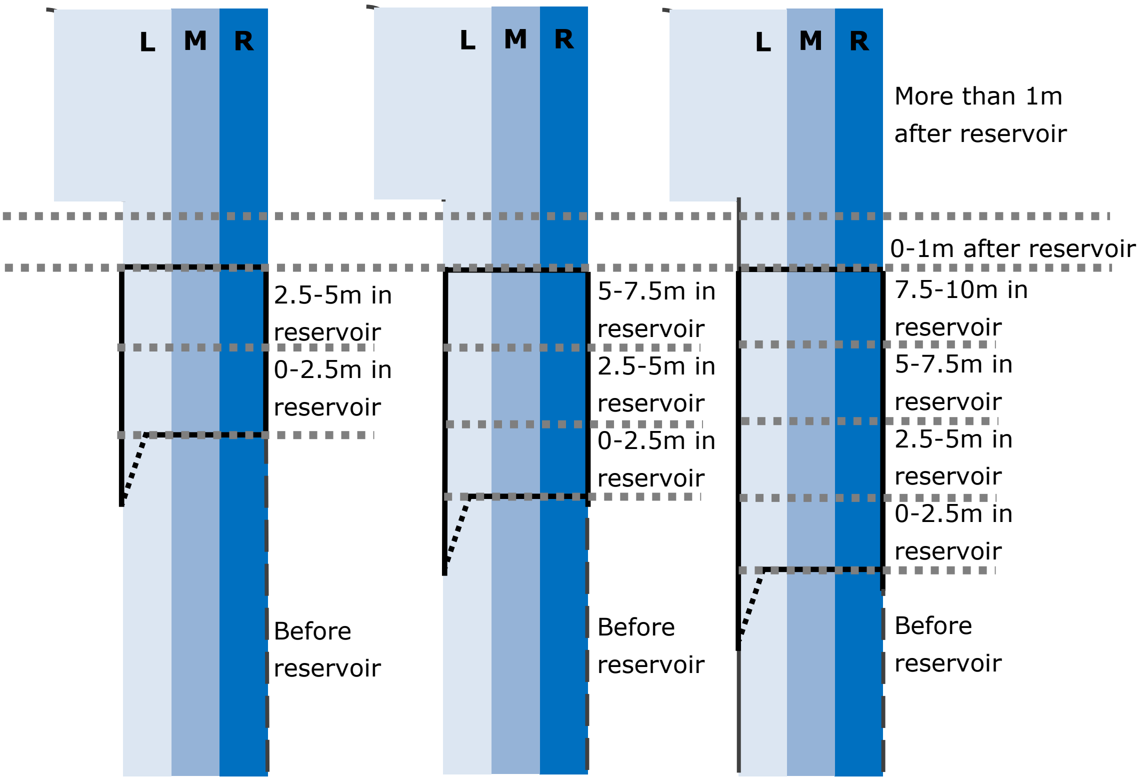


Figure 9 – Cycle trial: stopping zones

For the car trial data was not recorded on the lateral stopping position, although the longitudinal zones within the reservoir were broken down by half again: '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' and so on. Following anecdotal evidence in the M19 Trial, more precise data for the M24 Trials was also captured on the 'Before reservoir' zone: 'More than 7.5m before reservoir'; '5m to 7.5m before reservoir'; '2.5m to 5m before reservoir'; '0 to 2.5m before reservoir'.

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 three different sizes of cycle reservoir.

3 Findings – cycle trial

3.1 Did cyclists understand the LLCS and cycle reservoirs?

Table 7 – Research questions on understanding

Road user	Theme	Research question	Video	Q'naire
Cyclists	Understanding	Did cyclists understand the purpose of the LLCS and cycle reservoirs?	✗	✓
		To what extent did cyclists confuse LLCS with Toucan crossings?	✗	✓

3.1.1 Understanding of the cycle reservoirs and LLCS

In the post-trial questionnaire, participants were shown a photo of a cycle reservoir and asked "Have you ever seen markings like these before?" A relatively large proportion (25%) of the cyclists had not seen the markings before. As discussed in Appendix D, the sample consisted largely of residents of the Wokingham/Bracknell area, where only few junctions have ASLs. As such, many participants were not familiar with ASLs.

Participants were then asked "What do these markings mean to you?" The large majority of responses (97% from the small groups and 96% from the large groups) understood that the cycle reservoir was an area for cyclists to wait in. Neither the size of the cycle reservoir nor the size of the group affected participant perception of the purpose of the cycle reservoir. As in the previous trials, some cyclists (<1%) thought the cycle reservoir could be used by both motorcyclists as well as cyclists, whereas some (1%) said the cycle reservoir could be used by cars in some instances. Some cyclists (1%) considered the painted and unpainted cycle reservoirs to have different meanings, with the green reservoir being only for cyclists and the unpainted reservoir being for anyone, particularly if there were no cyclists around. These findings are very similar to previous trials.

As with previous trials, the majority of cyclists understood that the LLCS were either traffic signals for cyclists or normal traffic signals. Neither the size of the cycle reservoir nor the size of the group affected participant perception of the LLCS. About 2% of responses regarding LLCS were confused or indicated misconceptions, a similar proportion to the previous trials. A few cyclists (1%) confused the LLCS with Toucan crossings, saying they thought they were for cyclists or pedestrians crossing the road. As with the previous trials, some cyclists said they had to use the junction a few times before they understood how it worked.

F1.a. Most cyclists (97%) showed a good understanding of the cycle reservoir, although some (<1%) thought it could be used by both motorcyclists as well as cyclists, whereas some (1%) said it could be used by cars in some instances. A few cyclists (1%) thought there was a different meaning between the painted and unpainted reservoirs. The size of the cycle reservoir did not affect participant perception of the purpose of the reservoir.

F1.b. Similar to previous trials, most cyclists (96%) showed a good understanding of the LLCS, although a few cyclists (1%) confused the LLCS with Toucan crossings, saying they thought they were for cyclists or pedestrians crossing the road.

Further information in Appendix D

3.2 What attitudes did cyclists have towards the cycle reservoirs?

Table 8 – Research questions on attitudes

Road user	Theme	Research question	Video	Q'naire
Cyclists	Attitudes	What did cyclists think about the size of the cycle reservoir?	✗	✓
		What were the perceived benefits of cycle reservoirs?	✗	✓
		What improvements did cyclists suggest for cycle reservoirs?	✗	✓
		Would larger cycle reservoirs make cyclists more likely to cycle on busy roads?	✗	✓

3.2.1 Size of the cycle reservoirs

Participants were asked what they thought about 'the size of the area with the cycle symbol', i.e. the cycle reservoir, see Figure 10. This represents the perceptions of the participants; empirical evidence from video observations is discussed in Section 3.6.1.

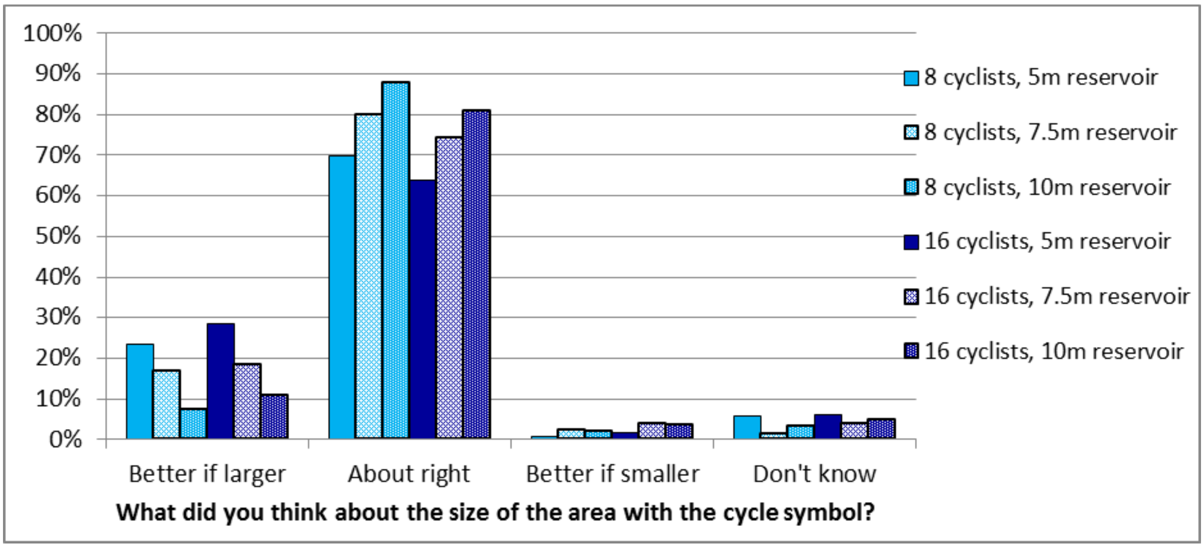


Figure 10 – Cycle trial: views on the size of the cycle reservoir (questionnaire)

The proportion of cyclists who said that the size of the cycle reservoir was 'about right' was 75% on average across all group sizes and reservoir depths in the 'M24' Trials; this proportion was lower than in the previous 'M19' Trials when participants experienced the junction as an individual cyclist (over 90%). Responses for the 'M24' Trials have been broken down by the three different reservoir sizes below.

The proportion of cyclists who said that the size of the cycle reservoir was 'about right' increased as the size of the reservoir increased, and the proportion of cyclists who said that the size of the reservoir would be 'better if larger' decreased as the size of the reservoir increased. This was the case for the small groups and the large groups.

When comparing group size, more cyclists in the large group reported that the reservoir would be better if larger for each of the reservoir sizes.

10% of cyclists in the large group who experienced the 5m reservoir said that they wanted to wait in the cycle reservoir but could not 'most times' and over a third said that this was the case 'several times'. About a quarter of cyclists in the small group also responded 'several times' compared with 2% who experienced the larger reservoir sizes. Over 90% of cyclists who gave this response said it was because the reservoir was already full of cyclists.

> *"Due to the amount of cyclists already crowding the area." (5m reservoir, 16 cyclists)*

A few participants said that if the cycle reservoir was bigger (than 5m), it would give cyclists more space and there would be a clear separation of cyclists from motor vehicles. However others said that it might annoy or frustrate drivers or encourage drivers to enter it if the cycle reservoir was too large:

> *"Seemed to be quite a generous area which could antagonise motor vehicle drivers if larger." (5m reservoir, 8 cyclists)*

> *"If it was too large motor vehicles would tend to encroach on the area thus reducing its effectiveness." (5m reservoir, 16 cyclists)*

These results suggest that based on a one-lane approach, participants thought that the 5m reservoir may be too small in areas where large volumes of cyclists use the road.

Of those who experienced the 7.5m reservoir, a third of cyclists in the large group said that they wanted to wait in the cycle reservoir but could not 'most times' (2%) or 'several times' (29%). This was the case for only 3% of cyclists in the small group suggesting that for a group of about 8 cyclists a 7.5m reservoir may be large enough.

Less than 10% of cyclists in both groups who experienced the 10m reservoir said that they wanted to wait in the reservoir but could not 'several times' (7% in the large group; 2% in the small group). However, it should be noted that 24% of cyclists in the large group said that this happened 'hardly ever' and 1% of cyclists said that this was the case 'most times'. This suggests that a minority of cyclists felt that the 10m reservoir was not large enough.

The results from the three different reservoir sizes strongly suggest that the size of the cycle reservoir should be based upon the volume of cyclists using the junction.

3.2.2 Perceived benefits of cycle reservoirs

The main perceived benefits of the cycle reservoir were that it gives cyclists more space away from vehicles and that it is a well-defined area. These sentiments were echoed across all of the reservoir depths.

> *"Roads designed better for cyclists with these junctions - they make you feel safer, gives you more space away from vehicles" (5m reservoir, 16 cyclists).*

> *"I view it as a 'safe zone' ahead of cars. Useful when pulling away on a bike as there is usually a bit of wobbling." (10m reservoir, 16 cyclists)*

3.2.3 Suggested improvements for cycle reservoirs

Cyclists were generally positive about the cycle reservoirs suggesting that they made them feel safer and gave them more space away from the traffic behind. Very few participants (15 cyclists) made comments on what improvements could be made, however from those that did were classified as below:

- All the cycle reservoirs should be painted (60%);

- The reservoirs should be larger (20%);
- Separate the reservoir into a lane for each manoeuvre: left turn, going straight on, right turn (20%).

3.2.4 Would larger cycle reservoirs make people more likely to cycle on busy roads?

When participants were asked about the likelihood of them cycling in busy traffic if more junctions were like this, two participants made specific reference to having large cycle reservoirs. One suggested that a large cycle reservoir is preferred:

> *"If there was a large safe cycle box at the front of junctions and cars behind but not too close… It felt safer to be in this box, especially when a car came up behind us." (10m cycle reservoir, 16 cyclists)*

However, the other suggested that a large cycle reservoir might take up top much space:

> *"Signal position is good as is extra time for cyclists to get moving before traffic. Larger cycle boxes pose problem of space at junctions." (10m cycle reservoir, 16 cyclists).*

F2.a. The results from the three different reservoir sizes strongly suggest that the size of the cycle reservoir should be based upon the volume of cyclists using the junction.

F2.b. The majority of cyclists (76%) said that the size of the cycle reservoir was 'about right' but those who experienced the smaller (5m) reservoir were more likely to say it would be better if larger (26%) than were those who experienced a larger cycle reservoir (18% from the 7.5m groups and 10% from the 10m groups said it would be better if larger).

F2.c. The main perceived benefits of the cycle reservoir were that it gives cyclists more space away from vehicles and also is a well-defined area.

F2.d. 60% of cyclists who put forward suggestions for improvements (15 cyclists) suggested that cycle reservoirs should be painted as this makes them more obvious to all road users.

3.3 What attitudes did cyclists have towards the LLCS?

Table 9 – Research questions on attitudes

Road user	Theme	Research question	Video	Q'naire
Cyclists	Attitudes	What were the perceived benefits of LLCS?	✗	✓
		Did cyclists like LLCS?	✗	✓
		What did cyclists think about the height and angle of the LLCS?	✗	✓
		What did cyclists think about the location of the LLCS and the main traffic signals?	✗	✓
		What improvements did cyclists suggest for LLCS?	✗	✓
		Would LLCS make cyclists more likely to cycle on busy roads?	✗	✓

This section considers attitudes of cyclists towards the LLCS, which has been discussed in previous reports; where possible the focus here is on the combined effect of LLCS with deeper reservoirs and with groups of cyclists.

3.3.1 Perceived benefits of LLCS

In the M24 Trial, 68% of cyclists said that cyclists on the road would benefit from the LLCS. This was slightly lower than in the earlier trials (M19a and M19b) in which single cyclists experienced the LLCS on separate poles and a 5m cycle reservoir (with 90% and 96% respectively saying that cyclists on the road would benefit). About 20% of cyclists thought that scooter riders and motorcyclists would benefit from the LLCS compared with about 30% in the M19 Trials.

When asked to specify the benefits from the LLCS, responses were very similar to the previous trials. The most common responses were that the LLCS gave cyclists a head start (21%) and improved safety (12%). Additional comments in the M24 Trial were that the LLCS kept the cyclists separate from the car drivers, preventing cyclists from getting in the way of motorists and improving traffic flow/easing traffic congestion:

> *"Cars would benefit from the delayed start and get the cyclists out of their way before proceeding…." (10m reservoir, 16 cyclists)*
>
> *"…everyone would benefit by getting the cyclists out of the way." (10m reservoir, 16 cyclists)*
>
> *"[The LLCS] could certainly help traffic management at problematic junctions" (10m reservoir, 16 cyclists)*
>
> *"These lights I do believe may filter congestion easier in high traffic areas." (7.5m reservoir, 16 cyclists)*

3.3.2 Did cyclists like LLCS?

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 (ambivalent), which also included people who made both positive and negative comments, see Figure 11.

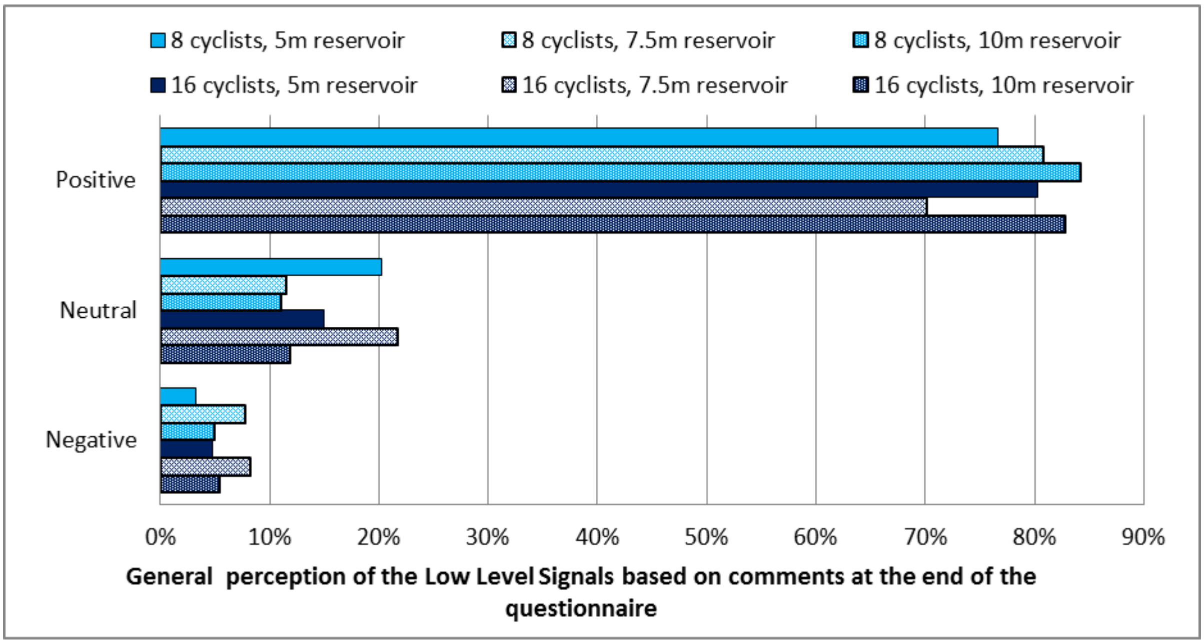


Figure 11 – Cycle trial: classification of attitudes (questionnaire)

The majority of cyclists (between 70% and 83%) in each group felt positively about the LLCS. This was less than in the previous trials when about 90% of cyclists gave positive comments. Less than 10% of cyclists in this trial were negative about the LLCS and between 10% and 25% were ambivalent towards the LLCS, depending on their group size and the size of the cycle reservoirs they experienced.

For both group sizes, those who experienced the largest size of cycle reservoir were the most positive (just under 85%), suggesting that this also influenced whether participants liked the junction layout and the LLCS.

In the focus groups the cyclists indicated that they were generally positive about the LLCS.

> *"[with the addition of the] low signals specifically for the cyclists, I think… most cyclists would feel more confident knowing that those signals were specifically aimed at them." (5m cycle reservoir)*

3.3.3 Height and angle of the LLCS

Just over half of the cyclists (58%) said that the height of the LLCS was 'about right' and 41% thought they would be 'better if higher', see Figure 12.

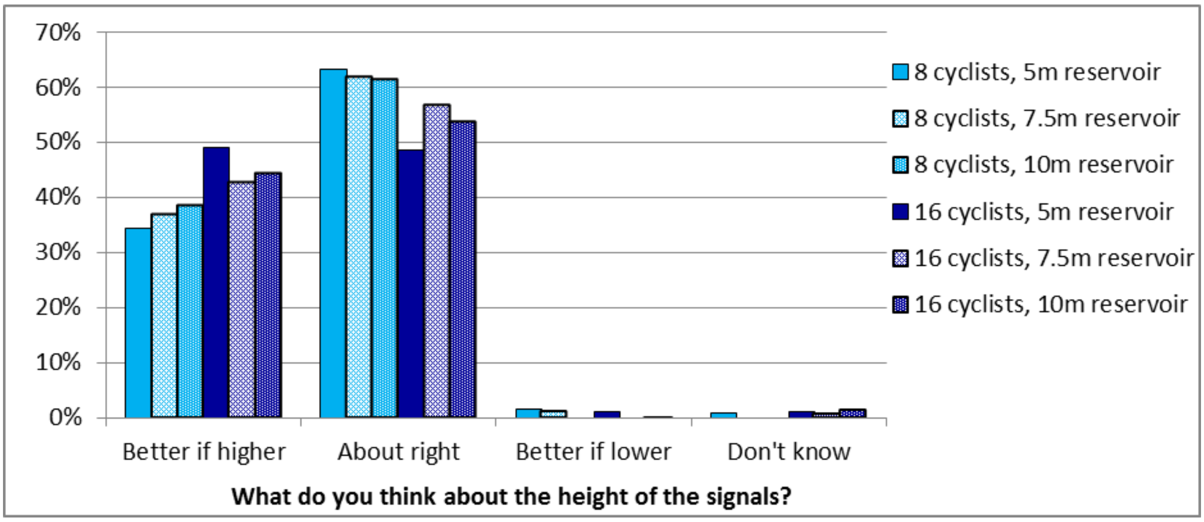


Figure 12 – Cycle trial: views on height of LLCS (questionnaire)

The cyclists in the large group were more likely to say 'better if higher' (ranging from 43% to 49%) than were those in the small group (ranging from 34% to 39% of cyclists). The proportion who said it would be better if the LLCS were higher was greater in this trial than in the previous trials where individual cyclists experienced the same junction ('M19'), in which about 20% of cyclists gave this response.

The majority of the cyclists (81%) said that the angle of the LLCS was 'about right' and 17% thought they should 'point more towards the road'.

3.3.4 Location of the LLCS

Almost two thirds (64%) of cyclists said that the location of the LLCS was 'about right', with 17% saying they would be 'better if on the same pole as the main signals' and 11% saying they would be 'better if nearer the main signals'. The proportion who said the location of the LLCS was 'about right' in this trial was similar to those in the previous 'M19' trial, where 68% said the location of the LLCS was 'about right'). Comments were also similar to those in the previous 'M19' trial.

3.3.5 Suggested improvements for LLCS

There were eight suggestions that recurred throughout the post-trial questionnaire responses from all groups of cyclists. These were:

- Locate the LLCS higher on the pole (29%);
- Give a longer early release for cyclists (24%);
- Make the LLCS bigger and brighter (18%);
- Have more LLCS, either on the off-side, ahead with the secondary signals or behind with the main signals (8%);
- Right turn filter for cyclists (7%);
- Use an audio/flashing signal to notify cyclists of the LLCS turning green (7%);
- An awareness campaign or signage explaining the LLCS to road users (4%);
- Locating the LLCS on the same pole as the main signals (1%).

More cyclists in the large groups (16 cyclists) said the LLCS should be located higher on the pole than in the small groups, whereas, more cyclists in the small group suggested they would prefer a longer early release, particularly in relation to the right turn across oncoming traffic. Also related to this manoeuvre was the suggestion for a right turn filter. More cyclists who experienced the larger reservoir sizes (7.5m and 10m) said they would like to have seen more sets of LLCS compared with those who experienced the 5m reservoir.

A small minority (1%) suggested that there should not be an early release for cyclists as this could be dangerous when turning right across oncoming traffic as cyclists may assume they have right of way when they may not.

3.3.6 Would LLCS make cyclists more likely to cycle on busy roads?

The influence of these facilities on willingness to cycle in London was inferred by asking whether it would affect how often participants would cycle in busy traffic if more junctions were like this. Results should be treated with caution as they indicate who would be more likely to consider cycling rather than that they would definitely cycle.

Two fifths (40%) of cyclists answered 'yes'; slightly more than in previous trials when about a third of cyclists gave this response. 33% of cyclists answered 'no' and the remaining 27% answered either 'it depends' or 'don't know'.

F3.a. Between 70% and 83% of cyclists were positive about the LLCS; those who experienced the 10m reservoir were more likely to be positive than those who experienced the 5m and 7.5m reservoirs. Less than 10% were negative about the LLCS.

F3.b. The proportion of cyclists who said that it would be better if the LLCS were higher increased with group size. Up to 49% in the largest group gave this response compared to 20% in the previous trials which consisted of individual trials.

F3.c. Similar to previous trials, the majority of the cyclists said that the angle of the LLCS was 'About right' (81%) and that the location of the LLCS was 'about right' (64%).

Further information in Appendix D

3.4 What information did cyclists use at the junction?

Table 10 – Research questions on use of LLCS

Road user	Theme	Research question	Video	Q'naire
Cyclists	Trial experiences	Did cyclists notice the LLCS?	✗	✓
		Did cyclists experience difficulties seeing the LLCS?	✗	✓
		Did cyclists look at the LLCS?	✗	✓
		What was the most important piece of information to cyclists?	✗	✓

3.4.1 Noticing the LLCS

Cyclists were asked, "How many runs through the junction did you do before you noticed the LLCS". Just over half (56%) of the cyclists noticed the LLCS on their first run through the junction. This is a similar proportion to the M19a and M19b Trials where 59% and 64% noticed the LLCS on their first run.

Participants using the smallest sized cycle reservoir (5m) were less likely to notice the LLCS on their first run compared to the other groups. Only 37% of participants in the 5m reservoir with 16 cyclists group and 46% of participants in the 5m reservoir with 8 cyclists group noticed the LLCS on their first run. A small minority (<5%) said they did not notice the LLCS at all.

3.4.2 Difficulties seeing the LLCS

Participants were asked whether there were any times when it was difficult or impossible to see the LLCS whilst waiting at the junction. Between 35% and 50% of cyclists in the small group said 'Yes' and around 60% of cyclists in the large group said 'Yes'. However, it is not appropriate to make direct comparisons between the small and large group, because half of the small group would relate to typically four cyclists and half the larger group would typically relate to eight cyclists. Those who said they did have difficulties seeing the LLCS were then asked how often this happened, see Figure 13.

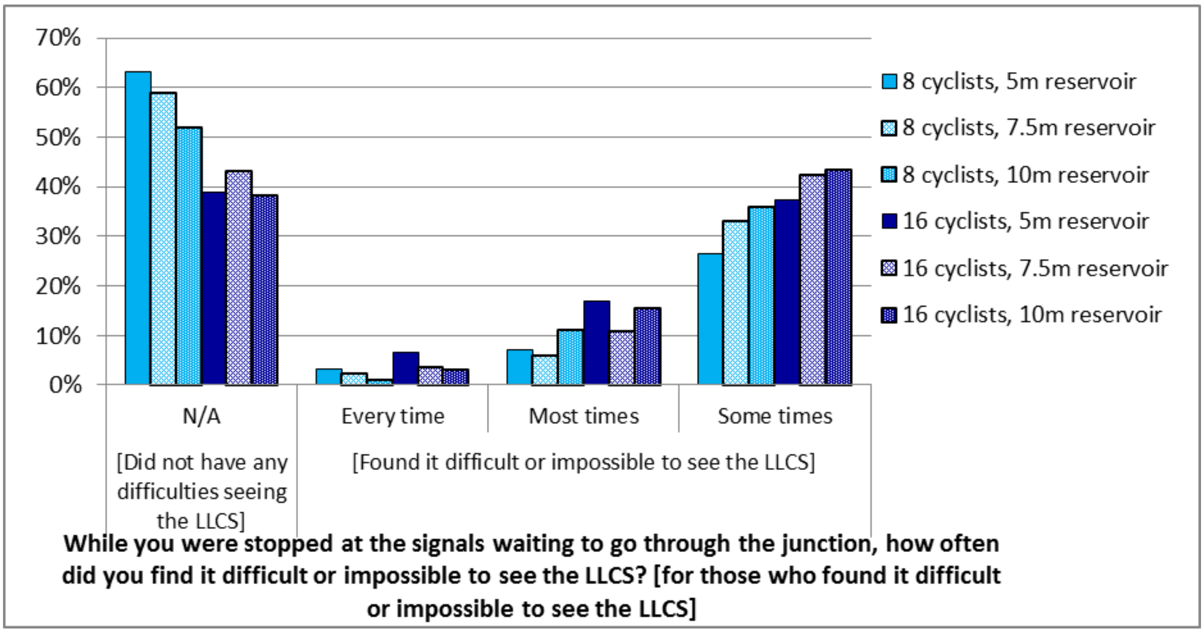


Figure 13 – Cycle trial: how often was it difficult or impossible to see the LLCS (questionnaire)

Over 10% of participants in the large group found it difficult or impossible to see the LLCS 'most times' and about 40% responded 'sometimes' compared with about 30% in the small group. The proportion of cyclists who responded 'some times' increased with reservoir size for both group sizes. Those in the small group who experienced the 5m reservoir were least likely to have difficulties seeing the LLCS. Those in the large group who experienced the 5m reservoir were more often likely to find it difficult or impossible to see the LLCS than those who experienced the larger cycle reservoirs or small groups. Group size had more of an effect that reservoir size as shown in Figure 13.

Cyclists were asked to explain the circumstances when this happened, see Figure 14. The main reason given for participants finding the LLCS difficult or impossible to see was that other cyclists obscured the LLCS (65% overall). Over 75% of cyclists in the large group who experienced the 5m reservoir gave this response. The cyclists' position within the group was also cited as a reason; primarily the back of the group (17% overall) and the right hand side of the reservoir (10% overall). Over a fifth of cyclists in the large group who experienced the 10m reservoir suggested that it was difficult to see the LLCS from the back of the group.

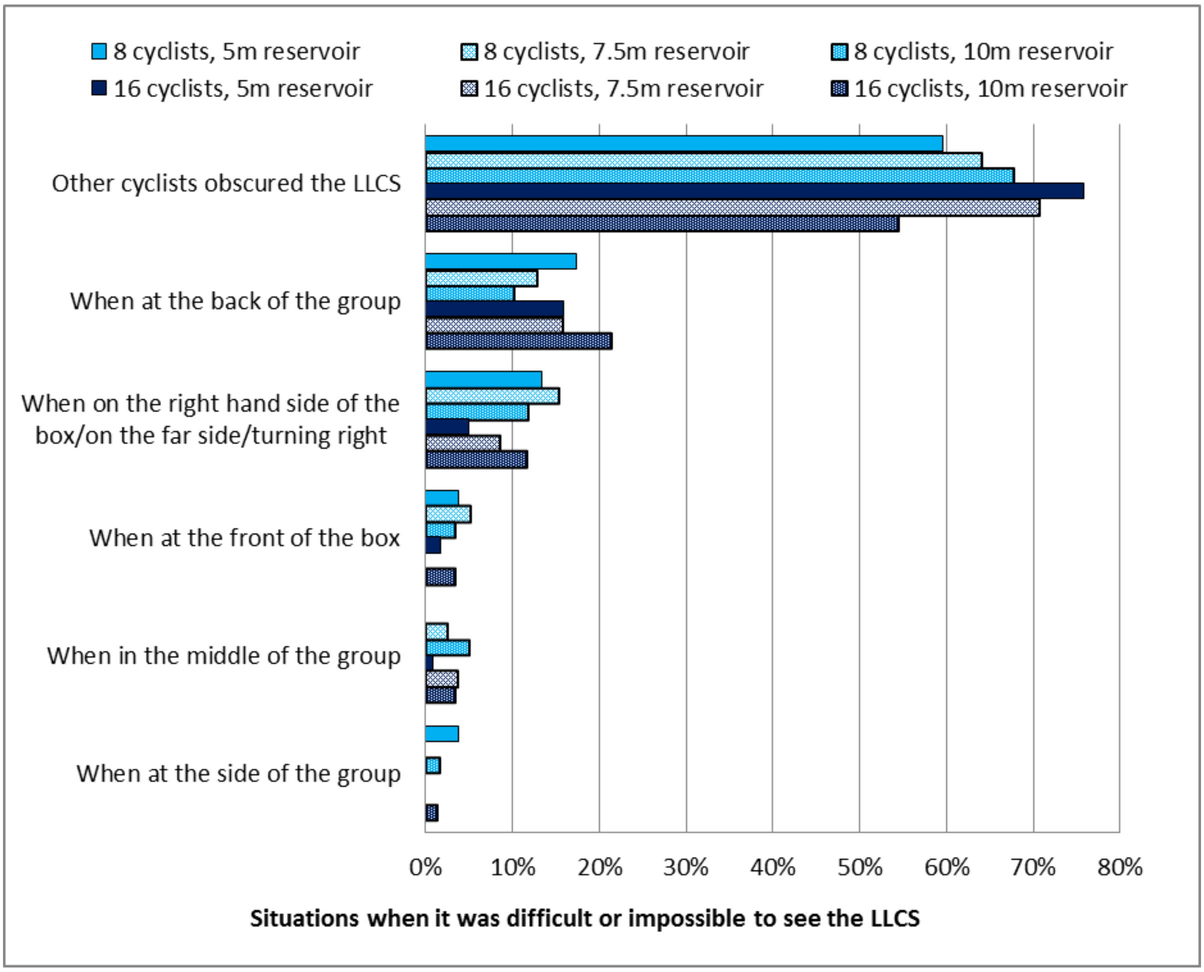


Figure 14 – Cycle trial: situations when it was difficult or impossible to see the LLCS (questionnaire)

Of the cyclists who said there were times when was difficult or impossible to see the LLCS, 38% said that this affected how they went through the junction. Of these, most tended to say they did at least one of the following:

- Follow cyclists in front (42%);
- Better position themselves in the box so that they could see the LLCS (25%);
- Wait until the cyclists in front of them had moved off so that they could see/ or check the LLCS before/when moving off (13%);
- Use the main traffic lights or the main lights repeater instead of the LLCS (8%);
- Follow the group but also check the LLCS as they passed (7%);
- Moved closer to the front (2%).

Participants were asked whether it was difficult to see the LLCS specifically at Arms A, B and D. As discussed in Section 2.2.4, Arm B had both nearside LLCS and off-side LLCS, whereas Arm D had only nearside LLCS. When comparing results for Arm B and Arm D, fewer cyclists said that they ‘could always see the LLCS’ at Arm D than at Arm B; this was 55% compared with nearly 65% for the small group and 35% compared with about 45% for the large group. Results are shown in Figure 15.

These findings suggest that having the LLCS on both sides of a single lane road increases the likelihood that cyclists will be able to see them, especially where larger groups of cyclists are present.

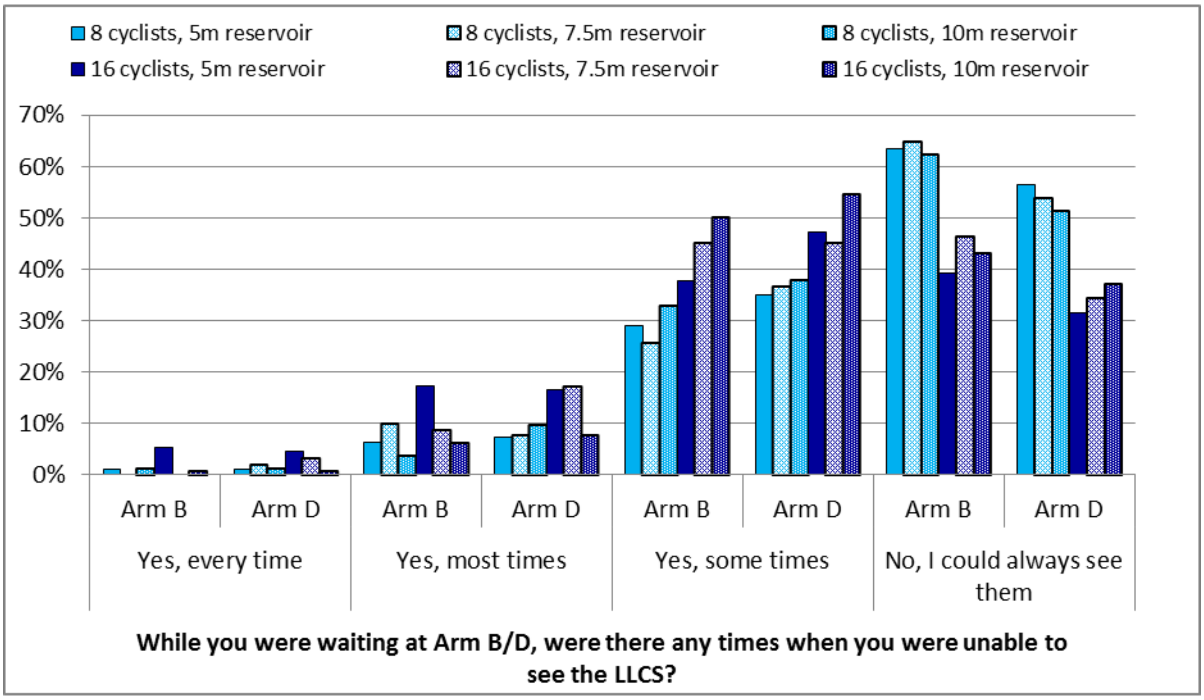


Figure 15 – Cycle trial: how often was it difficult or impossible to see the LLCS, by junction approach (questionnaire)

3.4.3 Did cyclists look at the LLCS?

Cyclists were asked what they looked at when they were approaching the junction from Arms A, B and D and when they were waiting and deciding when to enter the junction to go straight on. They were also asked what they looked at when turning right from Arm D. Of the cyclists who said they had difficulties seeing the LLCS, what they looked at depended to some extent on the size of the group and the cycle reservoir which they experienced. In the small groups they were slightly more likely to look at the secondary signals, while in the large groups they were more likely than others to look at the actions of other cyclists.

3.4.4 What was the most important piece of information to cyclists?

Approximately 60% of cyclists stated that the main signals were the most important cue when approaching the junction to go straight on from any of the arms. A similar proportion stated that the LLCS were the most important information when setting off. This is slightly less than cyclists in the M19b trial, which had a similar layout but only individual cyclists. For the groups of 8 cyclists, those using the larger cycle reservoirs were more likely to say that the LLCS were the most important. When making the right turn at Arm D (which did not have LLCS on the right), cyclists were more likely to say that the secondary signals or the speed and position of approaching vehicles were the most important pieces of information.

These findings support the idea that the LLCS can be small as their main purpose is to allow cyclists setting off from the cycle reservoir to see them. Approaching cyclists will be able to use the main signals so will not require the LLCS until they reach the cycle reservoir at the junction.

F4.a. 56% of the cyclists said that they noticed the LLCS on their first run through the junction and almost all of the others noticed it on their second run or after a few times. Cyclists who experienced the 5m reservoir were less likely to notice the LLCS on their first run.

F4.b. The volume of cyclists had more of an effect than the depth of the reservoir on how difficult it was to see the LLCS whilst waiting at the junction. Cyclists in the large group were more likely to find it difficult or impossible to see the LLCS. 50% of cyclists said that there were times when it was difficult or impossible to see the LLCS whilst waiting at the junction.

F4.c. When asked how often they found it difficult or impossible to see the LLCS, about 40% of the large group and 30% of the small group said ‘sometimes’. This was more likely to be the case as the reservoir size increased. The most common reason given for not being able to see the LLCS was that they were obscured by other cyclists (65%). Over 75% of cyclists in the large group who experienced the 5m reservoir gave this response.

F4.d. Of the cyclists who said there were times when it was difficult or impossible to see the LLCS, 38% said that this affected how they went through the junction. Of these, over 40% said that they followed the cyclists in front, whereas a quarter said that they tried to reposition themselves so that they could see the LLCS.

F4.e. More cyclists said that they had difficulties seeing the LLCS when they were only present on the nearside (Arm D) than when they were present on both sides of the road (Arm B); this was 55% compared with nearly 65% for the small group and 35% compared with about 45% for the large group.

F4.f. Cyclists who reported having difficulties seeing the LLCS in the small groups, were more likely to say they looked at the secondary signals, whereas those in the large groups were more likely to say they looked at the actions of other cyclists. Group size and size of the cycle reservoir both contributed to this.

Further information in Appendix D

3.5 Did the LLCS and cycle reservoirs affect whether cyclists stopped at a red light?

Table 11 – Research questions on red light compliance

Road user	Theme	Research question	Video	Q'naire
Cyclists	Compliance with red light	To what extent did the LLCS affect compliance with red lights?	✓	✗

Cyclists were released at times chosen so that they approached the junction whilst the red signals were displayed.

Table 12 shows the number of observations where at least one cyclist went through the junction while the signal was still on red, split by the reservoir depth and group size scenarios. A non-compliant observation was defined as where at least one cyclist entered the junction on a red signal[1] and then proceeded through the junction without stopping. This shows that there were very high levels of compliance with the red signal and that there were no differences between the different reservoir depths and group sizes.

Table 12 – Cycle trial: number of observations where at least one cyclist was non-compliant with a red signal (video data)

Trial	Reservoir depth	Cyclist group size scenario	Non-compliant observations (where at least one cyclist went through on red)	Total observations	Percentage non-compliant
M24	5m reservoir	8 cyclists	1	419	0.2%
		16 cyclists	5	357	1.4%
	7.5m reservoir	8 cyclists	1	465	0.2%
		16 cyclists	0	444	0.0%
	10m reservoir	8 cyclists	0	527	0.0%
		16 cyclists	1	471	0.2%

F5.a. There were very high levels of compliance with the red signal and that there were no differences between the different reservoir depths and group sizes.

3.6 How did the different cycle reservoir depths affect where cyclists waited?

Table 13 – Research questions on stopping position

Road user	Theme	Research question	Video	Q'naire
Cyclists	Longitudinal stopping position	To what extent did the LLCS, reservoir depth and group size affect the number of cyclists stopping before the first stop line and after the second stop line?	✓	✓
	Lateral stopping Position	To what extent did the LLCS, reservoir depth and group size affect the lateral stopping position? i.e. what position did they take in the reservoir (Left Zone / Middle Zone / Right Zone)?	✓	✓

3.6.1 Findings from the video analysis

The position that cyclists stopped at the traffic lights was captured from videos, as discussed in Section 2.6.3.2. 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). In this section results are presented for the average number of cyclists who stopped in each zone for the different reservoir depths, split by the small group (8 cyclists) and the large group (16 cyclists). The front wheel was taken as the stopping position.

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

3.6.1.1 *Longitudinal stopping position*

Figure 16 shows the average number of cyclists who stopped before the cycle reservoir for the two group sizes and three reservoir depths. There were some observations where not all the cyclists had stopped before the signals changed to green; these observations have been excluded from the analysis. An equivalent graph is shown in Appendix C, split by approach arm and turning movement.

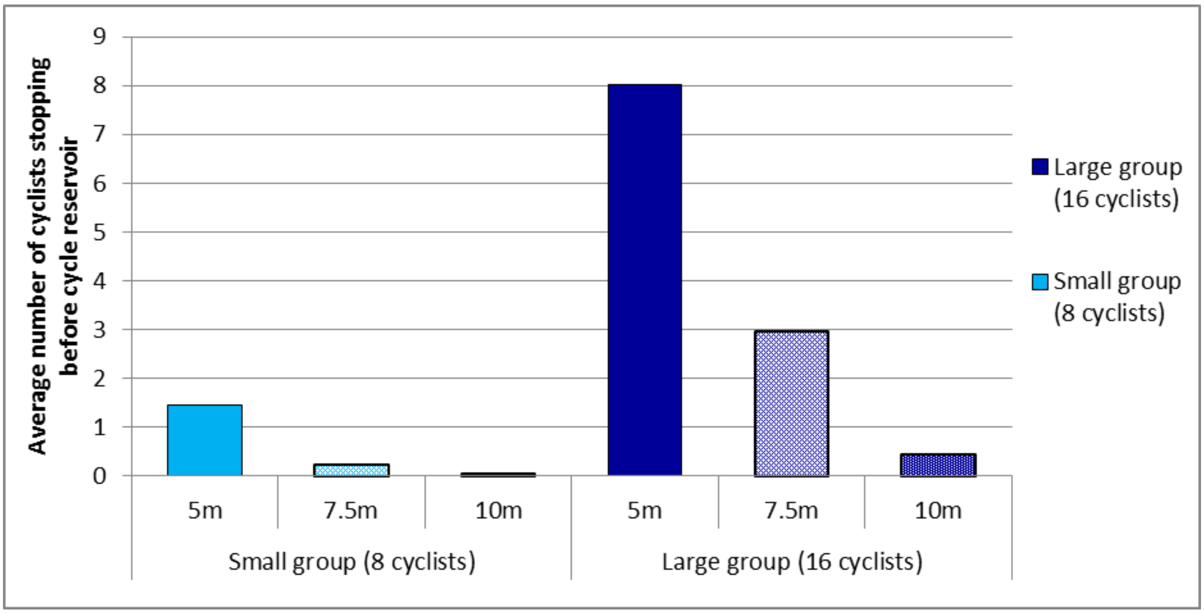


Figure 16 – Cycle trial: average number of cyclists who stopped before the cycle reservoir, by group size and reservoir depth (video data)

For the small group (eight cyclists) the average number of cyclists who stopped before the first stop line was:

- 1.5 for the 5m reservoir;
- 0.2 for the 7.5m reservoir;
- 0.1 for the 10m reservoir.

This suggests that the 7.5m and 10m reservoirs were sufficiently large enough to hold at least eight cyclists in almost all instances. There were similar results when broken down by the four different turning movements.

For the large group (16 cyclists) the average number of cyclists who stopped before the first stop line was:

- 8.0 for the 5m reservoir;
- 3.0 for the 5m reservoir;
- 0.4 for the 10m reservoir.

This suggests that the 10m reservoir was sufficiently large enough to hold at least 16 cyclists in almost all instances. Furthermore it suggests that the capacity of the 7.5m reservoir was about 13 cyclists. There were similar results when broken down by the four different turning movements, with the exception of slightly fewer cyclists stopping before the stop line on Arm A, which may be explained by this being the two-lane approach.

Comparing the results from the small and large groups for the 5m reservoir shows that the average number of cyclists who stopped after the first stop line was 6.5 for the small groups and 8.0 for the large groups. This suggests that typically up to 8 cyclists were able to fit in the 5m reservoir, but fewer chose to do so when there was a small group.

Figure 17 – Cycle trial: photos of cyclists stopped at the junction, by group size and reservoir depth

A similar analysis was conducted for the average number of cyclists in each group who stopped with their front wheel after the second stop line. As discussed in Section 2.7, levels of compliance can be difficult to study in a track trial environment and so the absolute values may not be replicated in an on-street environment, but it is expected that any relative differences between the different scenarios would. Cyclists did not encroach substantially into the space between the second stop line and the pedestrian studs and this did not vary by reservoir depth or group size. For the small group the average number of cyclists who stopped after the second stop line was 0.1, 0.3 and 0.2 for the 5m, 7.5m and 10m reservoirs, respectively; for the large group these were 0.2, 0.3 and 0.5 respectively.

3.6.1.2 Longitudinal and lateral stopping position

In this section 'heat maps' have been produced to show the distribution of the cyclists' stopping positions, both longitudinally (2.5m sections relative to the first and second stop lines) and laterally (left, middle and right). There is a separate map for each reservoir depth and group size. The values show the average number of cyclists that stopped in that position, coloured according to the key in Figure 18. The values shown in light blue are the sub-totals.

0	0 to 0.1	0.1 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0	2 or more

Figure 18 – 'Heat maps' key, average number of cyclists stopped in each zone

Figure 19 shows the stopping position heat maps for cyclists stopped at the junction and waiting to go straight on. For the small group (eight cyclists), there was a tendency to wait towards the front left of the reservoir, in particular for the deeper reservoirs. For the large group (16 cyclists), the left hand side of the reservoir also had the highest density, although cyclists filled the middle and right hand zones as well. For the large group and smaller reservoir lengths, the density was higher towards the back of the reservoir than the front and was spread across the full width of the lane, although this was not the case for the 10m reservoir. As discussed in Section 3.6.1.1, with a large group using a 5m reservoir, on average eight cyclists stopped upstream of the first stop line and were spread across the full width of the lane.

As discussed in Sections 2.2.4 and 2.3.3, three different junction approaches were trialled for the straight on movement:

- Arm A (two-lane, unpainted, with the left-hand lane for left turn and straight on movements and the right-hand lane for right turn movements, with nearside and offside LLCS);
- Arm B (one-lane, unpainted, with an island with nearside and offside LLCS); and
- Arm D (one-lane, painted, with only a nearside LLCS).

On Arm A, the additional lane was typically not used since this was marked as a right turn lane only.

There was little difference between Arm B and Arm D, suggesting that the island with the additional LLCS did not have a large effect on stopping position.

Appendix C contains the heat maps of the straight on movements for each of the three junction approaches.

Figure 20 shows the stopping position heat maps for cyclists stopped at the junction and waiting to turn right. There were similar trends to those who were going straight on, although there was the opposite tendency to wait on the right hand side of the reservoir instead of the left hand side.

5m reservoir

	8 cyclists waiting to go straight on				16 cyclists waiting to go straight on			
	L	M	R		L	M	R	
>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<1m after	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1
2.5 - 5.0m	1.1	1.0	0.6	2.8	1.4	1.2	0.8	3.5
0.0 - 2.5m	1.7	1.3	0.7	3.6	1.9	1.7	0.9	4.5
Before reservoir	0.8	0.5	0.1	1.4	3.2	3.1	1.5	7.9
	3.7	2.8	1.5	8.0	6.7	6.1	3.2	16.0

7.5m reservoir

	8 cyclists waiting to go straight on				16 cyclists waiting to go straight on			
	L	M	R		L	M	R	
>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<1m after	0.2	0.0	0.0	0.2	0.2	0.1	0.0	0.3
5.0 - 7.5m	1.2	1.0	0.6	2.7	1.4	1.3	0.9	3.6
2.5 - 5.0m	1.2	0.8	0.4	2.4	1.4	1.2	1.0	3.5
0.0 - 2.5m	1.4	0.7	0.2	2.4	2.5	1.6	1.6	5.6
Before reservoir	0.2	0.0	0.0	0.2	1.5	0.9	0.5	2.8
	4.2	2.6	1.2	8.0	6.9	5.0	4.1	15.9

10m reservoir

	8 cyclists waiting to go straight on				16 cyclists waiting to go straight on			
	L	M	R		L	M	R	
>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<1m after	0.2	0.0	0.0	0.2	0.3	0.1	0.1	0.5
7.5 -10.0m	1.4	0.9	0.6	2.8	1.6	1.1	1.1	3.7
5.0 - 7.5m	1.3	0.8	0.4	2.5	1.4	1.0	1.0	3.4
2.5 - 5.0m	1.1	0.5	0.2	1.8	1.6	1.2	1.0	3.8
0.0 - 2.5m	0.4	0.2	0.0	0.7	1.7	1.3	1.1	4.2
Before reservoir	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.4
	4.4	2.4	1.2	8.0	6.8	4.8	4.4	16.0

Figure 19 – Cycle trial: average number of cyclists in each stopping zone, waiting to go straight on, pooled across Arms A, B and D (video data)

		8 cyclists waiting to turn right				16 cyclists waiting to turn right			
		L	M	R		L	M	R	
5m reservoir	>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<1m after	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.3
	2.5 - 5.0m	0.4	1.0	1.3	2.7	0.6	1.2	1.3	3.1
	0.0 - 2.5m	0.6	1.1	1.7	3.4	1.0	1.5	1.8	4.2
	Before reservoir	0.1	0.2	1.3	1.7	1.5	2.9	4.0	8.4
		1.3	2.4	4.3	8.0	3.2	5.6	7.2	16.0
		L	M	R		L	M	R	
7.5m reservoir	>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<1m after	0.1	0.1	0.1	0.3	0.0	0.1	0.1	0.3
	5.0 - 7.5m	0.3	0.7	1.3	2.4	0.9	1.0	1.6	3.5
	2.5 - 5.0m	0.4	0.8	1.2	2.5	0.9	1.2	1.5	3.6
	0.0 - 2.5m	0.3	0.7	1.5	2.6	1.4	1.2	2.7	5.4
	Before reservoir	0.0	0.0	0.2	0.3	0.6	0.6	2.1	3.3
		1.2	2.4	4.4	8.0	3.8	4.1	8.0	16.0
		L	M	R		L	M	R	
10m reservoir	>1m after	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<1m after	0.1	0.0	0.0	0.2	0.1	0.2	0.3	0.6
	7.5 -10.0m	0.5	0.9	1.4	2.8	0.8	1.0	1.6	3.3
	5.0 - 7.5m	0.3	0.7	1.2	2.2	0.9	1.0	1.5	3.4
	2.5 - 5.0m	0.2	0.5	1.2	1.9	0.9	1.0	1.8	3.7
	0.0 - 2.5m	0.1	0.1	0.6	0.8	0.8	1.3	2.2	4.3
	Before reservoir	0.0	0.0	0.1	0.1	0.1	0.1	0.4	0.6
		1.2	2.3	4.5	8.0	3.6	4.6	7.8	16.0

Figure 20 – Cycle trial: average number of cyclists in each stopping zone, waiting to turn right, Arm D (video data)

3.6.2 Findings from the questionnaire analysis

As discussed in Section 3.4.2, one of the reasons given by cyclists for the LLCS being difficult or impossible to see was that it depended on their stopping position in the cycle reservoir. Participants found it difficult to see the LLCS on the left when on the right-hand side of the reservoir (turning right) and difficult when at the very front of the reservoir as the LLCS were not in their eye line.

> *"When turning right having to look in 'wrong' direction. Plus could be difficult to see when bike positioned at front of advance stop box." (5m, 16 cyclists)*

> *"Due to being at the front the lights were not in my line of sight. Had to almost lean back to see them." (10m, 16 cyclists)*

> *"When on right hand side of junction box it was unnatural/difficult to look at it then your direction of travel -you can't see/prepare to turn right/clock the oncoming traffic." (5m, 8 cyclists)*

As mentioned earlier, some participants said that they had tried to position themselves in the cycle reservoir so that they could more easily see the LLCS. Over half the comments suggested that cyclists stopped so that they could see the LLCS (56%). 31% of those who were influenced by the LLCS said they moved nearer to the signals, either further forward or further left in order to be able to see the LLCS better, and 5% suggested that they stopped further back in order to be able to better see the LLCS.

In order to see the LLCS when turning right, one cyclist said that they angled themselves more to the left than they usually would and another said they stopped more to the left of the reservoir than they would if the LLCS had not been present at all.

> *"When turning right I stopped further left than I usually would so I had a clearer view of the signal."*

F6.a. For the small group (eight cyclists) the average number of cyclists who stopped before the first stop line was 1.5 for the 10m reservoir. The 7.5m and 10m reservoirs were typically sufficiently large enough to hold all eight cyclists.

F6.b. For the large group, the average occupancy was 8.0 cyclists for the 5m reservoir and 13.0 for the 7.5m reservoir. The 10m reservoir was typically sufficiently large enough to hold all 16 cyclists.

F6.c. Cyclists did not encroach substantially into the space between the second stop line and the pedestrian studs and this did not vary by reservoir depth or group size.

F6.d. Cyclists waiting to go straight on predominantly waited at the front left of the cycle reservoir. With larger groups, the additional cyclists stayed towards the rear of the reservoir instead of filtering towards the front. Cyclists tended to wait on the right hand side when waiting to turn right. There was little difference between Arm B and Arm D, suggesting that the island with the additional LLCS did not have a large effect on stopping position.

F6.e. Over half (56%) of those who said that the LLCS affected where they stopped said that they tried to position themselves so that they could see the LLCS.

Further information in Appendix C

3.7 Did the LLCS and cycle reservoirs affect how cyclists moved off as the signals changed to green?

Table 14 – 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?	✓	✗

The times when participants started to move ('Reaction Time') and entered the junction ('Entry Time') were recorded as explained in Section 2.6.3.1. In the cycle trial, these were collected for three entities: the first cyclist who moved; the last cyclist who moved; and the controlled car. Cyclists encountered the junction with a controlled car behind them in all sessions.

The absolute values of Reaction Time and Entry Time should be treated with caution, due to the nature of the trial conditions, although relative comparisons between the scenarios can be made. The findings are a good basis for design speeds as a range of cycling abilities were present in the sample.

3.7.1 *Reaction Time*

Figure 21 shows the average Reaction Time, relative to the main signals in the cycle trial; this is pooled across all reservoir depths. The green line indicates when the signals turned to green (the LLCS for the participant cyclists and the main signals for the controlled cars).

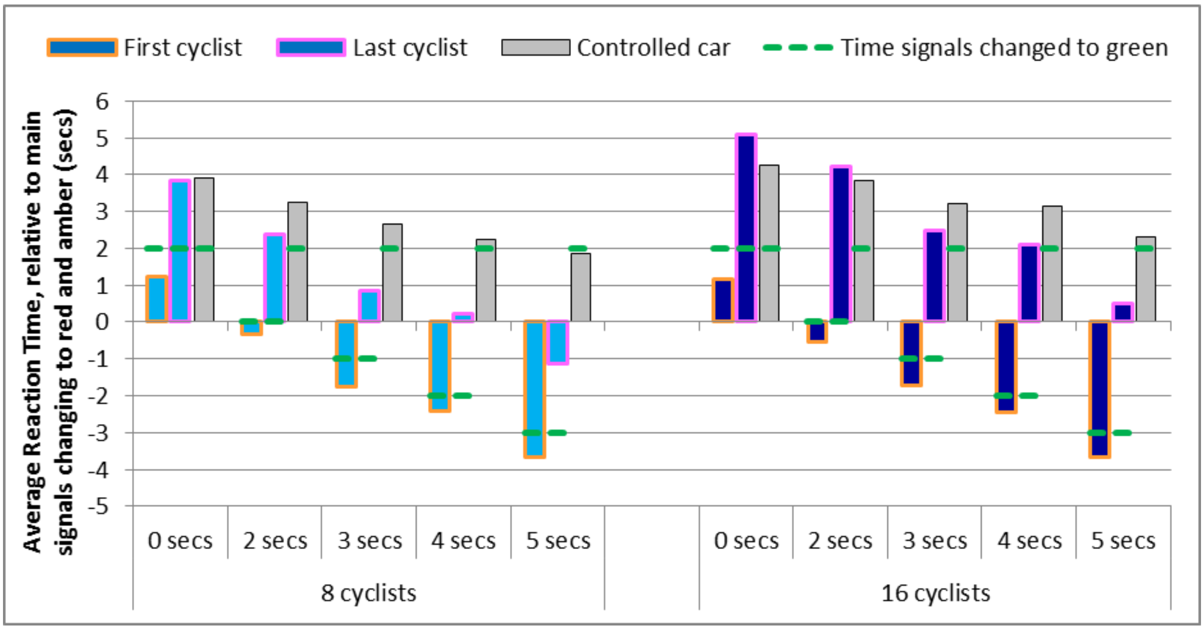


Figure 21 – Cycle trial: average Reaction Time of participant cyclists and controlled car drivers, relative to the main signals changing to red and amber, by early release scenario and group size (video data)

On average for both the small groups and large groups the first cyclist started moving around 0.5 seconds before the LLCS turned to green (i.e. 1.5 seconds after the LLCS changed to red and amber). For the small group (8 cyclists), the last cyclist started moving about 2.5 seconds on average after the first cyclist. For the large group (16 cyclists), the last cyclist started moving about 4 seconds on average after the first cyclist.

In previous trials either with an early release or with no cyclists present, the cars typically started moving on average around the time the main signals turned to green. This was the case for the small group with the 3-second, 4-second and 5-second early releases and for the large group with the 5-second early release. For the other early release scenarios, the controlled car started moving more than 3 seconds after the signals changed to red and amber and within 1 second on average of the last cyclist; this suggests that in these scenarios the car had to wait for the last cyclist before moving.

Figure 22 – Cycle trial: photo of groups of cyclists moving off when the LLCS were green and the main signals were red

3.7.2 Entry Time

Figure 23 shows the average Entry Time of the participants relative to the main signals; this is pooled across all reservoir depths. The green line indicates when the signals turned to green (the LLCS for the participant cyclists and the main signals for the controlled cars). In this graph, observations have been excluded where at least one cyclist entered the junction while both the main signals and LLCS were on red. It was not appropriate to pool the data across the different turning movements and so this is shown here separately for the three approaches where the cyclists went straight on.

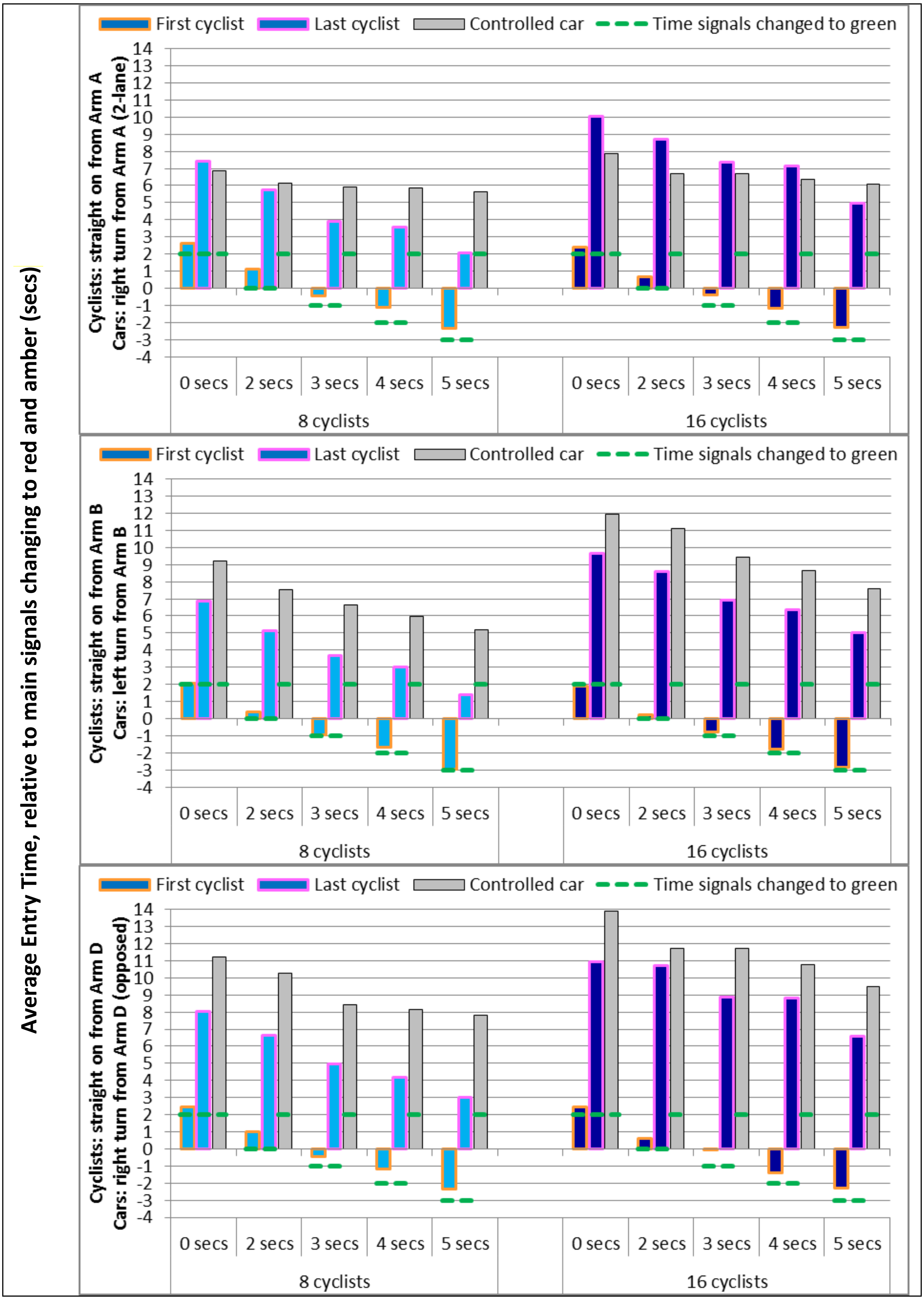


Figure 23 – Cycle trial: average Entry Time of participant cyclists (straight on) and controlled car drivers (turning), relative to the main signals changing to red and amber, by early release scenario and group size (video data)

For most scenarios and for both the small groups and large groups the first cyclist entered the junction around 0.5 seconds on average after the LLCS turned to green. For the small group (8 cyclists), the last cyclist entered the junction typically around 5 seconds on average after the first cyclist. For the large group (16 cyclists), on Arm A and Arm B, the last cyclist entered the junction about 8 seconds on average after the first cyclist, whereas for Arm D this was about 9 seconds, which was perhaps explained by this approach being slightly uphill.

In previous trials either with an early release or with no cyclists present, the average Entry Times (i.e. time after the main signals turned to red and amber) of the cars were typically 5 to 6 seconds. As will be discussed in Section 4.6.2, in the car trial with an early release the average Entry Times were about 5.7, 5.9 and 6.4 seconds for the 5m, 7.5m and 10m reservoirs, respectively.

For Arm A, the right-turning car used the off-side lane, whereas the cyclists going straight on typically used the near-side lane. Thus in many instances the controlled car was not delayed by the cyclists and in some scenarios the average Entry Time of the car was lower than that of the last cyclist.

For Arm D, it seems that the average Entry Times of the right-turning cars from Arm D were affected by waiting for the cyclists going straight on from the opposite direction on Arm B[2] and so this scenario is not considered further.

For Arm B and the small groups of cyclists, the average Entry Time of the controlled car was less than 7 seconds (i.e. comparable to other trials) when there was a 3-second, 4-second and 5-second early release. This suggested that the car was not delayed from entering the junction by the cyclists in these scenarios. However, for the 2-second early release, the average Entry Time of the controlled car from Arm B was about 7.5 seconds, suggesting that in most cases the car had just caught up with the last cyclist when entering the junction.

For Arm B and the large groups of cyclists and all early release scenarios, the average Entry Time was over 7.5 seconds, suggesting that in most cases the car had caught up with the last cyclist when entering the junction.

Figure 24 and Figure 25 show the average Entry Time of the last cyclist and the controlled car for the small group and large group respectively, broken down for the three reservoir depths. This is shown only for cyclists going straight on from Arm B and cars turning left from Arm B due to the reasons outlined above. The sample size for these scenarios were quite low (around 20 for each scenario) and so these findings should be treated with caution.

These suggests that the average Entry Time of the last cyclist was lower for the deeper cycle reservoirs, although it is not clear why the reservoir depth might have this effect. As discussed above, the cars were not delayed by the last cyclist from entering the junction when there was an early release of 3 or more seconds and a small group of cyclists; for these scenarios there were no consistent trends in how the reservoir depth

[2] The signals on Arms B and D changed at the same time and had one of two combinations of movements: [1] Arm B cyclists straight on and car left turn, Arm D cyclists straight on and car right turn; [2] Arm B no cyclists and car straight on, Arm D cyclists right turn and car straight on. Figure 23 relates to [1], whereas [2] is explored in Section 3.8.

affected the average Entry Time of the cars. However, for the other early release scenarios, it seems the cars waited for the last cyclist to enter the junction before they did and so a similar trend of lower average Entry Times for deeper reservoirs was also observed. The effect that the reservoir depth had on the average Entry Time of cars with an without an individual cyclist was explored in the trial with car driver participants, see Section 4.6.

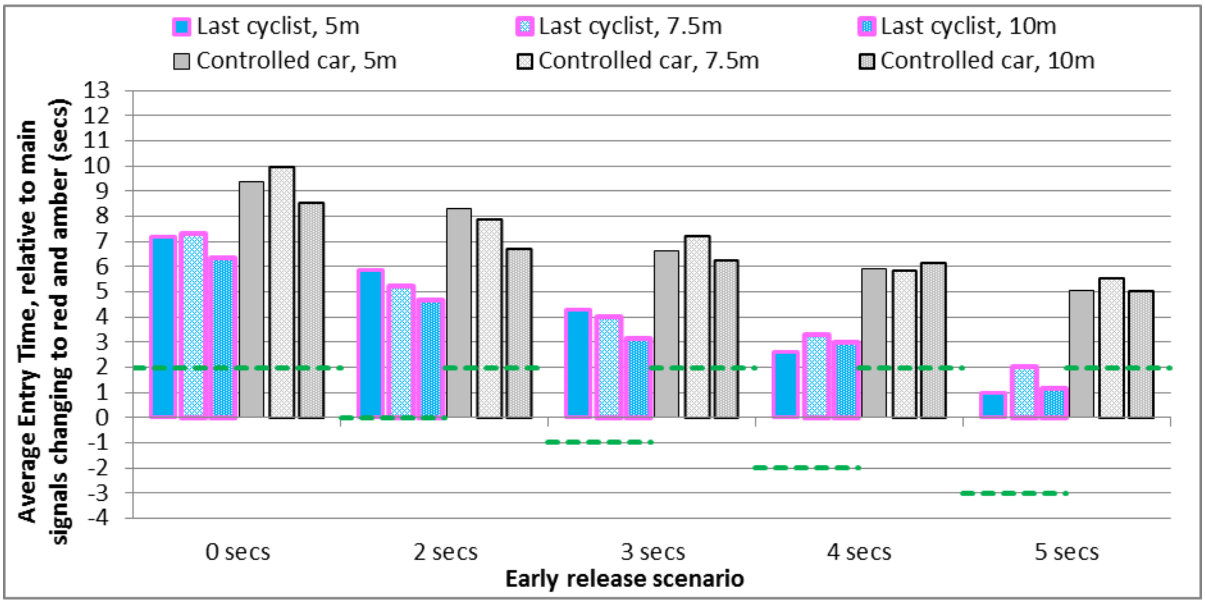


Figure 24– Cycle trial: average Entry Time of last cyclists (straight on from Arm B) and controlled car drivers (left turn from Arm B), relative to the main signals changing to red and amber, by reservoir depth, small group (video data)

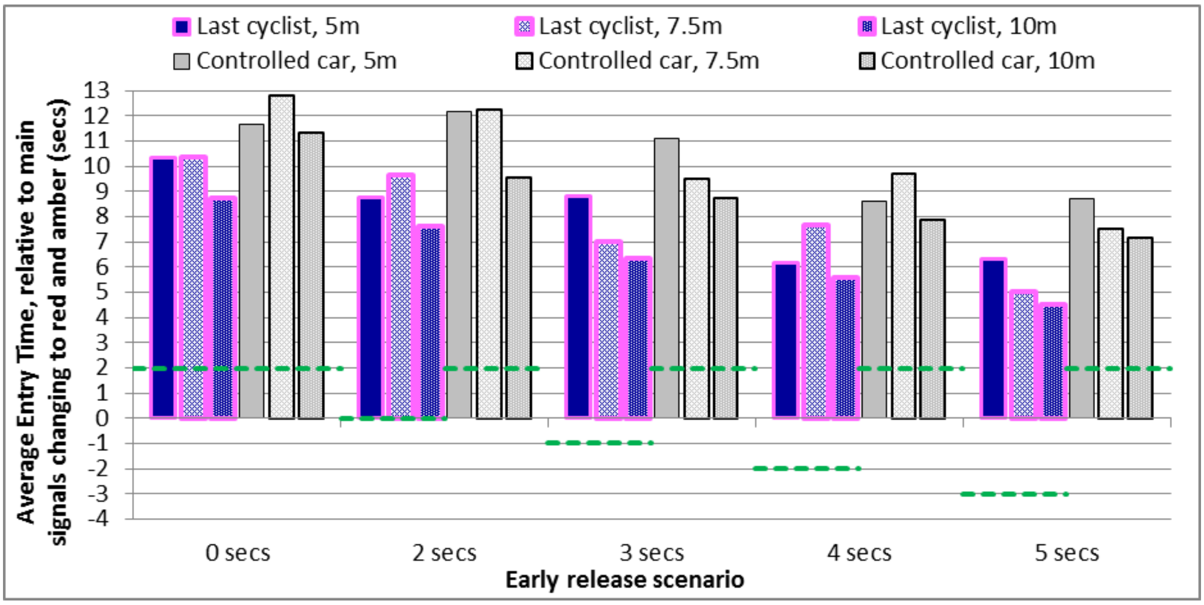


Figure 25– Cycle trial: average Entry Time of last cyclists (straight on from Arm B) and controlled car drivers (left turn from Arm B), relative to the main signals changing to red and amber, by reservoir depth, large group (video data)

F7.a. On average for both the small groups and large groups the first cyclist started moving around 0.5 seconds before the LLCS turned to green. On average for the small group, the last cyclist started moving about 2.5 seconds after the first cyclist and for the large group this was about 4 seconds.

F7.b. It was only meaningful to consider the gap between the last cyclist and the controlled car for one approach (Arm B). On this approach, for scenarios with an early release of 3, 4 or 5 seconds and a small group of cyclists in front, the average Entry Time of the controlled car was comparable to previous trials (i.e. less than 7 seconds). This suggested that the car was not delayed from entering the junction by the cyclists in these scenarios.

F7.c. On Arm B for the 2-second early release with a small group and the 5-second early release with a large group, the average Entry Time of the controlled car was about 7.5 seconds, suggesting that typically the car had just caught up with the last cyclist when entering the junction.

F7.d. On Arm B for other early release scenarios with a large group of cyclists in front, the average Entry Time of the controlled car was greater than 7.5 seconds. This suggested that typically the car was delayed from entering the junction by the last cyclist in these scenarios.

3.8 Did the LLCS and cycle reservoirs affect whether right-turning cyclists turned in front of oncoming cars?

Table 15 – Research on right turning cyclists

Road user	Theme	Research question	Video	Q'naire
Cyclists	Right turning cyclists	To what extent did right-turners from Arm D turn ahead of oncoming cars?	✓	✓

Previous trials found that:

- *"A substantial proportion of cyclists turned right in front of the oncoming car and this was more so for the scenarios with a longer early release; this was 24%, 38%, 54% and 69% for the 2, 3, 4 and 5-second early release scenarios, respectively… Of the cyclists in the trial that did turn right in front of the oncoming car, the most common explanation was that they thought they had enough time, although a few (5%) thought they had right of way."* – (Ball et. al 2015b)
- *"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… 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."* – (Ball et. al 2015c)

So that these previous findings could be investigated in more depth, the right turn was included in this trial to assess how this behaviour was affected by different reservoir depths and also when there were groups of cyclists.

In the previous trials with an individual cyclist, the participant cyclist turned right across the path of an oncoming cyclist (also a participant) as well as an oncoming car driver (controlled). In contrast for these trials, the groups of cyclists turned across the path of only an oncoming car driver (controlled). In both cases the opposing movement had the same reservoir depth and early release.

The analysis of right-turning cyclists in this section mirrors that of the analysis in the earlier reports, although there are now three key measures due to there being groups of cyclists rather than individual cyclists:

- **Proportion of observations where at least one cyclist** turned right in front of oncoming car – from video analysis, see Section 3.8.1.
- **Average number of cyclists** who turned right in front of oncoming car – from video analysis, see Section 3.8.2.
- **Proportion of cyclists** who said they turned or considered turning in front of the oncoming car – from questionnaire analysis, see Section 3.8.3.

There were some biases in the sample due to younger cyclists and male cyclists being more likely to turn in front of the oncoming car. Groups with dis-proportionate numbers of young and male cyclists were therefore filtered out of the analysis in this section, as detailed in Appendix C.

3.8.1 Proportion of observations where at least one cyclist turned right in front of oncoming car

Figure 26 shows the proportion of observations where at least one cyclist turned right ahead of the car from the opposite approach, broken down by early release and reservoir depth.

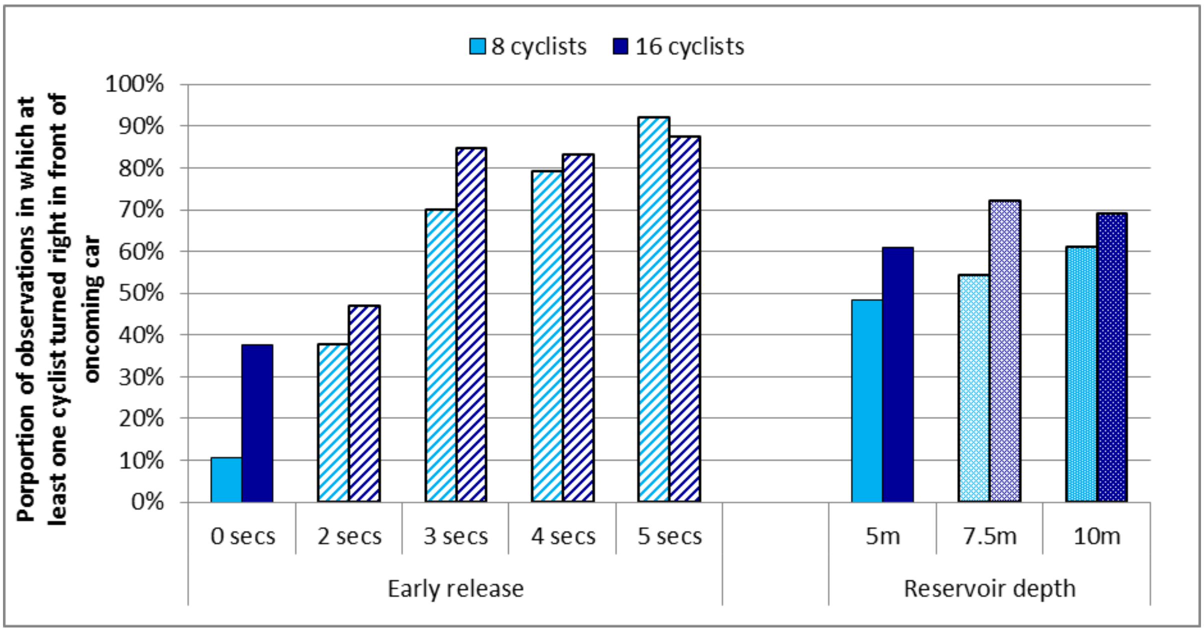


Figure 26 – Cycle trial: proportion of observations where at least one cyclist turned right in front of the oncoming car, by group size and early release (video data)

This shows that in each of the 3-second, 4-second and 5-second early release scenarios, in over three-quarters of right-turning observations, at least one cyclist turned in front of the oncoming car. The deeper cycle reservoirs also resulted in a higher proportion of observations where at least one cyclist turned right ahead of the car, although the effect was to a lesser extent than the early release.

Table 16 shows the proportion of observations where at least one cyclist turned right ahead of the car from the opposite approach, compared against the previous trial with an individual cyclist to see the effect of having a group of cyclists. This is shown here only for the 5m reservoir to be comparable with the previous trial.

Table 16 – Cycle trial: proportion of observations where at least one cyclist turned right in front of the oncoming car, 5m reservoir, compared with previous trial with individual cyclists

Reservoir depth	Early release scenario	1 cyclist ('M19')	8 cyclists ('M24, 5m')	16 cyclists ('M24, 5m')
5m	0 secs	0%	13%	25%
	2 secs	24%	19%	60%
	3 secs	52%	77%	63%
	4 secs	46%	43%	73%
	5 secs	71%	100%	73%

These findings suggest that when there was a group of cyclists, it was more likely for there to be some cyclists turning right in front of the car. In contrast to the earlier trials, there were some observations where cyclists turned right in front of the oncoming car in the scenario with no early release. This may be explained by the fact that in the trial with the groups of cyclists, participants experienced the LLCS both with and without an early release, whereas in the trial with the individual cyclist, participants experienced the LLCS either with or without an early release.

3.8.2 Average number of cyclists who turned right in front of the oncoming car

Figure 27 shows the average number of cyclists who turned right ahead of the car from the opposite approach, broken down by early release scenario. This clearly shows that the larger the early release, the higher the average number of cyclists who turned right ahead of the oncoming car. For the small group of eight cyclists, this ranged from 1.3 with the 2-second early release up to 5.6 with the 5-second early release. For the large group of 16 cyclists, this ranged from 1.6 with the 2-second early release up to 8.6 with the 5-second early release. This finding is consistent with the results from the earlier trials.

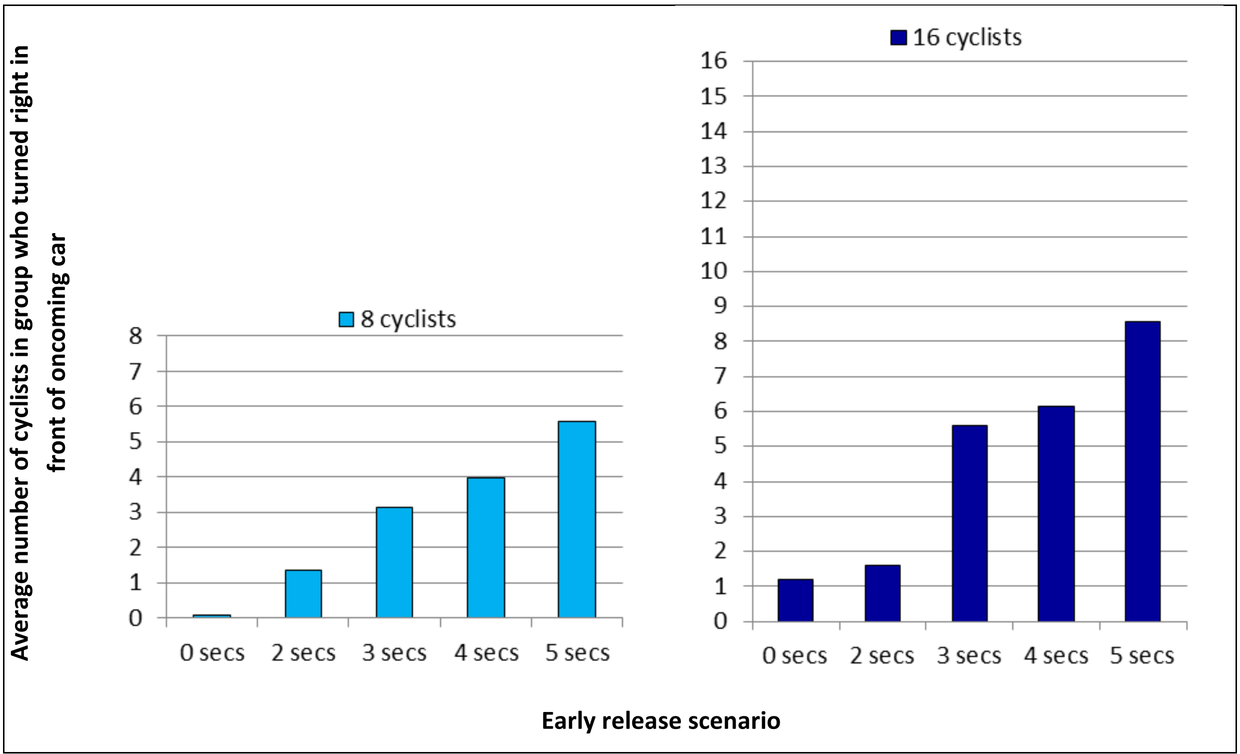


Figure 27 – Cycle trial: average number of cyclists who turned right in front of the oncoming car, by group size and early release (video data)

Figure 28 shows the average number of cyclists who turned right ahead of the car from the opposite approach, broken down by reservoir depth. This shows that the deeper the cycle reservoir, the higher the average number of cyclists who turned right ahead of the oncoming car. For the small group of eight cyclists, this was on average 1.9, 2.5 and 3.1 in the 5m, 7.5m and 10m scenarios, respectively. For the large group of 16 cyclists, this was on average 3.2, 5.5 and 5.0, respectively. This may be explained by the car being set back further on the opposite arm, thus creating a larger gap in which more cyclists could turn.

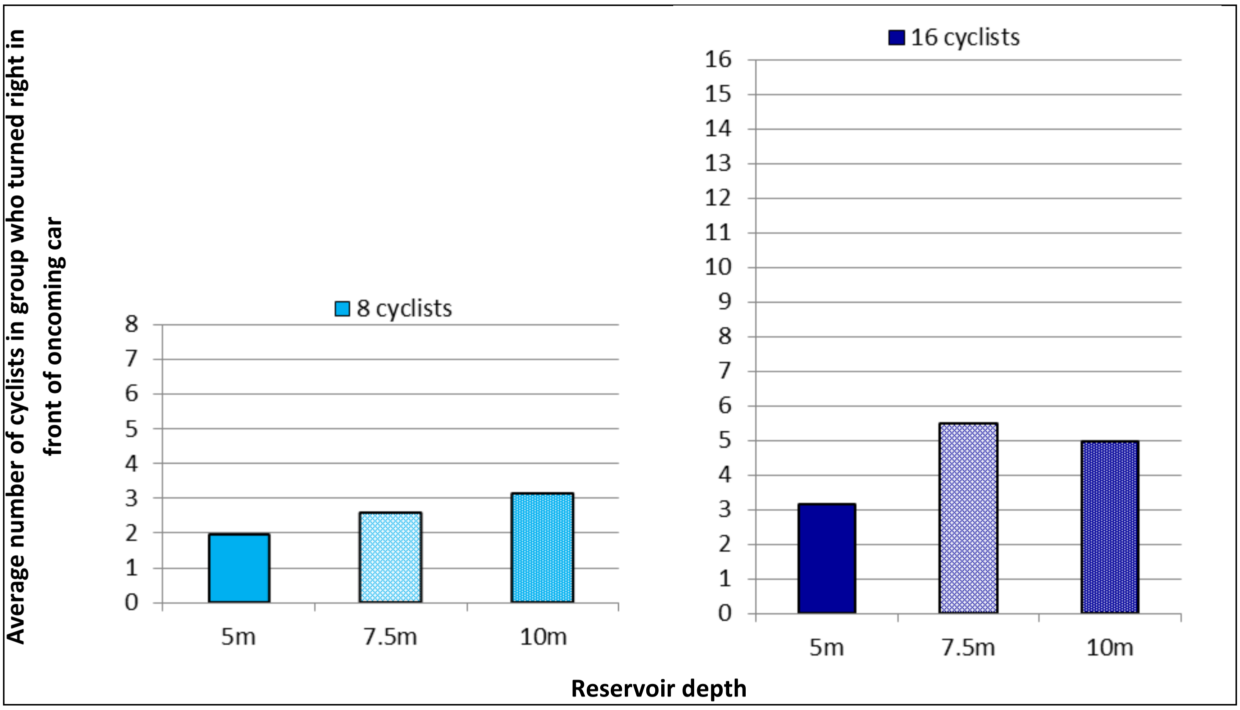


Figure 28 – Cycle trial: average number of cyclists who turned right in front of the oncoming car, by group size and reservoir depth (video data)

Figure 29 – Cycle trial: example of cyclists turning in front of oncoming car

3.8.3 Reasons for turning or considering turning in front of the car

In the post-trial questionnaire, cyclists were asked whether they considered turning in front of the car approaching from the opposite direction when turning right, and were asked to pick one of four responses. Figure 30 shows the results split across the various group sizes and reservoir depths.

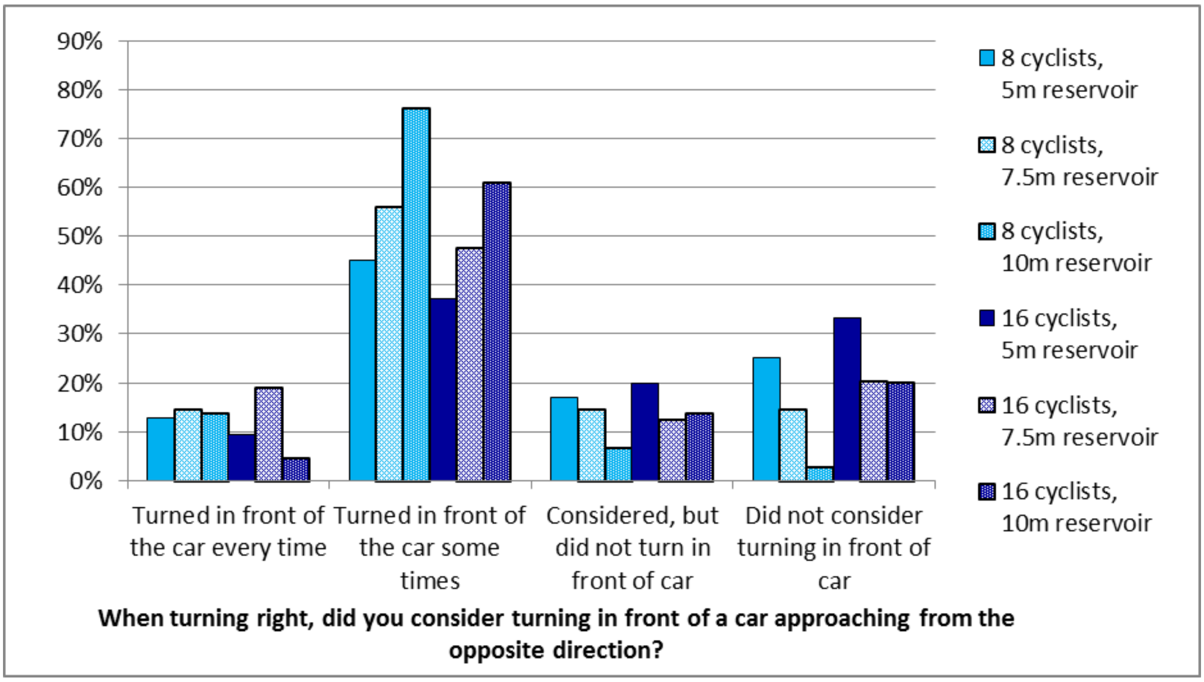


Figure 30 - Cycle trial: cyclists who said they considered and turned in front of the car, by group size and reservoir depth (questionnaire)

In the smaller sized groups (8 cyclists), a higher proportion of cyclists said they 'turned in front of the car 'every time' or 'sometimes', compared to the cyclists in a larger sized group (16 cyclists). This is as expected; for example, if four people said they did so in the group with eight cyclists this would be 50%, whereas if four people said they did so in the group with 16 cyclists this would be 25%. Observations from the video data in Section 3.8.2 showed the average number of cyclists who turned right in front of the car ranged from 1.3 to 5.6 in the small group and from 1.6 to 8.6 in the large group for the various early release scenarios.

For the small groups, the proportion of participants who said they turned in front of the car either 'Every time' or 'Sometimes' was 58%, 71% and 90% for the 5m, 7.5m and 10m trials, respectively. Comparatively, for the large groups (16 cyclists), these proportions were 46%, 67% and 66% for the 5m, 7.5m and 10m trials, respectively. These results suggest that the larger the cycle reservoir, the more likely a particular cyclist would be to turn right ahead of the car.

When asked to explain their responses, the most common comment for those who turned was that they felt they had enough time or space (34% of those who said 'every time' and 40% of those who said 'sometimes'). Cyclists also suggested that their decision to turn depended on the speed and position of the oncoming car and their position within the group, with some explaining that they followed the cyclists in front of them.

The most common reason given for not turning in front of the car was that it felt dangerous, unsafe and too risky (18% of those who said 'considered but did not turn' and just under 30% of those who said 'did not consider'). More detailed responses and quotes are included in Appendix D.

3.8.3.1 Factors that influenced the decision

The cyclists who said they turned right in front of the car either every time or sometimes were asked a multiple choice question, "What factors influenced your decision to turn in front of the car?". Figure 31 shows the results split across the various group sizes and reservoir depths.

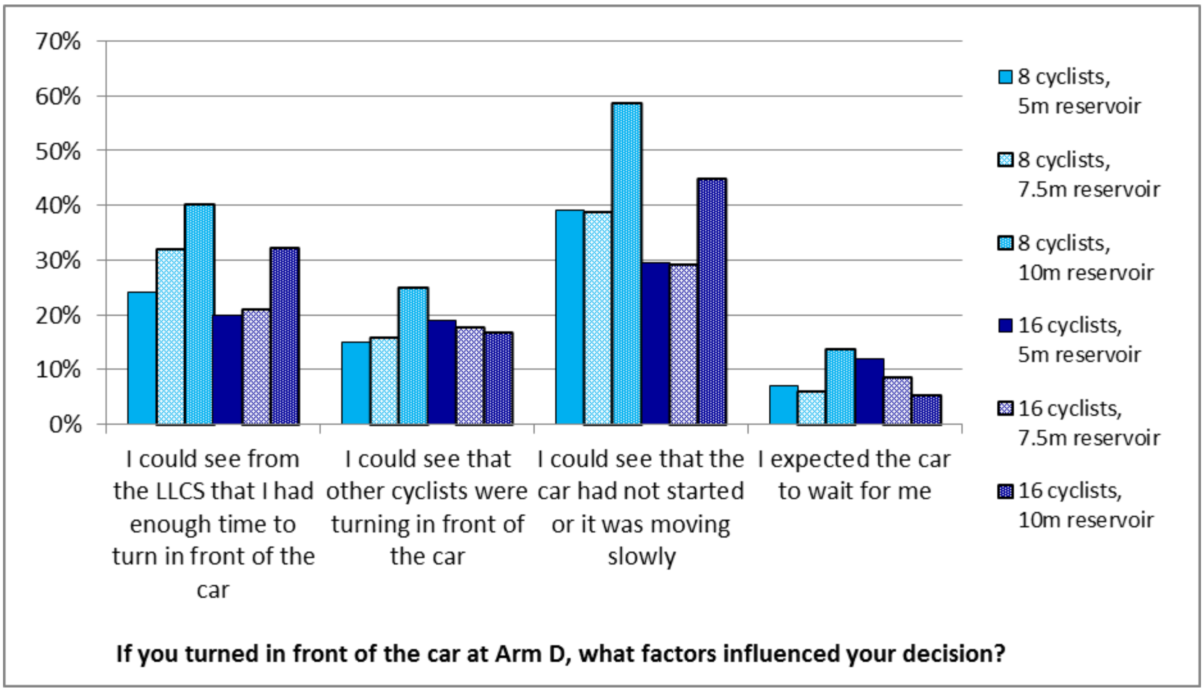


Figure 31 – Cycle trial: factors influencing cyclists' decision to turn in front of the car, by group size and reservoir depth (questionnaire)

The most common factor specified by those cyclists who said they turned right in front of the car was "I could see that the car had not started or it was moving slowly". This was the case for both group sizes. The results for the 5m and 7.5m reservoir sizes were about the same (about 40% in the small group and about 30% in the large group). Those who experienced the 10m reservoir were more likely to give this response (about 60% in the small group, 45% in the large group).

> *"If the car was not moving as I got to the junction, I would turn right. If it had started to move I gave way."*

> *"Once the car starts to move I stop and wait, but given the chance to get across while they were stationary I took it."*

The proportion of participants who said *"I could see from the LLCS that I had enough time to turn in front of the car"* was higher for the deeper cycle reservoirs: 24%, 32% and 40% for the small groups (8 cyclists) and 20%, 21% and 32% for the large groups (16 cyclists) for the 5m, 7.5m and 10m trials, respectively. This might be explained by the car on the opposing approach being set back further from the junction, resulting in a larger gap in which cyclists could turn.

> *"Only turned in front of car on 3rd session when cyclists had longer [early release]; only once during this session."*

"The low level cyclists' lights seemed to encourage this."

Between 15% and 25% of cyclists said that they turned ahead of the car because they *"could see that other cyclists were turning in front of the car"*. Results were similar across both group sizes and all reservoir sizes. These instances represent a potential safety concern, in that the decision of whether to turn was influenced by the behaviour of other cyclists and not based on their own judgement.

"Followed other cyclists and assumed OK to proceed."

"I followed the crowd (safety in numbers)."

Between 5% and 15% of cyclists who turned ahead of the car said *"I expected the car to wait for me",* suggesting that they mistakenly thought they had priority at the junction over the oncoming vehicle, which could be a potential safety concern.

"This was confusing as I assumed the bike light meant I could go first like a filter but there wasn't enough time before the car went. [I] had to stop suddenly."

3.8.3.2 Other comments and suggestions on the right turn

Cyclists were asked an open-ended question to explain their answer for whether they considered turning in front of the approaching car. These response were classified and are summarised in Section D.2.9 of the Appendices.

Of those who said they 'turned in front of the car every time', 4% gave comments suggesting they were confused over who had priority, whereas this proportion was 5% for those who said they 'turned in front of the car sometimes'. The confusion over who has priority led some participants to suggest that there is a potential need for education alongside any future introduction of LLCS.

"Implementation would require education/clarity for other road users regarding purpose."

Participants made a number of suggestions to improve the right turn facility and, in particular, to make it clearer to cyclists that they do not have priority at the junction. These included a filter arrow, give way road markings, an audio or countdown for cyclists, a warning sign about oncoming traffic and a central box/lane.

The facility was thought to be beneficial for cyclists turning left or travelling straight ahead, however there was some debate as to its suitability for turning right.

Some participants in both the 5m and 7.5m focus groups suggested that a longer early release would be needed to provide more of a gap if it was designed to allow them to turn in front of the car. Other participants suggested that a dedicated right turn for cyclists would be more suitable.

F8.a. For each of the 3-second, 4-second and 5-second early release scenarios, in over three-quarters of right-turning observations, at least one cyclist turned right in front of the oncoming car.

F8.b. The larger the early release, the higher the average number of cyclists who turned right ahead of the oncoming car.
- For the small group of eight cyclists, this ranged from 1.3 with the 2-second early release up to 5.6 with the 5-second early release.
- For the large group of 16 cyclists, this ranged from 1.6 with the 2-second early release up to 8.6 with the 5-second early release.

F8.c. The deeper the cycle reservoir, the higher the average number of cyclists who turned right ahead of the oncoming car.
- For the small group of eight cyclists, this was on average 1.9, 2.5 and 3.1 in the 5m, 7.5m and 10m scenarios, respectively.
- For the large group of 16 cyclists, this was on average 3.2, 5.5 and 5.0, respectively.

F8.d. The proportion of participants who said they turned right in front of the car either 'Every time' or 'Sometimes' was:
- For the small groups, 58%, 71% and 90% for the 5m, 7.5m and 10m trials, respectively.
- For the large groups, 46%, 67% and 66% for the 5m, 7.5m and 10m trials, respectively.

F8.e. Of the cyclists who said they turned right in front of the car either every time or sometimes:
- 30 to 60% said "I could see that the car had not started or it was moving slowly";
- 20 to 40% said "I could see from the LLCS I had enough time to turn in front of the car";
- 15 to 25% said "I could see that other cyclists were turning in front of the car";
- 5 to 15% said "I expected the car to wait for me".

F8.f. Of those who said they 'turned in front of the car every time', 4% gave comments suggesting they were confused over who had priority, whereas this proportion was 5% for those who said they 'turned in front of the car sometimes'. Some said they thought the LLCS gave them priority over oncoming vehicles, interpreting it as acting like a filter arrow.

F8.g. The proportion of participants who said "I could see from the LLCS that I had enough time to turn in front of the car" was higher for the deeper cycle reservoirs. This might be explained by the car on the opposing approach being set back further from the junction, resulting in a larger gap in which more cyclists could turn.

Further information in Appendices C and D

3.9 What did the cyclists think about the effect on safety of the LLCS and cycle reservoirs?

Table 17 – Research questions on safety

Road user	Theme	Research question	Video	Q'naire
Cyclists	Trial experiences	How much time did the cyclists feel they had to get through the junction?	✗	✓
		Did cyclists experience difficulties?	✗	✓
		What was the effect on the perceived safety?	✗	✓

3.9.1 How much time did the cyclists feel they had to get through the junction?

Participants were asked how much time they felt they had to get through the junction safely ahead of the car (Figure 32). The largest proportion of cyclists (44%) said they had 'just enough time', 33% said they did not have enough time and 19% said they had 'plenty of time' to get through the junction. Results were similar for the different reservoir depths and group sizes. These results contrast with the M19 Trials where around 40% of cyclists said they had 'plenty of time' and less than 15% said they did not have enough time.

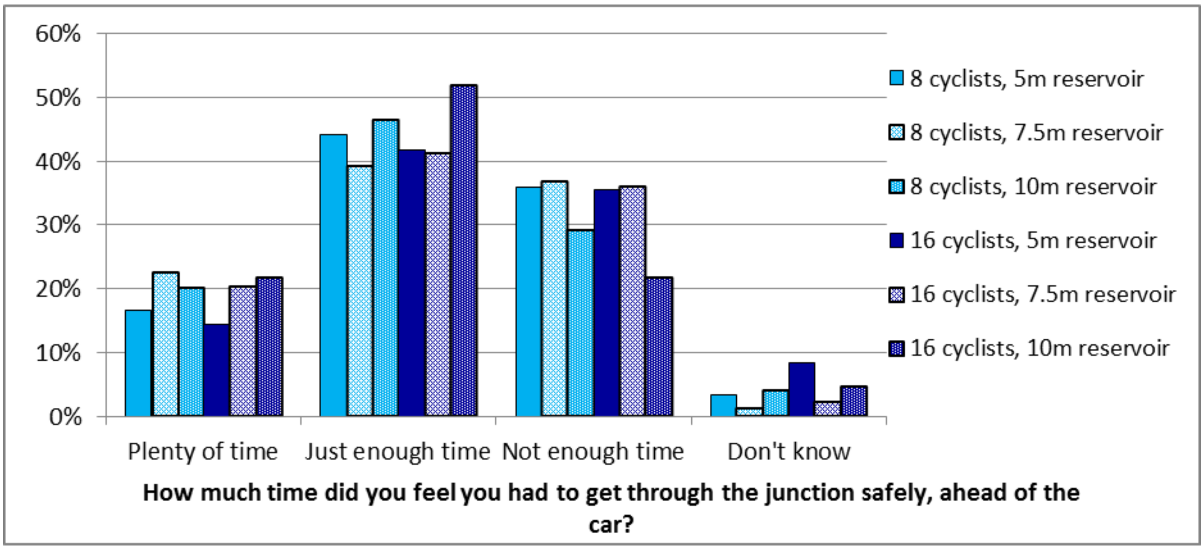


Figure 32 – Cycle trial: how much time cyclists felt they had to clear the junction ahead of the car (questionnaire)

3.9.2 Did cyclists experience difficulties?

When asked how easy it was to use the trial junction compared with an ordinary junction with traffic signals, 85% either said it was 'easier' or 'much easier'. This is a similar proportion to the previous trials when about 90% of cyclists said this. Fewer cyclists found the right turn at Arm D 'easy' or ' very easy', compared to the other turning movements.

Cyclists were more likely to say the junction was easier or much easier to use if there was a small group or a large cycle reservoir. This suggests that both group size and the size of the cycle reservoir influence how easy a junction is to use. Participants in in the large group who experienced the 5m reservoir with 16 cyclists group were less likely to say the junction was 'much easier' to use.

3.9.3 What was the effect on the perceived safety?

Cyclists were asked how safe they would feel using this type of junction (as a cyclist) compared with an ordinary junction with traffic signals; responses are shown in Figure 33.

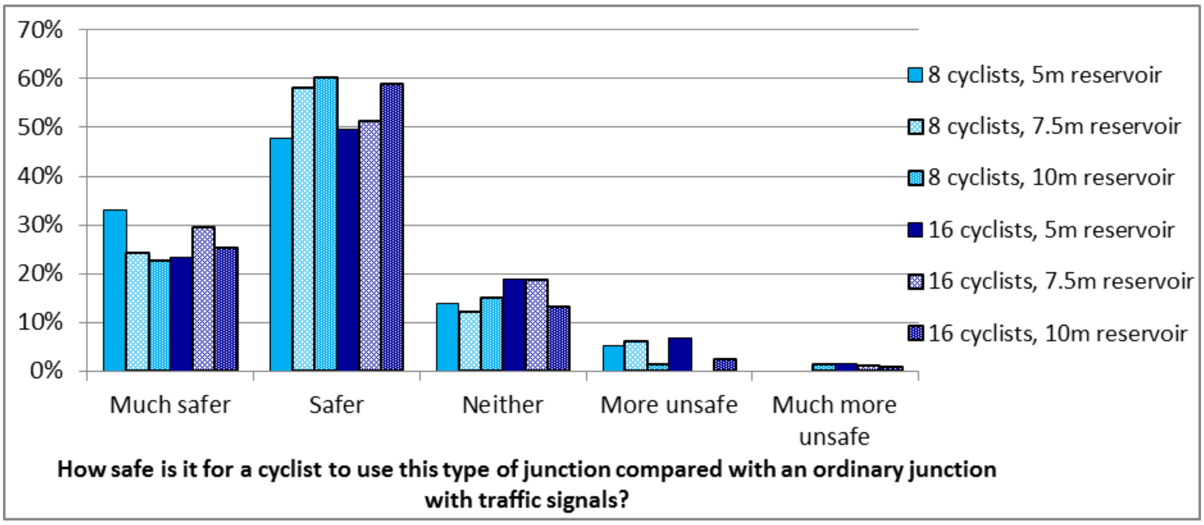


Figure 33 – Cycle trial: perceptions of safety compared with an ordinary junction (questionnaire)

80% of cyclists considered the junction to be either be 'safer' or 'much safer' to use compared to an ordinary junction with traffic signals (compared with around 90% in previous trials). A higher proportion of cyclists who experienced the larger cycle reservoir sizes (7.5m and 10m) were more likely to say that they thought the trial junction was 'safer'. Results were similar across the two group sizes. This suggests that cycle reservoir size has more of an effect on cyclists' perception of safety than the volume of cyclists.

> *"Safer if you have managed to gain access to area".*

Around 5% in most scenarios said the junction was more unsafe or much more unsafe. Of these the main concern was about turning right across oncoming traffic when there was an early release, suggesting that this could be more dangerous if cyclists rely on the LLCS and do not use their own judgement. Some cyclists commented that they followed the cyclists in front on occasion, despite thinking that that it was the oncoming traffic which had right of way:

> *"Cyclists up front were going before main light was green but those at rear/middle were confused at times as to why they had gone when we thought it was the cars right of way. Some went when car was going. Could cause accident and sometimes car didn't know to stop/go." (5m reservoir, 16 cyclists)*

> *"Don't have the low level signals change before the main lights. Some cyclists will assume they have right of way to turn right in front of on-coming cars, when the car doesn't start moving straight away." 10m reservoir, 16 cyclists].*

F9.a. 80% of cyclists considered the junction to be either be 'safer' or 'much safer' to use compared to an ordinary junction with traffic signals (compared with around 90% in previous trials).

F9.b. Around 5% in most scenarios said the junction was more unsafe or much more unsafe. Of these the main concern was about turning right across oncoming traffic when there was an early release.

Further information in Appendix D

4 Findings – car trial

4.1 Did car drivers understand the LLCS and cycle reservoirs?

Table 18 – Research questions on understanding

Road user	Theme	Research question	Video	Q'naire
Car drivers	Understanding	Did car drivers understand the purpose of the LLCS and cycle reservoirs?	✗	✓

4.1.1 Understanding of the cycle reservoirs

In the post-trial questionnaire, when asked "What does the area with the cycle symbol mean to you?" about 95% of car drivers had a safe interpretation, either that the cycle reservoir was a stopping area for cyclists or that cars should not enter it. Participants understood the different sized reservoirs equally well. A small minority (1%) of car drivers thought that motorcyclists were allowed to wait in the cycle reservoir, and another 1% thought that the colour of the reservoir gave it a different meaning. These participants understood the green cycle reservoir to be for cyclists only, but thought that car drivers could wait in the unpainted reservoir if there were no cyclists around. These findings were also observed in previous trials.

4.1.2 Understanding of the LLCS

As in previous trials, about 95% of car drivers showed a good understanding, that the LLCS were either traffic signals for cyclists or normal traffic signals. About 2% of car drivers thought that the LLCS gave cyclists priority or right of way at the junction. One car driver (<1%) thought that the LLCS were for both cyclists and motorcyclists; this participant also thought that motorcyclists were allowed to stop in the cycle reservoir.

F10.a. Almost all car drivers (about 95%) understood the purpose of the cycle reservoir. Participants understood the different sized reservoirs equally well.

F10.b. Similar to previous trials, three car drivers (less than 5%) thought the green unpainted cycle reservoirs had different meanings, with cars being able to enter the unpainted reservoir if there are no cyclists around.

F10.c. Similar to previous trials, almost all car drivers (95%) understood the LLCS.

4.2 What attitudes did car drivers have towards the cycle reservoirs?

Table 19 – Research questions on attitudes

Road user	Theme	Research question	Video	Q'naire
Car drivers	Attitudes	What did car drivers think about the size of the cycle reservoir?	✗	✓
		What were the perceived benefits of cycle reservoirs?	✗	✓
		Did car drivers like the cycle reservoirs?	✗	✓
		What improvements did car drivers suggest for cycle reservoirs?	✗	✓
		Would the LLCS with cycle reservoirs make people more likely to cycle on busy roads?	✗	✓
		What was the effect on the perceived safety?	✗	✓

4.2.1 What did car drivers think about the size of the reservoir

As discussed in Section 2.3.2, the car drivers experienced the junction either with one cyclist in front or with no cyclists.

In each scenario, the majority of car drivers said that the size of the cycle reservoir was 'about right'. The lowest proportion of car drivers to say this came from those who experienced the 10m cycle reservoir (64%). This was lower than those who experienced the 7.5m reservoir (81%) and the 5m reservoir (84%). Figure 34 shows the findings.

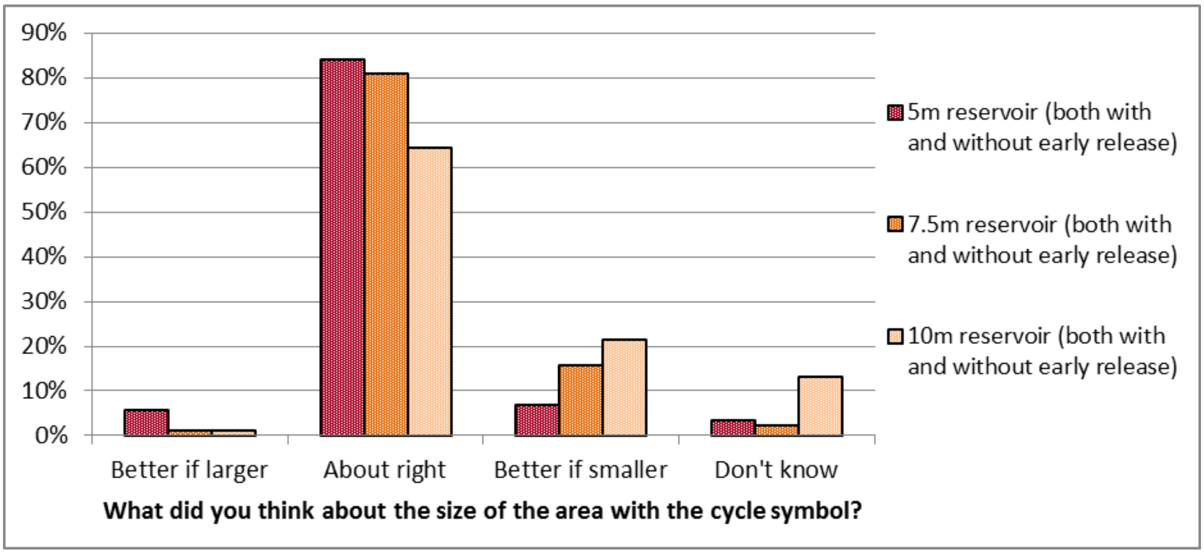


Figure 34 – Car trial: views on the size of the cycle reservoir (questionnaire)

Car drivers were more likely to say that the reservoir would be 'better if smaller' as the size of the reservoir that they experienced increased. Just over 20% of car drivers who experienced the 10m reservoir thought that this was the case compared with 7% of those who experienced the 5m reservoir. About 5% of car drivers who experienced the 5m reservoir thought that it would be 'better if larger'.

Common comments from car drivers relating to the size of the cycle reservoir were that it should be based on the location and volume of cyclists using the junction and that there is a need to strike a balance between space for cyclists and motor vehicles:

"If the area is too big in busy areas and there are no cyclists, drivers would tend to enter it" (5m reservoir, with early release)

"There is sufficient space for cyclists but not too much to cause anxiety or drivers behind to get irritated" (7.5m reservoir, with early release)

"If [the cycle reservoir was] smaller than it would encourage drivers to ignore it. If larger then it would be too big (waste of space)" (7.5m reservoir, no early release)

4.2.2 What were the perceived benefits of cycle reservoirs?

The most common benefits of the cycle reservoirs, highlighted by car drivers were that they provide cyclists with their own space and separate them from the rest of traffic. This in turn increases motorists' awareness and visibility of cyclists as they are primarily located in front of the car drivers.

4.2.3 Did car drivers like the cycle reservoirs?

A qualitative assessment was made to classify the comments about the cycle reservoirs in response to several questions into three categories: in favour (positive), against (negative) and neutral. In total 43% of car drivers (111 out of 261) provided feedback on the cycle reservoirs and of these, 90% were positive.

4.2.4 What improvements did car drivers suggest for cycle reservoirs?

When asked for suggestions to improve the junction, the comments made which specifically related to the cycle reservoir were similar to those in previous trials and included having more / improved / brighter cycle reservoirs (which are green), having a cycle lane leading into the reservoir, making the reservoirs smaller, moving the main signals further away from the reservoir, having yellow hatched markings in the cycle areas, and making the cycle reservoirs bigger.

As with previous trials, a number of car drivers (6%) said that they preferred the green painted cycle reservoirs as these were more obvious and thus car drivers were less likely to stop inside them.

"The cycle boxes/junctions should be all in green as it stood out more and would ensure motorists refrained from entering whilst waiting for signals to change." (5m reservoir, no early release)

4.2.5 Would the LLCS with cycle reservoirs make people more likely to cycle on busy roads?

Participants were asked, 'Do you think it would affect how often you cycle in busy traffic if more junctions were like this?'. As discussed in Appendix E, the participant sample consisted largely of residents of the Wokingham/Bracknell area, where only few junctions have ASLs. As such, many participants were not familiar with ASLs and interpreted an ordinary signal junction to be one without an ASL.

About a quarter of car drivers said that it would make them more likely to cycle in busy traffic; a higher proportion of drivers in the 10m reservoir with early release group (about 35%) said 'yes', than in other groups (between 20% and 30%). However, because of the make-up of the sample, there is not sufficient evidence to suggest whether the size of the cycle reservoir would influence the number of people cycling on busy roads.

4.2.6 What was the effect of LLCS with cycle reservoirs on the perceived safety?

When asked about how this compared with a normal junction with traffic signals, an average of 66% of car drivers said they considered the junction to either be 'safer' or 'much safer'. Participants who experienced the larger reservoir sizes (7.5m and 10m) were slightly more likely to say this than those who experienced the 5m reservoir (about 70% compared with 64%), and the participants who experienced the early release were more inclined to find the junction safer compared to those who did not experience the early release. Most responses tended to either say that the junction makes drivers more aware of cyclists or that it makes no difference.

F11.a. The majority of car drivers thought that the size of the cycle reservoir they experienced was 'about right' (84%, 81%, 64% for the 5m, 7.5m and 10m reservoirs respectively). Those who experienced the larger reservoir (10m) were the most likely to say it would be better if smaller (about 20%), although they only experienced the junction either with one cyclist in front or no cyclists.

F11.b. Common comments from car drivers relating to the size of the cycle reservoir were that it should be based on the location and volume of cyclists using the junction and that there is a need to strike a balance between space for cyclists and motor vehicles.

F11.c. The participants who experienced the larger reservoirs (7.5m and 10m) were slightly more likely to say the junction was 'safer' or 'much safer' than an ordinary junction than those who experienced the 5m reservoir (70% compared with 64%).

4.3 What attitudes did car drivers have towards the LLCS?

Table 20 – Research questions on attitudes

Road user	Theme	Research question	Video	Q'naire
Car drivers	Attitudes	What were the perceived benefits of LLCS?	✗	✓
		Did car drivers like LLCS?	✗	✓
		What did car drivers think about the height and angle of the LLCS?	✗	✓
		What did car drivers think about the location of the LLCS and the main traffic signals?	✗	✓
		What improvements did car drivers suggest for LLCS?	✗	✓

4.3.1 What were the perceived benefits of the LLCS?

As in previous trials over 90% of car drivers said that cyclists on the road would benefit from the LLCS, with a slight increase in this response as the size of the cycle reservoir increased (90% for the 5m reservoir and 100% for the 10m reservoir).

The main reasons for the LLCS being considered beneficial were similar to those from previous trials and included: improved safety; easier for cyclists to see; raising awareness of cyclists; and useful for anticipating the main signals changing. As in previous trials there was some concern that motorcyclists and scooter riders may also follow the LLCS rather than the main signals.

4.3.2 Did car drivers like LLCS?

A qualitative assessment was made to classify the comments about the LLCS in response to several questions into three categories: in favour (positive), against (negative) and neutral (as shown in Figure 35). Responses specifically referring to the cycle reservoirs were excluded for this question.

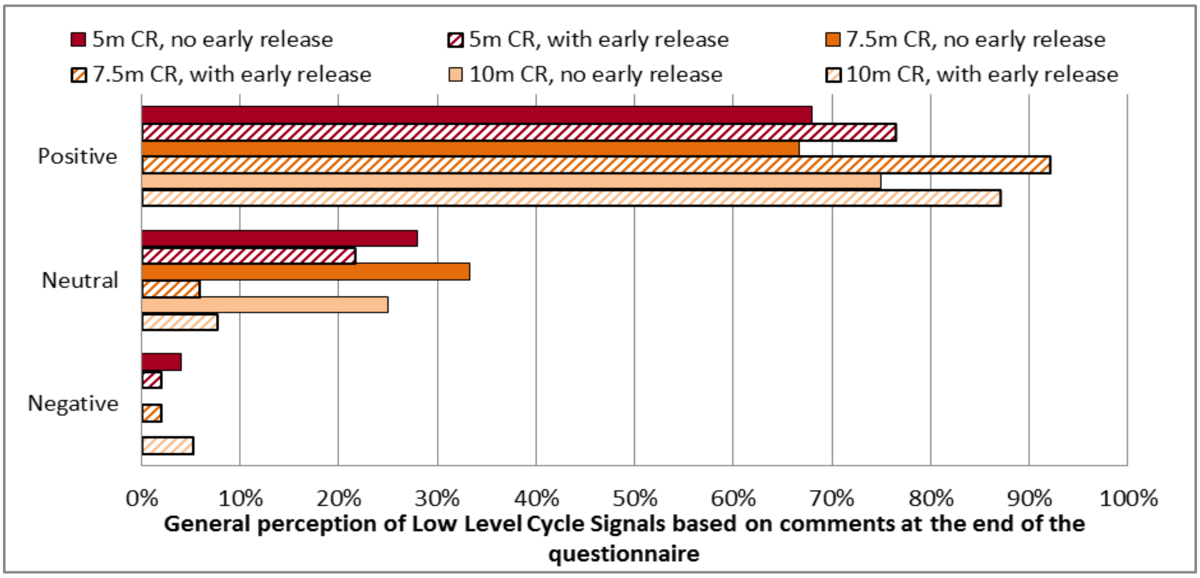


Figure 35 – Car trial: classification of attitudes (questionnaire)

Similar to previous trials, about 95% of car drivers were either positive or neutral about the LLCS; this was the case for all cycle reservoir depths. Car drivers who experienced the early release were more likely to give a positive response than those who did not for all reservoir depths.

Many participants referred to the signals being a good idea and related to potential improvements to safety.

> *"Good idea for cyclists using busy roads, would make cycling safer for all cycle users and increase awareness for motorists" (7.5m reservoir with early release)*

4.3.3 What did car drivers think about the height and angle of the LLCS?

As with previous trials, the majority of car drivers (between 75% and 85%) said that the height of the LLCS was 'about right' and between 10% and 20% thought that they would be 'better if higher'. The size of the reservoir did not have an effect.

The majority of car drivers also felt that the angle of the LLCS was 'about right' (over 70%). Those who experienced the early release were more likely to give this response than those who did not experience the early release (92%, 86% and 85% compared with 76%, 73% and 72%). About 10% of car drivers said that the angle should 'point more towards the road'.

4.3.4 What did car drivers think about the location of the LLCS?

The majority (75%) of car drivers said that the location of the LLCS was 'about right' with about 10% saying they would be 'better if on the same pole as the main signals'.

There was no clear effect from the early release or the size of the cycle reservoir experienced, although participants who experienced the 5m reservoir with no early release were more likely to say 'better if on same pole as main signals' compared to the other groups (21%). Comments from car drivers were no different from previous trials.

4.3.5 What improvements did car drivers suggest for LLCS?

When asked for suggestions to improve the signals, a common response (from about 6%) was to provide a longer early release so that cyclists have more time to get ahead of the traffic. Other improvements were similar to previous trials, including making them brighter or more obvious or bigger, changing their angle (towards the road), placing them higher up, providing an explanation sign, providing a filter arrow, providing a flashing green for cyclists, removing the red and /or amber for cyclist, having them duplicated higher up so car drivers could see them more easily, putting them on the same pole as the main signals, and making them less obvious to car drivers.

F12.a. The attitudes of the car drivers to LLCS were similar to previous trials, with the majority of car drivers saying that: the location of the LLCS was 'about right' (75%); the height of the LLCS was 'about right' (between 75% and 85%); and the angle of the LLCS was 'about right' (over 70%). For each of these, the size of the reservoir did not have an effect.

F12.b. As in previous trials over 90% of car drivers said that cyclists on the road would benefit from the LLCS, with a slight increase in this response as the size of the cycle reservoir increased (90% for the 5m reservoir and 100% for the 10m reservoir).

F12.c. Similar to previous trials, about 95% of car drivers were either positive or neutral about the LLCS; this was the case for all cycle reservoir depths.

4.4 What information did car drivers use at the junction?

Table 21 – Research questions on use of LLCS

Road user	Theme	Research question	Video	Q'naire
Car drivers	Trial experiences	What did the car drivers look at when deciding when to enter the junction? What was the most important factor in their decision?	✗	✓

4.4.1 Did car drivers look at the LLCS? / What was the most important piece of information to car drivers?

Participants were asked to list what information they used when approaching the junction and whilst waiting at the junction. The main findings were as follows:

- For the most part the reservoir depth did not affect what car drivers looked at; although in the trials with no early release, fewer drivers thought the position of cyclists ahead was the most important cue as the size of the reservoir increased (typically from around 30% for the 5m reservoir and about 10% for the 10m reservoir).

- Many participants said they used both sets of lights to inform their understanding and would use the LLCS as an indication of when the main lights would change.
- Many said they were conscious of the cyclist or waited for cyclist to move off first.
- Many seemed to be more likely to notice or look at the LLCS if there was a cyclist in front.

F13.a. For the most part the reservoir depth did not affect what car drivers looked at.

4.5 How did the different cycle reservoir depths affect where car drivers waited?

Table 22 – Research questions on stopping position

Road user	Theme	Research question	Video	Q'naire
Car drivers	Longitudinal stopping position	To what extent did the different reservoir depths affect whether drivers encroached into the cycle reservoir and how did this vary with and without a cyclist in front?	✓	✓

4.5.1 Findings from the video analysis

4.5.1.1 Compliance with the cycle reservoir

The position that participants stopped at the traffic lights was captured from videos, as discussed in Section 2.6.3.2. For car drivers the longitudinal position (i.e. the position along the road) was captured at 2.5m intervals before the first stop line and at 1.25m intervals after the first stop line within the reservoir.

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 the previous trials the observed compliance with the reservoir was substantially higher than values that have been observed on-street in other studies[3]. 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 any change would.

Figure 36 shows the proportion of observations where the car driver stopped within the reservoir; i.e. the front bumper of the vehicle was past the first stop line. This is shown for the different reservoir depths and whether there was a controlled cyclist present in the reservoir or not.

[3] See Section 1.2.4 of Ball et. al 2015c

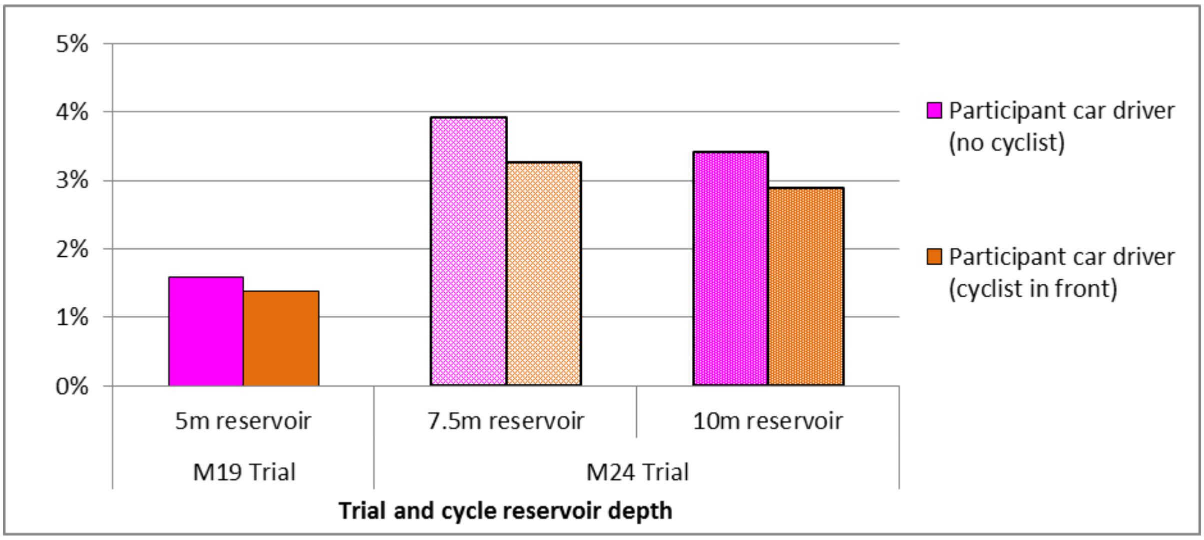


Figure 36 – Car trial: proportion of observations where the car stopped within the cycle reservoir, by reservoir depth (video data)

In the majority of observations (>96%), cars stopped before the reservoir entrance. The trials with the deeper cycle reservoirs were associated with a small decrease in compliance, i.e. slightly more car drivers stopped past the first stop line. Specifically in the scenarios with no controlled cyclists, the proportion stopping within the reservoir increased from 1.6% for the 5m reservoir: to 3.9% for the 7.5m reservoir and 3.4% for the 10m reservoir; both of which were statistically significant increases[4]. In the scenarios with one controlled cyclist in front, there were similar increases from 1.4% for the 5m reservoir: to 3.3% for the 7.5m reservoir and 2.9% for the 10m reservoir, both of which were statistically significant increases[5].

The majority of encroachment was only up to 1.25m past the first stop line. The 10m reservoir had slightly higher encroachment compared to the 5m reservoir when there was no cyclist present (0.9% compared to 0.0%), which although only a small difference was indicative of greater encroachment in the 10m scenario.

Figure 37 – Car trial: example of a car stopped past the first stop line

[4] $p<0.001$ and $p<0.01$, respectively

[5] $p<0.01$ and $p<0.05$, respectively

4.5.1.2 Distribution of stopping position before the reservoir

There was anecdotal evidence in the M19 trial 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 main signals, because these were mounted on a separate pole at the first stop line. More precise data for the M24 trials was therefore captured on the 'Before reservoir' zone. Figure 38 shows the longitudinal stopping positions in the 7.5m and 10m reservoir scenarios, pooled for both with and without the controlled cyclist present.

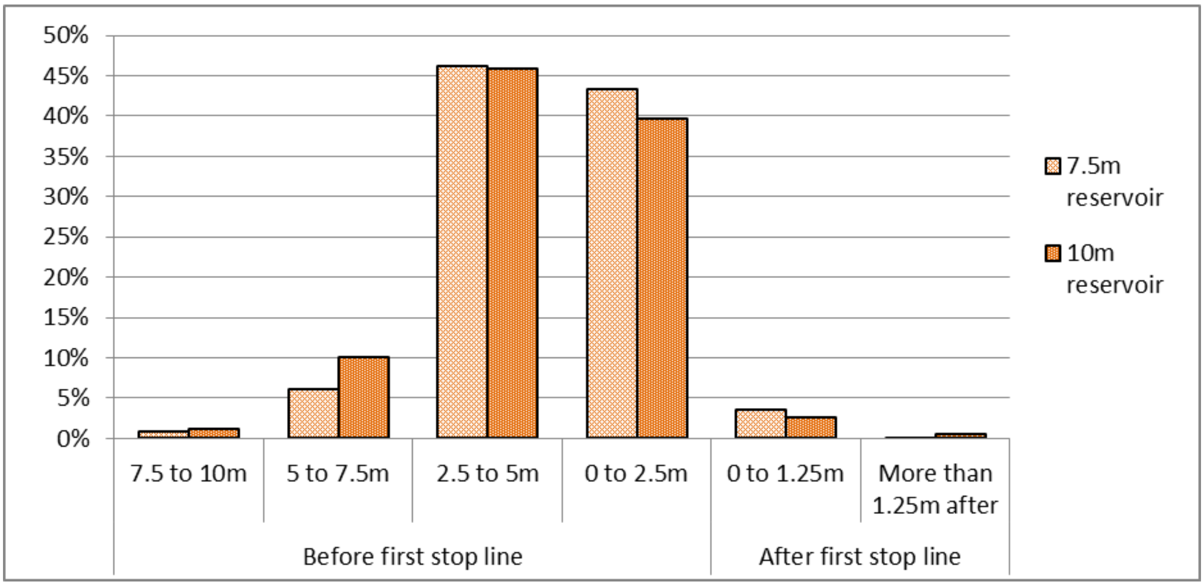


Figure 38 – Car trial: precise stopping positions in 7.5m and 10m reservoir scenarios (video data)

Over half of the car drivers stopped more than 2.5m before the first stop line. There was a similar distribution for the 7.5m and 10m reservoir depths. This data was not collected for the previous trials, but nevertheless supports the anecdotal evidence from the M19 trial that a substantial proportion of car drivers stopped quite far back from the stop line, possibly in order to see the main signals that were located on the separate poles at the first stop line.

Figure 39 – Car trial: example of a car stopped back from the first stop line

4.5.2 Findings from the questionnaire analysis

Car drivers were asked how often they stopped in the cycle reservoir while waiting for the signals to change and then to explain their decision. The majority of car drivers (over 80%) said that they 'never' waited in the cycle reservoir and there were no significant differences between the different sizes of reservoir.

About 4% of car drivers said that they 'sometimes' stopped in the cycle reservoir. This was more likely to happen when there were no cyclists around, although two drivers said that they may have crept into the area whilst anticipating the lights changing or stopped too late. One car driver said they didn't notice the reservoir on their first run as they were looking at the lights and another driver suggested that they waited in the unpainted reservoirs but not the green reservoirs.

Those car drivers who suggested that they stopped in the cycle reservoir 'every time' (6%) all understood that the reservoir was an area for cyclists and that cars should not stop in the area, suggesting that they may have misunderstood the question. In the previous M19 Trial, 1% of car drivers said they stopped in the cycle reservoir 'every time'.

Three participants who sometimes stopped in the cycle reservoir suggested that it was acceptable to do this if there were no cyclists about:

"Just stopped too late, but no cyclists= no problem" (7.5m, no early release)

F14.a. In the majority of observations (>96%), cars stopped before the reservoir entrance. The trials with the deeper cycle reservoirs were associated with a small but statistically significant increase in encroachment, from about 1.5% for the 5m reservoir up to between 3 and 4% for the deeper reservoirs.

F14.b. The majority of encroachment was only up to 1.25m past the first stop line. The 10m reservoir had slightly higher encroachment compared to the 5m reservoir when there was no cyclist present (0.9% compared to 0.0%), which although only a small difference was indicative of greater encroachment in the 10m scenario.

F14.c. Over half of the car drivers stopped more than 2.5m before the first stop line for the 7.5m and 10m reservoir depths. This supports the anecdotal evidence from the previous trial that some car drivers stopped quite far back from the stop line, possibly in order to see the main signals that were located on the separate poles at the first stop line.

F14.d. In the questionnaire, the majority of car drivers (over 80%) said that they 'never' waited in the cycle reservoir and this did not vary by the depth of the reservoir.

4.6 Did the LLCS and cycle reservoirs affect how car drivers moved off as the signals changed to green?

Table 23 – Research questions on moving behaviour

Road user	Theme	Research question	Video	Q'naire
Car drivers	Reaction to the LLCS	'Reaction Time' – To what extent did car drivers start moving forwards early? To what extent did they say would they do this in on-street conditions?	✓	✓
	Delay to enter the junction	'Entry Time' – To what extent were drivers delayed from the green light to reaching the junction entrance?	✓	✗

4.6.1 Reaction Time

4.6.1.1 Findings from the video analysis

Figure 40 shows the proportion of observations where the car started moving before the main signals changed to red and amber for each early release and reservoir depth scenario.

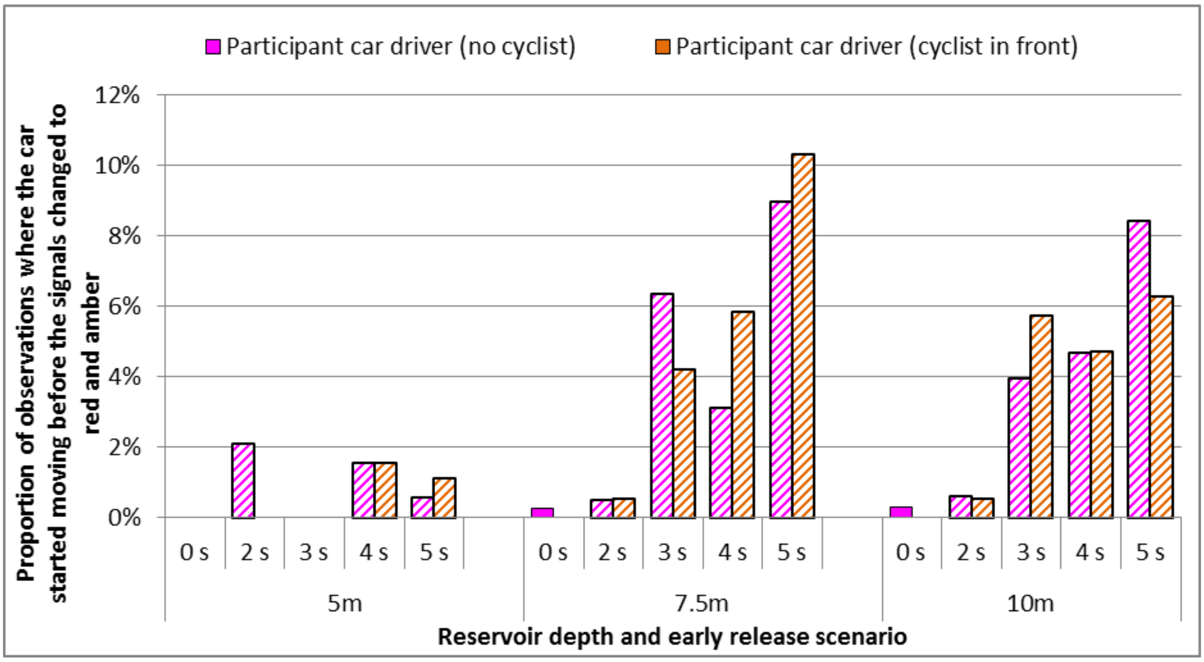


Figure 40 – Car trial: proportion of observations where the car started moving before the main signals changed to red and amber, by early release and reservoir depth (video data)

In the 5m reservoir scenario, in 0 to 2% of observations the car drivers started moving before the main signals changed to red and amber; this was also the case in scenarios with deeper reservoirs when there was either no early release or a 2-second early release. However, for the 7.5m and 10m reservoirs when there was an early release of 3 or more seconds, in 4-10% of observations the car driver started moving before the main signals changed to red and amber, i.e. they started moving on the LLCS early release. This suggests that when the reservoirs were 7.5m or 10m, the car drivers were more likely to start moving on the LLCS early release, compared to the 5m reservoir.

There were no consistent differences in the proportions with and without a cyclist in front.

Figure 41 shows the average Reaction Time of the car drivers to the main signals; the green line indicates when the signals turned to green.

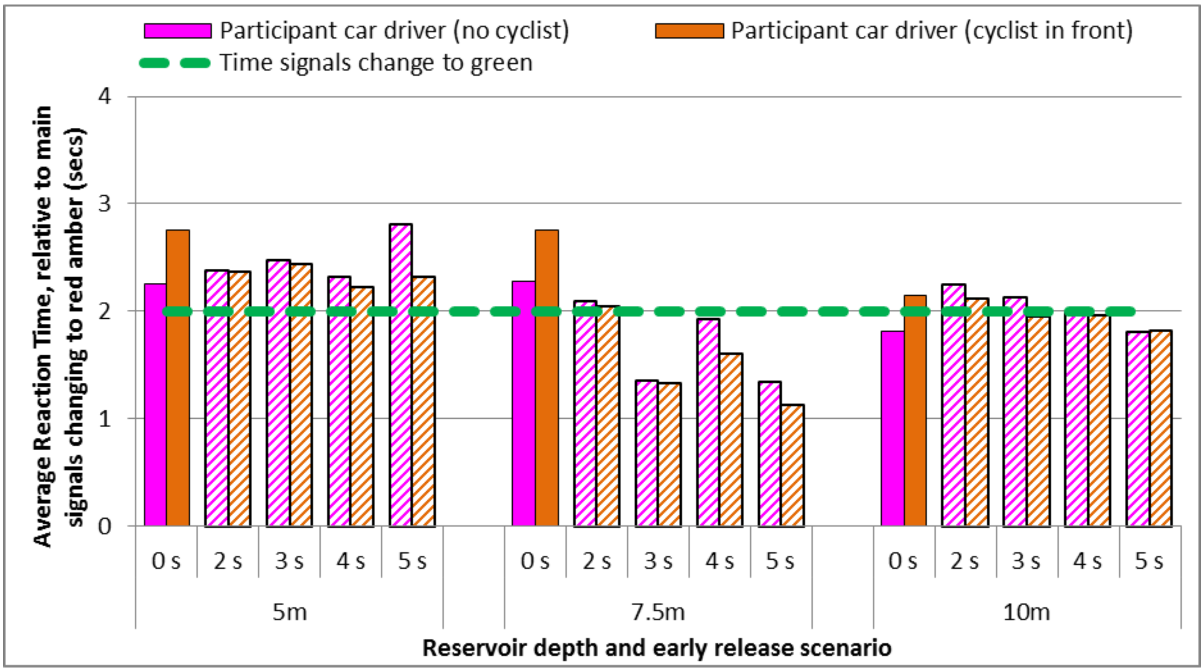


Figure 41 – Car trial: average Reaction Time, relative to the main signals changing to red and amber, by early release and reservoir depth (video data)

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 typically around half a second faster in the trials with the deeper reservoirs, compared to the trial with the 5m reservoir. The average Reaction Times were lowest for the 3-second and 5-second early release scenarios when there was a 7.5m reservoir; this is partly explained by the high proportion of observations for these scenarios where the car driver started moving on the LLCS early release (see Figure 40). As discussed in Section 2.4.1, the 3-second and 5-second trials were conducted on the same day and so came from the same sample of participants. It seems that on this particular trial day there were a few participants who consistently started moving before the main signals turned to green, which affected the overall average. This behaviour on this particular day was present across all junction approaches.

4.6.1.2 Findings from the questionnaire and focus groups

In the questionnaire, car drivers were asked "Thinking about how you might use these signals on normal roads, do you think you would ever start moving into the junction when the cycle signal was green and the main signal was red?". About 85% responded 'No', about 5% said 'Yes' and about 10% said 'It Depends'.

The results from those who experienced the 'no early release' scenarios suggested that car drivers may be more likely to move off early with a larger reservoir compared with a smaller one. In the questionnaire, car drivers were more likely to answer either 'yes' or 'it depends' as the size of the reservoir increased; this was 3% for the 5m reservoir, 14% for the 7.5m reservoir; and 24% for the 10m reservoir. These results support the video evidence (see Figure 40) that reservoir size may have a small effect on whether car drivers move off early.

When looking at the results from the 'with early release' scenarios, there were no significant differences between reservoir size. This is possibly due to participants in the early release trial being able to experience the hypothetical situation for themselves, thus affecting their response.

Of those who responded 'yes', a third said they may move off on a cycle green if they were not concentrating or distracted by the LLCS, and a quarter said they might if they were not aware of the early release. 17% said they would start moving early if there were no cyclists around.

Of those who responded 'it depends', 50% said they might move early if there were no cyclists around and 20% said they might in anticipation of the main signals. Just under half of the car drivers who gave the reason 'no cyclists around' had experienced the 10m reservoir, which suggests that this may be more likely with a larger reservoir, however the sample was small (17 car drivers).

4.6.2 Entry Time

Figure 42 shows the average Entry Time of the car drivers relative to the main signals; the green line indicates when the signals turned to green.

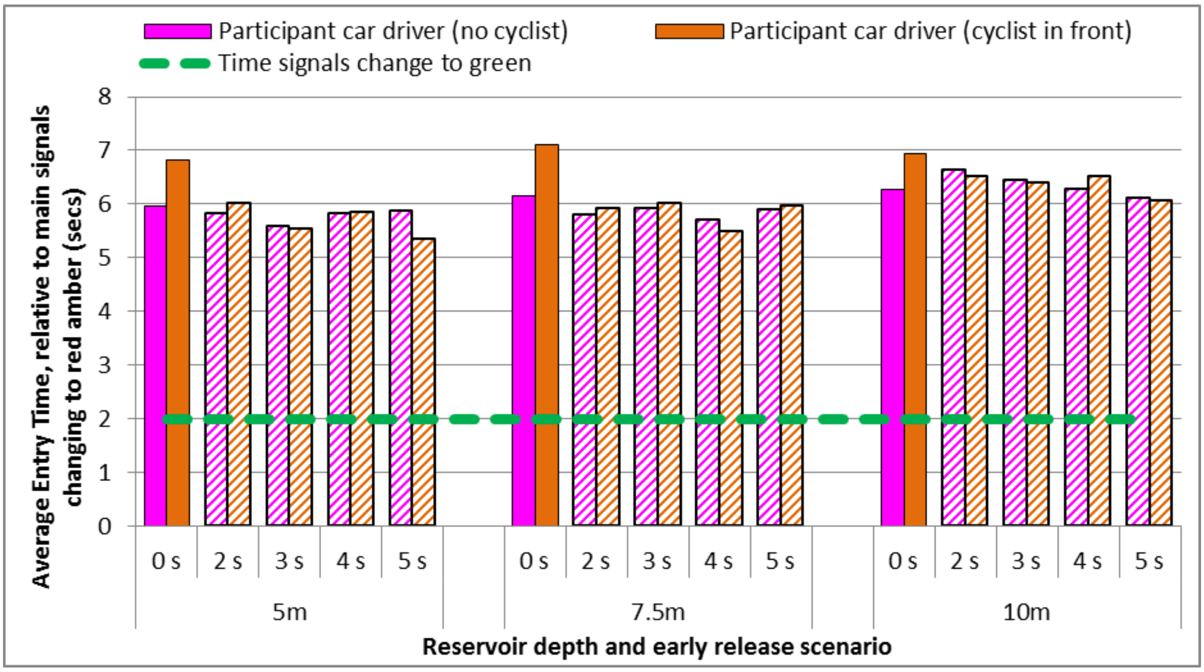
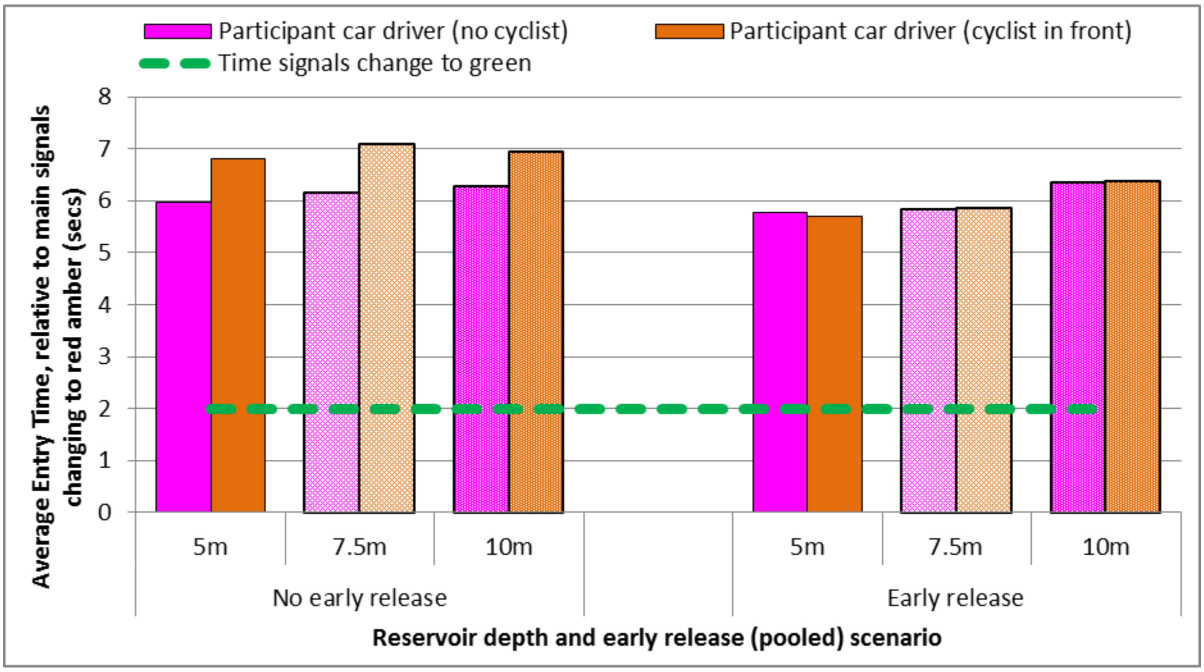


Figure 42 – Car trial: average Entry Time, relative to the main signals changing to red and amber, by early release and reservoir depth (video data)

The average Entry Time was highest in the scenario with no early release and a cyclist in front, suggesting that the car driver often had to wait for the cyclist before entering the junction. For each reservoir depth, the average Entry Times were consistent across the different early release scenarios and so it was possible to pool the data across the early release scenarios.

Figure 43 also shows the average Entry Time of the car drivers, but with the data pooled for all early release scenarios. The numbers that are highlighted in bold indicate a statistically significant increase, compared against the 5m reservoir baseline scenario.



		Average Entry Time			Difference against 5m baseline	
Early release	With / without cyclist	5m reservoir	7.5m reservoir	10m reservoir	7.5m reservoir	10m reservoir
No early release	No cyclist present	5.97	6.16	6.27	**+ 0.19**	**+ 0.3**
	With cyclist in front	6.82	7.10	6.94	**+ 0.28**	**+ 0.12**
With early release	No cyclist present	5.78	5.84	6.35	**+ 0.06**	**+ 0.58**
	With cyclist in front	5.71	5.86	6.37	**+ 0.15**	**+ 0.66**

Figure 43 – Car trial: average Entry Time, relative to the main signals changing to red and amber, by early release (pooled) and reservoir depth (video data)

As discussed previously, in the scenario with no early release and a cyclist in front, the car driver often had to wait for the cyclist before entering the junction and so this scenario is not considered further. For the scenarios with no early release and no cyclist present, the average Entry Time increased by about 0.2 seconds for each additional 2.5m of reservoir.

For the trials with an early release, the 7.5m reservoir resulted in a small increase of about 0.1 seconds to the average Entry Time, whereas the 10m reservoir resulted in an increase of about 0.6 seconds, compared against the 5m reservoir. As discussed in Section 4.6.1.1, the Reaction Times were typically around half a second faster in the trials with the deeper reservoirs, compared to the trial with the 5m reservoir. This perhaps explains why there was only a small difference in average Entry Time between the 5m and 7.5m reservoir scenarios. There was little difference in average Entry Time between the scenarios with and without a cyclist present, because in most instances the cyclist had already moved off and so the car driver was not delayed in entering the junction.

Figure 44 – Car trial: example of a car entering the junction after the cyclist

An alternative measure of the time advantage that cyclists have is shown below. Figure 45 shows the average time that the controlled cyclist entered the junction before the car entered the junction.

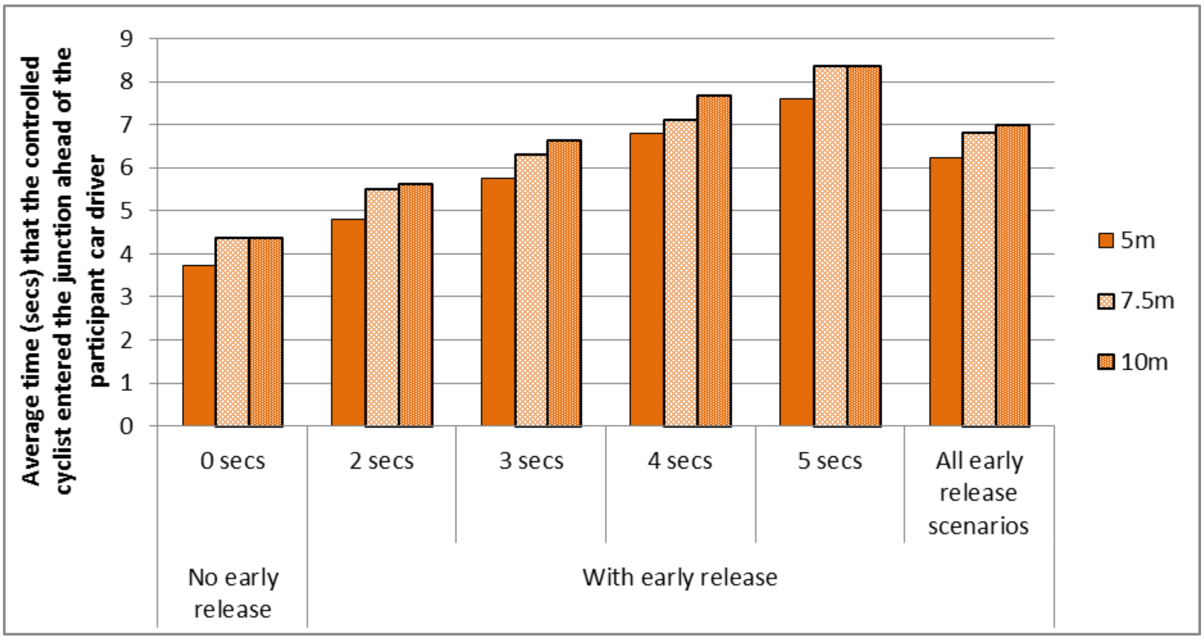


Figure 45 - Car trial: average time (secs) that the controlled cyclist entered the junction before the participant car driver entered the junction, by reservoir depth and early release (video data)

Pooling the averages across all early release scenarios suggests that increasing the depth of the reservoir from 5m to 7.5m gives an additional time advantage to the cyclist of 0.6 seconds, whereas increasing from 5m to 10m gives an additional time advantage of 0.8 seconds. It is difficult to interpret this measure, because similar to the average Entry Time measure, it implicitly includes other variables, such as the stopping position and Reaction Time of the car driver. Furthermore, this measure is also affected by any variations in the Entry Time of the controlled cyclists.

4.6.3 Estimated impact of Entry Time on distance travelled

Table 24 summarises the data in Figure 45 and also includes an average estimate of how far a cyclist would travel past the Junction Entrance before the car entered the junction if turning left or going straight on. This estimate assumes a speed of 5.4m/s[6]; 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 24 – 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	5m reservoir (M19a)	3.7	20.2
	7.5m reservoir (M24)	4.4	23.6
	10m reservoir (M24)	4.4	23.7
2 secs	5m reservoir (M19a)	4.8	25.9
	7.5m reservoir (M24)	5.5	29.8
	10m reservoir (M24)	5.6	30.4
3 secs	5m reservoir (M19a)	5.8	31.1
	7.5m reservoir (M24)	6.3	34.0
	10m reservoir (M24)	6.6	35.9
4 secs	5m reservoir (M19a)	6.8	36.8
	7.5m reservoir (M24)	7.1	38.5
	10m reservoir (M24)	7.7	41.6
5 secs	5m reservoir (M19a)	7.6	41.0
	7.5m reservoir (M24)	8.4	45.2
	10m reservoir (M24)	8.4	45.2

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

F15.a. When the reservoirs were 7.5m or 10m, the car drivers were more likely to start moving on the LLCS early release, compared to the 5m reservoir. Specifically for the 5m reservoir this was between 0% and 2% of observations, but for the 7.5m and 10m reservoirs this rose to between 4% and 10% of the observations when there was an early release of 3 or more seconds.

F15.b. The average Reaction Times for the car drivers were typically around half a second faster in the trials with the deeper reservoirs, compared to the trial with the 5m reservoir.

F15.c. In the questionnaire when asked whether during normal driving they would ever start moving on the LLCS early release, more car drivers answered either 'Yes' or 'It Depends' as the size of the reservoir increased; this was 3%, 14% and 24% for the 5m, 7.5m and 10m reservoirs, respectively. Reasons for doing so included: not concentrating; being distracted by the LLCS; if they were not aware of the early release; if there were no cyclists around; in anticipation of the main signals.

F15.d. The average Entry Time was highest in the scenario with no early release and a cyclist in front, suggesting that the car driver often had to wait for the cyclist before entering the junction. For the scenarios with no early release and no cyclist present, the average Entry Time increased by about 0.2 seconds for each additional 2.5m of reservoir.

F15.e. For the trials with an early release, the 7.5m reservoir resulted in a small increase of about 0.1 seconds to the average Entry Time, whereas the 10m reservoir resulted in an increase of about 0.6 seconds, compared against the 5m reservoir.

F15.f. An alternative measure relative to the Entry Time of the controlled cyclists suggested that the 7.5m reservoir gave an additional time advantage to the cyclist of 0.6 seconds, whereas the 10m gave an additional time advantage to the cyclist of 0.8 seconds, both compared against the 5m reservoir. However, this measure was subject to variability in the Entry Times of the controlled cyclists.

5 Conclusions

5.1 Findings against each research question

Previous trials involved the LLCS being accompanied by a 5m cycle reservoir: used as repeaters of the main signals (trial code: 'M14'); with an early release (trial code: 'M18'); and mounted on a separate pole to the main signals (trial code: 'M19'). This report presents the results from a trial with LLCS accompanied by three difference cycle reservoir depths of 5m, 7.5m and 10m (trial code: 'M24').

- Section 3 contains the findings from this trial with groups of cyclists, either 8 cyclists or 16 cyclists.
- Section 4 contains the findings from this trial with car drivers.

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 6; 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 different sizes of cycle reservoir for groups of cyclists and individual car drivers, specifically when combined with LLCS being mounted on separate poles to the main signals. As discussed, in Section 1.2.1.1, the standard depth of ASLs is currently 4 to 5 metres, although orders have been granted for a small number of sites to have ASLs that are 7.5m deep and DfT's consultation update to the TSRGD (May 2014) includes 7.5m ASLs.

The findings from these trials are discussed below in relation to the study objectives.

5.2.1 Cycle trial: occupancy of reservoir

The average occupancy of the different reservoirs was found to be as follows:

- The average occupancy of the 5m reservoir was 8.0 cyclists when trialled with large groups (16 cyclists) and 6.5 cyclists when trialled with small groups (eight cyclists) [F6.a, F6.b].
- The average occupancy of the 7.5m reservoir was 13.0 cyclists when trialled with large groups (16 cyclists) [F6.b].
- The 10m reservoir was sufficiently large enough to hold at least 16 cyclists in almost all instances when trialled with large groups (16 cyclists) [F6.b].

These findings suggest that the following reservoir depths may be considered for a junction with a one-lane approach:

- A cycle reservoir between 5m and 7.5m deep when the required storage space is 8 to 13 cyclists.
- A cycle reservoir greater than 7.5m deep when the required storage space is 13 or more cyclists.
- A rule of thumb seems to be 1.7 cyclists per metre of reservoir depth for a one-lane approach.

For cyclists waiting to go straight on, the front left of the reservoir typically had the highest density, although for the large group and smaller reservoir lengths, the density was higher towards the back of the reservoir. There were similar trends for right-turning cyclists, although there was the opposite tendency to wait on the right hand side [F6.d].

5.2.2 Cycle trial: difficulties in seeing the LLCS and the height of the LLCS

Around half of the cyclists said that there were times when it was difficult or impossible to see the LLCS when waiting at the junction [F4.b]. This was greater with the larger groups (40%). The most common reason being that the LLCS was obscured by other cyclists [F4.c]. Of the cyclists who said it was difficult to see the LLCS and it affected how they went through the junction, over 40% said that they followed the cyclists in front, whereas a quarter said that they tried to reposition themselves so that they could see the LLCS [F4.d].

When asked specifically about the height of the LLCS, the most common response was "about right" (58%). Again the larger the group the more cyclists thought that the LLCS should be mounted higher (43-49% in the largest group) [F3.b].

These findings suggest that the height of the LLCS is about right, although could be mounted higher where large groups of cyclists are likely to be present.

5.2.3 Cycle trial: right-turning behaviour of cyclists

Similar to the previous trials, the longer early releases encouraged a higher proportion of cyclists to turn right ahead of the oncoming car. For scenarios with an early release of 3 or more seconds, in over three-quarters of right-turning observations, at least one cyclist turned right in front of the oncoming car [F8.a]. For the small group of eight cyclists, the average number of cyclists who turned right ahead of the oncoming car ranged from 1.3 with the 2-second early release up to 5.6 with the 5-second early release. For the large group of 16 cyclists, this ranged from 1.6 with the 2-second early release up to 8.6 with the 5-second early release [F8.b].

It was also found that in the scenarios with the deeper cycle reservoirs there was a higher average number of cyclists who turned right ahead of the oncoming car [F8.c]. This might be explained by the car on the opposing approach being set back further from the junction, resulting in a larger gap in which more cyclists could turn.

When asked in the questionnaire for the reasons for turning right in front of the car, the most popular responses were "I could see that the car had not started or it was moving slowly" and "I could see from the LLCS that I had enough time to turn in front of the car". Similar to previous trials a small proportion (between 5 and 15%) said they "expected the car to wait for me" and that they thought the LLCS gave them priority over oncoming vehicles, interpreting it as acting like a filter arrow. Some cyclists (between 15 and 25%) said "I could see that other cyclists were turning in front of the car", which was partially explained by not being able to see the LLCS. [F8.e, F8.f, F4.d].

In the previous reports, the factors that affected the right turning behaviour of cyclists were discussed. One factor was the "The distance between the car starting position and the conflict point", which would vary depending on the size of the junction, the stopping behaviour of the car driver and also the size of the reservoir. Another factor was "What information the cyclists use to make the turn, i) whether they use information from the LLCS and/or the main signals, ii) whether they follow the behaviour of other road users".

There is evidence from this trial to suggest that when cyclists experienced this junction layout in groups of cyclists, some couldn't see the LLCS and made their decision to turn right based on the behaviour of the other cyclists in front. However, the findings indicate that most of the cyclists who undertook the right turn movement in front of the oncoming car made a judgement to undertake this movement safely based on the junction layout, amount of early release and time required to clear the junction.

5.2.4 Car trial: how the different reservoir depths affected car drivers

Car drivers understood the different sized reservoirs equally well [F10.a]. The majority of car drivers thought that the size of the cycle reservoir they experienced was 'about right'; those who experienced the larger reservoir were the more likely to say it would be 'better if smaller', although car drivers only experienced the junction either with one cyclist in front or no cyclists [F11.a]. Common comments were that the size of the reservoir should be based on the location and volume of cyclists using the junction and that there is a need to strike a balance between space for cyclists and motor vehicles [F11.b].

The trials with the deeper cycle reservoirs were associated with a small but statistically significant decrease in compliance [F14.a], although the majority of encroachment was only up to 1.25m past the first stop line [F14.b]. Over half of the car drivers stopped more than 2.5m before the first stop line for the 7.5m and 10m reservoir depths, suggesting that a substantial proportion of car drivers stopped quite far back from the stop line, possibly in order to see the main signals that were located on the separate poles at the first stop line [F14.c].

When the reservoirs were 7.5m or 10m, the car drivers were more likely to start moving on the LLCS early release, compared to the 5m reservoir [F15.a]. Thus, the average Reaction Times for the car drivers were typically around half a second faster in the trials with the deeper reservoirs, compared to the trial with the 5m reservoir [F15.b].

The average Entry Time was highest in the scenario with no early release and a cyclist in front, suggesting that the car driver often had to wait for the cyclist before entering the junction. For the scenarios with no early release and no cyclist present, the average Entry Time increased by about 0.2 seconds for each additional 2.5m of reservoir [F15.d]. For the trials with an early release, the 7.5m reservoir resulted in a small increase of about 0.1 seconds to the average Entry Time, whereas the 10m reservoir resulted in an increase of about 0.6 seconds, compared against the 5m reservoir [F15.e].

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