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Cycle Facility Trials Work Stream 6

Literature Review considering ways for cyclists to turn right at signalised junctions

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Abstract

As part of a programme of off-street trials of innovative cycling infrastructure, Transport for London (TfL) commissioned the Transport Research Laboratory (TRL) to investigate ways to make cycling safer and more attractive. As part of this larger project the issue of turning right at signal controlled junctions is being considered. This report is a review of literature covering a number of different approaches to providing for cyclists turning right in the UK and overseas.

A particular focus is made on the method often referred to as the 'two stage turn'. This is a facility at a signalised junction not currently used in the UK in which cyclists avoid the need for turning right across the traffic flow by moving to a designated waiting area at the front of the adjacent arm on the left, turning through 90 degrees, and then proceeding ahead into their exit arm in a later signal phase. The pros- and cons- of this approach are discussed and trials proposed to answer a number of key questions that need to be resolved before such junctions can be considered for on-street trials.

Executive summary

Introduction

As part of a programme of off-street trials of innovative cycling infrastructure, Transport for London (TfL) commissioned the Transport Research Laboratory (TRL) to investigate ways to make cycling safer and more attractive. As part of this larger project the issue of turning right at signal controlled junctions is being considered. This report is a review of literature covering a number of different approaches to providing a safer and more comfortable facility for cyclists turning right, drawing from sources in the UK and overseas.

A particular focus is made on the method variously known as the 'two stage right turn', 'Copenhagen Turn' or 'box junction'. This is a facility at a signalised junction in which cyclists avoid the need for turning right across the traffic flow by moving to a designated area at the front of the adjacent arm on the left, turning through 90 degrees, and then proceeding ahead into their exit arm in a later signal phase. The pros- and cons- of this approach are discussed and trials proposed to answer a number of key questions that need to be resolved before such junctions can be confidently implemented in the UK.

General

There are many collisions at signal controlled junctions with two-thirds of cyclists being killed or seriously injured (KSI) at or near junctions and 38 per cent of all cyclists KSI involved a car or taxi in an urban area at a junction (Knowles, J et al, 2009). Most junction collisions involve either the vehicle or cyclist making a turning manoeuvre.

There is also a perceived safety problem associated with right-turns- cyclists will respond to their safety concerns by avoiding junctions where turning right is perceived to be dangerous, which may discourage them from cycling at all for many journeys.

A number of alternative approaches to providing for right turning cyclists are either already in existence or being suggested for the UK. Some are being trialled in this project, as part of other workstreams. The range of options available may not cover all eventualities and introducing the two-stage right turn may widen the scope of application to a larger number of junctions.

Making the right turn easier and safer

Making the right-turn manoeuvre less stressful and hazardous includes a number of fundamental approaches that are currently being considered within this project, summarised below.

- Make the manoeuvre in two stages, by initially pulling left, waiting in a waiting area, and then proceeding. See Figure 1.
- Provide cycle tracks that allow the cyclist to complete the manoeuvre away from motorised traffic.
- Provide cycle signal phases that give them an early start or allow them to complete their manoeuvre at a different time in the signal cycle to the motorised traffic.

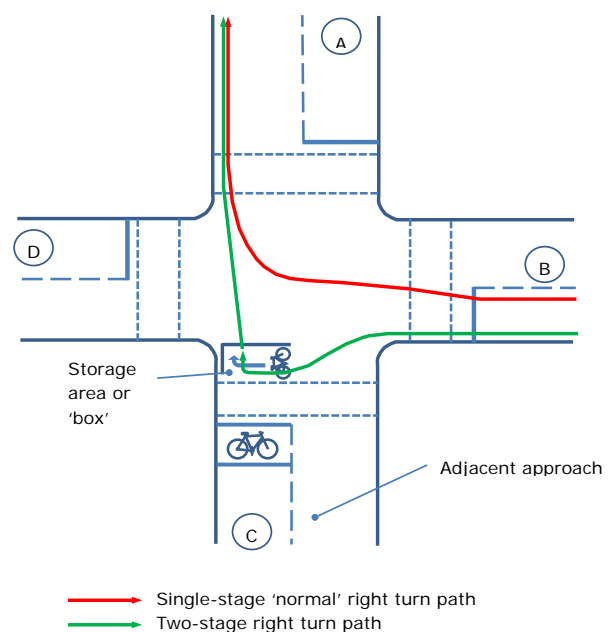


Figure 1: Two-stage right turn

Guidance, literature and practice

Literature from UK and overseas was reviewed. In the case of LTN 2/08, which is DfT's overarching guidance document for cycle facilities for the UK, there is no guidance for the two-stage turn, but it has guidance relevant to turning right in general. It says that local behaviour of road users will be a big influence on the effectiveness of cycle facilities, which together with land take and legal aspects, means that local conditions need to be considered. LTN 2/08 also states that measures for pedestrians and cyclists should offer positive provision that reduces delay or diversion and improves safety.

Most of the literature that discusses the two-stage turn was found to be guidance on implementation, or other technical documents that provide examples of use of the two-stage turn. However, no published research was found on this topic.

The main issues include the ability of cyclists to see the traffic signals that apply to cyclists in the waiting area and the position of the waiting area to avoid encroachment by turning vehicles. Also important is not increasing the conflict between cyclists and left-turning vehicles, already one of the more significant causes of cycle collisions, and keeping signal cycle times as low as possible to minimise delay and encourage cyclists to use the two-stage turn. The interaction with pedestrians is also an important issue.

Issues to be resolved by trial

A number of issues may need further investigation by trial before the two-stage turn can be considered for use:

- How to mark it to help understanding by road users and to encourage cyclists to use it as intended;
- The provision and placement of traffic signals;
- The provision and placement of advanced signage
- Movement of cyclists during various parts of the green;
- Conflicts between left turning traffic and cyclists on the approach;
- Conflicts between cyclists and pedestrians
- Optimal location of the waiting area;
- Signal stage sequence that minimises delay
- Traffic flow conditions that are suitable/unsuitable.
- Pedestrian understanding of the facility

Summary

A number of ways of dealing with right turning cyclists are either in existence or being suggested for UK use. The two-stage right turn, which is not currently used in the UK, is one being considered as part of the larger TfL Cycle Facility Trials project. However, there needs to be more confidence with how and when it can be applied. A number of issues to do with turning right at signal controlled junctions have been identified and trials to investigate the issues have been proposed.

References

Department for Transport, Local Transport Note (2008). *Cycle Infrastructure Design. LTN 2/08.* London. DfT.

Knowles, J S Adams, R Cuerden, T Savill, S Reid and M Tight (2009). *Collisions involving pedal cyclists on Britain's roads: establishing the causes.* Published Project Report PPR 445. TRL, Crowthorne.

1 Introduction

The Transport Research Laboratory (TRL) is currently undertaking a project for Transport for London (TfL) to consider how to make cycling safer and more attractive by conducting off-street trials of innovative cycling infrastructure. As part of this larger project the issue of turning right at signal controlled junctions is being considered. This report is a review of literature covering work stream WS6 – Ways of Turning Right and of the status for all the facilities designed to help cyclists turn right currently used in the UK and a number from overseas countries. One method being considered in detail in the overarching project is the Dutch style signal controlled junction. This is covered by Millard and Knight (2013) under Work Stream 5 (WS5). Other facilities for turning right are being considered in other work streams in the project and still more are already in use in the UK. See Section 1.4 and Appendix A for further details.

1.1 The safety issue

In a review of national accident statistics for DfT, Knowles, J et al (2009) report that:

- Almost two-thirds of cyclists killed or seriously injured (KSI) were at or near junctions;
- 38 per cent of all cyclist KSI involved a car/ taxi in an urban area at a junction;
- Collisions involving a large vehicle such as an HGV were more likely to result in a fatality because of their size. Most of the collisions occurred when large goods vehicles were travelling at less than 10mph. This was because most collisions occurred during manoeuvres, in particular left turns and at roundabouts. When an HGV was involved, the main collision configuration was the HGV driver making a left turn while the cyclist was going ahead;
- The main collision configurations involving a bicycle and car were the car turning right or left while the cyclist was going straight ahead; and the cyclist making a right turn while the car was going straight ahead;
- In collisions involving a bicycle and another vehicle, 'failed to look properly' was found to be a key contributory factor at junctions for drivers and riders (reported in 60 per cent of serious collisions at junctions). 'Failed to look properly' was attributed to the car driver in 57 per cent of serious collisions. Available sources fail to show whether drivers were looking but failing to see the cyclist or rather failing to look for them. Equally, the strategies adopted by cyclists at junctions are also not well understood: 'cyclist failed to look properly' was attributed to the cyclist in 43 per cent of all serious collisions.

According to TfL statistics (e.g. TfL, 2010) there were 0.57 million cyclists' trips made London's roads every day and increasing year on year. This compares with 6 million passenger trips per weekday by bus and 1,107 million trips/year by London Underground (around 3 million per day on average, though higher during the week compared with weekends). Around 30 million trips per day in total are made by all modes. Cycle use has risen 173% since 2001. The Mayor's Vision for Cycling in London (TfL, 2013) sets a target for doubling the number of trips made by bicycle over the next 10 years.

1.2 Defining the right-turn issue

For a cyclist, turning right at either a T junction (either into or out of the stem of the 'T') or a cross roads is often uncomfortable and potentially dangerous. Perceived danger is an important barrier to people's willingness to cycle in the first place (see for example

TfL Attitudes towards cycling survey, 2011: "Safety concerns remain most likely to put off non-cyclists from taking it up"¹).

The following situations can occur when a cyclist is trying to turn right.

- During the period when the traffic signals are green, the discomfort and perceived danger of the right turn manoeuvre stems from the need for the cyclist to cross from the nearside to the offside of the approach to the junction to take up a position to make the turn. This will involve crossing at least one lane of traffic. It is the speed difference between the cyclist and the other traffic that makes crossing the lanes uncomfortable and potentially dangerous. This manoeuvre is made more difficult still where cyclists are required to cross multiple lanes of traffic, especially when traffic volumes or speeds are high.
- The discomfort can continue as the cyclist travels along the offside of the lane potentially obstructing following traffic (or at least feeling that they are). This can lead to increased danger if misjudgements are made either by motor vehicles or the cyclist carrying out the manoeuvre. The cyclist may then be vulnerable whilst waiting to turn right in gaps during an opposed signal stage.
- During the period when the traffic signals are red, ideally the cyclist could make their way to the front of the queue either by moving to the offside through queuing or moving vehicles as they approach, or approaching on the nearside and moving across within the ASL (if present). However, this can be uncomfortable and hazardous; especially should the signals change to green before the cyclist gets there, particularly if s/he approaches on the left with the intention of moving to the right within the ASL.
- Another potential for danger is when a cyclist is waiting within the junction for a gap in the opposing traffic. Assuming there is no unopposed stage, if the signals change away from green, the cyclist could be in a vulnerable position should they then have difficulty in completing their manoeuvre before the conflicting approaches turn green. One should remember that on a quiet approach, where traffic levels are low, there may be no queues, and vehicles approaching the junction may still be moving as the signals turn to green. This means that vehicles on conflicting approaches may rapidly reach the point where the cyclist is waiting, leaving very little time for cyclists to move out of the way during the intergreen particularly if drivers do not anticipate their presence or fail to see them (the use of appropriate detection equipment to extend the intergreen period may help mitigate this issue).
- A further hazard can occur if the offside-most lane is a shared right-turn and ahead, particularly if the right-turn movement is light (such that it is mostly ahead traffic that uses the approach) and/or the junction is geometrically tight. This could leave the cyclist vulnerable to ahead traffic as they slow or stop prior to turning.

1.3 Making the right turn easier and safer

Given that there are a number of situations that make turning right stressful and potentially hazardous, the question is what can be done to help. Cycling facilities can be categorised into four broad types:

- Integrated – where cyclists use the road space with motorised vehicles with no attempt keep the two apart;
- Spatially separated – where cyclists share the road space with motorised vehicles, but either have their own lanes marked with solid lines (mandatory for motor vehicles) or dashed lines (advisory for motor vehicles);

¹ www.tfl.gov.uk/assets/downloads/customer-research/attitudes-towards-cycling-presentation.pdf

- Temporally separated – where cyclists again share road space with other traffic modes, but instead traffic signals are used that control cyclists separately from the different modes with different phases of the traffic signals; and
- Segregated – where a separate cycle track is available to cyclists which is separate from the carriageway used by motor vehicles. The cycle track may be shared with pedestrians.

In the UK, bicycles are classed as vehicles. This means that cyclists are legally entitled to use the carriageway unless specifically prohibited (apart from on roads classified as Motorways). It also means that they are not allowed to cycle on footways that run alongside roads unless specifically permitted to do so (which would involve changing footway status to that of a shared-use cycle track).

Amongst cyclists there is a wide variety of different types exhibiting different behaviours, from the very experienced, who can complete the right turn manoeuvre confidently in many circumstances, to the inexperienced and unconfident who may completely avoid making the manoeuvre the normal way.

Some of the latter may be discouraged from cycling because of the need to turn right. Even with experience the manoeuvre may be impossible under very heavy flows and/or multi-lane roads especially if speeds are higher.

Experienced cyclists may also deal with the challenge of the right turn by making unorthodox manoeuvres. Often these can give an indication of how cyclists may be assisted in their passage through the junction. One example could be using the shelter of an island as a position to wait half-way through the junction.

1.4 Ways of turning right at signal controlled junctions

There are a number of alternative ways in which right-turning cyclists can be assisted, of which a selection is described below (see also Appendix A for a summary).

Advance Stop Line (ASL, used extensively already): This is where a second stop line is placed on the approach for cyclists only (see Figure 2). The permitted depth of the ASL is between 4.0m and 5.0m, but recently the DfT has given TfL authorisation to extend this depth to 7.5m on the Transport for London Road Network (TLRN). The ASL is a complementary facility that enables the cyclist to position themselves ahead of the traffic, and on the right hand side of the carriageway. Though its use is well established, and it is a visible form of cycle infrastructure, research into the effectiveness of ASLs is relatively limited. In particular it is thought that they provide minimal benefit to approaching cyclists when the traffic signal is already green or about to turn green.

Problems for cyclists turning right with ASLs include:

- motor vehicles encroaching into the ASL;
- right turning cyclists being required to wait in an often uncomfortable position in the centre of the junction before making their turn; and
- a risk of collision with opposing vehicles when making the turn.



Figure 2: Advance Stop Line example

G-turn or 'Jug handle' turn - allows cyclists to cross the road from the left rather than make a right turn. This method is suitable for T-junctions but not cross roads (see Figure 3) and is most commonly used for cyclists travelling on the main road and wishing to turn right into the side road. Suitable for signal controlled junctions where there is enough room, though may cause diversion and delay to cyclists.



Figure 3: Jug Handle example

'Advance Reservoir'² storage area for right turners. One example has been identified—see Figure 10 in Section 2. This allows cyclists to wait to make their turn in an area that is safe from opposing traffic, but still requires cyclists to move across from nearside to offside on the approach.

² Unofficial name used in this report for the cycle waiting area ahead of the right turn waiting area for motor vehicles.

ASLs plus early start for cyclists (being extensively trialled as Work Stream 4 (WS4) of TfL's cycling facility trials, to be reported separately) is designed to get cyclists established in position, and in drivers' view, starting to move, and possibly to complete their manoeuvre, before vehicular traffic starts to move. However, this is still not effective during the green to vehicles phase.

A version of the early-start has been approved by the DfT in Cambridge. This uses a single Green Aspect acting as a 'filter' to provide an early-start for cyclists.

Formal two-stage right turns allow cyclists to turn right in two stages, moving to the adjacent approach on the left then proceeding ahead (see Figure 1). This allows the right turn without moving across lanes on the approach and does not require much change to the infrastructure. However, cyclists on the adjacent approach may treat the waiting area as an additional advance stop line, conflicting with pedestrians and taking up space required by the right turning cyclists. Cyclist delay will usually be increased as compared with making the turn in the traditional way.

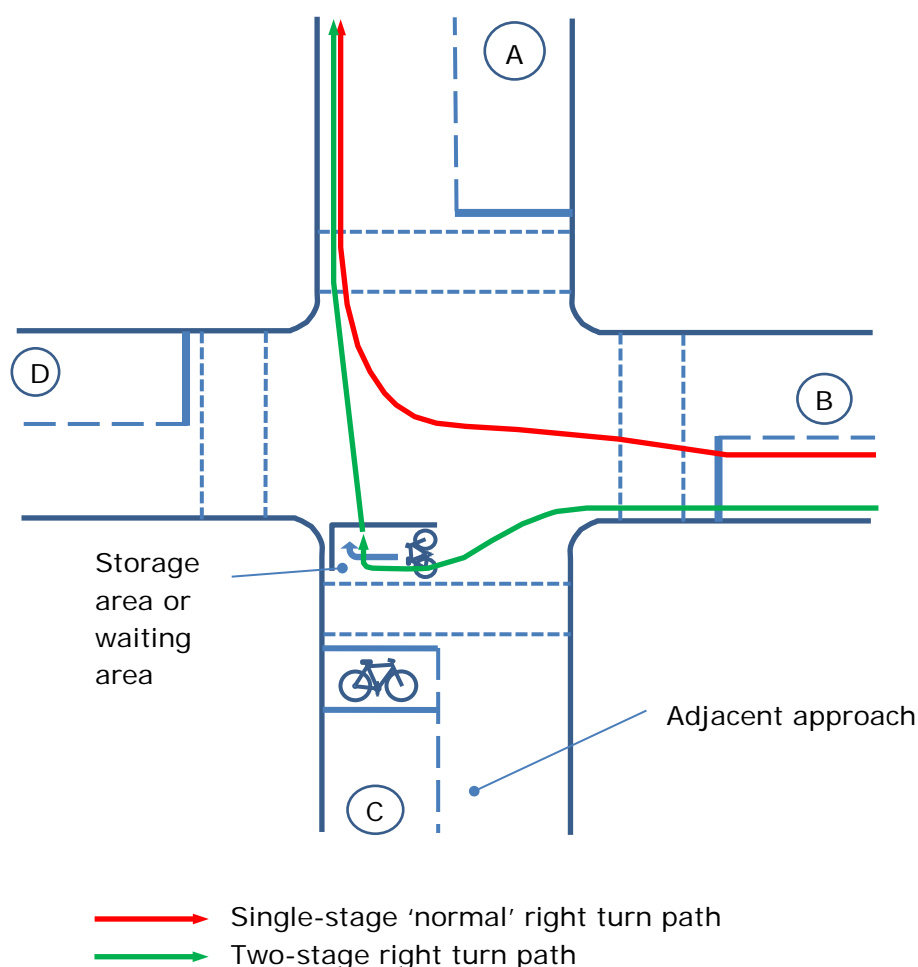


Figure 4: Two-stage right turn

Informal two-stage right turn is the same as the formal version except that there are no road markings. In the absence of markings, cyclists are not encouraged to

make the manoeuvre, which may lead to them being cautious, but may also lead to them taking unexpected routes through the junction and waiting in unsafe locations.

Dutch style fully segregated signal controlled junction, in which cyclists are physically segregated on the approach to the junction and when waiting. Cyclists then progress through on a separate phase. Junction capacity may be an issue as will the interaction with pedestrians. Cyclist delay will be significant as will the land take required. Dutch style junctions are being investigated as a separate workstream within the TfL innovative cycle facility trials project.



Figure 5: Dutch style signal controlled junction

Dutch style 'scramble': (also known as an 'all green for cyclists', see Figure 6) junction (including potentially more formal diagonal crossing). The same advantages and issues as for Dutch style junction apply, though there will be additional conflict between cyclists.



Figure 6: Dutch 'scramble' cycle stage

1.5 Ways of turning right at Roundabouts

Figure 7 shows a Dutch style roundabout which achieves full segregation. In the example below, cyclists have full priority over motorised vehicles and mopeds are not allowed on the cycleway. In The Netherlands, priority is given to cyclists if the roundabout is in an urban area. Giving cyclists priority is likely to be necessary to avoid additional delay. Without this it is possible that they will go around the roundabout with the other vehicles. To provide this facility, land take is substantial, which will limit its applicability.

The Dutch style roundabout is also being investigated in detail within the innovative cycle facility trials project being carried out for TfL.



Figure 7: Dutch style roundabout – cyclists segregated

Other features on roundabouts exist which are designed to assist cyclists in general and may help with the right turn in particular. Figure 8 and Figure 9 show two examples of lane marking using coloured road surface. Right turning cyclists may be made more visible or obvious by their presence on the cycle lane, but may also be vulnerable as they cross the exit that would be ahead for them to cars leaving the roundabout at that point. It will be difficult for drivers to judge whether the cyclist is also leaving the roundabout at the same exit or continuing around. In Figure 8 the exit is probably too narrow for vehicles to pass cyclists even if they are leaving at the same exit, so the driver has to be cautious anyway. In Figure 9 cyclists have a choice of lane which will allow them to show drivers whether the cyclist is intending to leave the roundabout or continue around. It is not yet known how effective the measures are.



Figure 8: Roundabout in the Netherlands with marked cycle lane



Figure 9: Roundabout in York (UK) with marked cycle lanes

2 Guidance, literature and practice

2.1 UK guidance

2.1.1 LTN 2/08

Local behaviour of cyclists, motor vehicles and even pedestrians will be a big influence on cycling facilities that work well and those that won't. Add to that the geometric, land take and legal aspects and the need to consider the local conditions becomes paramount.

The following extracts from LTN 2/08 are particularly relevant when considering ways of turning right:

1.3 'The underpinning principle is that measures for pedestrians and cyclists should offer positive provision that reduces delay or diversion and improves safety'.

1.3.2 'and the preferred way of providing for cyclists is to create conditions on the carriageway where cyclists are content to use it, particularly in urban areas.'

1.3.5 'convenience: and new facilities should offer an advantage in terms of directness and/or reduced delay compared with existing provision'.

'Delay for pedestrians and cyclist at signalled crossings should be minimised'

'Safety: Not only must infrastructure be safe, but it should be perceived to be safe'

1.3.7 'Some cyclists are more able and willing to mix with motor traffic than others. In order to accommodate the sometimes conflicting needs of various user (i.e. cyclist) types and functions, it may be necessary to combine measures or to create dual networks offering different levels of provision'

'Some authorities fear litigation if they implement innovative schemes or schemes that do not meet all the safety criteria'

9.2 'Signalised junctions are one of the safest types of junction for cyclists'

All of which makes the implementation the two-stage right turn to be quite exacting. In particular, when compared with using the road normally (i.e. just like any other vehicle) neither facility will offer a reduction either in delay or diversion for right turning cyclists.

2.1.2 London

London Cycle Network design manual (2004) specifically mentions the two-stage right turn as an option, without going into any detail about the legal aspects (i.e. whether it is legal or not) nor the specific circumstances under which it is likely to be beneficial. The illustration used in the manual is of a Toucan crossing rather than a junction.

London already uses 'Jug Handle' turns (also referred to as 'G turn' in the London Cycling Design Standards, TfL 2005) to aid cyclists across a busy main road (shown previously in Figure 3).

Another example of assisting cyclists in turning right with greater safety can be found at Chelsea Bridge/Embankment (see Figure 10). Here there is an additional space within the centre of the junction (circled in blue in Figure 10 that allows right turning cyclists to get ahead of motorised vehicles. This reduces conflict and allows cyclists to be seen. It can be seen that the geometry at this junction allows the room for the storage area to be created and there is a significant cyclist right turn here too. The signal sequence also includes an indicative right turn green arrow.

2.1.3 Other UK guidance

Sustrans, (2007) states that where multiple traffic lanes exist on the approach to an intersection with heavy cyclist right-turn flows, a central advisory lane is more advantageous than a nearside lane where vehicle flows are greater than 200 to 300 vehicles per lane per hour. Another advantage of the central approach lane is where a nearside left-turn lane exists for traffic; the presence of the lane will aid in making the presence of cyclists more obvious to drivers.

ASLs can only provide a benefit to cyclists when the red phase allows them to progress to the head of the traffic queue. This means that where arms of an intersection have a short red period or high percentage of green time, ASLs may not be suitable as there will be a reduced chance of cyclists reaching the intersection at red, particularly for those wishing to perform a right-turn. In these circumstances, the installation of an ASL would not be beneficial. The same effect can happen when there are quick changes between phases.

Peck (2011) states that braking to a stop, and starting up again, loses the equivalent energy to travelling 100m. Thus, he states, a 5km journey with 10 stops (e.g. for traffic lights) takes at least 20% more energy to complete. Use of the two-stage right turn has the consequence that a cyclist will always have to stop, even if the right turn movement at the junction is fully signalled. This could reduce its applicability if cyclists normally turn right the traditional way at a particular junction.

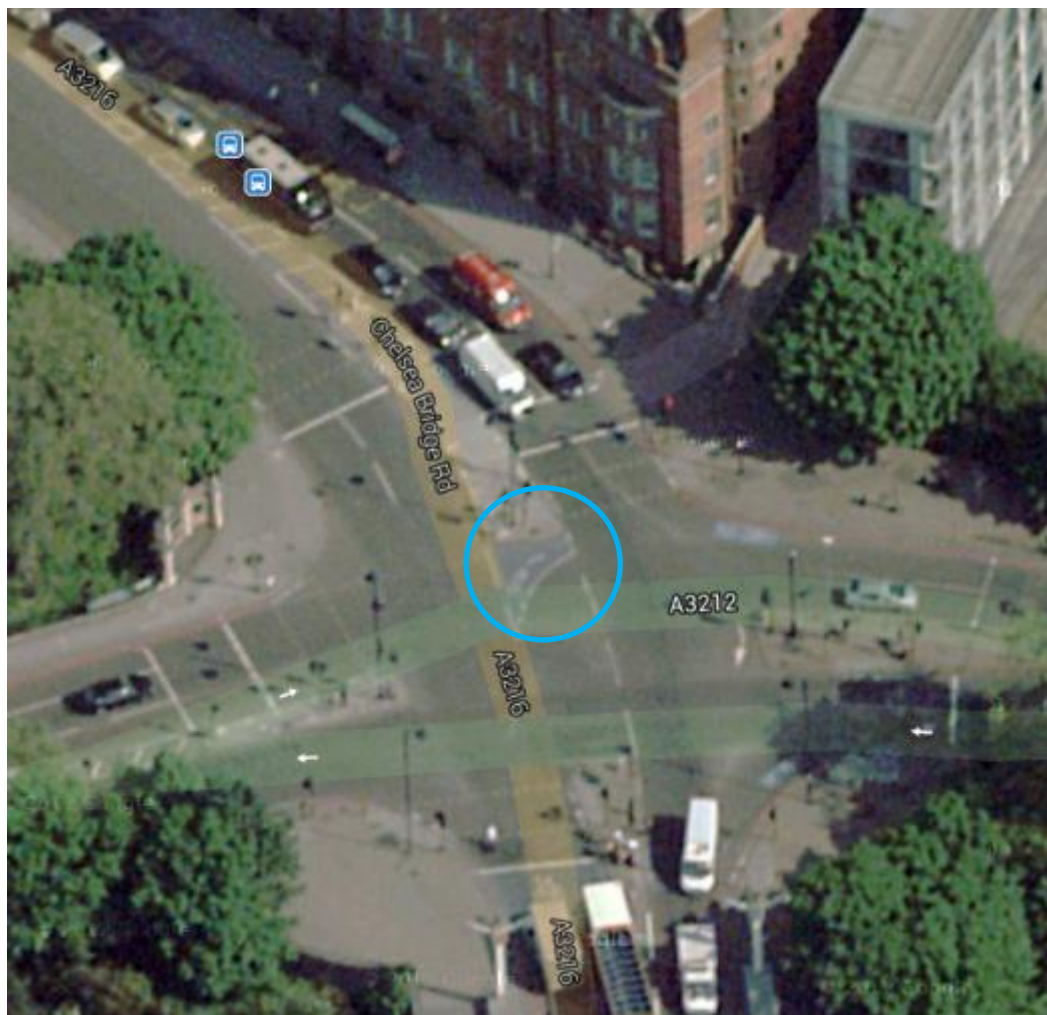


Figure 10: Chelsea Bridge/Embankment 'Forward Reservoir' (source, Google maps)

2.2 Non UK Guidance and literature

2.2.1 Right turning treatments

In Denmark it is illegal for cyclists to turn left (UK right), which has meant that the use of the two-stage right turn is common place. However, a definitive English Language description of the law has not been found. The Visit Denmark website provides the following advice: "You must always cycle on the right-hand side of the road and if there's a bike path, you should use this. If you are turning left, cross over the road you will join, so that you are waiting with the traffic on the right-hand side. Then go with the traffic when the light is green. Cyclists must use their arms to signal that they are slowing down, turning or stopping."³

³ www.visitdenmark.com/a-z/6237/2911

Steve Melia (2008) of UWE provides the following more detailed description:

'One peculiarity of cycling practice in Denmark, which has influenced the design of many facilities, relates to left turns. Cyclists are supposed to cross the junction on the right hand side, raise one arm to show they are stopping, then wait for a traffic light or an opening to cross both carriageways at once. Moving to the middle of the road before turning is apparently an offence, although a minority of cyclists do break this rule, and I did not notice any of them being stopped by the police'.

The two-stage turn (and presumably therefore the banning of the left turn by cyclists) is implemented in Denmark to reduce the inconvenience to other road traffic and reduce conflicting collisions with opposing traffic flows where there are multiple lanes. In such instances where this is used, the advice is that the second movement should be incorporated in the next phase to minimise the additional delay.

2.3 International Experiences with the two-stage right turn

2.3.1 Ireland

Ireland has produced a manual covering cycling facilities to be used in the country (National Cycle Manual, 2011). The manual is principles-derived and applied to circumstances in Ireland (similar to UK conditions and behaviour) (Aherne, 2013). For example, many elements of Dutch design (in particular) have not been adopted because of the differences between the two countries. At the same time German advice regarding two-way cycling crossing side roads has been included. Many of the elements of the manual have been taken forward into projects in the past two years, and have been well received by cyclists (and not particularly noticed by drivers).

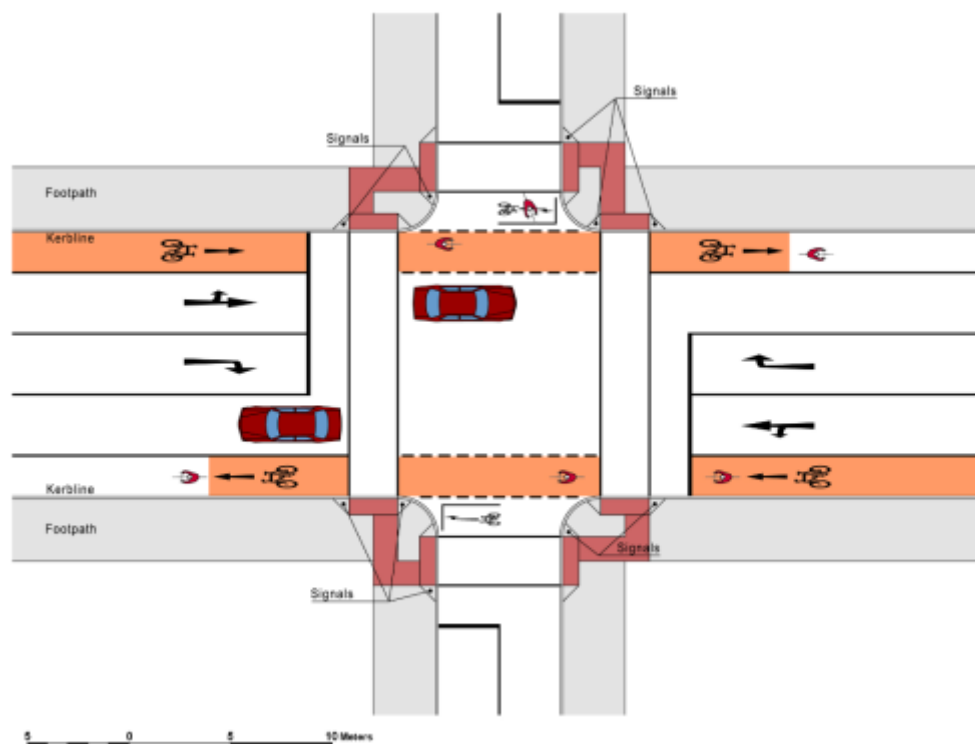


Figure 11: Box turn as shown in the Irish cycle manual

Box turns (which is the term used for the two-stage turn by the Irish and others) were highlighted in the Irish manual because designs were being put forward by consultants that proposed either multi-lane ASLs or invited cyclists into prolonged exposure between multiple (and weaving) traffic lanes.

Box turns used to be a normal cycling behaviour in Dublin until the early 70's – after that, signal cycle times went up, and cyclists would not wait anymore at the side road leading to an increase in casualties.

In Ireland various versions of box turns have been implemented in the past two years, together with some pre-existing examples (box turns were included in the first manual for Ireland). Two examples are shown below (Figure 12) which are side roads of a main route into Dublin City, hence not much used. However it can be seen that turning right in the traditional manner at either location would be difficult.

One of the main issues that arose with box turns is the fact that cyclists wait ahead of the primary signal poles so therefore rely on the secondary signals to see when the green appears. The secondary signals then have to be on the far side, so it needs to be obvious which signal applies. The other main issue was one of understanding about both what the 'boxes' are for and how to use them.

A potential problem also develops where the side road has detection fitted, and this does not cover the cyclist waiting area, leading to this stage not appearing.

Consideration has been given to the amount of room required by large vehicles turning into the side road. The box has to be well away from any possible swept paths, otherwise it would be unsuitable – the issue would arise particularly with junctions with tight kerb radii and/or narrow lane widths. The junctions shown below have plenty of room, and in the second example, left turners are separated from the waiting area by an island.

For two-stage right turns a key issue is cycle time. Sixty seconds was suggested for small junctions, with an absolute maximum of 90s for larger junctions.

Note that in the first example below an ASL exists on the side road, and there are no pedestrian facilities.

Their guidance says to exclude the use of ASLs on the main road presumably as a means of discouraging right turning the normal way. The only other encouragement for cyclists to make the turn in two stages is the addition of the waiting area painted on the road. The guide states that this may require geometric modifications such as moving the pedestrian crossing further back from the junction to make room.



Figure 12: Box turn examples in Ireland

2.3.2 *New Zealand*

A number of instances of the two stage right turn have been implemented in New Zealand. Experience has not revealed any particular concerns about a potential increase in conflicts with left-turning vehicles.

2.3.3 *USA*

Shown below are two examples that appear in the Portland Oregon cycling guidance (Figure 13 and Figure 14).



Figure 13: Example from Portland Oregon cycling guidance



Figure 14: Another example from Portland Oregon cycling guidance

Smith and Helen (2009) carried out a survey of 118 commuters in Portland, Oregon, specifically asking about the left (UK right) turn issue. Although not entirely clear from the wording, the suggestion was that 50 per cent of cyclists that used a particular left turn said that they would modify their route if the turn was made easier, and the Copenhagen left turn was specifically mentioned.

Guidance to cyclists using the road from the Portland authorities suggests that they choose one of three left turning methods. Two methods involve cyclists moving to the right (UK left) and waiting until the phase on the adjacent approach turns green. In the first of those methods the cyclist then proceeds across the junction using the road, and in the second the cyclist uses the pedestrian walkway. The third method is the traditional method where the cyclist completes the manoeuvre by moving to the left (UK right) on the approach and completes the turn from that position.

In the last case - if the approach does not have a separately signalled left (UK right) turn, such that the cyclist has to give way to opposing traffic, the guidance also suggests that cyclists should take up a position that stops ahead vehicles in the same direction getting past them whilst they are waiting to turn. Such action could frustrate motorists particularly if cyclists are given an alternative.

2.3.4 Netherlands

Figure 15 shows the two-stage right turn as given in the CROW manual. The three alternative layouts cater for different junction constructs, and in the first a cycle lane is depicted whilst in the other two a cycle track is shown.

Description	Stacking facility for cyclists turning left at traffic control system
Function	stacking facility for cyclists at traffic lights
Application	<ul style="list-style-type: none"> • intersection with traffic control system • inside and outside built-up areas (V_{max} outside built-up areas 60 km/h)
Implementation	<ul style="list-style-type: none"> • marked stacking area; if all cyclists turning left have to stack in this area a 'gap light' is required
Dimensions	<ul style="list-style-type: none"> • depending on intensity; width of stacking area > 1.20 m
Considerations	<ul style="list-style-type: none"> • cyclist is standing in an illogical place • subjectively unsafe • without physical refuge unsafe should traffic control system fail
Alternatives	<ul style="list-style-type: none"> • green light for all directions • ECSL (when maximum of two lanes per section)

Figure 15: Two-stage right turns as shown in the CROW manual

3 Implementation of the two-stage right turn

3.1 Expected advantages

The main advantage of the two stage right turn is in allowing cyclists to avoid crossing a lane or lanes on the approach to a junction. As discussed above, moving across lanes is considered to be a stressful and potentially dangerous manoeuvre. Some groups of cyclists, in particular the inexperienced, are likely to want to avoid the manoeuvre at any junction, whilst even the most experienced may be forced to avoid it when the approach is busy with fast moving traffic covering multiple lanes.

3.2 Legal obstacles

All the examples and guidance covered in this report use similar methods of marking the two-stage right turn. These methods all have a solid line at the front of the waiting area. This layout is not covered in TSRGD and it is a requirement that a stop line is accompanied by primary and secondary traffic signals (also see 3.4.1). It may be possible to find a means of marking the waiting area consisting of approved items. Therefore it is not clear at this stage whether any given layout will require DfT approval or not. It seems possible that the only problem is the use of solid lines and the likely current need for them to accompany primary traffic signals.

3.3 Other issues

3.3.1 Conflict with left turning vehicles

Conflict may arise between cyclists manoeuvring slowly in front of left-turning vehicles during the first stage – this gives rise to the same problem as left turning vehicles not seeing ahead-bound cyclists, compounded by the increased time the cyclist will spend in the conflict zone because they are slowing down ready to turn and stop in the waiting area.

3.3.2 Low level cycle signals

Low-level bicycle signals and their use are being investigated as part of TfL's innovative cycle facility trials project and are being considered for implementation in London (TfL, 2013). One reason for using low-level signals is to allow cyclists to start early ahead of vehicles. If the two-stage right turn was formally in use at a junction with an early start, cyclists waiting to make the second part of their turn will be in front of the primary low level signals, and hence the right turn waiting area would require its own low level cycle signal.

The positioning and operation of the low level signal and the right turn waiting area will need careful consideration and be investigated as part of a further trial.

3.3.3 Combining right- turning options

Another important consideration is dealing with cyclists that will still turn right the normal way even if offered the two-stage option. Preventing cyclists from turning right normally would have legal implications and is unlikely to be possible in the short term and the legislation to force this would be difficult.

This means that two ways of turning right will be available to cyclists. Motorists may not expect cyclists to be turning right normally when they know an alternative way is available. There may also be 'interaction' between cyclists making the manoeuvre in the two ways available. It will be important to understand the implications of this (if any). Designing to allow both possibilities will be necessary and could even be desirable. In places where the two-stage turn has been implemented, there has been no indication

that having both options available has been a problem. However, this needs to be considered.

3.3.4 *New reservoir treatments*

As part of the CFT project, the original layout for ASLs as described in TAL 8/93 (see Figure 16) is being updated with the provision of low level cycle signals. The arrangement allows cyclists into an area in front of other vehicles, in a way that is similar to ASLs. The difference is that the primary traffic signals are at the first stop line, which includes a cycle filter that allows cyclists to proceed to the next stop line, which is controlled by low-level cycle signals. Cyclists can then be given an early start.

There will be a need to consider how the new reservoir and the two-stage turn interact and whether the latter will work better or worse with the former.



Figure 16. Cycle filter in use in Cambridge

3.3.5 *Additional conflicts with two-stage turning*

There are a number of conflicts that may arise with the introduction of two-stage turns.

3.3.5.1 *Conflicts with pedestrians*

Two conflicts may arise with pedestrians as shown in Figure 17. The first is with cyclists making the right turn in two stages and pedestrians who walk across the junction in a straight (desire) line without deviating towards the pedestrian studs. The second conflict, which may arise regularly even without a formal two-stage turn, is between cyclists who move forward and wait as close to the junction as possible and pedestrians crossing normally. However, the addition of the waiting area may encourage cyclists to move forward.

3.3.5.2 *Conflict with left-turning vehicles*

Another conflict, as mentioned in 3.3.1, is between vehicles turning left and the cyclists making the right turn in two stages (Figure 17). This conflict exists anyway between cyclist travelling ahead and left turning vehicles. It is, nevertheless, one of the more serious problems at signal controlled junctions and encouraging cyclists to complete the right turn in two stages may increase the risk of this conflict, which in turn may be a greater issue than turning right the normal way, at least at some junctions and for some cyclists.

Ways to reduce conflicts with left-turning traffic need to be considered and the early start of cyclists may be of some help with this. If cyclists can establish themselves in view after the green has started, possibly even completing their manoeuvre before vehicles reach the conflict point, the problem should be reduced. The early start of cyclists may be helpful. However, it is unlikely to offer a complete solution, particularly for cyclists that arrive later in the green. Where there are large numbers of cyclists waiting not all will be able to get away early enough to completely avoid conflict.

Some form of segregation on the approach to junctions may also help to reduce such conflicts.

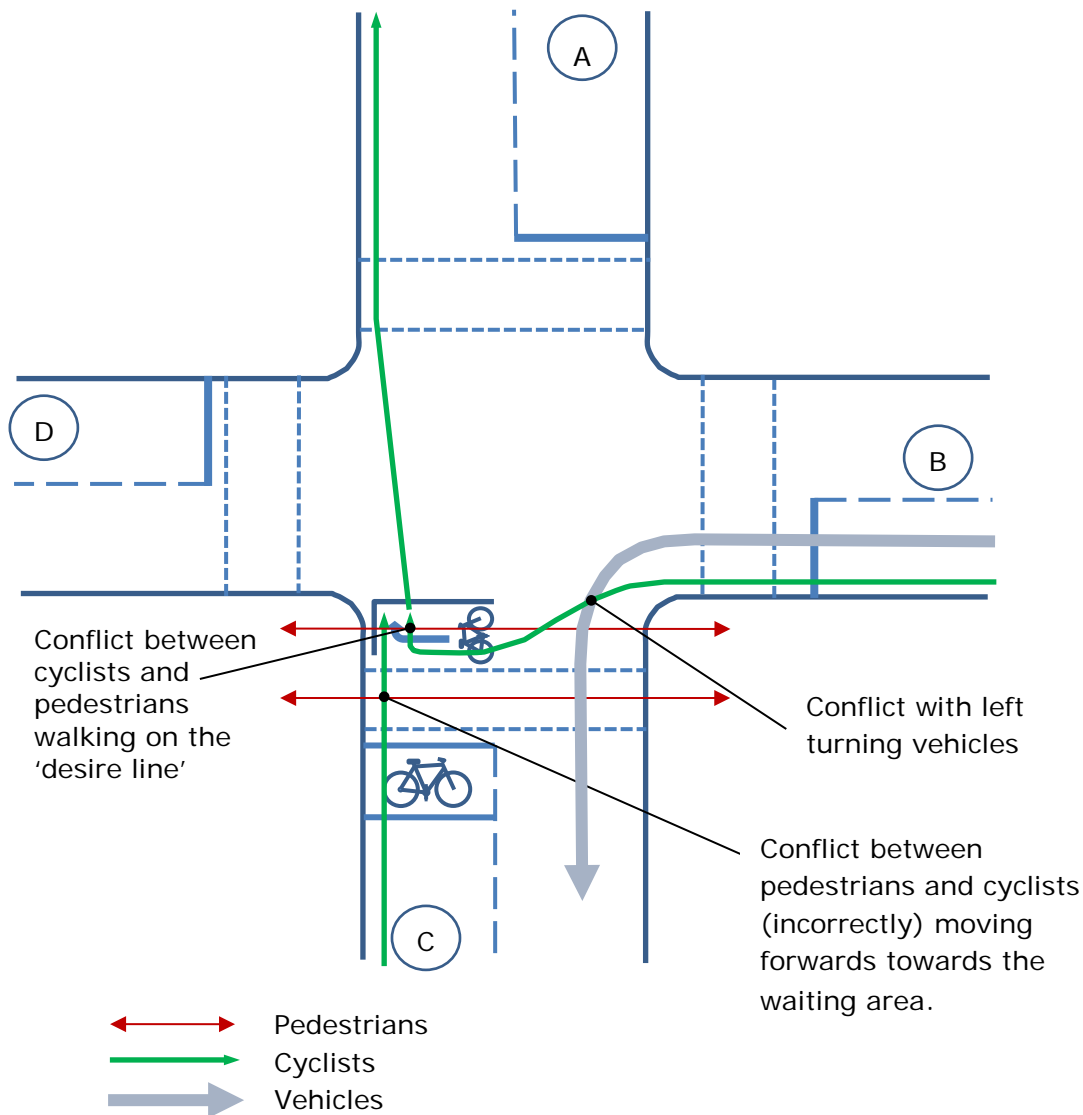


Figure 17: Additional potential conflicts caused by introducing 2-stage right turn.

3.4 Alternative line markings

3.4.1 Legal implications

It is anticipated that the formal two-stage right turn facility will predominantly be located where turning right any other way is an issue for one reason or another. Thus it is likely that encouraging use of the two-stage turn will be both desirable and easier. Clear road markings will be an important way of encouragement. However, there are likely to be some legal implications as follows:

- A solid white line (stop line) is legally enforceable only if it is accompanied by primary traffic signals (and, although not relevant here, a 'stop' sign).
- Signals do not require a stop line to be legally enforceable (there are examples of part time signals at roundabouts that have just the priority road markings); A stop line that is associated with a primary traffic signal is required to indicate where vehicles should stop (except where ASLs are involved). This is always upstream of any pedestrian facility (i.e. the pedestrian studs, where they exist);
- It is possible to have two stop lines on the approach to a junction with their own signals with a filter to allow cyclists through. This allows the use of the reservoir, as is being investigated as part of the low- level signal work stream of the TfL innovative cycle facility trials project.
- The two-stage waiting area will always be downstream of the pedestrian studs, hence cannot be associated with a normal primary signal. Cyclists waiting in the waiting area may be able to use the secondary signal to indicate when it is safe to continue, or;
- It may be possible to use a low-level signal close to the front of the waiting area but only if there is enough room to locate the waiting area such that cyclists can see the signals and it is clear what they are signalling, and not confusing or misleading to other road users;
- Solid white lines at a junction can only be associated with a primary traffic signal or an un-signalised stop sign. The signals indicate when it is permitted to cross the solid line. When the white lines are worn away, the primary signals indicate approximately where vehicles need to stop (except where ASLs exist);
- By moving into the waiting area cyclist will have legally crossed one stop line. After that, cyclists can legally complete their manoeuvre at any time 'if the way (ahead) is clear';
- A dashed line cannot be used with traffic signals. If used to mark the waiting area they will not prevent cyclists from 'legally' completing their manoeuvre since once in the waiting area they will be downstream of the stop line.

It is not known at this stage how the legal issues can be overcome or worked around. However, cyclists will have to cross the stop line on the first approach in order to get to the waiting area, and having done so will be within the junction downstream of any 'legal' stop line and would be entitled to proceed at any time provided that 'the way ahead is clear' (Highway Code). Since this is the case, a dashed line in place of a solid line may be an option. An advantage of a dashed line is that it will be more obvious that it is not meant as a further ASL for cyclists on the adjacent approach, but with the disadvantage that it may encourage cyclists using the waiting area to cross the junction when the signals are red for the second stage direction (though this may not be a

disadvantage because it is exactly what many cyclists will do anyway). TfL is proposing to investigate different road markings and waiting area designs in future trials, prior to any track trials. Three example stop line markings and a give-way marking are shown in

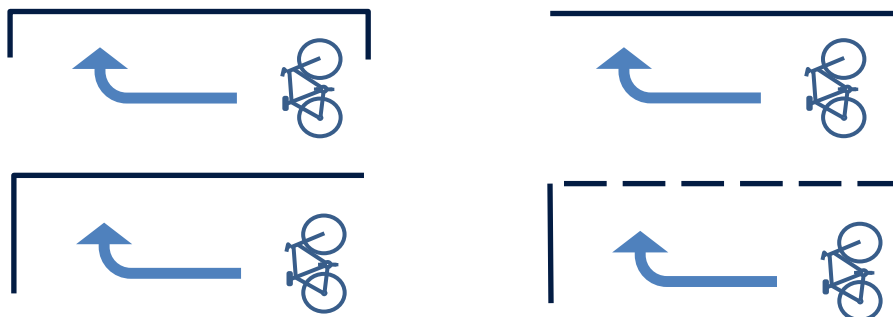


Figure 18.

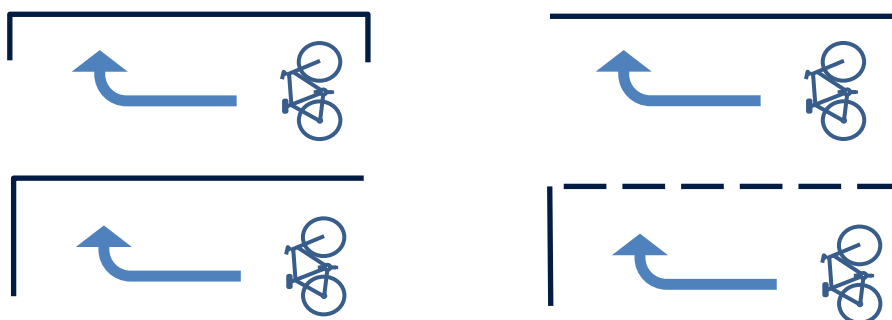


Figure 18: Stop line alternatives

In order to encourage the use and as an aid to understanding of the two-stage movement, marking of a path to the waiting may be worth investigating. Figure 19 and Figure 20 show two examples of the principle. Naturally there is scope for use of different colours, additional road markings, not to mention signs. However, the road markings will be subject to heavy wear and tear where they are located and care will be needed in their application to avoid confusing other road users. The desire line may also be modified by the presence of low-level cycle signals, which have the advantage that they are not subject to wearing.

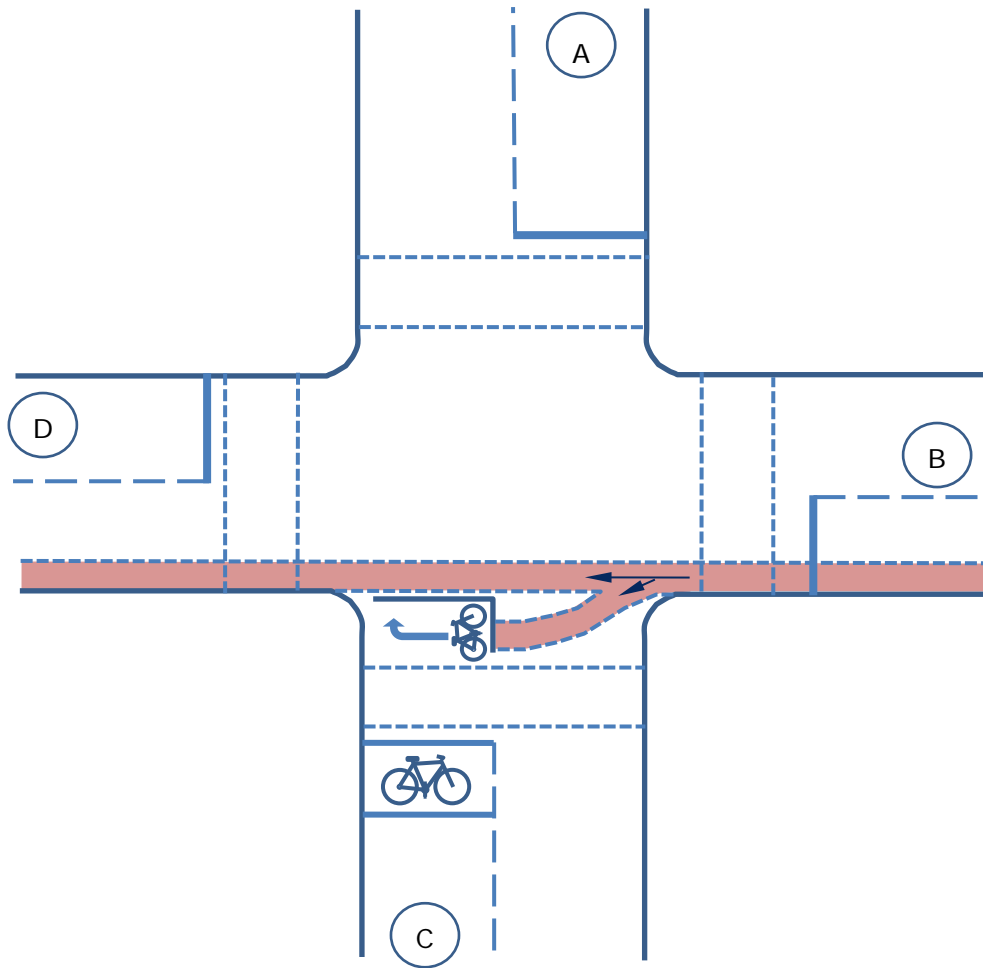


Figure 19: Example layout - small junction

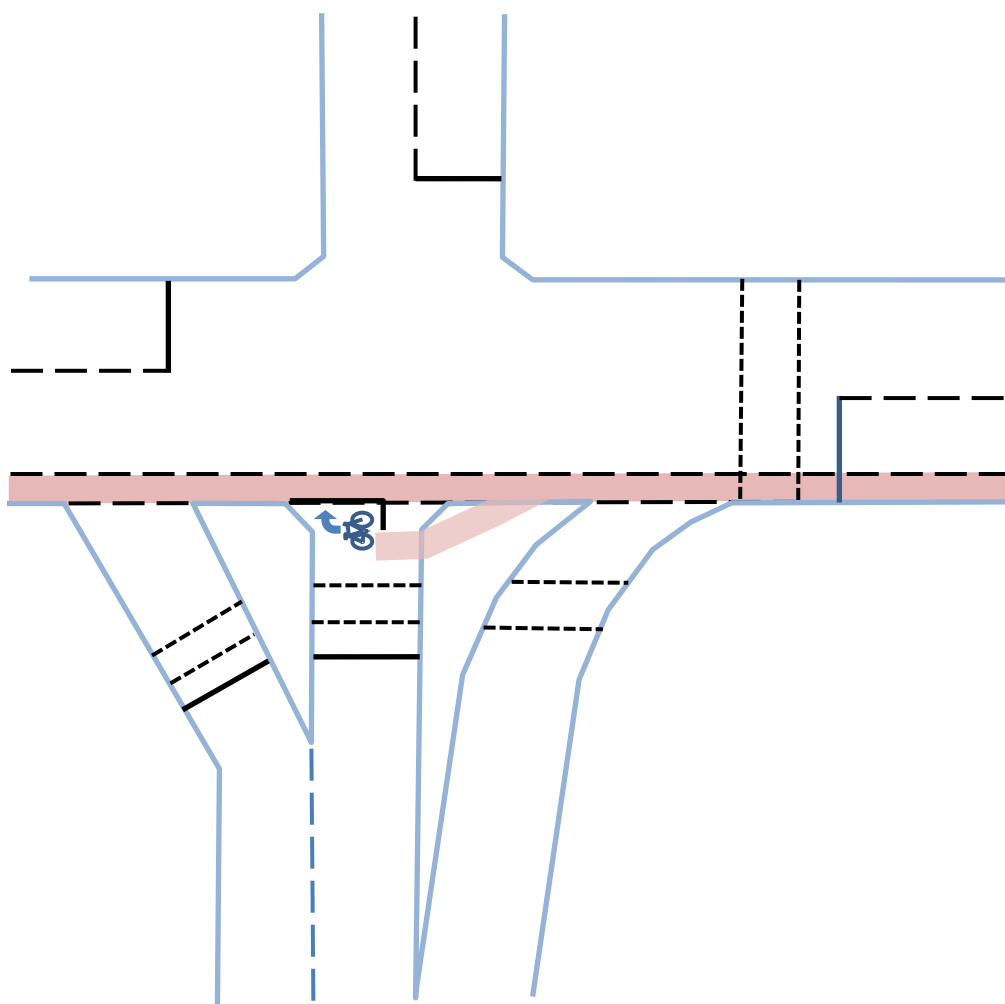


Figure 20: Example layout – junction with islands

3.5 Signal stage sequence, cycle time and reducing delay

It is an objective to encourage cycling by introducing facilities that improve safety, comfort and delay and encouraging use of the facilities provided (DfT, 2008). It seems unfortunate that, with the two-stage right turn, additional delay is inevitable when compared with making the turn the normal way. However, in cases where turning right the normal way is difficult even for experienced cyclists, turning right in two stages informally (or by some other means) can occur. Formalising the right turn in such circumstances may reduce delay in by comparison.

At some junctions it may be that a minority of cyclists will insist on turning right the normal way with the majority happy to make the turn in two stages because of the reduced delay, greater comfort and (perceived) safety. It may be necessary to accept that not all cyclists will 'conform' and in any case may not be desirable for full conformance. Indeed it is unlikely that the necessary legislation would be possible to prevent cyclists having the choice.

As has been mentioned, there is some evidence that cyclists are prepared to modify their route if right turns are made easier (Smith and Helen, 2009). Thus introducing the two-stage turn at problematic junctions potentially reduces delay if it means a cyclist

becomes happy to take a shorter route. It may even mean that some travellers become willing to cycle rather than use other modes, which may also reduce their journey times.

Even so, it is important that delay is minimised. Cyclists will not use the two-stage turn when the delay starts to become high. In order to minimise delay, the underlying principle with the two-stage turn is to ensure the cyclist receives green at the second stage stop line soon after receiving green at the first stop line. Two parts of signal operation are key to achieving this – cycle time and stage sequence.

The cycle time needs to be short with 90 seconds being considered to be the longest acceptable (Ahern, 2013, CROW, 2006). Pedestrians also tend to benefit from a short cycle time. Of course the capacity of some junctions may be severely hampered if the cycle time is short because the relative proportion of lost time increases. Cyclists may also suffer if congestion increases noticeably with both safety and delay suffering.

Signal staging can help, but it depends on the site. If the junction in question was simple with very few pedestrians, the simplest arrangement is two stages. This being the case, the second stage will always appear after the first, no matter which direction the cyclist came from in the first place.

As soon as more stages are introduced, it becomes possible for cyclists to have to wait for other stages to run before completing the second stage of their manoeuvre. Figure 21 shows a three stage junction with two traffic stages plus an 'all round pedestrian' stage.

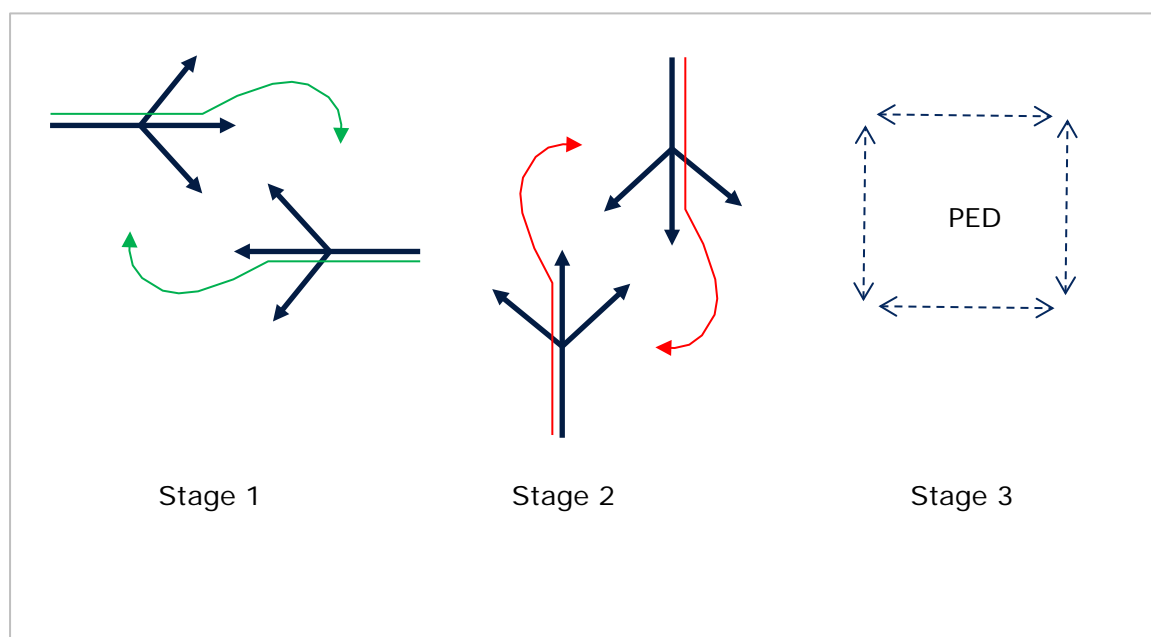


Figure 21: Two traffic plus pedestrian stage sequence

It can be seen that the cyclists starting the two-stage turn in stage 1 (in green) can complete their manoeuvre in stage 2 whilst cyclists in stage 2 (in red) have to wait for the pedestrian stage before they can complete their manoeuvre in stage 1. In practice most cyclists are likely to make use of the pedestrian stage, and possibly quite legally too provided the way ahead is clear (of pedestrians).

Should the staging be such that the second stage cannot be shown green immediately, pedestrians are likely to 'nip' across the junction during an intergreen. There will be times when this is quite risky.

The stage sequence arrangement shown in Figure 21 is relatively common in London. It would normally be possible to change the sequence (there is only one alternative with a three-stage sequence) if this helps. This may help reduce the number of cyclists who have to wait for the pedestrian stage to pass, depending on where the majority of cyclists come from and /or going to, or whether the two-stage turn has been applied to both directions.

Once junctions start becoming more complex and there are two-stage turns in conflicting directions, it becomes difficult or impossible to arrange for all two-stage turns to run consecutively. However, it seems likely that selected approaches will be chosen to receive the facility, rather than all of them, making it more likely that the staging could be arranged favourably.

Some junctions operate in 'clockwise' fashion (e.g. Bessborough Gardens, Grosvenor Road, Vauxhall Bridge) whereby each approach runs separately. The need for an all-red pedestrian stage can be avoided, provided that there are islands dividing each approach between inbound and outbound traffic. Such junctions tend to run anti-clockwise as this generally minimises the intergreens, though the difference is likely to be small if all right turns are permitted. However, this is the wrong direction if the two-stage turn cyclists are going to receive green in the next stage. On the other hand, clockwise operation permits all approaches to run the two-stage turn with the second stage running immediately after the first.

CROW (2006) mentions several ways of minimising delay which are relevant in general and to turning right in particular (comments regarding application to the two-stage right turn are shown in *italics*).

- Short cycle times – maximum of 90 seconds; short cycle times are easier to realise at compact junctions; *key to the success of two-stage turns*;
- Concurrent extension of public transport priority – extend non-conflicting cycle greens; *could help cyclists with either of the two stages in turning right*;
- Increasing motorised traffic flow capacity – additional capacity reduces congestion and if achieved by the addition of traffic lanes can keep cycle times down too; *helps allow cyclists to complete their manoeuvre with minimum delay*;
- Concurrent extension of non-conflicting phases (similar in principle to walk-with-traffic pedestrian phases, which could be extended to benefit cyclists); *could help cyclists with either of the two stages in turning right*;
- Using long-range detection/pre requests – traffic control can be made to react to cyclists more effectively; *could be used to help cyclists with either stage*;
- Permitting of sub-conflicts – by permitting sub-conflicts (e.g. with pedestrians or other slow moving traffic) the cycle time can be reduced; *allowing cyclists to manoeuvre in gaps on the second stage*;
- Realising additions (sic) cycle directions (green light twice/cycle) – *not likely to help with turning right unless the non-conflicting traffic can run twice in the cycle*;
- By keeping mutual conflicts between slow traffic outside of the control – *only relevant to cycle tracks*;
- Using green light for all directions (scramble) – *see Millard and Knight (2013)*

3.6 Encouraging the use of the two-stage turn

If and where the two-stage turn facility is employed, the reason will be to provide cyclists with a facility that improves their safety, reduces their journey times and encourages them to cycle. It therefore seems logical to encourage cyclists to use the facility if it exists. If all cyclists turn using the same method the added consistency may aid safety. However, some cyclist may wish to turn in the traditional way, being able to do so quite safely, and may feel discouraged from cycling if forced to turn right in two stages.

Unlike Denmark, where turning left (right in UK) the normal way is illegal, in the UK there will be nothing to stop cyclists from turning right that way. It may be desirable to encourage cyclist to make the turn in two stages where the facility is provided to lend consistency to traffic movements. It is possible that in some situations turning right in two stages does provide improvements to nearly all cyclists using the facility. However, there may be some other situations where the two-stage turn is a desirable facility for some, but not for others. The question arises about the extent to which use of the facility needs to be encouraged and how to do that.

Ensuring cyclists benefit from the facility is likely to be the most important way of encouraging its use. This is difficult because cyclists will take longer over the manoeuvre than if they turned right normally, unless turning right is notably difficult and dangerous. Hence cyclist are likely to welcome a facility if it formalises a way of turning right in the absence of being able to turn right normally.

Further encouragement can be achieved by bringing attention to the facility through signs and road markings. This helps cyclists know what to do and also tells motorists that cyclists may be using the facility so they know what to expect. A modification to the ASL may help make it clear that turning right normally at a particular junction is being discouraged. See Figure 22. This shows the ASL as being reduced in width. It is shown as still being wider than the cycle lane that feeds it. It is not clear at the time of writing what dimensions would be appropriate, but the width may need to be flexible, or in some other way, take account of the principles of ASLs in that they are designed to allow cyclists to establish a position ahead of a queue to be more visible to drivers.

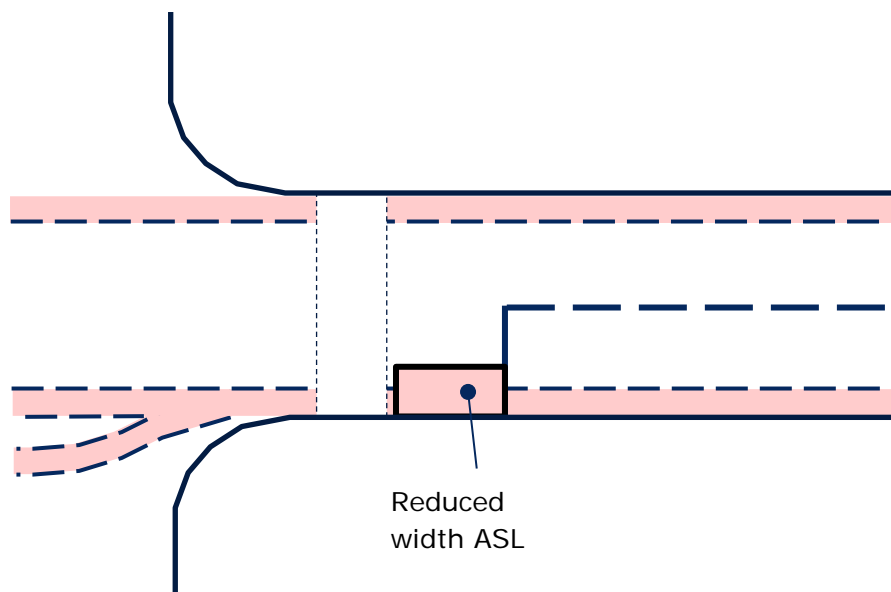


Figure 22: Reduced width ASL

4 Issues to be resolved by future trials

Appendix B describes all the issues that have been thought of together with an analysis of the implications. A number of them may need further investigation by trial.

These are the issues that need further consideration prior to on-street trials:

- How should the two-stage turn be marked particularly in respect of encouraging its use and understanding how to use it;
- Interpretation of traffic signals – cyclists who have stopped in the waiting area will not be able to see the primary signal heads. Therefore they need to be able to see either:
 - the secondary traffic signals, and it needs to be clear which ones apply to the approach they are on, and/or
 - Low level cycle signals placed next to the waiting area.

Low level signals will be used in the trial as part of the proposed standardised junction with the intention of making it clear to cyclists what they are meant to do and when. Results from the trial and consultation with DfT will be used in the decision as to whether the low-level cycle signals will be designated as primary or secondary signals.

- Movement of cyclists during intergreen – how vulnerable are cyclists who cross the first stop line at the end of green to drivers starting up on the next stage.
- Left turning traffic conflicting with cyclists making the two-stage right turn;
- Location of the waiting area in relation to the lanes with given turning movements – where would it be best to put the waiting area particularly in relation to left-turn only lanes;
- Signal staging – to what extent is it desirable to ensure the second stage of the two stage turn is shown green immediately;

- Traffic flow conditions – are there any traffic conditions where the two-stage turn is particularly suited or particularly unsuited;

5 Suggested signing for the two-stage right turn

As already discussed, the objective of the two-stage right turn is to encourage cycling by making it safer as well as to appear to be safer. At the same time, experienced cyclists may well still prefer to turn right directly at many junctions. Therefore it would not be desirable to make the two-stage turn compulsory.

The two-stage turn will be unfamiliar at first and one way of informing as to how to make the turn and also to encourage turning right in this way is to place signs on the approach to the junction. However, the concept is quite complex and a sign that gets the message across needs careful thought.

Signs that convey similar information have been found in Melbourne (for cars) and Toronto.

Figure 23 shows two examples for vehicles, though the intent is conveyed simply and should be easily understood, assuming a reasonable command of English.



Figure 23 – Example signs from Australia

Figure 24 shows two examples from Toronto. Both make it clear that they are for cyclists and that they are suggesting making the turn indirectly and conveying what that means in practice. It is not clear how easily the detail of the box, stop line, crosswalk etc., would be assimilated on the approach to the junction. It is also not clear why two versions of the same sign exist when a one design would be consistent which could be more effective.



Figure 24 – Example signs from Toronto, Canada

The Department for Transport (DfT) has an on-line resource entitled ‘Know your traffic signs’. This gives many example signs that provide information to the road user. Figure 25 shows examples of signs that convey similar information and provide formats that are potentially acceptable to DfT. In particular the cycle direction sign is white on a blue background.

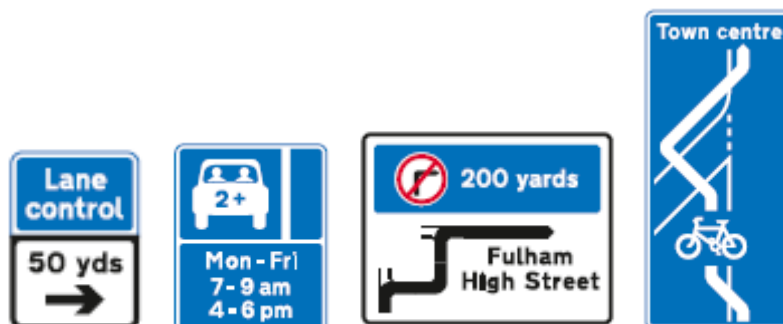


Figure 25 – Signs from DfT ‘Know your traffic signs’

The objective of the signs is to convey the information to the cyclist in way that is easy to assimilate as they cycle by, and in a way that avoids confusion. The information may also be useful to motorists, though it must be absolutely clear the sign is indicating that the manoeuvre is for cyclists only. It must also be as clear as possible that the two-stage right turn is optional for cyclist to avoid motorists antagonising cyclists turning right the normal way. (Road users should realise this from the format of the sign that it is information and not compulsory).

To avoid issues with language, use of diagrams and symbols is suggested as an option to consider. In any case it could be difficult to convey the intention with just two or three words; more words than that and the sign becomes difficult to assimilate whilst cycling past. This issue will be investigated during the trial by use of different sign options.

The following three figures show potential signs and also include variations in the components of the signs. Figure 26 shows a potential sign with words at the top to indicate who it is for and includes a cycle symbol at the bottom to underline that the sign

is for cyclists. The sign has the advantage that there are two ways in which cyclists are made aware that it is for them, but the potential disadvantage that words are included which will take additional time to assimilate. However, there are plenty of examples of signs with writing in the UK.

The inclusion of the pedestrian crossing to the left is an attempt to make it clear to cyclist that they are not meant to go into or cross it when making this manoeuvre.

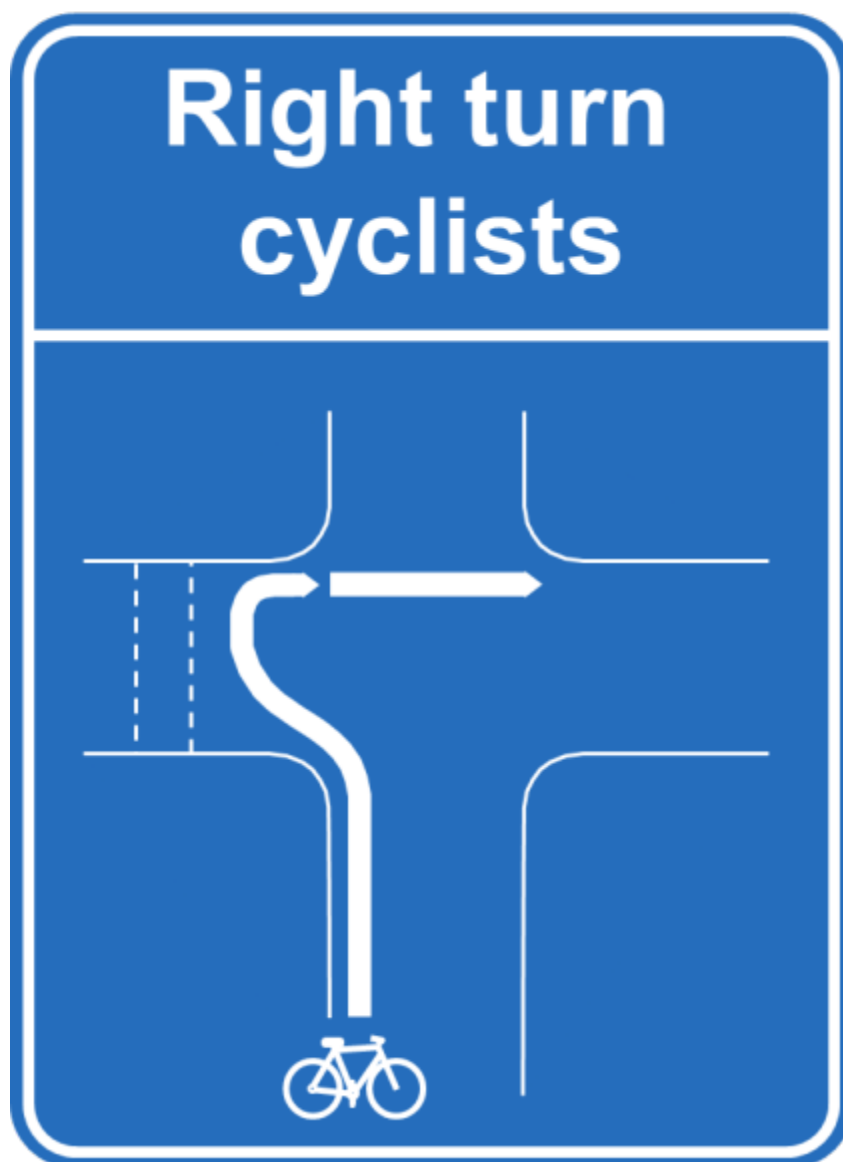


Figure 26 – Potential sign using words and a cycle symbol

Figure 27 is similar in most respects, though has a cycle symbol in place of the words at the top, with no other cycle symbols. The inclusion of the traffic signals is to indicate that cyclist have their own signals (taken from current thinking about the standardised junction). They are full discs in this example because it may not be possible for the detail of a cycle symbol to be discernable on the move. Figure 28 shows an alternative form of traffic signal symbol. Another difference between this sign and Figure 26 is the use of three arrows to indicate the manoeuvre, showing both potential stopping points.

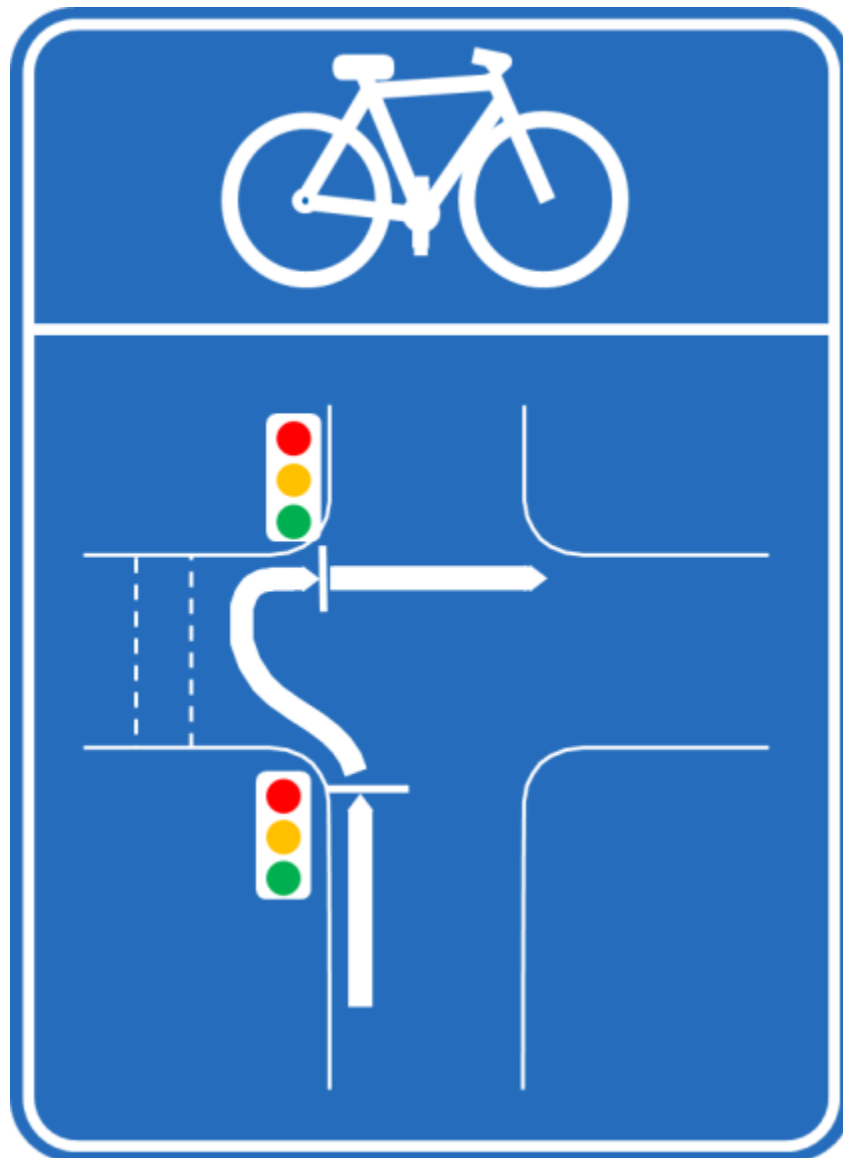


Figure 27 – Potential sign using cycle symbol and includes traffic signals

Figure 28 shows the sign in black-on-white with a white-on-blue cycle symbol. The components could be changed to suit of course and the diagram shows the traffic signals with cycle symbols.

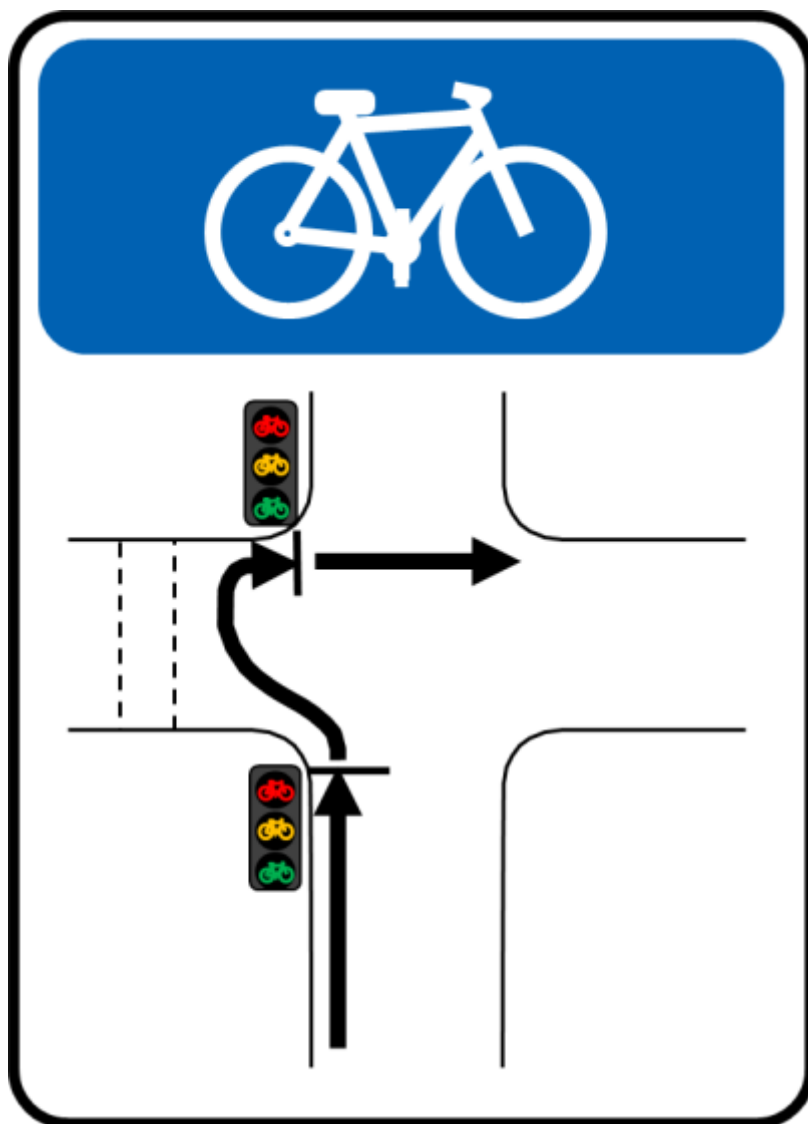


Figure 28 – Potential sign, black on white with alternative traffic signals

The white-on-blue signs are in keeping with current signing for cyclists in the UK. The size of the sign needs to be considered and dimensions for existing signs suggested a suitable size would be 320mm x 420mm. Mock ups of the signs will be created prior to trials before confirming that this size is likely to be suitable

The black-on-white is included to demonstrate an alternative form of the sign. This also shows the signals with cycle symbols included in the traffic signal heads. It is thought that this form will not be generally acceptable.

6 Conclusions

A comprehensive worldwide search for literature has been undertaken in an effort to find research carried out on the two-stage right turn. Sources identified were mostly technical guidance or descriptions of example schemes; no research papers or reports have been found.

There are many collisions at signal controlled junctions and there is a need to try to reduce them. Certainly when considering the right turn issue, there is a safety problem

both real and perceived. The problem may not be as large as it is perceived to be, though this is possibly because cyclists tend to avoid making the manoeuvre particularly at junctions where it is likely to be genuinely very dangerous (e.g. multi-lane high speed junctions).

LTN 208 states 'Some cyclists are more able and willing to mix with motor traffic than others. In order to accommodate the sometimes conflicting needs of various user (i.e. cyclist) types and functions, it may be necessary to combine measures or to create dual networks offering different levels of provision'

A number of alternative ways of dealing with right turning cyclists are already either in existence or being suggested (for UK use). These facilities are summarised in Appendix A and, apart from the two-stage right turn, are either already in use or being trialled in other work streams of the innovative cycle facilities trials project. The range of options available may not cover all eventualities. Adding the two-stage right turn as another way will increase the possibility of making right turns easier at more junctions.

Both current UK and international guidance for providing facilities for cyclists to turn right at signal controlled junctions has been reviewed. Many countries already include the two-stage right turn in their guidance and there are many examples of its use. Experiences with the two-stage right turn have been quite low key. It appears that no one has felt the need to research their use. Rather, careful thought as to their application appears to have been the approach. The main issues are:

- The ability to see the traffic signals that apply to cyclists in the waiting area – usually this requires far-sided or low-level secondary signals, in which case it needs to be obvious which ones are relevant.
- Placement of the waiting area such that there is no risk of vehicles turning left or right into the exit encroaching upon it.
- Ensuring that the delay to cyclists making the manoeuvre in two stages is minimal primarily by ensuring a short cycle time and also arranging for the next signal stage to be the one catering for the second stage of the manoeuvre.
- The legality of road marking and signs and generally what should be used to encourage use of the facility
- That the problem with left turning vehicles and ahead cyclists is not exacerbated

7 Summary

A number of alternative ways of dealing with right turning cyclists are either in existence or being suggested (for UK use). These facilities are summarised in Appendix A and, apart from the two-stage right turn, are either already in use or being trialled in other work streams of this project.

The two-stage right turn may be a useful addition to the options of dealing with right turning cyclists. However, there needs to be more confidence with how and when it can be applied. A number of issues to do with turning right at signal controlled junctions have been identified for further consideration, some of which would require off street trial. The issues have been summarised in Appendix B.

8 Recommendation

TfL are proposing a 'standardised junction' layout to include the low-level cycle signals and cycle reservoir and the two-stage right turn. It is recommended that trials of the two-stage right turn are arranged as part of the investigation of the standardised junction in order to clarify and assess the issues presented and to produce guidance on how the facility is used and what on-street trialling may be required.

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Appendix A Advantages and disadvantages of right-turning methods

The following table describes the facility being considered, followed by the advantages and disadvantages as compared to making the right turn movement in the normal way without any special facilities for cyclists. The current status of the facility is also given.

Right turn method	Advantages	Disadvantages	Current status
Advance Stop line (used extensively already)	Established and proven as enabling the right turn to be made more safely.	Not effective when the approach is on green or about to turn green. Advantages are eroded by the lack of compliance by motor vehicles	In widespread use throughout the UK.
'Jug handle' turn (used already – suitable for T-junctions but not cross roads)	Cyclist not required to cross lanes to turn right. Wait in safe area away from traffic. Suitable for most signal controlled T junctions where there is enough room to provide the facility.	May cause delay and diversion to cyclists. Not feasible where there is insufficient room.	In use in the UK
'Advance Reservoir' ⁴ storage area for right turners (one example in existence – see Figure 10)	Segregates cyclists and other traffic waiting to turn right during opposed stage.	Cyclists are still required to cross lanes on the approach and get to the waiting area.	One known example in London (see Figure 10)
ASLs plus early start for cyclists (being considered as part of WS4)	Gets cyclists established and in view ahead of traffic. May assist with traffic capacity by getting cyclists out of the way first allowing motor vehicles to then move more freely.	Not effective when the approach is green for motorised traffic, or about to turn green. May encourage cyclists to attempt to complete their turn before other traffic starts – misjudgements may	Not currently in use in the UK. Subject of a trial in WS4 of this project. Trial scheduled for June 2013.

⁴ Unofficial name used in this report for the waiting area for cyclists which is ahead (downstream) of where right turn motor vehicles wait.

		occur.	
Dutch style signal controlled junction (being considered as part of WS5)	Full segregation achieved.	Signals need to accommodate cyclists. Possible interaction with pedestrians. Significant temporal and spatial deviation. Significant additional land take required.	Not in use in the UK. Being considered as part of WS5 of this project. Literature review currently underway (Millard and Knight, 2013). Track trial being considered.
Dutch style 'scramble' junction (including potentially more formal diagonal crossing)	Full segregation achieved. May reduce lost time by reducing the number of intergreens under some circumstances	As for Dutch style junction, plus: Conflict between cyclists Intergreens may need to be long The junction may also require a separate all-red pedestrian phase, further reducing the proportion of green to motorised traffic.	Not in use in the UK. Being considered as part of WS5 of this project. Literature review currently underway (Millard and Knight, 2013).
Dutch style roundabout (being considered as part of WS2)	Greater separation achieved and reduced delay because of cyclist priority over turning vehicles .	Adds potential conflicts on the exits between cyclists and motor vehicles Many cyclists will use the roundabout itself to avoid potential conflicts with vehicles turning across the orbital cycle lane. Considerable land take required. Implications for traffic capacity	Not in use in the UK. Being considered as part of WS2 of this project. Track trials currently being undertaken
Formal two-stage right turn (being considered	Cyclists can avoid moving across lanes on the approach.	May encourage cyclists on the adjacent approach (Figure 1) to cross	Not in use in the UK. Track trials required to study a

<p>here and as part of WS6)</p>	<p>Little change to the infrastructure needed.</p>	<p>the pedestrian studs to move into the waiting area which means that they will conflict with pedestrians and take up space meant for the two stage turning cyclists.</p> <p>May place cyclists in a situation similar to the left turn issue whereby cyclists are overtaking on the nearside, unseen, particularly by lorries, and coming into conflict.</p> <p>Will delay cyclists in comparison with making the manoeuvre in the traditional way.</p>	<p>number of potential issues</p>
<p>Informal two-stage right turn</p>	<p>As for the formal two-stage right turn plus:</p> <p>No change to the infrastructure required.</p> <p>Cyclists may be cautious in making the manoeuvre because they are doing something unusual or unexpected.</p> <p>No waiting area to encourage cyclists on the adjacent approach to cross the pedestrian studs.</p>	<p>As for the formal two stage right turn plus:</p> <p>Cyclists may wait in an inconvenient or unsafe location.</p> <p>Cyclists may attempt the manoeuvre when/where inappropriate.</p> <p>Motorists may be unaware of what the cyclist is doing.</p>	<p>Occurs at junctions in the UK. Track trials required to consider the issues and to compare with formal operation of the two-stage right turn.</p>

Appendix B Table summary of issues for two-stage right turns

Issue	Implications	Influence on trial	Influence on real world	Action
Not in current TSRGD.	Possibly requires departure hence approval from DfT.	Trials should include a test of designs that are consistent with current TSRG, as well as non-standard ones, to see if there is a need for non-standard lining or signs.	Trials need to show the solution is effective enough to be included in TSRGD. <i>Should be OK within current TSRG as long as solid white lines or non-standard signs are not used.</i>	Keep in mind as necessary throughout trial. The need for DfT approval will depend on the road markings used. Consult with DfT
Ability of cyclist to correctly interpret signalling, being downstream of the stop line (hence not able to see the primary signals).	It may not be clear to the cyclist which signal applies unless cyclist-specific aspects are used.	Junction layout needs to be such that this is considered and participants asked about their understanding of the signals. Consider the implications of lamp failure.	Far side secondaries may be necessary, or nearside low level cycle signals and it must be obvious to cyclists which ones apply when in the waiting area. May require additional repeaters to overcome issues with lamp failure.	Design trial such that this issue is included and considered, including potential use of cycling specific Low Level Signals. Visit a number of real potential sites and consider the issue.
Potential exacerbation of the problem of left turning HGVs not seeing cyclists going straight ahead, because the cyclist who is preparing to use the waiting area is making an unpredictable manoeuvre. Possibly doubles the opportunity for this conflict to arise as it may happen on both stages of the turn.	Cyclist slows and deviates from the ahead path getting in the way of the left turning traffic. Possibly encourages cyclists to make a hazardous manoeuvre: turning right normally (i.e. a single stage) may in fact be safer under some circumstances. Likely to be very location specific.	Consider either a layout that would test the issue or consider how the issue can be avoided (e.g. an island separating lanes into and out of junction).	Likely to limit the applicability, for example to approaches with separator islands.	Consider whether to test for this issue during the trial or consider layouts that avoid this issue. It depends on what the real issue is.

Visibility of cyclist to HGVs once in the waiting area.	Cyclists needs to be visible to HGVs once in the waiting area.	Include HGVs in the trial and test visibility (or find previous research).	The waiting area and the route to the waiting area will need to be located such that visibility is not an issue.	Calculate or measure visibility distances from example HGVs. Measurements may already exist.
Signal staging issue – wide road (e.g. 25m).	It may take a cyclist more than the minimum green to complete the second stage of their manoeuvre. This may reduce capacity by encouraging a manoeuvre that hitherto might not have occurred. However, this needs to be compared with time taken to turn right from ASL in conventional fashion- this is likely to involve a greater distance.	Test how long it takes for a slow cyclist to travel 25m to confirm that more than the normal minimum green may be required at some junctions. Ensure trial participants ride at a variety of speeds.	May require cyclist detection so the additional time only happens when necessary.	Check whether cyclist will need additional time and if they do how to mitigate that.
Position of waiting area relative to the swept path of vehicles turning left or right.	A large vehicle may 'swing' out to the offside of the exit as they turn left or right into the exit. A cyclist waiting in the waiting area to complete their manoeuvre may be in the way, and may not have been seen.	Not an issue for the trial as swept paths can be worked out for each junction and use of the waiting area would not be practicable in a situation where the swept path potentially overruns it.	Limits the applicability to junctions with sufficient room to place the waiting area out of harm's way.	Advice about minimum dimensions to be included in future guidance.

<p>Placement of waiting area where there are multiple lanes on the second stage approach.</p>	<p>Placement of the waiting area will be important in these situations. It cannot be placed to the offside of a lane having an ahead movement. At the same time it may not be ideal if the lane it was ahead of was left only. However, the situation is comparable to a full width ASL- cyclists will be clearly visible ahead of traffic and positioned for prompt get away.</p>	<p>Consider all the likely issues with placement and then further consider whether any unresolved issues may be resolved by trials. May need to consider the desirability of nearside placement of the waiting area in the trial.</p>	<p>Placement of the waiting area will need consideration at some junctions, possibly requiring a change in lane usage.</p>	<p>Sketch combinations of lane configuration likely to be a problem together with potential issues of that particular layout and consider whether any issue can be resolve by trial.</p>
<p>Combination of waiting area markings with other cycling facilities such as cycle lanes or tracks.</p>	<p>The CROW manual gives some example layouts having cycle lanes and tracks. Likely to have implications only upon the placement of the waiting area.</p>	<p>Not an issue for the trial.</p>	<p>May limit the applicability in some circumstances.</p>	<p>Consider all the circumstances and the advice needed to cover this.</p>
<p>Traffic flow conditions.</p>	<p>At what level of traffic flow is the feature likely to be most useful. This could be in terms of safety, or in terms of when cyclists are likely to be willing to divert to make the turn in two stages.</p>	<p>Arrange the trial to consider different traffic flows and find out from participants their willingness to make the right turn in two stages or as normal.</p>	<p>At junctions where there isn't a clear cut option (i.e. at the margins) some cyclists will make the turn in the normal way whilst others will make it in two stages. The implications of this will need to be thought through for each junction.</p>	<p>Use a range of traffic flows in the trial Consider the implications of cyclists making their turns in both the normal and two-stage ways at the same time.</p>

Traffic speeds	The speed differential is likely to be the main reason why cyclists feel moving to the offside is hazardous, and also the main reason why it is unsafe in practice. At what speeds do cyclists start to prefer the two-stage option.	It is not likely that different speeds can be considered in the trial for safety reasons. The opinion of participants and possibly other experienced cyclists could be sought.	The two-stage right turn may be more desirable when speeds are higher as cyclists may be more inclined to put their safety before time saving as speeds go up.	Seek the opinion of suitable cyclists.
Number of lanes on the first approach	As the number of lanes on the first approach increases so does the hazard of moving to the offside. (Flows and speeds are relevant here too.) Sometimes having a dedicated right turn lane may make turning right normally easier. But then finding a gap in two or more lanes simultaneously may be hard particularly when traffic flows and/or speeds are high.	We need to consider whether we want to encourage use of the two stage turn when on offer, and the circumstances as to when it is likely to be made use of. If we are to encourage it, we may need to consider this as a trial option. On the other hand, asking participants/other cyclists about this may provide an answer.	The two stage turn is likely to be more desirable as the number of lanes increases (occasionally even in London there may be up to 4, e.g. A30/The Parkway).	Ask participants/other cyclists their views.

Cyclist still moving towards the waiting area when the traffic on the approach starts up	At large junctions the cyclist may cross the stop line at the end of green or during leaving amber and still be moving towards the waiting area as the signals change in favour of the traffic on that approach. Could happen at small junctions with slow cyclists or red-running.	Watch for this specifically during the trial.	May make use of the two-stage turn problematic.	Consider the issue in light of the trial results.
Suitability for high cycle flows	If the demand for the right turn is high, the waiting area may not be big enough to hold all cyclists. Cyclist not able to get into the waiting area may be left in a very vulnerable location. This has implications for capacity if the cyclists would have otherwise turned right normally.	It will be necessary to determine the cycle flows and other parameters under which this could become a problem. This could be modelled.	The problem is one of where the overspill is located and whether cyclists are left in a vulnerable location as a result.	Consider the implications of this carefully and what advice to give for high flow sites. Visit sites to consider implications. Ask cyclists what they would do if presented with this situation.

Use of cycle signals	The facility may be made more attractive if there are cycle-specific signals that allow cyclists to start before the other traffic. It may also be possible to locate a low-level signal next to the waiting area to indicate precisely when it is safe for the cyclist to start. Could be used with cycle detection and help with the minimum green issue.	Could add signals to the trial site and ask cyclists' views as to whether they would be more inclined to use the facility with the additional signals.	Could make the facility more attractive and with decent detection provide cyclists with an advantage but only when any were there to use it.	Consider the feature for the trial and whether it is desirable. Ask participants if it helps make the facility more desirable.
Potential to introduce additional delay – who are we designing for?	Need to understand what cyclists will find acceptable in terms of the trade-off between additional delay and additional comfort, and whether the improvement to the RT encourages cyclists to cycle or adopt shorter route hitherto avoided because of the RT issue	An understanding needs to be sought from participants as to how much safer they feel with the 2-stage turn – do they avoid them now; does it influence their route? Even their mode choice?	Will limit applicability, but knowledge about the psychology needed to understand where the 2-stage turn can be used	Ensure questions asked to gain understanding about what cyclists are prepared to trade in terms of delay and comfort and perceived safety
Where cyclists are excluded from banned movements	An example is at a crossroads where there is a contraflow cycle lane on one arm. Without any cars making the same manoeuvre, cyclists may face additional issues.	Is a two-stage turn possible in these circumstances?	May limit applicability, but depends on how many instances there are of this situation	Probably not worth special consideration at this stage.