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Low Level Cycle Signals with an early release

Track trial report

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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 second sub-trial of a larger track trial investigating the reactions of road users to Low Level Cycle Signals (LLCS) under different junction configurations. In this trial the LLCS were positioned on the same pole as the standard traffic signals and gave an 'early release' for cyclists ahead of the vehicle traffic.

The trials were conducted at a specially constructed typical "urban" four-arm junction built at TRL's test track. The trial consisted of "control" and "treatment" experiments, with four different durations of early release in which the LLCS changed to green 2, 3, 4 or 5 seconds earlier than the main signals. These were then compared to the previous trial of LLCS with no early release to understand the relative effect on behaviour of the early release. Trials were conducted for three different road user groups over 7½ days, with a total of 200 participants: cyclists (4½ days); car drivers (2 days); and motorcyclists (1 day).

Key findings are listed at the end of each sub-section and are referenced here in square brackets. In summary:

- Almost all participants (more than 95%) in all road user groups understood that LLCS were traffic signals for cyclists [F1.a]. A small minority of cyclists (2%) were initially confused and said they took a while to understand how to use the early release [F1.b] and a small minority (<1%) of cyclists confused the LLCS with a Toucan crossing, although this was less than in the trial with no early release [F1.c].
- 2. When asked specifically about the early release, all the car drivers and about 95% of cyclists and motorcyclists said they noticed it [F2.a] and over 80% in each road user group were positive about it [F2.b]. About 15% of cyclists and 5% of car drivers and motorcyclists were negative about the early release with the most common reasons being 'Found the junction to be confusing' and 'Concern that it would delay motorists' [F2.c].
- 3. Over 90% of participants thought that cyclists on the road would benefit from LLCS, which was similar to the trial with no early release [F3.a]. About 90% of cyclists and car drivers and 75% of motorcyclists were positive about LLCS in general, which was higher compared with the trial without an early release [F3.b]. Over three-quarters of the cyclists said that the height of the LLCS was 'about right' and about 60% of cyclists thought the angle was 'about right'. About 10% of cyclists described turning right as 'difficult' due to the angle of the LLCS and not being able to see the junction and the signal at the same time [F3.c].
- 4. Cyclists looked at the LLCS more than the trial with no early release [F4.a] and the LLCS were the most important source of information for the majority of cyclists [F4.c].
- 5. The early release had no effect on compliance with the red signals [F5.a] or on compliance with the stop lines [F5.c].
- 6. A large majority of cyclists started moving as the LLCS changed to red and amber [F6.a] and the cyclists entered the junction approximately 1.5 to 2 seconds after the LLCS changed to green [F6.e]. Combining the findings from the cyclist trial



and car trial suggests that a cyclist would enter the junction 'on average': 3.5 seconds before a car would enter the junction with a 2-second early release; 4.5 seconds ahead with a 3-second early release; 5.5 seconds ahead with a 4-second early release; and 6.5 seconds ahead with a 5-second early release [F6.g]. Some motorists started moving before the main signals changed to red and amber [F6.b], and when asked what they would do in the real world some said they would do this or 'it depends' [F6.c].

- 7. A longer early release resulted in a larger proportion of observations where the cyclist turned right in front of the oncoming car, ranging from 24% for the 2-seconds early release up to 69% for the 5-seconds early release [F7.a]. The most common explanation was that they thought they had enough time, although a few (5%) thought they had right of way [F7.f].
- 8. Typically for each second of early release, the average Clearance Time decreased by one second [F8.a]. A higher proportion of cyclists said the junction was 'safer' or 'much safer' than an ordinary junction in the trial with an early release (about 85%), compared to the trial without an early release (about 50%) [F8.b]. A small proportion of cyclists (5%) said that the early release made the junction less safe, because of other road users using the early release and confusion over right of way when turning right [F8.c].

The evidence from this trial supports the progression to on-street trialling of LLCS with an early release. The evidence suggests that the system would be quickly understood by nearly all road users, would not adversely affect safety and could offer a benefit to cyclists in getting up to speed, clearing the junction ahead of motorists and feeling safer.

The only caveats are that a small proportion of cyclists thought they had right of way when turning right across oncoming traffic and some motorists started moving before the main signals changed to red and amber.



1 Introduction

This report summarises the results from the second sub-trial of a larger track trial investigating the reactions of road users to Low Level Cycle Signals (LLCS) under different junction configurations. In this trial the LLCS were positioned on the same pole as the standard traffic signals and gave an 'early release' for cyclists ahead of the vehicle traffic. This sub-trial involved four different durations of early release in which the LLCS changed to green 2, 3, 4 or 5 seconds earlier than the main signals.

This document is structured as follows:

- Section 2 summarises the methodology of the trial.
- Section 3 presents the findings to eight key research questions.
- Section 4 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.



Table 1 – Colour scheme

1.1 Scope and relation to other trials

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



Figure 1 – Low Level Cycle Signals

The scope of this report, is to present the findings from the second of four sub-trials (trial code "M18"). This trial assessed the impact of the early release by testing scenarios where the LLCS changed to green by different amounts of time before the main signals, compared against the scenario in the first LLCS trial ("M14") in which the LLCS changed at the same time as the main signals. Additionally, the LLCS were an enabler for layout changes and operational mechanisms in the later trials. Table 2 shows how the scope of



this trial compares with the three other LLCS trials in the programme in which the LLCS: provided no early release or were covered ("M14"); were on a separate pole ("M19"); and were accompanied by deeper cycle reservoirs ("M24").

In addition to the trials summarised in Table 2, two further trials are relevant: an earlier track trial, which assessed the impact of high level signals with a red cycle aspect (Ball et al. 2014); and a trial in which the LLCS with an early release are part of a 'standardised' junction design with a two-stage right turn (www.gov.uk 2013a).

Road layout	LLCS early release	Cycle trial	Cycle groups trial	Car trial	Motorcycle trial	HGV trial	Pedestrian trial	Partially sighted pedestrian trial
	Covered	M14		M14	M14			
5m ASL, LLCS	Uncovered, no early release	M14		M14	M14	M14	M14	M14
on same pole	Early release (2,3,4,5 seconds)	M18		M18	M181			
5m "cycle reservoir", LLCS on separate pole	Uncovered, no early release	M19	1404	M19	M19	M19	M19	
	Early release (2,3,4,5 seconds)	M19	MZ4	M19				
7.5m "cycle reservoir", LLCS on separate pole	Uncovered, no early release		1404	M24				
	Early release (2,3,4,5 seconds)		MZ4	M24				
10m "cycle reservoir", LLCS on separate pole	Uncovered, no early release		MOA	M24				
	Early release (2,3,4,5 seconds)		IVIZ4	M24				

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

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. 2015). This covers:

- Existing UK regulations for cycle signals
- Existing UK regulations for Advanced Stop Lines (ASLs)
- Previous research into compliance of cyclists with signals
- Previous research into compliance of drivers with ASLs
- Enforcement of signals and ASLs.

¹ Only one level of early release was tested in the M18 motorcycle trial



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, onstreet 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. 2015). 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).

1.2.3 LLCS with an early release in other countries

A short review of LLCS in other countries was provided in the report for the trial with no early release (Ball et al. 2015). The only findings from this review relating to early releases were in Germany, as summarised below.

In Muenster, guidance states that where low level cycle signals are installed, they should typically be accompanied by an early release. There is no standard amount of time for the early release, although the guidance shows: two examples where the early release is three seconds (both for two-stage left turns); one example where the early release is four seconds (with an ASL); and one example where the early release is four seconds (on a cycle path) (Alrutz 2013). To allow for their lower clearance speed, cyclists can also be given an earlier stop signal than the motorised traffic to ensure that the junction is clear of cyclists at the end of the green phase. This time also depends on the size of the junction, and expected clearance speed of the cyclists. ASLs are not always combined with low level signals with an early release (RiLSA 1992). Junctions with cycle signals can have two green phases for cyclists within a signal cycle and can also have extended green phases for cyclists, depending on the flow of cyclists (Alrutz 2013).



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 The Low Level Cycle Signals: early release

The trial was carried out as part of a "control" and "treatment" experiment. In this second trial, half of the cyclists experienced early releases of 2 and 4 seconds and the



other half experienced early releases of 3 and 5 seconds. Similarly, half of the car drivers experienced 2 and 4 second early releases for cyclists and the other half experienced 3 and 5 second early releases for cyclists. However in order to limit the number of trial days and participants required, the motorcyclists experienced only the 4-second early release.

To understand the relative effect of the signals on behaviour, the results are compared with the "uncovered scenario" in the first trial ("M14") in which the LLCS did not provide an early release (see Figure 3). In the figures in this report the results from the trial with the early release have a diagonal pattern, whereas results from the trial with no early release have a solid fill.



Figure 3 – "Control", LLCS with no early release (left) and "Treatment", LLCS with early release (right)

When comparing the scenarios with and without an early release, statistical tests² were undertaken to distinguish whether results were likely to be due to introduction of the early release, or whether they were likely to have occurred by chance. In this report, findings from the trial with no early release are shown in solid bars, whereas findings from the trial with an early release are shown as diagonal stripes.

2.2.2 Size of the ASL and location of the LLCS

The road layout of a junction arm is illustrated in Figure 4. In this trial, the LLCS were mounted on the same pole as the main signal, with a 5-metre ASL on each approach to the junction. The LLCS were set to change 2, 3, 4 or 5 seconds before the main signals.

² The Two Proportion Z-Test was used to assess the differences in proportions, whereas the T Test was used to assess differences in averages.





Figure 4 – Location of signals and size of ASL

2.2.3 Junction layout

A scale drawing of the junction is shown in Figure 5 and a description of the junction layout and placement of the LLCS and other signals is shown in Figure 6 and Table 3.



Figure 5 – Junction layout, scale drawing





Figure 6 – 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 ASL	Turning movements
Α	\checkmark	>	\checkmark		\checkmark		Not painted	Left, Right
В	\checkmark	>		>	\checkmark		Not painted	Left, Straight
С	\checkmark		\checkmark				Not painted	Left, Right
D	\checkmark		\checkmark		\checkmark	\checkmark	Green	Straight, Right
Р	\checkmark				\checkmark		No ASL	N/A

One of the approaches 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 the centre of the road at Arm B. Each approach had an ASL, 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.

2.2.4 Stand-alone crossing

LLCS were also mounted on a Puffin crossing (P) away from the junction. In this trial the signals were always green.

2.3 Other variables

2.3.1 *Participant types and trial days*

Trials were conducted for three different road user groups over 7½ days, with a total of 200 participants: 118 cyclists (4½ days); 54 car drivers (2 days); 28 motorcyclists (1 day). The number of days of trialling was determined by the target sample sizes of 40 independent observations for cyclists and 30 independent observations for other road users; see Appendix B for the sample size collected.

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

2.3.2 Controlled vehicles/cycles

In some cases there were other vehicles/cycles present at the junction, which were controlled by TRL staff. Table 4 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.

	Type of participant			
	Cycle trial	Car trial	Motorcycle trial	
No other vehicles	\checkmark	\checkmark	×	
With controlled cyclist	x	\checkmark	\checkmark	
With controlled car	\checkmark	×	\checkmark	
With controlled cyclist and controlled car	x	x	×	

 Table 4 - Controlled vehicles used in each of the trials

In the cycle trial, participants encountered the junction both with and without a controlled car; similarly in the car trial, participants encountered the junction both with and without a controlled cyclist. In the motorcycle trial, participants experienced the



junction both with a controlled car and with a controlled cyclist, but not at the same time.

2.3.3 Turning movements

Because Arm A was a one-way street, there were nine possible turning movements. It was decided however to exclude the straight-on movement from Arm A in order to make the experiment more balanced, see Table 3. Cars did not make the left turn from Arm A, because of restrictions imposed by the optimal 'reset routes'³. The signals at Arm B and Arm D changed to green at the same time and so right-turning vehicles from Arm D had to turn across the path of traffic from Arm B.

2.3.4 Release times

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

2.4 Trial setup

2.4.1 Daily structure

The typical daily structure involved four groups of participants, two in the morning and two in the afternoon. Groups would undertake the trial in three 'sessions' of approximately 30 to 40 minutes. The schedule was designed so that participants would experience the signals with different durations of early release (see Section 2.2.1) and with and without controlled vehicles (see Section 2.3.2).

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

2.4.2 Runs within a session

The different groups of road users experienced the LLCS a number of times over a period of between approximately 80 and 130 minutes. They traversed eight numbered routes, which continually looped them through the junction and back to a different start point. Routes 1-4 from the cycle trial are shown in Figure 7. Routes 5-8 are shown in the appendices of the report for the trial with no early release (Ball et al. 2015).

³ See Section 2.4.2 for examples of 'reset routes'





Figure 7 – Cycle trial: routes through the junction and to next starting point (Routes "1-4")

2.5 Study objectives and research questions

The overall objective of LLCS is:

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

Further objectives include:

- ii. to increase the compliance of cyclists with red signals;
- iii. to improve compliance of drivers with the ASL;
- 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.

The main study objective was to gather evaluation evidence on LLCS with an early release in the context of an application to the DfT for an experimental order for an onstreet trial. Several specific research questions were set, which instructed the design of the trial and the analysis. These research questions were grouped into the eight more general questions as listed below.

- 1. Did people understand the LLCS with an early release?
- 2. Did people notice the early release and what did they think about it?



- 3. What attitudes did people have towards the LLCS with an early release?
- 4. Did people use the information from the LLCS with an early release?
- 5. Did the LLCS with an early release affect compliance: i) whether cyclists stopped at a red light; ii) where people waited?
- 6. Did the LLCS with an early release affect how people moved off as the signals changed to green?
- 7. Did the LLCS with an early release affect whether right-turning cyclists turned in front of oncoming cars?
- 8. Did the LLCS with an early release affect perceived safety?

2.6 Measures collected to answer the research questions

Measures were collected to inform each of the research questions through a combination of a post-trial questionnaire 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 ASLs. 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 the questionnaire; see Section 2.3.1 for the number of participants in each road user group. The responses to closed questions are presented in graphs with vertical bars, whereas responses to open questions have been classified and are presented in graphs with horizontal bars.

2.6.2 Video analysis

The video analysis of the behaviour at the junction was aimed at extracting data to describe the behaviour of road users with regards to '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. 2015).

2.6.2.1 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 'ASL Entrance' (5 metres before main stop line)



- TP3 'ASL 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
 - \circ $\;$ 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).
- '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.
- 2. Between this trial and the trial without early releases ("M14") for a particular road user.
- 3. Between the values for participants in the cycle trial and the values for the participants in the car and motorcycle trials.

2.6.2.2 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 ASL. For this exercise those cyclists who did not stop were excluded.



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

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, the dimensions of which are shown in Section 3.7.1.2. 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. This is discussed further in Section 4.2.
- 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 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 cyclist behaviour.
- Participants had clear information about their route and continuously repeated manoeuvres through the same junction.

Previous experiments have been conducted under similar 'artificial' conditions, where behaviour is often found to differ from reality. However, the extent of immersion in the conditions simulated has been found to be sufficient for participants to realistically adapt their natural behaviour. Thus, it is possible to investigate the relative (although not absolute) effects of controlled design changes. Specifically, this trial enabled relative comparisons to be made between the LLCS with different durations of early release and no early release.



3 Findings

3.1 Did people understand the LLCS with an early release?

Table 5 – Research questions on understanding

Road user	Theme	Research question	Video	Q'naire
All road users	Understanding	Did they understand the purpose of the LLCS?	×	\checkmark
		To what extent did they confuse LLCS with Toucan crossings?	×	\checkmark

3.1.1 Understanding of the cycle signals

Following the track trial, participants were shown a photograph of the LLCS and asked "What do these signals mean to you?" The responses are summarised in Figure 10.



Figure 10 - Understanding of the LLCS (questionnaire)

Almost all participants in all road user groups understood that LLCS were traffic signals for cyclists. Compared to the trial without an early release, slightly more participants in each road user group understood what the LLCS meant.

Also, about 15% of cyclists interpreted them as normal traffic signals, but did not explicitly state they were for cyclists, and so this is not a safety concern.

About a third of car drivers and motorcyclists and about a quarter of cyclists mentioned the early release:

"These signals apply to the cyclist and when the sign is green the cyclist can go even when the main traffic lights are red." (Cyclist)



"For me as a car driver, I notice when the cyclist lights changed mine would be next. So I prepared to leave and looked about and into the junction for hazards." (Car driver)

"I believe their main purpose is to allow cyclists a head start to clear the traffic at the junctions" (Motorcyclist)

Two cyclists (out of 117) were initially confused and said they took a while to understand how to use the early release:

"Was not sure if I could go on green or had to wait for main signal i.e. these acting as get ready." (Cyclist)

There was a small minority (<1%) of participants whose explanation about the meaning of the signals indicated that they confused the LLCS with a Toucan crossing, although this was less than in the trial with no early release:

"Controlled crossing instruction for cyclists" (Cyclist)

- F1.a. Almost all participants (more than 95%) in all road user groups understood that LLCS were traffic signals for cyclists. Compared to the trial without an early release, slightly more participants in each road user group understood what the LLCS meant.
- F1.b. A small minority of cyclists (2%) were initially confused and said they took a while to understand how to use the early release.
- F1.c. There was a small minority (<1%) of cyclists whose explanation about the meaning of the signals indicated that they confused the LLCS with a Toucan crossing, although this was less than in the trial with no early release.

Further information in Appendix D.

3.2 Did people notice the early release and what did they think about it?

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

 Table 6 – Research questions on the early release

This section relates to questions from the post-trial questionnaire where participants were asked specifically about the early release. As such there is no comparison with the earlier trial.

3.2.1 Noticing the early release

Participants were asked specifically about the early release, "Did you notice that the Low Level Cycle Signals changed to green before the main signals?". All the car drivers and about 95% of cyclists and motorcyclists said they noticed the early release.

They were then asked, "What did you think of this? (Please write in)". Their responses were classified into groups of answers and are summarised in Figure 11⁴.



Figure 11 – What they thought about the early release (questionnaire)

About 80% of cyclists, 90% of car drivers and 85% of motorcyclists gave comments that were classified as being positive about the early release. The most common responses were 'Enabled cyclists to get up to speed first' and 'Enabled cyclists to clear junction / complete turn'. Examples of the comments made in each of the 'positive' categories in Figure 10 are listed below.

• Enabled cyclists to get up to speed first:

"Allows cyclists to move off and therefore not be wobbling as they start whilst cars are also starting" (Cyclist)

• Enabled cyclists to clear junction / complete turn:

"Gives you a chance to clear the junction before the cars start" (Cyclist)

• Felt safer for cyclists:

⁴ See Section 2.3.1 for sample size



"It made me feel safer as the car wasn't pulling off at the same time as me" (Cyclist)

• Creates a gap between cyclists and motorists:

"Gives the cyclists a chance to move off and spread out without causing congestion or slowing other traffic too much" (Motorcyclist)

"I really liked the fact that the cyclists were able to go first so that I could clearly see their intention and were out of the way in most cases before I set off." (Car driver)

• General positive comment after got used to it:

"Confusing to start but soon got used to it when reassured there was only a couple of second's difference." (Cyclist)

• Felt less pressure for cyclists:

"Gives the bikers more time to set off than the cars so you don't feel as pressured" (Cyclist)

• Enabled motorists to be prepared:

"Gives motorists warning that main signals are about to change and allows driver to select first gear and release handbrake." (Car driver)

• Made motorists more aware of cyclists:

"I was more aware of where cyclist was going before I moved off" (Motorcyclist)

• Gives time to get to correct position for manoeuvre:

"Gives time to move to the correct position at the junction prior to completing the manoeuvre" (Cyclist)

Examples of the comments made which were categorised as 'suggestions' in Figure 10 are listed below.

• Would prefer a longer early release:

"This may benefit if one or two seconds could be added. I found that I had not completed my turn before regular green lights changed" (Cyclist)

• Would like a LLCS on opposite side of junction:

"The lights were positioned alongside the cyclist and often out of their range of vision so they waited for the main light before moving off. Could there have been repeater signals on the other side of the junction for cyclists?" (Motorcyclist)

About 15% of cyclists and 5% of car drivers and motorcyclists gave comments that were classified as being negative about the early release. Examples of the comments made which were categorised as 'negative' in Figure 10 are listed below.

• Found the junction to be confusing:

"Bit unsure whether to go at first because I was expecting the main lights to be synchronised with them" (Cyclist)

"Little nervous at first but soon made sense." (Cyclist)

• Concern that it would delay motorists:



"May delay numbers of cars allowed through as time reduced" (Car driver)

• Cyclists may turn right across oncoming traffic. Some thought this was a positive feature and some thought it was negative; this is discussed further in Section 0:

"No good if turning right across possible incoming traffic as they give a false sense of priority" (Cyclist)

"It's good particularly when turning right across oncoming traffic. They might annoy some drivers who think they have more of a right to be on the road than cyclists since they effectively give cyclists priority." (Cyclist)

• Was difficult to see LLCS when turning right; this is discussed further in Section 3.4:

"When turning right and positioned far right, couldn't see without constantly turning which meant taking my eyes off the road" (Cyclist)

• Motorists may go on the cycle signal; this is discussed further in Section 3.6.1:

"As a driver I may be more inclined to set off a fraction early" (Car driver)

3.2.2 Duration of early release

As discussed in Section 2.2.1 and 2.4.1, the cyclists and car drivers experienced a shorter early release in some sessions and a longer early release in other sessions.

Participants who said they noticed the early release were also asked: "Did you notice that in some sessions this 'early start' was greater than in other sessions?". About threequarters of cyclists and about half of car drivers did not notice the difference between the shorter and longer early releases.

Those who did notice the difference were then asked: "Did this affect the way you went through the junctions?". Their responses are shown in Figure 12.



Figure 12 – Whether the length of early release affected the way they thought they went through the junction (questionnaire)



A small proportion of cyclists (12%) and car drivers (18%) said that they noticed the difference in duration of the early release and this affected the way they went through the junction. Some cyclists said that with the longer early release they realised they had more time and the car wasn't close behind them, whereas other cyclists said they were more cautious and hesitated because they weren't as sure that they should go. Comments from car drivers indicated that the shorter duration required them to take more account of cyclists, whereas with the longer one they didn't have to worry about catching up with the cyclist.

About 20% of the cyclists who experienced the 2 and 4 second early release said they noticed that the early release was longer in some sessions than others, compared with about 30% of those who experienced the 3 and 5 second early release. In contrast a large proportion (70%) of drivers who experienced the 2 and 4 second early release said they noticed that the early release times were different, but only 35% of drivers who experienced 3 and 5 second early releases said they noticed the difference.

- F2.a. All the car drivers and about 95% of cyclists and motorcyclists said they noticed the early release.
- F2.b. Over 80% in each road user group were positive about the early release with the most common reasons being 'Enabled cyclists to get up to speed first' and 'Enabled cyclists to clear the junction'.
- F2.c. About 15% of cyclists and 5% of car drivers and motorcyclists were negative about the early release with the most common reasons being 'Found the junction to be confusing' and 'Concern that it would delay motorists'.
- F2.d. About three-quarters of cyclists and about half of car drivers did not notice the difference between the shorter and longer early releases. A small proportion of cyclists (12%) and car drivers (18%) said that the difference in duration of the early release affected the way they went through the junction.

Further information in Appendix D.



3.3 What attitudes did people have towards the LLCS with an early release?

Road user	Theme	Research question	Video	Q'naire
All road users	Attitudes	Who would benefit and what were the perceived benefits from LLCS with an early release?	×	~
		Did people like the LLCS with an early release?	×	\checkmark
		What did people think about the height and angle of the cycle signals?	×	~
		What improvements did people suggest for LLCS with an early release?	×	✓
		Would LLCS with an early release make people more likely to cycle on busy roads?	×	✓

 Table 7 – Research questions on attitudes

This section relates to questions from the post-trial questionnaire where participants were asked about the cycle signals in general. Their responses have been compared to the previous trial, although where possible the analysis focuses on comments relating to the early release.

3.3.1 Who would benefit and what were the perceived benefits?

After being asked about their experiences in the trial, participants were then asked, "Thinking about the 'Low Level Cycle Signals' which you have experienced today, who do you think would benefit from them? (Tick all that apply): cyclists on the road; cyclists elsewhere; cyclists with an electric bicycle; scooter riders; motorcyclists; other (please specify)".

Most participants (over 90% of cyclists and motorcyclists and all car drivers) thought that cyclists on the road would benefit from the LLCS. This was a similar proportion to that in the trial with no early release. Cyclists elsewhere, cyclists with electric bikes, scooter riders and motorcyclists were thought to benefit by between about a quarter and a half of participants.

About a quarter of car drivers said they thought they or other motorised users would benefit and nearly half of motorcyclists thought they would benefit, mainly because the early release gave motorcyclists a clear path through the junction.

These responses were similar to those in the trial without an early release; the main difference was that in the trial with an early release, a larger proportion of motorcyclists said they would benefit compared with the trial with no early release.

Participants were then asked to explain their answer; comments were classified as shown in Figure 13.





Figure 13 – Explanations when asked about who would benefit (questionnaire)

Many of the explanations about the benefits referred to the early release. The most common responses were: 'Enables cyclists to get up to speed first'; 'Creates a gap between cyclists and motorists'; 'Feels safer for cyclists'; 'Enables cyclists to clear junction / complete turn'; 'Enabled motorists to be prepared'.

The most common explanations that didn't refer to the early release were: 'Provided a clearer direction for cyclists '; 'Feel more safe / secure'; 'Clear they are for cyclist use' and 'Relating to a good height/position for cyclist'.

In comparison, the participants in the trial without an early release saw the main benefits of the LLCS as providing cyclists signals at a better height and angle, and giving clearer directions for cyclists.

As in the trial without the early release, the main negative comments when asked who would benefit related to concerns about motorcyclists using the LLCS; this is explored further in Section 3.6.1.2.



3.3.2 Did people like the LLCS with an early release?

A qualitative assessment was made to classify the comments about the LLCS in response to several questions (including the general comments at the end of the questionnaire) into three categories: in favour (positive), against (negative) and neutral; this last group also included people who made both positive and negative comments. These have been summarised in Figure 14.



Figure 14 – Classification of attitudes (questionnaire)

About 90% of cyclists and car drivers and about 75% of motorcyclists were positive about the LLCS. For each road user group this was a significant increase compared with the trial with no early release.

The cyclists who were not positive tended to mention the perceived ambiguity about priority when turning right across on-coming traffic.

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

Participants were asked what they thought about the height and angle of the LLCS.

Over three-quarters of participants thought the height of the LLCS was about right; about 20% of cyclists and motorcyclists and about 10% of drivers thought they should be higher. Similar responses were made in the first trial without an early release.

Over 90% of the drivers and motorcyclists thought the angle of the LLCS was about right (see Figure 15). However over a third of cyclists thought they should point more towards the road, which was a significant increase compared with the first trial in which 20% of cyclists thought they should point more towards the road. In particular more cyclists described turning right as "difficult" (10% compared with 5%) due to not being able to see the junction and the signal at the same time.

"Low level signal [on arm D] is difficult to see and angle is wrong but I knew that [it] changed earlier so I wanted to see it." (Cyclist)





Figure 15 – Views on the angle of the LLCS (questionnaire)

3.3.4 What improvements did people suggest for LLCS with an early release?

Participants were asked, "Do you have any suggestions for improving the signals you used today?". The suggestions were classified as illustrated in Figure 16. These results should be treated with caution, because many participants gave no suggestions, while others gave multiple responses.



Figure 16 – Comments when asked to suggest improvements (questionnaire)

The most common suggestions for improvements from cyclists were to make the cycle signals more obvious: ten cyclists said they should be bigger (out of 118 cyclists) and nine cyclists said they should be brighter, many of whom experienced the signals in bright sunlight. Nine cyclists suggested they should be higher; however, when the



participants were specifically asked about the height earlier in the questionnaire, threequarters thought it was 'about right', as discussed in Section 3.3.3.

"I would suggest they are raised half a metre higher and I feel they are too small and not bright enough. They have to be bolder and larger." (Cyclist)

"I feel the signs could be bigger [so that it would be] easier for car drivers to see the sign and know to wait and look before driving off." (Cyclist)

"They were sometimes not bright enough when the sun shone directly onto them." (Cyclist)

A longer early release was suggested by nine cyclists and five drivers. Two cyclists said that a longer early release would enable them to complete their turn at the junction.

"Larger gap between both sets of signals [to] allow more time for cyclists to engage with the road." (Cyclist)

"[When] turning right [there was a] temptation to beat traffic coming straight on. This manoeuvre should be allowed for in the timings." (Cyclist)

"More seconds to complete turns at junctions." (Cyclist)

Changing the angle of the signals was suggested by seven cyclists and greater visibility of the cycle signals when turning right was suggested by nine cyclists.

"Have a set of signals on lights on the right if there is a post there." (Cyclist)

"Different positioning for turning right as difficult to see." (Cyclist)

A filter arrow on the cycle lights was suggested by five cyclists:

"Arrows could be added so the cyclist knew that it was safe to go left, right or straight on. When a car was in the other direction and I was turning right I wasn't sure when the car would set off or the cyclist who was also there. This made me hesitate." (Cyclist)

3.3.5 Would LLCS with an early release make people more likely to cycle on busy roads?

The influence of these facilities on willingness to cycle in London was inferred by asking, "Do you think it would affect how often you cycle in busy traffic if more junctions were like this? (Please tick one): yes; no; it depends; don't know".

About a half of cyclists, a third of motorcyclists and a fifth of drivers said "yes". A quarter of the cyclists, half of the drivers and over half of the motorcyclists said "no". Many of those who said "no" either did not cycle at all, or avoid cycling on roads.

Among cyclists and motorcyclists, the proportion who said their frequency of cycling would be affected was significantly higher than in the trial without an early release. However in the case of cyclists, this may be associated with a difference in the age distribution of the participants in the two trials rather than the early release. The proportion of drivers whose frequency of cycling would be affected did not vary between the two trials.

Reasons why the frequency of cycling in busy traffic would be affected were primarily about feeling safer, it being easier and giving cyclists more confidence. While the reasons were similar in the first trial, there was a focus on the early release in this trial.



"I would feel more confident knowing that I had time to get across, that I could be seen and that other road users didn't need to hurry to get past the cyclist and would be less angry." (Cyclist)

"It seemed to take into consideration that it takes cyclists longer to get going." (Cyclist)

"[I] would be more likely to cycle in busy traffic knowing I would be able to turn at a junction and not have cars trying to overtake me." (Cyclist)

"Junctions are the worst place for cyclists as cars can often miss them so for cyclists to have their own signal and time delay would be excellent." (Cyclist)

These results, although generally positive towards the LLCS, should be treated with caution, because they indicate participants who would be more likely to consider cycling rather than that they definitely would cycle.

- F3.a. Over 90% of cyclists and motorcyclists and all car drivers thought that cyclists on the road would benefit from LLCS. This was a similar proportion to that in the trial with no early release. The main reasons given were that cyclists would be kept separate from vehicles and that this would give cyclists time to get up to speed.
- F3.b. About 90% of cyclists and car drivers and 75% of motorcyclists were in favour of LLCS. For each road user group this was a significant increase compared with the trial without an early release.
- F3.c. Over three-quarters of the cyclists said that the height of the LLCS was 'about right' and about 60% of cyclists thought the angle was 'about right'. Over a third of cyclists thought the LLCS should point more towards the road; this was a significant increase compared with the trial without an early release. In particular more cyclists described turning right as "difficult" (10% compared with 5%) due to the angle of the LLCS and not being able to see the junction and the signal at the same time.
- F3.d. The most common suggestions for improvements from cyclists were to make the cycle signals more obvious.
- F3.e. About a half of cyclists, a third of motorcyclists and a fifth of drivers said they would be more likely to cycle in busy traffic if more junctions were like this.

Further information in Appendix D.



3.4 Did people use the information from the LLCS with an early release?

Road user	Theme	Research question	Video	Q'naire
Cyclists	Trial experiences	What did the cyclists look at when deciding when to enter the junction? What was the most important factor in their decision?	×	\checkmark
Car drivers and motorcyclists	Trial experiences	What did the other road users look at when deciding when to enter the junction? What was the most important factor in their decision?	×	\checkmark

Table 8 – Research questions on use of LLCS

As discussed in Figure 6 in Section 2.2.3, there was a near-side LLCS on the left on each of the approaches; on two approaches (Arm A and Arm B) there was also an additional off-side LLCS (on the right at Arm A and in the centre of the road at Arm B).

Following the track trial, participants were presented with photographs of each arm of the junction and asked, "what did you look at: i) when you were approaching the junction; ii) when you were waiting and deciding when to enter the junction for turning left / going straight on / turning right?". They were then given a list of sources of information to choose from: 'Main traffic signal in front on left'; 'Main traffic signal in front on right (Arm A and Arm B only)'; 'Traffic signal for cyclists on left'; 'Traffic signal for cyclists on right (Arm A and Arm B only)'; 'Additional traffic signal in front'; 'Traffic signals on other roads into the junction'; 'Whether the junction was empty'; 'The position and speed of approaching vehicles'; 'The position and speed of vehicles behind'. They were then asked to note which was the most important to them.

3.4.1 Did they look at the LLCS?

Figure 17 shows the proportion of participants who looked at the LLCS on the left, pooled across all four junction approaches.



Figure 17 – Proportion of participants who said they looked at the near-side LLCS (questionnaire)



Figure 18 shows the proportion of participants who looked at the LLCS on the right, pooled across all four junction approaches.



Figure 18 – Proportion of participants who said they looked at the off-side LLCS (questionnaire)

Cyclists

Cyclists were more likely to say they used the main signals when approaching (about 90%), and the LLCS while they were waiting at the signals. In this trial about half also said they looked at the near-side LLCS when they were approaching; this was slightly more than in the trial with no early release when a third of cyclists said they looked at the near-side LLCS as well as the main signals as they approached.

When waiting, cyclists said they looked at the near-side LLCS more than in the trial with no early release, and this was the case for all movements through the junction (90% looked at them when turning left, about 75% when going straight on and 60% when turning right).

For the off-side LLCS, 20% said they looked at them when approaching, about 45% when turning right, 40% when going straight on and 12% when turning left. There were no significant differences to the trial with no early release, except for an increase when going straight on (on Arm B).

Car drivers and motorcyclists

Car drivers typically said they looked at the LLCS more in this trial than in the trial with no early release, but this was not as an alternative to looking at the main signals. Car drivers reported looking at the near-side LLCS rather less than cyclists, but reported looking at the off-side LLCS more than the cyclists.

Fewer motorcyclists reported looking at the nearside LLCS as they approached the junction in this trial than in the trial with no early release. However when waiting to turn, more motorcyclists reported looking at the near-side LLCS than in the trial with no


early release. In this trial motorcyclists experienced the junction with a car behind them in some sessions and with a cyclist in front in other sessions, whereas in the first trial motorcyclists only experienced the junction with a car behind them, see Section 2.3.2. The presence of a cyclist in this trial may have made the cycle signals more noticeable and therefore may explain the result that the motorcyclists looked at the cycle signals more in this trial.

3.4.2 What was the most important piece of information?

Cyclists

In this trial about 60% of cyclists said the main signals were the most important cue when approaching the junction, which was similar to the trial with no early release.

When waiting at the junction in this trial, the near-side LLCS were reported to be the most important cue by the majority of cyclists for seven out of the eight turning manoeuvres. In each of these, there was a significant increase compared to the trial with no early release, in which the main signals were often regarded as the most important cue.

Figure 19 shows the proportion of cyclist participants who said the near-side LLCS were the most important cue they looked at when waiting to turn at each arm of the junction. The proportion of cyclists saying that the LLCS were the most important to them when waiting at the lights was about 75 - 80% for turning left, 50 - 70% for going straight on and about 55% for turning right at Arm D; only about 10% said it was the most important when turning right at Arm A, although there was also an off-side LLCS at this location.



Figure 19 – Proportion of cyclists who said the LLCS on the left was the most important piece of information (questionnaire)

Figure 20 shows the proportion of cyclist participants who said the off-side LLCS were the most important cue they looked at when waiting to turn at the two arms of the junction with off-side LLCS. The LLCS on the right were reported as the most important cue by 40% of cyclists waiting to turn right in the two-lane one way street at Arm A; this was higher than in the trial with no early release, although the sample size was very



small in the first trial⁵. The LLCS on the island in the centre of the road were reported as the most important cue for about 10% of cyclists waiting to go straight on at Arm B, a similar proportion to the trial with no early release.



Figure 20 – Proportion of cyclists who said the LLCS on the right was the most important piece of information (questionnaire)

Thus reported importance of the LLCS when waiting to turn was related to the position of the LLCS in cyclists' line of sight for the manoeuvre they were about to make.

Car drivers and motorcyclists

When waiting at the junction, the main traffic signals on the left were the most important cue for about 30% of car drivers; the position and speed of vehicles behind were the most important for 25% of drivers and the LLCS were the most important for 15% of drivers. Drivers' views on which cues were the most important were similar in the trials with and without an early release.

For motorcyclists waiting at the junction the secondary signals were the most important cue for about 70% of participants. Motorcyclists' views on which cues were the most important were generally similar in the trials with and without an early release.

⁵ Only 11 cyclists were offered this question in the M14 trial.



- F4.a. When waiting, cyclists said they looked at the near-side LLCS more than in the trial with no early release, and this was the case for all movements through the junction (90% looked at them when turning left, about 75% when going straight on and 60% when turning right).
- F4.b. Car drivers and motorcyclists said they only used the LLCS in conjunction with the main signals in most cases.
- F4.c. While waiting to turn, cyclists reported relying more on the LLCS if they were positioned conveniently in their line of sight for the manoeuvre they were going to make. The near-side LLCS were described as the most important cue for about 75 80% when turning left, 50 70% for going straight on and 55% for turning right where there was no off-side LLCS. The off-side LLCS were described as the most important cue for about 40% of those waiting to turn right from the one-way street and by about 12% of those waiting to go straight on in the one-lane approach where the off-side LLCS were in the centre of the road.

Further information in Appendix D.

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

Road user	Theme	Research question	Video	Q'naire
Cyclists	Compliance with red light	To what extent did the LLCS with an early release affect compliance with red lights?	\checkmark	×
	Lateral stopping position	To what extent did the LLCS with an early release affect the lateral stopping position? i.e. what position did they take in the ASL (Left Zone / Middle Zone / Right Zone)?	~	~
	Longitudinal stopping position	To what extent did the LLCS with an early release affect the compliance of cyclists stopping past the ASL Exit?	~	×

Table 9 – Research questions on red light compliance and stopping position

In the cycle trial, two types of compliance were studied: Section 3.5.1 assesses to what extent cyclists went through the junction whilst a red signal was still showing; Section 3.5.3 assesses the stopping position of cyclists relative to the main stop line. For other road users, the stopping position relative to the first stop line was analysed, i.e. their compliance with the ASL Entrance.

3.5.1 Compliance with red signals

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



compliance with the signals would be mainly through participants entering into the junction whilst a red signal was still showing.

Table 10 shows the number of observations where a participant cyclist went through the junction while the signal was still on red, split by the LLCS early release scenarios. A non-compliant observation was defined as where they entered the junction on a red signal⁶ and then proceeded through the junction without stopping.

Trial	Scenario	Non-compliant observations	Total observations	Percentage non- compliant
M14	LLCS covered 14		838	1.7%
IVI 14	LLCS uncovered	1	910	0.1%
M18	2 secs early release	6	668	0.9%
	3 secs early release	14	717	2.0%
	4 secs early release	5	711	0.7%
	5 secs early release	16	686	2.3%

Table 10 – Cycle trial: number of observations where the cyclist was noncompliant with a red signal (video data)

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

As discussed in Section, 2.2.1, the 3-second and 5-second early release were trialled on the same day; there was one participant who took part in the 3-second and 5-second trial and went through the junction on red almost every time, which skewed the results for these scenarios.

3.5.2 Lateral stopping position

The position that participants stopped at the traffic lights was captured from videos, as discussed in Section 2.6.2. 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).

3.5.2.1 Video analysis

The lateral stopping position of the cyclists was measured for the eight different turning movements and approaches. There was no consistent trend in lateral stopping position, with the exception of an increase in the proportion of left-turning cyclists stopping in the left-hand zone for the two-lane approach (Arm A) from 70% in the trial with no early release to 90% for the trial with an early release, as shown in Figure 21.

⁶ i.e. passed "Timing Point 4 (TP4)", 1.7 metres after the main stop line, before the signals changed from red





Figure 21 – Cycle trial: lateral stopping position in lane for left turners, by junction layout and LLCS scenario (video data)

3.5.2.2 Reported stopping position from the questionnaire

Participants were asked whether the LLCS affected their stopping position. The majority of participants said they were 'never' affected by the LLCS. However, compared with the trial with no early release, there was a small increase in the proportion of cyclists who said the LLCS sometimes affected where they stopped, from 17% in the trial with no early release to 30% in this trial. Explanations were mostly about stopping in a position to see the signals:

"I want to clearly see these low level signals" (Cyclist)

Others stated that they had difficulties seeing the signals when turning right

"When turning right, slightly more difficult to see if right over [on the right side of the road]." (Cyclist)

3.5.3 Longitudinal stopping position

There was no change in cyclists' longitudinal stopping position compared to the trial with no early release, with around 95% of cyclists stopping in the ASL and about 5% of cyclists stopping with their front wheel up to one metre after the ASL Exit.

- F5.a. There were no consistent trends in the proportion of cyclists who went through the junction on a red signal for the different early release scenarios.
- F5.b. Compared with the trial with no early release, there was an increase on one junction approach in the proportion of left-turning cyclists who stopped in the left-hand zone. This was supported by a finding from the questionnaire in



which there was a small increase in the proportion of cyclists who said they 'sometimes' modified their stopping position so they could see the LLCS.

F5.c. There was no change in cyclists' longitudinal stopping position compared to the trial with no early release.

Further information in Appendix C.

3.6 Did the LLCS with an early release affect how people moved off as the signals changed to green?

Road user	Theme	Research question	Video	Q'naire
Cyclists	Reaction to the LLCS	'Reaction Time' – To what extent did cyclists react to the LLCS with an early release?	\checkmark	×
	Time to enter the junction	'Entry Time' – To what extent did cyclists enter the junction ahead of cars?	~	×
Car drivers and motorcyclists	Reaction to the LLCS	'Reaction Time' – To what extent did other road users start moving forwards early? How did this vary by when there were some or no cyclists?	~	>
	Time to enter the junction	'Entry Time' – To what extent were other road users delayed from the green light to reaching the junction entrance?	~	×

 Table 11 – Research questions on moving behaviour

The times when participants started to move ('Reaction Time'), entered the junction ('Entry Time'), and cleared the junction ('Clearance Time') were recorded as explained in Section 2.6.2.1. In this section results are presented for the Reaction Time and Entry Time.

In the cycle trial, participants encountered the junction both with and without a controlled car; similarly in the car trial, participants encountered the junction both with and without a controlled cyclist. In both the cycle trial and car trial, the cyclist always approached the junction ahead of the car. In the motorcycle trial participants encountered the junction either with a car behind them or a cyclist in front of them.

It should be noted that the sample in the cycle trial included a large proportion of inexperienced cyclists and more cyclists aged over 50 than would be expected in London, see Appendix D. As such, the absolute values of Reaction Time should be treated with caution, although relative comparisons between the scenarios can be made.



3.6.1 Reaction Time

3.6.1.1 Video analysis

Cycle trial and car trial

Figure 22 shows the proportion of observations where the cyclist started moving before the main signals changed to red and amber. The data was pooled across all turning movements and junction approaches. This shows that the majority of cyclists had started moving before the main signals changed to red and amber for most early release scenarios. In the 2-second early release scenario, the LLCS changed to green at the same time that the main signals change to red and amber; these observations in the 2-second early release therefore relate to cyclists starting moving before the LLCS changed to green (i.e. LLCS on red and amber). There was no difference between the scenarios with and without the controlled car behind them.



Figure 22 – Cycle trial: proportion of observations where the cyclist started moving before the main signals changed to red and amber (video data)

Figure 23 shows the proportion of observations where the car driver started moving before the main signals changed to red and amber. For all early release scenarios this was less than 6%. This proportion was slightly higher in the scenario with the controlled cyclist in front of the participant car driver.





Figure 23 – Car trial: proportion of observations where the car started moving before the main signals changed to red and amber (video data)

Figure 24 shows the average Reaction Time of the participants to the main signals in both the cycle trial and the car trial. The green line indicates when the signals turned to green (the LLCS for the cycle trial and the main signals for car trial).

This shows that the average Reaction Times for cyclists were close to the time the signals turned to green for each early release scenario.

In the car trial for the scenarios with a controlled cyclist in front, the average Reaction Time of the car driver was slightly lower in the early release scenarios compared to the trial with no early release.



Figure 24 – Cycle trial and car trial: average Reaction Time of cyclists and car drivers, relative to the main signals changing to red and amber, by early release scenario (video data)



Figure 25 shows the distribution of the Reaction Time in the cycle trial and car trials for each early release scenario (dotted line), compared against the trials with no early release (full line). This is shown here just for the scenario with the controlled vehicles. The proportions shown in Figure 22 and Figure 23 relate to the observations with negative values on the horizontal axis.

This illustrates the variability in how fast the cyclists started moving. Specifically for the 5-second early release, a 'twin-peak' distribution can be seen: about 95% of observations where the cyclists reacted to the LLCS to the left and a smaller peak to the right with about 5% of observations where the cyclist reacted to the main signals. For the other early release scenarios this split is not as clear, because some of the cyclists with lower Reaction Times who were looking at the LLCS may have actually started moving as the main signals were changing.

The peak of the distribution for most early release scenarios in the car trials was slightly to the left of the trial with no early release, further into the red and amber phase. One explanation of this may be that, as discussed in Sections 3.2.1 and 3.3.1, some car drivers said that they used the LLCS to know when to be ready to move and this enabled them to be more prepared, for example to get into gear. Another explanation may be that in the car trial with no early release, the car driver was delayed from starting as the signals changed, because of the controlled cyclist in front; however, with the early release, the cyclist had (in most cases) already started moving by the time the main signals changed.





Figure 25 – Cycle trial and car trial: Reaction Time of cyclists and car drivers relative to the main signals changing to red and amber (video data)



Motorcycle trial

In the previous motorcycle trial (M14), participants experienced sessions with a controlled car behind them, no early release and no cyclists. In this motorcycle trial (M18) participants experienced three different configurations in three sessions:

- 4-second early release and controlled car (behind), no cyclist
- 4-second early release and controlled cyclist (in front), no car
- No early release and controlled cyclist (in front), no car

Figure 26 shows the proportion of observations where the motorcycle started moving before the main signals changed to red and amber. In the early release scenarios some did start moving before the main signals changed to red and amber, although this was relatively low, being less than 2%. As discussed in Section 2.7, this may be lower than would be observed in an on-street environment; the attitudes of the motorcyclists to this were also explored further in the questionnaire, see Section 3.6.1.2.



Figure 26 – Motorcycle trial: proportion of observations where the motorcycle started moving before the main signals changed to red and amber (video data)

Figure 27 shows the average Reaction Time of the participants to the main signals in the motorcycle trial. The green line indicates when the cycle signals turned to green. In all scenarios, the average Reaction Time was approximately 2 seconds, i.e. the time the main signals changed to green. Similar to the car trial, for the sessions with the controlled cyclist in front, the average Reaction Time was slightly lower in the scenario with an early release.





Figure 27 – Motorcycle trial: average Reaction Time of motorcyclists, relative to the main signals changing to red and amber, by early release scenario by early release scenario (video data)

3.6.1.2 Questionnaire analysis

In the questionnaire, car drivers and motorcyclists were asked whether during normal driving they thought they would ever start moving into the junction when the LLCS were green and the main signal was red. In the trial with an early release, 2% of car drivers and around 10% of motorcyclists said they would do this and 10% of car drivers and 20% of motorcyclists said 'it depends'. The results were similar in the trials without an early release, although more car drivers said they would do this (5%) and more motorcyclists said 'it depends' (40%), perhaps because they didn't understand what an early release might be like.



Figure 28 – Proportion of participants who said they would go on a cyclist early release in normal driving conditions (questionnaire)

The explanations to their answers were classified and are shown in Figure 29. From the explanations given by the car drivers, moving off into the junction during the early release would be unintentional, in some cases depending on the circumstances. Some of



the motorcyclists, however, said they would deliberately take the opportunity offered by the safe space, if there were no cyclists, or to get ahead of the traffic. A few motorcyclists referred to situations in which they might unintentionally move off during the early release.



Figure 29 – Explanation of participants who said they would go on a cyclist early release in normal driving conditions (questionnaire)

Drivers who explained why they would unintentionally go on an early release gave examples of situations: if they were not concentrating, were following a cyclist, or saw a green signal and assumed it was for them:

"It is in your eye line and when you see the cyclist go in front you may go too." (Car driver)

"There is a tendency to slowly move forward in anticipation of a green [signal]." (Car driver)

"It can be easy to glance at the green cycle and just take off if you are not concentrating." (Car driver)

"If I could not see the main signal or read the cycle signal wrongly." (Car driver)

Some drivers said they might intentionally go on an early release if there were no cyclists:

"I might be tempted to if the cycle box was empty and I knew the time before main signals go green." (Car driver)

"If [there was] no cyclist about it should be safe to move off." (Car driver)

Motorcyclists who said they would go on the early release were also comfortable using the ASL and creating safe spaces for themselves:

"I use the box anyway." (Motorcyclist)

"Motorcycles need space and safety." (Motorcyclist)

The motorcyclists who said 'it depends' either said it would be if they made a mistake or the decision would be based on the traffic conditions:

"Not intentionally but I put 'it depends' as occasionally you get caught out." (Motorcyclist)



"Depends on quantity of traffic, whether I was filtering before reaching the junction and on prevailing traffic conditions at the time." (Motorcyclist)

"Yes [I would use the early release] if [there were] no cyclists, [I would not] if [there were] cyclists in area". (Motorcyclist)

3.6.2 Entry Time

Figure 30 shows the average Entry Time of the participants relative to the main signals in both the cycle trial and the car trial. The green line indicates when the signals turned to green (the LLCS for the cycle trial and the main signals for car trial). In this graph, observations have been excluded where the participant entered into the junction while both the main signals and LLCS were on red⁷.



Figure 30 – Cycle trial and car trial: average Entry Time of cyclists and cars, relative to the start of the main signals, by early release scenario (video data)

This shows that the average Entry Times for cyclists were approximately 1.5 to 2 seconds after the LLCS changed to green. The average Entry Times of the cyclists were slightly lower in the scenario with the controlled car behind them, suggesting the cyclists showed more urgency when there was other traffic in the trial.

In the car trial, the average Entry Times of the cars were around 5 seconds in most scenarios, i.e. around 3 seconds after the main signals changed to green. There was no difference in the scenarios with longer early releases, suggesting that car drivers did not show the desire to 'make up the lost time'.

In the car trial with no early release, the average Entry Times were higher in the scenario with the controlled cyclist in front, compared to the trial with no cyclist; this suggested that in this scenario the car driver was delayed by the cyclist in front. In the trial with an early release, there were no differences in average Entry Times between the scenario with and without the cyclist in front, suggesting that the cars were not delayed

⁷ See Section 3.5.1 for analysis of compliance of cyclists with the red signals



waiting for the cyclists in this trial. This is likely because in most instances cyclists would have already entered the junction and were hence out of the way of the cars.

Combining the results from the cycle trial (with controlled car behind) and the car trial (with controlled cyclist in front) suggest that 'on average' a cyclist would enter the junction: 3.5 seconds ahead of a car with a 2-second early release; 4.5 seconds ahead with a 3-second early release; 5.5 seconds ahead with a 4-second early release; and 6.5 seconds ahead with a 5-second early release. It should be noted that for the most part the car driver's stopping position was compliant with the ASL, before the first stop line.

Figure 31 shows the proportion of observations where the controlled cyclist had entered the junction before the car started moving in the car trial. This shows that with a 2-second early release, in around 80% of observations the controlled cyclist had already entered the junction before the car had started moving; for the longer early release scenarios this proportion was over 95%.



Figure 31 – Car trial: proportion of observations where the cyclist had already entered the junction before the car started moving, by early release scenario (video data)

Figure 32 shows the average time that the controlled cyclist entered the junction before the car started moving in the car trial. This shows that with a 2-second early release, on average the participant car driver did not start moving until 1.5 seconds after the controlled cyclist had already entered the junction; for the longer early release scenarios there was a linear increase up to over 4 seconds in the 5-seconds early release scenario.



Figure 32 – Car trial: average time (seconds) that the cyclist entered the junction before the car started moving, by early release scenario (video data)



- F6.a. A large majority of cyclists started moving as the LLCS changed to red and amber. In the 5-second early release scenario, in 95% of observations the cyclist reacted to the LLCS, whereas in 5% of observations the cyclist reacted to the main signals.
- F6.b. The majority of motorists waited for the main traffic signal to change to green before moving; the proportion of observations where the car or motorcycle started moving before the main signals changed to red and amber ranged from 0% to 6% across the different early release scenarios. This proportion was slightly higher in the scenario with the controlled cyclist in front of the participant.
- F6.c. When asked what they would do in the real world, 2% of car drivers and 10% of motorcyclists said they would start moving on the early release while the main signals were still red and 10% of car drivers and 20% of motorcyclists said 'it depends'. Explanations for why they would do this included if they were not concentrating or that they would be tempted to do so if there were no cyclists present. Some motorcyclists said they would do this intentionally because they said they need space and safety.
- F6.d. In the scenario with the controlled cyclist in front, the average Reaction Times of motorists were slightly faster than in the trial with no early release; participants remarked that they noticed the LLCS early release and used it as a cue to get ready, for example by getting in to gear.
- F6.e. The average Entry Times for cyclists were approximately 1.5 to 2 seconds after the LLCS changed to green.
- F6.f. In the car trial, the average Entry Times of the cars were around 5 seconds in most scenarios, i.e. around 3 seconds after the main signals changed to green. There was no difference in the scenarios with longer early releases, suggesting that car drivers did not show the desire to 'make up the lost time'. There were no differences in average Entry Times between the scenario with and without the cyclist in front, suggesting that the cars were not delayed waiting for the cyclists when there was an early release.
- F6.g. Combining the findings from the cyclist trial and car trial suggests that a cyclist would enter the junction 'on average': 3.5 seconds before a car would enter the junction with a 2-second early release; 4.5 seconds ahead with a 3-second early release; 5.5 seconds ahead with a 4-second early release; and 6.5 seconds ahead with a 5-second early release.
- F6.h. In the car trial, with a 2-second early release, in around 80% of observations the controlled cyclist had already entered the junction before the car had started moving; for the longer early release scenarios this proportion was over 95%.
- F6.i. In the car trial, with a 2-second early release, on average the participant car driver did not start moving until 1.5 seconds after the controlled cyclist had already entered the junction; for the longer early release scenarios there was a linear increase up to over 4 seconds in the 5-seconds early release scenario.

TRL

3.7 Did the LLCS with an early release affect whether right-turning cyclists turned in front of oncoming cars?

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?	\checkmark	\checkmark

Table 12 – Research questions on right-turning cyclists

As discussed in Section 2.1, the signals on Arm B and Arm D changed to green at the same time. This section assesses the impact of the early release on whether right-turning cyclists turned in front of the oncoming car. This is explored further in the M19 and M24 trials.

3.7.1 Video analysis

Table 13 and Figure 33 give the percentage of observations where the right-turning cyclist turned in front of the car going straight on. This clearly shows that 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%, 38%, 54% and 69% for the 2, 3, 4 and 5-second early release scenarios, respectively.

Table 13 – Cycle trial: sample size and proportion of observations where cyclists turned right in front of cars from opposite approach, by early release (video data)

Trial	Early release scenario	Number of observations where cyclist turned right in front of car	Sample size	% of observations where cyclist turned right in front of car
"\\ / / / "	Covered	1	41	2.4%
IVI 14	0 seconds (Uncovered)	0	49	0.0%
"M18" -	2 seconds	10	41	24.4%
	3 seconds	18	47	38.3%
	4 seconds	20	37	54.1%
	5 seconds	31	45	68.9%



Figure 33 – Cycle trial: proportion of observations where cyclists turned right in front of cars from opposite approach, by early release (video data)



Figure 34 is a sequence of images of a cyclist turning right in front of the car going straight on; the car going straight on can be seen towards the top right of each image. In this instance there was a 3-second early release for the cyclist.



Figure 34 – Cycle trial: cyclist turning right with a 3-second early release in front of oncoming car

In the M18 Trial, in total, there were 170 observations of cyclists turning right; of these, there were 79 occurrences of cyclists turning right in front of the oncoming car. The remainder of this section is an analysis of these 79 observations. Proportions shown are as of a percentage of the total number of right turning observations.

3.7.1.1 Severity Level classification

To gain a better understanding of how dangerous these manoeuvres may have been, each observation was categorised depending on how severely the car was forced to modify their behaviour. These were classified as described in Table 14.

Severity Level	Description
0	The cyclist had completed their manoeuvre before the car started to move.
1	The car had begun to move by the time the cyclist had completed.
2	The car moved off normally, but regulated acceleration to allow cycle to complete turn.
3	Similar to Level 2, but the change was more noticeable.
4	The car was forced to slow down, but was able to do so safely.
5	The car had to perform an emergency stop.

Table 14 - Severity	Level	descriptions
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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.

As shown in Figure 35, most manoeuvres were categorised as Severity Level 1, where the oncoming car (from Arm B) had usually begun to move slowly, but appeared to be aware of the cyclist's intentions; this was sometimes caused by the oncoming car being



restricted by the cycle in front (also oncoming from Arm B) reacting slowly to the signals.

None of the manoeuvres resulted in an emergency stop, but 3% (5 of the 170 observations) were categorised as Severity Level 4, where the car was forced to slow down, but was able to do so safely.





Figure 36 shows how these were spread across the early release scenarios. Of the five Severity Level 4 observations, two were in each of the 2-second and 3-second scenarios, with one being in the 5-second early release scenario.







3.7.1.2 Gap relative to the main traffic signals

The "conflict point" was defined as the location where the path of the right-turning cyclist crossed the path of the oncoming car; this is illustrated in Figure 37.



Figure 37 – Cycle trial: "Conflict point" of right-turning cyclist and oncoming car (video data)

The distance between the expected starting position of the car (Timing Point 2 on Arm B) and the conflict point was 17m. The distance between the expected starting position of the cyclist (Timing Point 3 on Arm D) and the conflict point along the path shown in Figure 37 was 16m.

As shown in Table 15, the average Entry Times (i.e. the difference between the main traffic signals changing to red and amber and the car passing Timing Point 4) of the car drivers in the M14 and M18 car trials were typically around 5 seconds⁸. This suggests that in the 4-second early release scenario, for example, on average there would be about 9 seconds from the time the LLCS changed to red and amber to the time when the oncoming car would enter the junction. In other words a right turning cyclist would have about 7 seconds from the time the LLCS changed to green to travel the 16 metres to pass the conflict point ahead of the oncoming car.

In a real-world situation, the Entry Time of the car driver may be different, depending on their stopping position and also the aggressiveness of their acceleration. Also, for larger

⁸ Although it was 6.5 seconds on average with a cyclist in front and no early release. See Section 3.6.2.



junctions there would likely be a greater distance between the cyclist starting position and the conflict point. As such, the results for each of the early release scenarios are not directly transferable to the real world. When deciding on the length of early release if deployed on-street, it is recommended that the actual entry times of cars and the distances cyclists have to travel to pass the conflict point are taken into account.

Traffic scenario	Early release scenario	Average Entry Time (seconds) of car participants from car trial	Average time (seconds) right- turning cyclists would have to pass the conflict point – between the LLCS changing to red and amber and the cars entering the junction (seconds)	Average time (seconds) right- turning cyclists would have to pass the conflict point – between the LLCS changing to green and the cars entering the junction (seconds)
	0 secs (M14)	5.1	5.1	3.1
No cyclist	2 secs (M18)	4.9	6.9	4.9
in front of car	3 secs (M18)	5.2	8.2	6.2
	4 secs (M18)	5.3	9.3	7.3
	5 secs (M18)	5.1	10.1	8.1
	0 secs (M14)	6.5	6.5	4.5
With a cyclist in- front of car	2 secs (M18)	5.3	7.3	5.3
	3 secs (M18)	5.2	8.2	6.2
	4 secs (M18)	5.1	9.1	7.1
	5 secs (M18)	5.0	10.0	8.0

Table 15 – Average Entry Times of the participant car drivers from the car trials and average time cyclists would have to turn right in front of the oncoming car

Figure 38 shows the distribution of time taken for right-turning cyclists to reach the conflict point after the main traffic lights changed to red and amber. The longer a cyclist takes to do this relative to the main signals, the more likely they are to experience a conflict. This shows that most of these manoeuvres involved the cyclist crossing the path of the car 3 or 4 seconds after the lights for the car had changed from red to red-amber (i.e. 1 or 2 seconds after the main lights had changed to green).





Figure 38 – Cycle trial: time taken for right turning cyclists to reach the conflict point after the main traffic lights changed to red and amber (video data)

Figure 39 shows how these were spread across the early release scenarios. This shows that the longer examples of 5 or 6 seconds to reach the conflict point were most likely observed during the 3-second early release scenarios. One quick cyclist in the 5-second early release scenario passed the conflict point while the car signals were still on red (-1 on the chart).



Figure 39 – Cycle trial: time taken for right turning cyclists to reach the conflict point after the main traffic lights changed to red and amber, by early release (video data)



3.7.1.3 Gap relative to the car

Whether or not these cyclists experienced a conflict also depended on how quickly the driver reacted to the signals. Figure 40 shows the time elapsed between when the cycle and car passed through the same point. The longer this interval, the safer it should be for the cyclist. For most cyclists there was at least a 3-second interval, and this was never less than 2 seconds.

As discussed in Section 3.7.1.1, the controlled car drivers were instructed that safety was paramount and so the observed gaps between cars and cyclists may have been shorter if they were not under controlled conditions.



Figure 40 – Cycle trial: interval between cycle and car reaching the conflict point (video data)

Figure 41 shows how these were spread across the early release scenarios. This graph shows that the occasions when the time interval between the cyclist and the car reaching the conflict point was two seconds or less were mainly in the 2-second and 3-second early release scenarios.

Track trial report, LLCS with early release (M18)





Figure 41 – Cycle trial: interval between cycle and car reaching the conflict point, by early release (video data)

3.7.2 Questionnaire analysis

Cyclists were asked whether they considered turning in front of the car. Compared with the trial with no early release, in this trial there was a significant increase in cyclists stating that they turned in front of the car⁹ and in those stating that they considered turning but did not turn¹⁰ (see Figure 42). There was a significant decrease in cyclists stating that they did not consider turning¹¹. This result remains significant when the age of participants across the two trials is taken into account. Note however that in the trial with no early release some participants appear to have misunderstood this question.¹²

⁹ p<0.001

¹⁰ p<0.1

¹¹ p<0.001

¹² In trial with no early release, 5 out of 70 participants said they had turned right in front of an oncoming car but no such observations were recorded on the video

Track trial report, LLCS with early release (M18)





Figure 42 – Cycle trial: proportion of cyclists who said they had turned or considered turning in front of the car (questionnaire)

In this trial, of the 34 (out of 107) who said they did turn ahead of the car, most said that they judged they had enough time:

"[I] felt there was time to turn by judging speed and position of car." (Cyclist)

About 5% (5 out of 107) said that they felt they had right of way:

"Because of the cycle lights I assumed I had priority" (Cyclist)

"This confused me. [I] didn't know whether to proceed the first time and turn as I thought cyclists maybe [had] priority" (Cyclist)

The factors that influenced whether cyclists turned right in front of the oncoming car will be explored further in the trial with groups of cyclists and deeper cycle reservoirs (M24'').



- F7.a. 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%, 38%, 54% and 69% for the 2, 3, 4 and 5-second early release scenarios, respectively.
- F7.b. The observations where the cyclist turned right in front of the oncoming car did not usually lead to a conflict. In some instances this was because the car was restricted by the cyclist in front of them on Arm B. Most drivers had begun to move slowly and just a few were forced to slow down (3%); no drivers made an emergency stop.
- F7.c. Cyclists tended to cross the path of the car 3 or 4 seconds after the main lights had changed to red and amber; i.e. 1 or 2 seconds after changing to green.
- F7.d. For most cyclists there was at least 3 seconds between them reaching the conflict point and the car reaching that point.
- F7.e. The shorter early release for cyclists was associated with cyclists crossing the conflict point a longer time (3 or 4 seconds) after the main signals changed to green, a shorter time interval between the cyclist reaching the conflict point and the car passing it, and more instances where the driver had to slow down.
- F7.f. The responses to the questionnaire showed that a larger proportion of cyclists said they had turned in front of the car in the trial with the early release for cyclists, compared to the trial with no early release. The most common explanation was that they thought they had enough time, although a few (5%) thought they had right of way.
- F7.g. Compared with the trial with no early release, the early release also led to a significant increase in the proportion of cyclists who said they considered turning in front of the car but did not do so.

3.8 Did the LLCS with an early release affect perceived safety?

Road user	Theme	Research question	Video	Q'naire
Cyclists	Time to clear conflict zone	'Clearance Time' – To what extent did the LLCS with an early release prioritise cyclists to remove potential conflict points mid- junction between cyclists and motorised vehicles?	~	~
All road users	Trial experiences	What was the effect on the perceived safety?	×	\checkmark

Table 16 – Research questions on safety

The times when participants started to move ('Reaction Time'), entered the junction ('Entry Time'), and cleared the junction ('Clearance Time') were recorded as explained in Section 2.6.2.1. In this section results are presented for the Clearance Time.

3.8.1 Clearance Time

Figure 43 shows the average Clearance Time of the cyclists relative to the main signals changing to red and amber; this is shown only for the cycle trial with a controlled car behind. As discussed in section 3.7.1.1, this would depend on the size of the junction and so is not directly applicable to junctions of different sizes.



This shows that typically for each second of early release, the average Clearance Time decreased by one second. The lowest average Clearance Time was for left-turning cyclists in the 5-second early release scenario, who had cleared the junction about 3 seconds on average after the main signals had change to red and amber.



Figure 43 – Cycle trial: average Clearance Time of cyclists, relative to the start of the main signals, by early release scenario and turning movement (video data)

3.8.2 What was the effect on the perceived safety?

Participants were asked "How safe is it... to use this type of junction compared with an ordinary junction with traffic signals?". Each type of road user was asked about safety for their own road user group. The LLCS were not explicitly mentioned in the question, because the same question was used for all of the trials, including the later trial where larger ASLs were one of the design variables, enabling a direct comparison to be made between responses to different trials.

As discussed in Appendix D, the participant sample consisted largely of residents of the Wokingham/Bracknell area, where few junctions have ASLs. Thus many participants interpreted an "ordinary" signal junction to be one without an ASL; as such many of the comments related to ASLs. Comments that related to ASLs or did not specifically mention LLCS have been filtered out of the analysis in this section.

Cyclists

Of the cyclists who specifically mentioned the LLCS, a higher proportion of cyclists said the junction was 'safer' or 'much safer' than an ordinary junction in the trial with an early release (about 85%), compared to the trial without an early release (about 50%). There was a complementary decrease in the proportion of cyclists who said the LLCS had no effect on safety. However, a small proportion of cyclists (5%) said that the LLCS made the junction either 'more unsafe' or 'much more unsafe' in the trial with an early release, whereas none said so in the trial without an early release (see Figure 44).





Figure 44 – Cycle trial: proportion of cyclists who thought the junction was safer or more unsafe due to the LLCS, by early release scenario (questionnaire)

Cyclists 40% 35% 30% 25% 20% 15% 10% 5% 0% Much Safer Neither More Much Much Safer Neither More Much safer unsafe more safer unsafe more unsafe unsafe Comments about LLCS Comments about LLCS with an early release How safe is it for cyclists to use this type of junction compared with an ordinary junction with traffic signals (of those who mentioned the LLCS)?

Those cyclists who commented on the LLCS in this trial were classified further into those who mentioned the early release and those who did not (see Figure 45).

Figure 45 – Cycle trial: proportion of cyclists who thought the junction was safer or more unsafe due to the LLCS and the LLCS with an early release

In explaining their answers to this question about safety, the most common types of comment from cyclists were positive comments about the early release and improving cyclists' confidence. Many of the responses were similar to the findings when they were asked what they thought specifically about the early release (Section 3.2.1) and the perceived benefits of the LLCS (3.3.1):

"Without having to look up at the main lights, I felt more stable less inclined to wobble about." (Cyclist)



"Enable those who wobble on setting off to get going before cars from behind are rushing off." (Cyclist)

The 5% of cyclists who said the early release would make the junction 'more unsafe' or 'much more unsafe' were concerned about other road users using the early release and confusion over right of way when turning right.

"It could create confusion - need to be clear about priorities when turning right" (Cyclist)

"I would worry that vehicles from other directions would jump red lights if they knew it was cyclists who would go first" (Cyclist)

Car drivers and motorcyclists

Car drivers and motorcyclists were also asked how safe they thought 'this type of junction' was for them compared to an ordinary junction. Of those who specifically mentioned the LLCS, none thought that this was 'more unsafe' and similar proportions thought it was safer than in the trial with no early release. However relatively few comments were specific to the LLCS. Drivers and motorcyclists who commented on the safety impacts of LLCS, commented on awareness and visibility of cyclists and the benefits of the early release.

"... the cyclists are not moving away with me. They are ahead in my vision and set off ahead. Less surprises." (Motorcyclist)

"You know what the bike intends to do before you move off so are prepared." (Car driver)

- F8.a. Typically for each second of early release, the average Clearance Time decreased by one second.
- F8.b. Of the cyclists who specifically mentioned the LLCS, a higher proportion of cyclists said the junction was 'safer' or 'much safer' than an ordinary junction in the trial with an early release (about 85%), compared to the trial without an early release (about 50%). There was a complementary decrease in the proportion of cyclists who said the LLCS had no effect on safety. The most common types of comment from cyclists were positive comments about the early release and improving cyclists' confidence.
- F8.c. A small proportion of cyclists (5%) said that the LLCS made the junction either 'more unsafe' or 'much more unsafe' in the trial with an early release, whereas none said so in the trial without an early release. These cyclists were concerned about other road users using the early release and confusion over right of way when turning right.
- F8.d. Drivers and motorcyclists who commented on the safety impacts of LLCS, commented on awareness and visibility of cyclists and the benefits of the early release.

Further information in Appendix D.



4 Conclusions

4.1 Findings against each research question

Section 3 contains the findings from the trial of LLCS with an early release (trial code: `M18'), compared against a previous trial where the cycle signals had no early release ('M14'). The key findings are summarised at the end of each sub-section in Section 3. Each finding has an ID (e.g. "F1.a"), where the number relates to a corresponding research question as defined in Section 2.5; these findings are referenced in this section below. These key findings are also summarised in a table in Appendix A.

In summary:

- Almost all participants (more than 95%) in all road user groups understood that LLCS were traffic signals for cyclists [F1.a]. A small minority of cyclists (2%) were initially confused and said they took a while to understand how to use the early release [F1.b] and a small minority (<1%) of cyclists confused the LLCS with a Toucan crossing, although this was less than in the trial with no early release [F1.c].
- 2. When asked specifically about the early release, all the car drivers and about 95% of cyclists and motorcyclists said they noticed it [F2.a] and over 80% in each road user group were positive about it [F2.b]. About 15% of cyclists and 5% of car drivers and motorcyclists were negative about the early release with the most common reasons being 'Found the junction to be confusing' and 'Concern that it would delay motorists' [F2.c].
- 3. Over 90% of participants thought that cyclists on the road would benefit from LLCS, which was similar to the trial with no early release [F3.a]. About 90% of cyclists and car drivers and 75% of motorcyclists were positive about LLCS in general, which was higher compared with the trial without an early release [F3.b]. Over three-quarters of the cyclists said that the height of the LLCS was 'about right' and about 60% of cyclists thought the angle was 'about right'. About 10% of cyclists described turning right as 'difficult' due to the angle of the LLCS and not being able to see the junction and the signal at the same time [F3.c].
- 4. Cyclists looked at the LLCS more than the trial with no early release [F4.a] and the LLCS were the most important source of information for the majority of cyclists [F4.c].
- 5. The early release had no effect on compliance with the red signals [F5.a] or on compliance with the stop lines [F5.c].
- 6. A large majority of cyclists started moving as the LLCS changed to red and amber [F6.a] and the cyclists entered the junction approximately 1.5 to 2 seconds after the LLCS changed to green [F6.e]. Combining the findings from the cyclist trial and car trial suggests that a cyclist would enter the junction 'on average': 3.5 seconds before a car would enter the junction with a 2-second early release; 4.5 seconds ahead with a 3-second early release; 5.5 seconds ahead with a 4-second early release; and 6.5 seconds ahead with a 5-second early release [F6.g]. Some motorists started moving before the main signals changed to red and amber [F6.b], and when asked what they would do in the real world some said they would do this or 'it depends' [F6.c].



- 7. A longer early release resulted in a larger proportion of observations where the cyclist turned right in front of the oncoming car, ranging from 24% for the 2-seconds early release up to 69% for the 5-seconds early release [F7.a]. The most common explanation was that they thought they had enough time, although a few (5%) thought they had right of way [F7.f].
- 8. Typically for each second of early release, the average Clearance Time decreased by one second [F8.a]. A higher proportion of cyclists said the junction was 'safer' or 'much safer' than an ordinary junction in the trial with an early release (about 85%), compared to the trial without an early release (about 50%) [F8.b]. A small proportion of cyclists (5%) said that the early release made the junction less safe, because of other road users using the early release and confusion over right of way when turning right [F8.c].

4.2 How the findings relate to the study objectives

The main study objective was to gather evaluation evidence on LLCS with an early release in the context of an application to the DfT for an experimental order for an on-street trial.

The evidence from this trial supports the progression to on-street trialling of LLCS with an early release. The evidence suggests that the system would be quickly understood by nearly all road users, would not adversely affect safety and could offer a benefit to cyclists in getting up to speed, clearing the junction ahead of motorists and feeling safer.

The only caveats are that a small proportion of cyclists thought they had right of way when turning right across oncoming traffic and some motorists started moving before the main signals changed to red and amber.

4.3 Considerations for on-street trials

This section discusses areas for consideration when designing on-street trials of LLCS with an early release. It should be re-iterated that these findings are based on a situation when there was only one cyclist stopped at the junction. Later trials will investigate the effect of the different early release durations: when the main signals are mounted on a separate pole at the first stop line ("M19"); and when there are groups of cyclists and different cycle reservoir depths ("M24").

4.3.1 Confusion caused by the early release

A minority of cyclists (2%) were initially confused and said they took a while to understand how to use the early release. This is not a major concern, because it is a relatively small proportion and if a cyclist didn't understand the early release at first, it is likely they would wait until the main signals changed, which would not present a safety risk.

4.3.2 Misinterpretation of the LLCS to be a crossing for cyclists

In the trial with no early release, it was found that:



"A small percentage (less than 5%) of pedestrians, cyclists and car drivers misinterpreted the LLCS as indicating when pedestrians should cross the road, so they could have incorrectly judged that they had priority". (Ball et al. 2015)

Following this finding, the following recommendation was made:

"The only caveat is that a small number of pedestrians misinterpreted the meaning of the signals to be for cyclists crossing the road. It is probable that pedestrians would correctly interpret them in the context of on-street applications; however, some monitoring of behaviour to confirm this would be advisable. In particular there may be concerns if LLCS are to be installed on sites where there is an uncontrolled pedestrian crossing at the junction or there is a Toucan crossing. In these instances greater care would need to be taken in the design specific to each implementation. Public information and awareness campaigns associated with the introduction of LLCS on-street would also help to reduce potential misunderstandings of their purpose." (Ball et al. 2015)

In this trial with an early release, a small minority (<1%) of cyclists confused the LLCS with a Toucan crossing, although this was less than in the trial with no early release. The recommendation from the first report remains valid.

4.3.3 Whether motorists go on the cycle signal early release

The proportion of observations where the motorist started moving before the main signals changed to red and amber ranged from 0% to 6% across the different early release scenarios, although when asked what they would do in the real world, 2% of car drivers and 10% of motorcyclists said they would start moving on the early release while the main signals were still red and 10% of car drivers and 20% of motorcyclists said 'it depends'.

In such instances, the cyclist would be moving into the junction falsely assuming that the motorists were waiting for their later release, which may potentially introduce a conflict where cyclists would expect none to exist.

If there are on-street trials, it is recommended to monitor the extent to which the motorists go on the early release and the impact that this has.

4.3.4 Right turning behaviour

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. The observations where the cyclist turned right in front of the oncoming car did not usually lead to a conflict. Cyclists tended to cross the path of the car 1 or 2 seconds after the main lights had changed to red and amber and in most cases there was at least 3 seconds between them reaching the conflict point and the car reaching that point.

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.

The shorter early release for cyclists was associated with cyclists crossing the conflict point a longer time (3 or 4 seconds) after the main signals changed to green, a shorter



time interval between the cyclist reaching the conflict point and the car passing it, and more instances where the driver had to slow down.

The extent to which this behaviour would occur in an on-street trial is not clear. Factors that are likely to affect the right-turning behaviour of cyclists both in the track trials and in an on-street trial may include the following:

- 1. The distance between the cyclist starting position and the conflict point
 - i. This distance to the conflict point will be different for larger junctions and as such the results are not directly applicable to all junctions. The results from this trial relate to a small four-arm junction, the dimensions of which are shown in Section 3.7.1.2.
 - ii. The stopping position of cyclists depends on their ability to position themselves as they wish at the red signal.
- 2. The distance between the car starting position and the conflict point
 - i. As above, the distance to the conflict point will be different for larger junctions.
 - ii. The stopping position of the car driver depends on the size of the cycle reservoir, i.e. if there is a larger cycle reservoir, they will be positioned further back from the junction.
 - iii. The stopping position of the car driver also depends on their level of compliance with stopping before the reservoir.
- 3. The time gap available to make the turn ahead of the car
 - i. In a real-world situation, the Entry Time of the car driver depends on their aggressiveness of their acceleration.
 - ii. The amount of early release from LLCS increases the time available to make a right turn ahead of an oncoming car.
- 4. Other junction characteristics, such as slope
- 5. Whether cyclists understand/misunderstand the priority at the junction
 - i. Some may understand that a right turn while oncoming traffic has a green signal is legal if it is safe to do so, i.e. normal give way rules apply, whereas others may misunderstand in that they assume they have priority as if it were a green filter arrow.
- 6. 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.
- 7. Trial realism

The trials have tested different levels of design variables, namely the amount of early release [3ii]. Other variables have been controlled with a set value, including [1i] i.e. one junction size and [2iii] i.e. the controlled drivers were told to stop before the reservoir. Some of the variables listed above are likely to be quite different in real-world conditions, in particular [2iii] and [3i], or might vary for different junctions, such as [1i] and [4]. The results from the questionnaires from the trials have offered some insights



into what factors influenced participants' decisions when turning right [5i, 6i, 6ii]. There are certain simplifications that were required as discussed in Section 2.7; however, the realism of the trial was sufficient to observe 'relative behaviour' between the various scenarios, although not 'absolute behaviour' [7].

In summary, the results for right-turning cyclists in each of the early release scenarios are not directly transferable to the real world. When deciding on the length of early release if deployed on-street, it is recommended that as many of these other variables are taken into account, in particular the distances cyclists have to travel to pass the conflict point, relative to the time they have available, as discussed in Section 3.7.1.2. Other variables that can't be controlled should be monitored where appropriate, such as the actual entry times and stopping positions of cars.

In an on-street trial it is recommended to monitor the extent to which cyclists turning right in front of oncoming cars leads to conflicts. The main concern is the small proportion of cyclists who mistakenly thought they had right of way; raising awareness through public information could help to address this issue.

Some cyclists suggested a filter arrow could be used on the cycle lights; this could resolve issues around ambiguity for turning movements, although would need to be considered carefully to not introduce other issues on the clarity of the signals and logos.

4.3.5 Difficulties seeing the LLCS when turning right

Almost all cyclists noticed the cycle signals and a majority of cyclists said they used the signals. This is possibly because without the early release they could use any of the signals depending on whichever had the most comfortable sightline, but with early release they had to use the LLCS. The most common suggestions were to make the cycle signals more obvious, namely bigger, brighter and higher; however, given that most cyclists used the signals this may not be necessary.

When turning right, about 10% of cyclists described it as 'difficult' due to the angle of the LLCS and not being able to see the junction and the signal at the same time. This may explain why there was a higher proportion of cyclists who suggested making the angle of the LLCS point more towards the road. However, it is recommended that the angle of the LLCS is not pointed more towards the road, because this would likely increase the risk of confusion with Toucan crossings, as discussed in Section 4.3.2.

There is sufficient evidence to suggest that an additional off-side LLCS is considered useful by cyclists when turning right, but is not required when turning left or going straight on. As such, an additional off-side LLCS is not required where there is no right turn or a low flow of right-turning cyclists.

4.3.6 Duration of early release

Evidence from the trials has shown that either the 2, 3, 4 or 5-second early releases could be used in an on-street trial.

Combining the findings from the cyclist trial and car trial suggests that a cyclist would enter the junction 'on average': 3.5 seconds before a car would enter the junction with a 2-second early release; 4.5 seconds ahead with a 3-second early release; 5.5 seconds ahead with a 4-second early release; and 6.5 seconds ahead with a 5-second early release.



Cyclists experienced a shorter early release in some sessions and a longer early release in other sessions (either 2 and 4 or 3 and 5). About three-quarters of cyclists did not notice the difference between the shorter and longer early releases and only a small proportion of cyclists (12%) said that the difference in duration of the early release affected the way they went through the junction.

If an early release was to be deployed on-street, the impact of reducing green time on the junction capacity would need to be taken into consideration, along with how close the junction is to capacity and the flows of cycles and cars.



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