Appendix O
Preliminary Design Guidance Booklet

Preliminary Design Guidance Booklet
for BusConnects Core Bus Corridors

NTA
Údarás Náisiúnta Iompair
National Transport Authority

Project Ireland 2040
Building Ireland's Future

BUS CONNECTS
TRANSFORMING CITY BUS SERVICES

Contents

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for BusConnects Core Bus Corridors

1. Background

The aim of the BusConnects programme is to transform Dublin's bus system, with the Core Bus Corridor (CBC) project aiming to provide 230kms of dedicated bus lanes and 200km of cycle tracks and lanes on sixteen of the busiest bus corridors in and out of the city centre. This project is fundamental to addressing the congestion issues in the Dublin region with the population due to grow by 25% by 2040, bringing it to almost 1.55m.

The purpose of this design booklet is to provide guidance for the various design teams involved in the CBC Project, to ensure a consistent design approach across the project. To this end, a number of workshops have been held between the various CBC project Engineering Designers (EDs) to enable agreement on standard design approaches and details.

2. CBC Design Guidelines Objectives

The main objectives of the CBC project are to:

- Facilitate a modal shift from private vehicle use to public transport use and cycling;
- Improve public transport accessibility across the city;
- Deliver a more attractive, reliable and convenient bus system for Dublin; and
- Deliver safe, segregated cycling facilities along each corridor.

The project proposes to meet these objectives through the delivery of 230km of dedicated bus lanes and 200km of cycle tracks and lanes on sixteen radial corridors in and out of the city centre. The CBC project will aim to implement an optimum project cross-section to include footpaths, cycle tracks and bus lanes on both sides of the road throughout the CBC network where feasible (see Figure 1). In some instances, this will necessitate a Compulsory Purchase Order (CPO) process to include portions of private land to achieve the project objectives.

This design booklet will focus on the engineering geometry and CBC operation. It is acknowledged, however, that the design evolution will result in the rationalisation of junction and link layouts, presenting opportunities to increase the public realm footprint and improve the placemaking offering of the CBC network.

It is also recognised that the CBC project is being planned and designed within the context of an existing city, with known constraints. This document provides guidance, however, a more flexible approach to the design of CBCs, utilising engineering judgement, may be necessary in some locations due to these constraints.

In the approach to cycle infrastructure design, the BusConnects project not only aims to cater for existing cyclists, but more particularly for younger and older cyclists, mobility impaired cyclists and new cyclists as well as those who currently do not cycle but would be prepared to, subject to improved safety and greater cycle infrastructure provision.

3. Relevant Standards and Guidance

The purpose of this design booklet is to complement existing guidance documents relating to the design of urban streets, bus facilities, cycle facilities and public realm. A non-exhaustive list of these guidelines is outlined below:

- The Design Manual for Urban Roads and Streets (DMURS);
- The National Cycle Manual (NCM);
- TII Publications;
- The Traffic Signs Manual (TSM);
- Guidance on the use of Tactile Paving;
- Building for Everyone: A Universal Design Approach, and
- Greater Dublin Strategic Drainage Study (GDSDS).

This is a design booklet to assist the design of typical corridor scenarios and layouts. Whilst all corridors will have individual challenges, this document does not purport to address all scenarios. Any constraints in cross section will require a case-by-case approach to design.

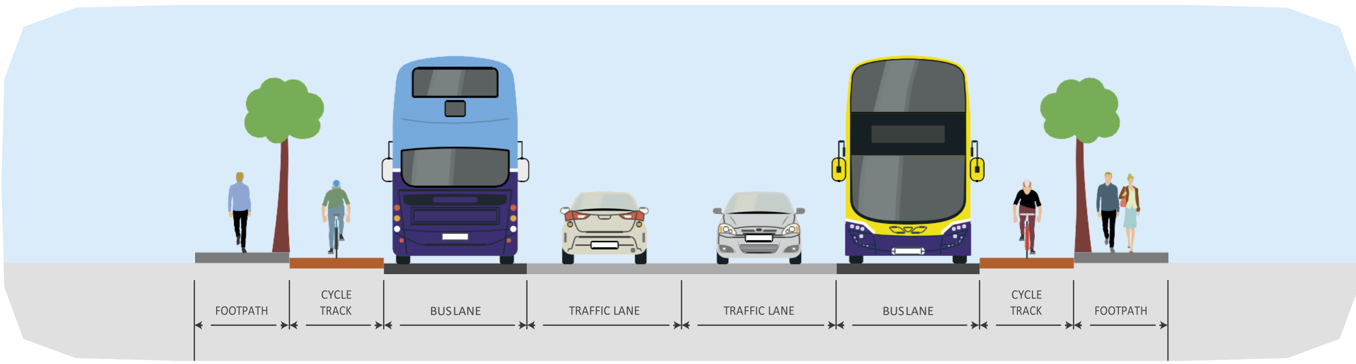


Figure 1: Optimum CBC Cross-Section

4 Project Terminology

The following terminology was agreed to form a standard glossary of phrases and titles for the CBC project.

4.1 Signal Controlled Bus Priority

Signal Controlled Bus Priority uses traffic signals to enable buses to get priority ahead of other traffic on single lane road sections, but it is only effective for short distances. This typically arises where the bus lane cannot continue due to obstructions on the roadway. An example might be where a road has pinch-points where it narrows due to existing buildings or structures that cannot be demolished to widen the road to make space for a bus lane. It works through the use of traffic signal controls (typically at junctions) where the bus lane and general traffic lane must merge ahead and share the road space for a short distance until the bus lane recommences downstream. The general traffic will be stopped at the signal to allow the bus pass through the narrow section first and when the bus has passed the general traffic will then be allowed through the lights.

4.2 Bus Gate

A Bus Gate is a sign-posted short length of stand-alone bus lane. This short length of road is restricted exclusively to buses, taxis and cyclists plus emergency vehicles. It facilitates bus priority by removing general through traffic along the overall road where the bus gate is located. General traffic will be directed by signage to divert away to other roads before they arrive at the Bus Gate.

4.3 Cycle Lane

A cycle lane is a lane on the carriageway that is reserved either exclusively or primarily for cycling and is separated from general traffic or bus lanes by road markings.

4.4 Cycle Track

A cycle track is a separate section of the road dedicated for cycling only. This space will generally be isolated from other vehicular traffic by a physical kerb.

4.5 Quiet Street Treatment

Where CBC roadway widths cannot facilitate cyclists without significant impact on bus priority, alternative cycle routes are explored for short distances away from the CBC bus route. Such offline options may include directing cyclists along streets with minimal general traffic other than car users who live on the street. They are called Quiet Streets due to the low amount of general traffic and are deemed suitable for cyclists sharing the roadway with the general traffic without the need to construct segregated cycle tracks or painted cycle lanes. The Quiet Street Treatment would involve appropriate advisory signage for both the general road users and cyclists.

Figure 2: Signal Controlled Bus Priority

Figure 3: Bus Gate

Figure 4: Cycle Lane

Figure 5: Cycle Track

5 Cross Sections and Geometry

The following sections identify the agreed optimum lane widths for the CBC cross section.

5.1 Traffic Lane Width

Traffic lane widths will follow the guidance outlined in DMURS, with the preferred width of traffic lanes on CBCs being:

- **3.0m** in areas with a posted speed limit ≤ 60 km/h; and
- **3.25m** in areas with a posted speed limit > 60 km/h.

Traffic lane widths of 2.75m are permissible but not desirable and should only be permitted on straight road sections with very low HGV percentage and where all desirable minimum widths for footpaths, cycle tracks, parking, bus lanes are not achievable without impacting on third-party lands.

Bus lanes should not be less than **3m** in width. Existing and proposed drainage infrastructure should be located outside of the bus lanes to avoid damage from the wheel tracks of buses. The provision of side-entry drainage systems is preferable along the edge of 3m wide bus lanes.

Some areas require particular attention in determining the appropriate lane width, namely:

- **Turning Pockets:** DMURS does not currently define the appropriate widths for turning lanes at junctions, whether they can be narrower or not, and if so, what an appropriate minimum width is. These are to be assessed on a case-by-case basis, led by appropriate swept path requirements.
- **Corners and Bends:** All lanes generally need to be locally widened on bends, and this should be designed based on swept path requirements. It is accepted that urban streets and junctions cannot be designed explicitly for larger vehicles and that some larger vehicles will need to encroach on the adjacent lane to make turns at some junctions.
- **Larger Vehicles:** DMURS identifies the desirable width for lanes on streets frequently used by larger vehicles (e.g. HGVs) as 3.25m to 3.5m. Swept paths of larger vehicles such as buses and HGVs may require larger lane widths at local bends on links.

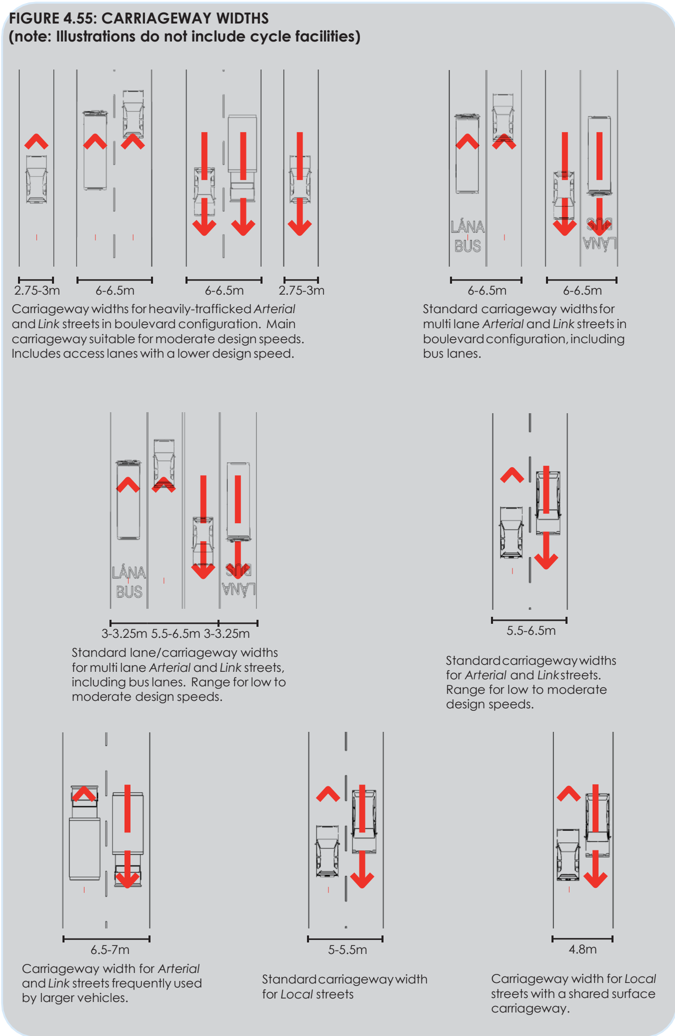


Figure 6: Extract from revised DMURS illustrating permitted lane widths

5.2 Headroom

5.2.1 Cyclists

The National Cycle Manual and the Traffic Signs Manual note that the desirable minimum vertical clearance to be provided to cycle tracks should be **2.5m**.

5.2.2 Vehicles

Bus headroom at structures should be provided in line with Table 5.1 of DN-GEO-03036 as replicated below.

Type of Structure	New Construction Headroom (m)	Maintained Headroom (m)
Overbridges	5.30	5.03
Footbridges and Sign/Signal Gantries	5.70	5.41
Free Standing Temporary Structures	N/A	5.41

Table 1: Replication of Table 5.1 from DN-GEO-03036 (Standard Headroom at Structures)

5 Cross Sections and Geometry

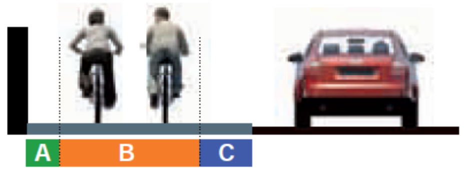
5.3 Cycle Track Width

The desirable minimum width for a single-direction, with-flow, raised-adjacent cycle track is 2.0m. This arrangement allows for two-abreast cycling. Based on the National Cycle Manual (NCM) Width Calculator (see Figure 7); this allows for overtaking within the cycle track. The minimum width is **1.5m**, which, based on the NCM Width Calculator, allows for single file cycling. Localised narrowing of the cycle track below 1.5m may be necessary over very short distances to cater for local constraints (e.g. mature trees).

It may be the case that some CBC routes consist of long sections of proposed cycle tracks that need to fit in and around existing constraints such as trees, or other physical constraints which may reduce the effective width of the cycle track below 2.0m. Reducing the width of the cycle track locally will have implications on the Level of Service achievable and will restrict the track to a single file regime. Long stretches of cycle track of less than 2.0m in width are to be avoided if possible. Where such circumstances are unavoidable, designers should consider the provision of additional complementary cycle facilities on an alternative route.

Diversions of proposed cycle facilities on to quieter parallel routes, to avoid localised narrowing of cycle tracks on the main CBC route, is to be considered in the context of the CBC route being listed as a primary cycle route as per the Greater Dublin Area Cycle Network Plan. These diversions, however, may also be considered where appropriate cycle facilities cannot be provided along the CBC route without significant impact. In such cases, turning movements and diversions for bicycles onto and off of the diversion route should have minimal delay for cyclists.

The desirable minimum width for a two-way cycle track is **3.25m**. In addition to this, a desirable minimum buffer of **0.5m,** with an absolute minimum of **0.3m,** should be provided between the two-way cycle track and the carriageway. Using the NCM width calculator, reduction of these desirable minimum widths can be considered on a case-by-case basis, with due cognisance of the volume of cyclists anticipated to use the route as well as the level of service required. The preferred arrangement for a two-way cycle track is for cyclists to 'cycle on the left'. This is contrary to the current guidance provided in the National Cycle Manual, which recommends that the with-flow cyclist be placed closest to traffic to reduce relative speeds (i.e. a 'cycle on the right' regime). Notwithstanding this, a 'cycle on the left' regime is considered best practice in terms of legibility and has been successfully implemented on a number of projects in Ireland to date (e.g. Grand Canal Cycleway, Royal Canal Cycleway and S2S at Clontarf). In certain circumstances, it may be preferable to switch to a 'cycle on the right' regime approaching or at interchanges, and/or junctions to accommodate transitions from a two-way cycling regime to a single direction cycling regime.



A Inside Edge		B Cycling Regime		C Outside Edge		D Additional Features	
Kerb	0.25m	Single File	0.75m	30kph, 3.0m wide lane	0.50m	Uphill	0.25m
						Sharp bends	0.25m
Channel Gully	0.25m	Single File + Overtaking, Partially using next lane	1.25m	50kph, 3.0m wide lane	0.75m	Cyclist stacking, Stopping and starting	0.50m
Wall, Fence or Crash Barrier	0.65m	Basic Two-Way	1.75m	Raised kerb, dropped Kerb or physical barrier	0.50m	Around primary schools, Interchanges, or for larger tourist bikes	0.25m
Poles or Bollards	0.50m	Single File + Overtaking, Partially using next lane	2.00m	Kerb to vegetation etc. (ie. cycleway)	0.25m	Taxi ranks, loading, line of parked cars	1.00m (min 0.8m)
		2 Abreast + overtaking (tracks and cycleways)	2.50m			Turning pocket cyclists	0.50m

Example:
To determine required cycle width, select the appropriate Inside Edge, Cycling Regime, Outside Edge and any Additional Features

Kerb	0.25m	Single File + Overtaking, Partially using next lane	1.25m	Raised kerb, dropped Kerb or physical barrier	0.50m	

0.25m
+ 1.25m
+ 0.50m

Required width = 2.00m

Figure 7: Extract from the National Cycle Manual illustrating the Width Calculator

5 Cross Sections and Geometry

5.4 Cycle Facility Segregation (Horizontal and Vertical)

One of the core objectives of the CBC project is to provide segregated cycling facilities along the routes. Physical segregation ensures that cyclists are protected from motorised traffic as well as independent of vehicular congestion, thus improving cyclist safety and reliability of journey times for cyclists. Physical segregation can be provided in the form of vertical segregation, (e.g. raised kerbs), horizontal segregation, (e.g. parking/verge protected cycle tracks), or both.

The 'preferred cross-section template' developed for the CBC project consists of protected cycle tracks, providing vertical segregation from the carriageway to the cycle track and vertical segregation from the cycle track to the footway.

In addition, a full height 120mm upstand kerb between the carriageway and the cycle track should be provided (120mm kerb height on the bus lane side and 60mm minimum kerb height on the cycle track side). This will provide increased protection of the cycle track from errant vehicles on the traffic side. 45-degree chamfer kerbs should be provided between the cycle track and the road to deflect an errant bicycle wheel.

In a retro-fit situation where the plan layout places the cycle track within reallocated space from the existing road carriageway, it may be desirable for the cycle track to sit on the existing road surface (see Figure 9). In this case, the upstand segregation kerb may be 120mm high on both the bus lane side and the cycle track side.

Suitable adjustments will be required for the drainage system such as provision of side-entry gullies along the bus lane kerb, or gaps in those kerbs for drainage to reach gullies at the rear of the cycle tracks where applicable (See Figure 9). Cross-falls on the cycle tracks may be to the left or to the right as may best fit when retro-fitting along an existing street with reference to the constraints of the existing footpath levels.

A 60mm high minimum vertical kerb is required on the footpath side of the cycle track to ensure that the kerb is properly detectable by visually impaired pedestrians using the footpath.

Cyclist segregation at junctions is discussed further in Sections 7 and 8 of this document.

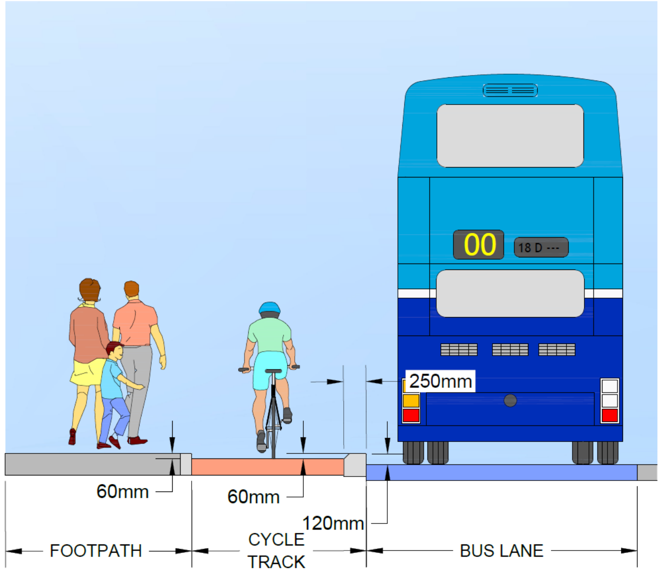


Figure 8: Preferred CBC Cycle facility segregation (example shows a two-way cycle track)

5.5 Cycle Track Material

As illustrated in Figure 8, the use of machine laid asphalt for the cycle track has proven to be an effective way of providing a high level of service with a safe, smooth and continuous surface. This, however, offers very little contrast to the adjacent carriageway, and depends on the type of edge kerb and the presence of road markings to offer a visual differentiation between the carriageway and the cycle track. Consideration should be given to including an additional colour contrast to the cycle track in the form of an alternative coloured asphalt (e.g. red, buff, etc) or adding coloured chips to the asphalt surface during installation (e.g. red chip). Designers should refer to Section 5.6 of the NCM for further guidance on appropriate cycle track materials.

At junctions, the chosen cycle track material should be continued (as a surface course layer) through the junction for consistency. Alternatively, coloured epoxy resin (cold-applied anti-skid layer) is a robust alternative measure in terms of longevity and maintenance for making cycle lanes more conspicuous at junctions.

Figure 9: Retro-fit kerb solution (example shown is Benildus Avenue)

5 Cross Sections and Geometry

5.6 Pedestrian Crossing Distances

Where possible, DMURS recommends that designers provide pedestrian crossings that allow pedestrians to cross the street in a single, direct movement. To facilitate road users who cannot cross in a reasonable time, the desirable maximum crossing length without providing a refuge island is 19m. This is applicable at stand-alone pedestrian crossings as well as at junctions. It may be necessary to provide crossing lengths greater than 19m in village settings where large pedestrian volumes are expected and where space for central medians cannot be provided.

Stand-alone pedestrian crossings in mid-block locations between junctions should be shorter where possible with fewer turning lanes provided, which should avoid the need for a refuge island in the middle of the crossing. At major junctions in suburban areas it is likely that staged crossings will be necessary, and pedestrian delay can be minimised by the provision of overlapping stages so that the crossing can be completed as quickly as possible.

Where possible, pedestrian crossings should be provided on all arms of a junction, to provide maximum connectivity and pedestrian permeability. In exceptional circumstances, there may be justification for not providing a crossing on all arms, e.g. junction phasing for optimum operation, desire line provision, etc.

5.7 Refuge Islands

Pedestrian crossings should generally operate as “Toucan” crossings for use by cyclists as well, unless there is a separate cyclist crossing in parallel.

Where a refuge island is provided, straight crossings are desirable and the refuge island should be 4m wide or more. At a staggered crossing, islands of less than 4m in width may be provided, and these should have a minimum effective width of 2m between obstacles such as signal poles.

Where space allows, crossing lengths can be minimised by accommodating a suitable landing area for pedestrians between the road carriageway and cycle track, with the cycle track crossing controlled by mini-zebra markings. This reduced pedestrian crossing distance will have the added benefit of improving overall junction performance due to reduced intergreen times.

Tactile paving is to be designed in accordance with the Guidance on the use of Tactile Paving Surfaces, by the Department of Environment, Transport and the Regions (DETR UK).

5.8 Footpath widths

2.0m is the desirable minimum width for a pedestrian footpath. This width should be increased in areas catering for significant pedestrian volumes where space permits. DMURS defines the absolute minimum footway width for road sections as **1.8m** based on the width required for two wheelchairs to pass each other (see Figure 10).

At specific pinch points, Building for Everyone: A Universal Design Approach, defines acceptable minimum footpath widths as being **1.2m** wide **over a 2m length** of path (see Figure 11).

Figure 10: Extract from DMURS indicating appropriate footpath widths

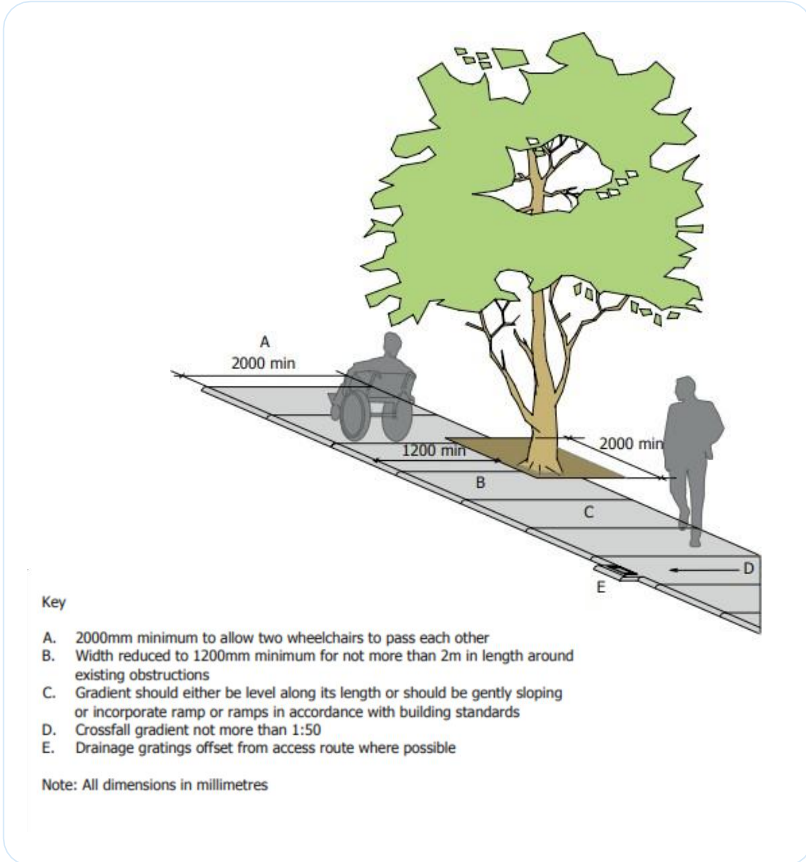


Figure 11: Figure 1.6 from Building for Everyone: A Universal Design Approach - Booklet 1, indicating absolute minimum footpath widths allowable over a short section

6 Parking / Loading Bay Widths

6.1 Parallel Parking

The desirable minimum width of parallel parking spaces is to be **2.1m**. Where wheelchair accessible parking bays are proposed, these should be a minimum of **3.6m** in width and **7m** in length with the appropriate dropped kerb and tactile paving in accordance with the requirements of the Building Regulations TGD Part M. Where parallel parking spaces are provided alongside a cycle track, a buffer must be provided to allow space for opening car doors. This buffer should be a minimum of **0.75m** in width. (The buffer strip may encroach into the cycle track with localised narrowing where space is confined subject to a minimum 1.5m clear width).

Designers should refer to the Traffic Signs Manual in specifying the marking of parallel parking bays. Three options for parallel parking bay designation are specified in the TSM (RRM 011, RRM 012 and RRM 016), and designers should designate parking bays in line with the requirements of the applicable local authority.

Designers should consider the potential impact on visibility splays when considering the location of proposed parking or loading spaces, in particular when parking spaces are located in proximity to side road junctions or accesses. Designers should refer to DMURS for further details of the required visibility splays at junctions.

6.2 Parking Protected Cycle Tracks

Where parking is provided along the CBC, the preferred location for raised adjacent cycle tracks is between the pedestrian footpath and any proposed parking spaces to provide additional protection for cyclists (see Figure 12). As outlined in Section 6.1 above, a buffer of a minimum width of **0.75m** should be provided between parking bays andthe cycle track. The cycle track should be deflected behind the parking bays at an angle of 3:1 as indicated in Figure 12.

In locations with short, isolated pockets of parallel parking including isolated disabled parking spaces, it may be better for the cycle route alignment if the parking spaces were located on the footpath side so as to avoid too many horizontal deflections for cyclists.

Where electric vehicle charging points are to be provided in combination with parking protected cycle tracks, the charging kiosk should be located within the buffer, to avoid the need for charging cables to extend across the cycle track.

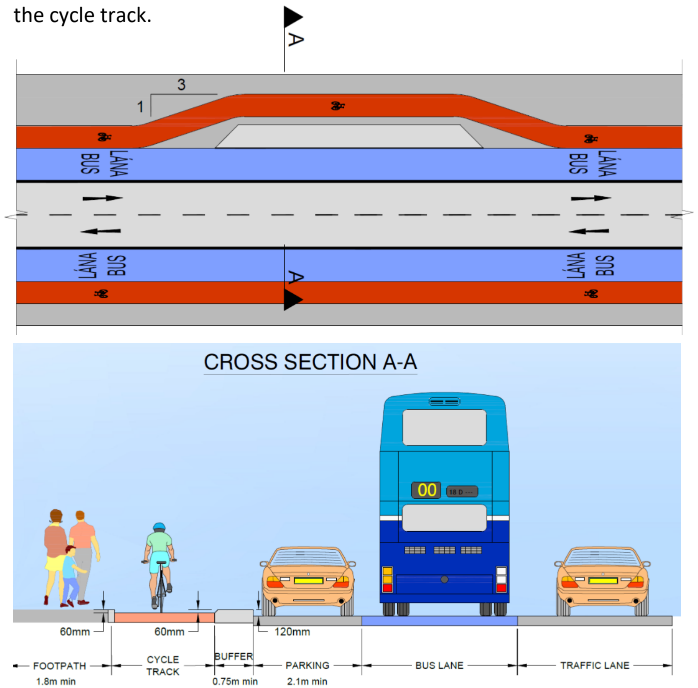


Figure 12: Parking protected cycle track

6.3 Loading Bays

Dimensions for loading bays should be the same as for parking bays with a similar buffer zone. It is important that the proposed infrastructure doesn't inhibit loading bay activities, therefore chamfered kerbs with a maximum height of 60mm should be used which will facilitate trollies, pallet trucks, etc. Figure 13a shows a proposed cross section detail for loading bay kerbs.

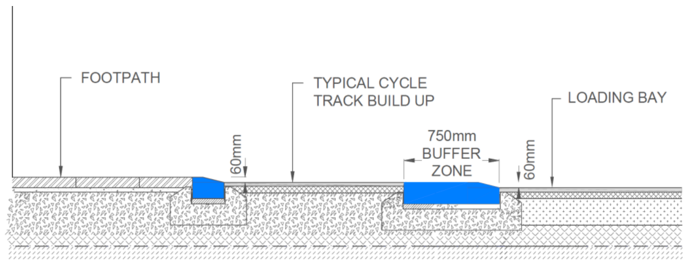


Figure 13a: Proposed Loading Bay Cross Section with Chamfered Kerbs

In confined locations it may be appropriate to provide a part-time loading bay to operate at off-peak periods (such as 10am to 12pm) and it may be necessary for the loading bay to partly straddle the footpath and cycle tracks so long as a clear passage is provided on both sides. Figure 13b shows a proposed cross section detail for a loading bay in a confined location.

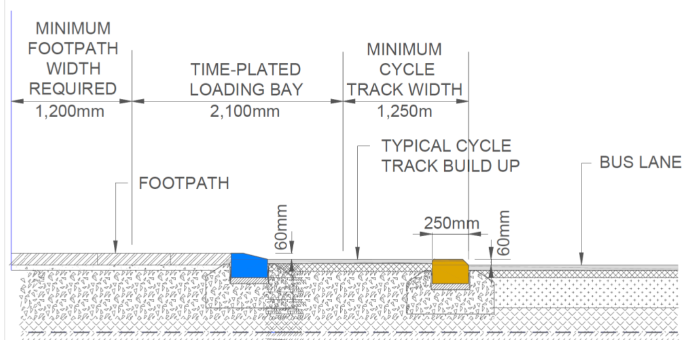


Figure 13b: Loading Bay in confined location that straddles both cycle track and footpath

6 Parking / Loading Bay Widths

Figure 14 shows an image of a loading bay on Main Street, Bray, which is time-plated and which straddles both the footpath and the carriageway during the hours of operation, and avoids blocking both the footpath and carriageway.

Figure 14: Loading bay treatment detail at Main Street, Bray

In urban centres, which have relocated the cycle facilities to parallel or off-road routes (Templeogue), consideration can be given to the treatment and material palette used at loading bays, with the possibility of providing for enhanced public realm, with the loading bay acting as an effective footpath outside its hours of operation. Figure 15 provides an example of such treatment in Camden High Street, London.

Figure 15: Loading bay treatment detail at Camden High Street, London

7 Signalised Junctions

The purpose of traffic signals is to regulate movements safely with allocation of priority in line with transportation policy. On the Core Bus Corridors, that policy is to ensure appropriate capacity and reliability for the bus services so as to maximise the overall throughput of people in an efficient manner. The junctions will provide safe and convenient crossing facilities for pedestrians with as little delay as possible. Particular provisions are required for the protection of cyclists from turning traffic, as well as ensuring suitable capacity for a rapidly increasing demand by this mode.

The design of signalised junctions, or series of junctions, as part of the Core Bus Corridor Project will be approached on a case-by-case basis. The following presents an approach to the design of signalised junctions which outlines a hierarchy of junction layout options, as well as discussing operational issues such as staging, to be considered by designers.

7.1 Protected Junction for Cyclists

Due to the inherently complex nature of mixed mode movements at junctions, the provision for cyclists at junctions is a critical factor in managing conflict and providing safe junctions for all road users. The primary conflict for cyclists is with left-turning traffic. On the basis of international best practice, the preferred layout for signalised junctions within the CBC project is the “Protected junction”, which provides physical kerb build-outs to protect cyclists through the junction. This is a new innovation in addition to the range of junction options in the *National Cycle Manual.* It is most applicable at larger junctions where there are numerous traffic lanes and extended crossing widths.

The key design features and considerations relating to this junction type are listed below:

- The traffic signal arrangement removes any uncontrolled conflict between pedestrians and cyclists.
- Kerbed corner islands should be provided to force turning vehicles into a wide turn and remove the risk of vehicles cutting into the cycle route at the junction corner which has been the cause of serious accidents in various places. These raised islands create a protected ring for cyclists navigating the junction, improving safety for right turning cyclists. This is the most significant new safety feature that is being introduced as part of the BusConnects programme.
- Cycle tracks that are protected behind parking or loading bays, should return to run along the edge of carriageway approaching a junction (removal of localised parking / loading immediately upstream of a junction will be necessary to achieve sufficient visibility).
- The cycle track should be ramped down to carriageway level on approach to the junction and proceed to a forward stop line ahead of the vehicular stop line, placing them within view of traffic waiting at the junction. The desirable maximum gradient of this ramp should be 1:20 in line with the National Cycle Manual. A raised kerb buffer should be provided between the bus lane and the cycle lane on approach to the junction.
- Consider locating bus lane stop line 4m behind general traffic lane stop line to ensure maximum visibility of cycle track from general traffic lane (in instance where bus is stopped at red light in bus lane).
- A secondary stop line and stacking room behind the kerb build-outs should be provided for right-turning cyclists making a hook-turn. Cycle signals will control the second stage of movement of these cyclists.
- Cyclist and Pedestrian crossings should be kept as close as possible to the mainline desire line, however, cyclist and pedestrian crossings should be separate, with between 2-3m space between them. This is to ensure that motorists infer a clear differentiation between the cycle lane crossing through the junction and the pedestrian crossing across the same arm.

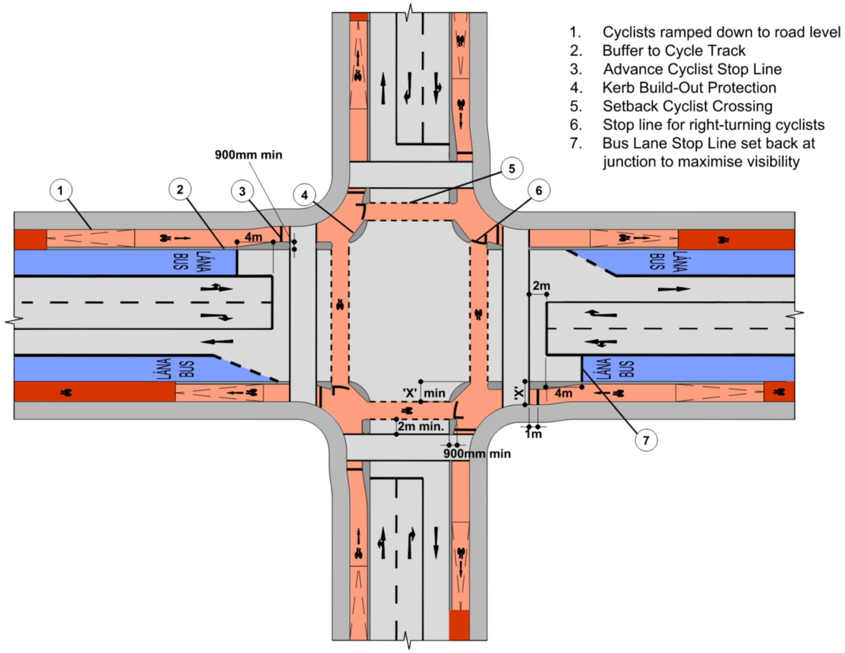


Figure 16: Key Infrastructure Elements of Protected Junction

7 Signalised Junctions

- The arrangement illustrated in Figure 16 requires that cyclists and pedestrians deviate slightly from the direct lines through the junction but it improves the angle of conflict between straight-ahead cyclists and left-turning vehicles at the point where their paths cross, and this should reduce the "blind spot" effect for drivers using their wing mirror to check for a cyclist. This visibility improves further if the left-turning vehicle turns from the general traffic line outside the bus lane, in which case the deflection of the cycle lane can be minimised. Designers should consider the cycle track deflection requirements for each approach on a case by case basis.
- Further delineation of the areas should be considered, including elephant's footprint markings at cycle tracks and studs to delineate pedestrian crossings. As a principle, cycle facilities should be coloured through junctions. Bus lanes are not to be coloured.
- All of the cycle crossings will be signalised and the signal phasing for each junction will be designed on a case-by-case basis. For low volumes of left turning traffic, consideration can be given to allowing cyclists to proceed straight ahead on the same signal phase as straight ahead and left turning traffic, subject to an early start signal being provided for cyclists, plus a flashing amber left turn signal for traffic and additional warning signage for traffic. Where it is unsafe to allow straight ahead cyclist movement on the same signal phase as left-turning traffic, the design of the signal phasing will separate these movements into different signal phases.

No two junctions are the same. Even junctions with similar geometry and layout will cater for different traffic volumes and varying turning demands. As such, the BusConnects junction designs have been developed to allow for as much flexibility as possible with respect to traffic phasing and staging. Section 7.4 of this document provides further details on different design options for protected junction design. In addition to this, Appendix A of this document includes a suite of reference drawings of protected signalised junctions, developed across the various CBCs. These layouts are intended to be used as a reference for designers, when applying the principle-led design approach described here within.

7.2 On-Road Cycle Lane Junction

It is acknowledged that due to the constrained nature of many of the CBC routes, that the preferred 'Protected' junction configuration may not be implementable in all locations. Where spatial constraints do not allow for the preferred junction arrangement to be implemented, designers should consider a junction arrangement whereby cyclists are brought through the junction on-road without physical kerb/island protection, with box-turns provided for right turning cyclists.

The key design features and considerations relating to this junction type are listed below:

- The cycle track is ramped down to carriageway level and proceeds to a forward stop line ahead of the vehicular stop line, placing cyclists within view of traffic waiting at the junction.
- Box-turns should be provided for right-turning cyclists.
- This arrangement requires slightly less land take than the protected junction alternative to construct and should only be considered in particularly constrained locations.

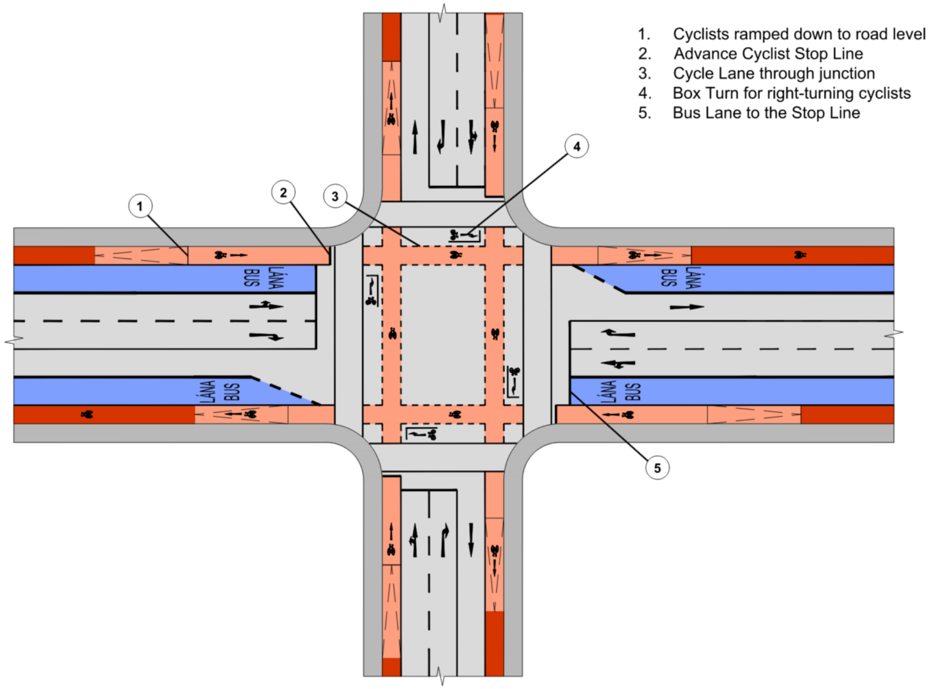


Figure 17: Key Physical Features of On-Road Cycle Lane Junction

7 Signalised Junctions

7.3 Signalised Junction Operation

7.3.1 Staging and Phasing

The optimum staging for each junction will be determined by the required junction operational parameters and local site conditions.

Notwithstanding this, one of the key considerations in the design of signalised junctions is the conflict between left-turning traffic and buses, cyclists and pedestrians continuing along the main CBC route.

For junctions to operate safely and effectively, it is critical that the control of all movements is considered. All road users can have their own traffic signals at junctions (pedestrians, cyclists, buses, vehicles). To achieve optimum operational effectiveness including the efficient movement of cyclists, it is also possible for some movements to occur safely at the same time. To assist with these design decisions, thresholds for turning movements have been used. Chapter 6 (Page 153) of the Dutch Design Guide Ontwerpwijzer Fietsverkeer discourages partial conflicts between cyclists and vehicles if the volume of turning vehicular traffic exceeds **150 PCUs per hour**.

Figure 18 illustrates what scenarios are suitable for allowing cyclists to advance at the same time as turning vehicles and which warrant phase separation of both movements.

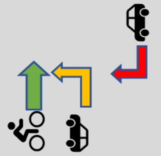
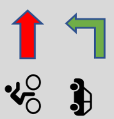
CYCLING THRESHOLD ASSESSMENT		
Turn Flow Thresholds (PCU/Hr)	Flashing Amber Cycle Priority Scenario	Separate Phase Scenario
0-100	100	100
101-150	150	150
>150	151	151

Figure 18: Threshold for Controlling Cycle and Vehicle Conflict

Additionally, where large volumes of left-turning vehicles are present, the progression of the bus through the junction can be compromised if the bus has to share the approach to the junction with those left-turners. This has been found to cause delay to the bus at volumes of turning traffic in excess of **100 PCUs per hour**.

As such, when the volume of left-turning vehicular traffic exceeds 100 PCUs per hour, designers should continue the bus lane to the stop line, as per Junction Type 1 (see Figure 24), to ensure bus priority at the junction. Left turners in this scenario will turn from the shared general traffic lane, with left-turning taxis/coaches required to merge into the adjacent general traffic lane in advance of the junction. For left-turning volumes less than the 100 PCUs per hour threshold, designers should consider allowing left turning vehicles to enter the bus lane in advance of the stop line, as per Junction Type 3 (see Figure 26).

The following presents guidance that should be followed in the design of junction staging and has been developed based on a typical urban junction (in tight urban areas without a dedicated left-turn lane) and in the absence of traffic modelling information.

1. The preferred arrangement will be for a wrap-around pedestrian signal stage at the start of the signal cycle for appropriate priority. No pedestrian crossings should be permitted to run with conflicting turning traffic.
2. Cyclists travelling straight through the junction across the side road will run with straight ahead traffic movements, including buses in a dedicated bus lane. A short "early start" stage will enable buses and cyclists to advance before general traffic. The amount of time given to cyclists by the early release depends on the junction dimensions and signal operation. It should be a minimum of 3 seconds.
3. Cyclists travelling straight through the junction across the side road or the mainline, may also be permitted to run with conflicting left-turning vehicles, subject to appropriate thresholds of turning traffic as outlined in Figure 18. In this scenario, a flashing amber signal should be provided to left-turning traffic to warn of the interaction with cyclists. Cyclists should be given an early start in this scenario.
4. Cycle movements crossing a side road can run simultaneously with the bus stage in the same direction, so long as it is not permitted to turn left from the bus lane in this scenario. Taxis and other bus types wishing to turn left will need to exit the bus lane and merge with general traffic in advance of the stop line. In some cases, a separate left-turn lane may be provided with a red signal while other straight movements progress on a green signal. Designers should specify appropriate road markings and signage to inform road users of the requirement for taxis and buses to merge with general traffic to turn left. A sample of such road markings is shown in Figure 19 where taxis and buses/coaches are advised to exit the bus lane and merge with general traffic in advance of CBC bus priority traffic signals. Merging traffic blocking the buses in the bus lane should be mitigated against through careful design. A nominal distance of 50m from the junction stop line is suggested for locating the merge point.
5. Buses travelling straight through the junction in dedicated bus lanes and left-turning traffic from adjacent shared straight/left-turn lanes should not usually be permitted to run together, i.e. when the bus lane has green, the adjacent shared lane has red and vice versa.
6. Left-turning vehicles may be permitted to run at the same time as straight-ahead cyclists after the initial early start stage for the bus lane when waiting cyclists will have cleared the junction, in cases where left-turning traffic volumes are low and it is considered safe to do so. In this scenario a flashing amber signal and additional warning signage should be provided to the left-turning traffic to warn of the interaction with cyclists. This principle is applicable on all approaches including from side roads at T-junctions, where a right-turning cyclists from the side road will cycle straight across the mainline initially before joining the CBC cycle track on the opposite side of the road to execute the right turn.
7. Cycle movements at junctions are to be controlled by cycle signal aspects where there is an advance stop line ahead of the traffic signals, including for hook-turns at the far side of the side street crossing. Cycle phases should not run in conflict across pedestrian crossings. (i.e. cyclists should not cross pedestrian crossings during the pedestrian phase), except with the cycle signal flashing in appropriate situations (as for example on the Grand Canal Cycle Route in Dublin).
8. Additional cycle signals should also be provided for right-turning cyclists, i.e. right turning cyclists who have travelled straight through the junction to the next corner, will require additional signals on this corner to control their right turning progression across the opposite arm of the junction.
9. The provision of separate cycle signals should allow for the unimpeded left-turn for cyclists at all junctions, once conflict with pedestrian phases is avoided, e.g. during all red wrap-around stage.

It should be noted that, in locations where space permits and where large left-turning volumes will require the inclusion of dedicated left and right-turn lanes (similar to Junction Type 2 in Figure 25) or where the sharing of bus lanes and left-turning traffic is required (similar to Junction Type 3 in Figure 26), these principles should still be considered.

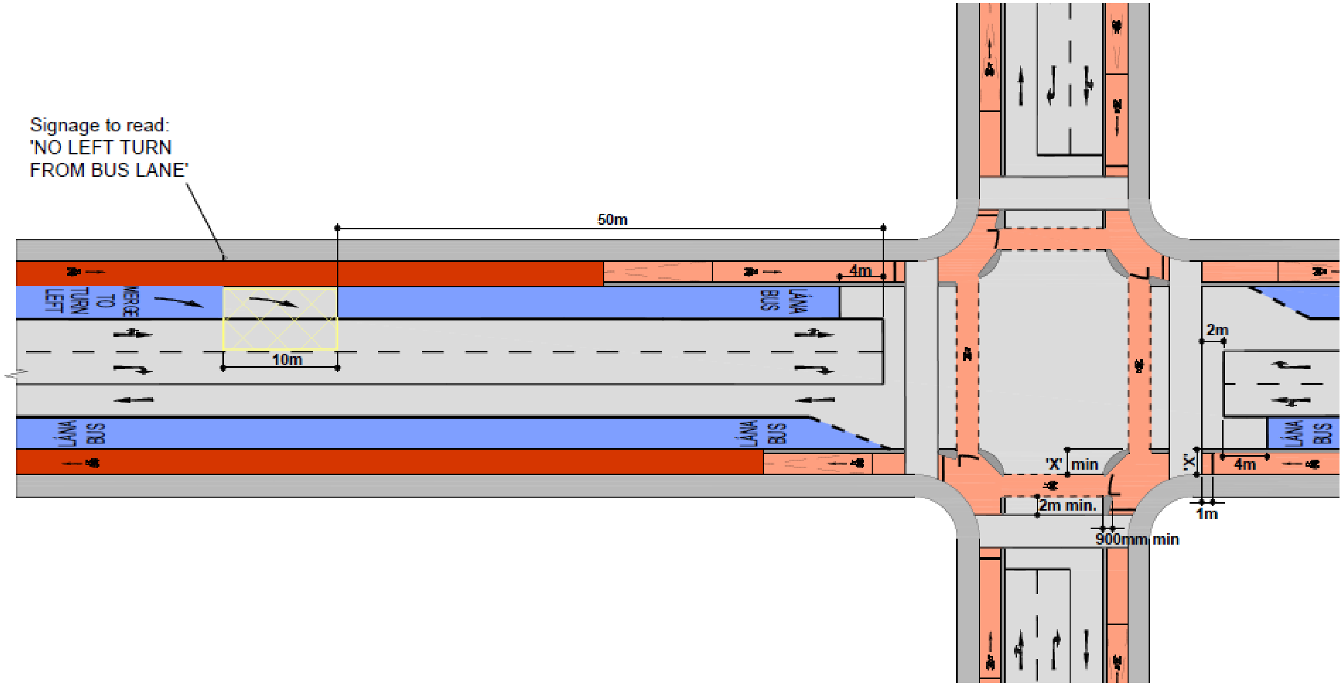


Figure 19: Example of location-specific Road Markings in advance of Bus Priority Traffic Signals

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7 Signalised Junctions

7.3.2 Application of the Staging and Phasing Principles

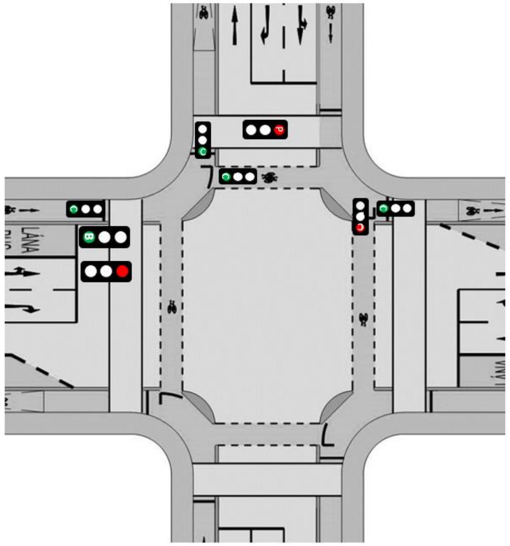
Figure 20, Figure 21a and Figure 21b demonstrate the practical application of the aforementioned staging and phasing and illustrate a potential sequencing of the traffic signals from one stage to the other. For example, when the bus and cycle phases are green (Figure 20), the traffic light controlling the general traffic lane is red. When the general traffic phase is green (Figures 21a and 21b), the bus phase will be red. Where the volume of left turning traffic is <150 PCUs per hour, the cycle phase for cyclists crossing the side arm remains green and a flashing amber left-turning arrow is now controlling general traffic that wish to turn left. Where the volume of left turning traffic is >150 PCUs per hour, the cycle phase for cyclists crossing the side arm will turn red and a green arrow will be provided for left-turning traffic. This arrangement suits a relatively short signal cycle time so that buses receive frequent green signals, even if the duration is necessarily short.

The phasing of the cycle signals in Figures 20, 21a and 21b all allow the left-turning cyclist from the mainline to the side road to make an unimpeded left turn during all stages.

Figure 22 shows a fairly large-scale junction with an indicative traffic signals layout which includes the practical requirements for locating cycle aspects around each corner of the junction. Depending on the space available, the requirements for high-level traffic signals on overhead gantries will be assessed on a case-by-case basis at each junction. In this case the pedestrian crossing distances are quite long and exceed the desirable maximum length of 19m for a single stage crossing. Consideration should be given to a staged crossing for pedestrians in such a situation, if a minimum 4m wide central median can be provided.

Figure 23 shows an indicative staging and phasing diagram. The staging arrangements are to be assessed on a case-by-case basis, e.g. Stages 5 and 6 could be merged to allow both opposing side road arms travel during the same stage but would need to satisfy health and safety criteria and be subject to junction operation assessment.

Section 14 of this Design Guidance Booklet outlines more general design guidelines for Traffic Signals.



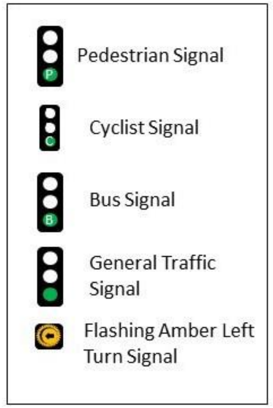


Figure 20 : Junction Staging for Bus Stage

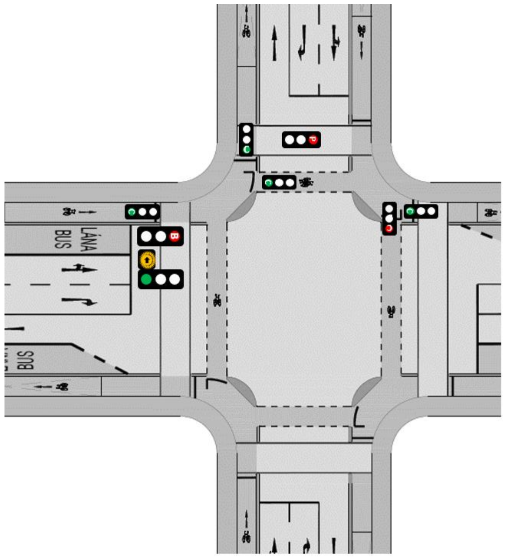


Figure 21a: Junction Staging for Straight Ahead / Left-Turning Traffic where left-turning volumes < 150 PCUs per hour

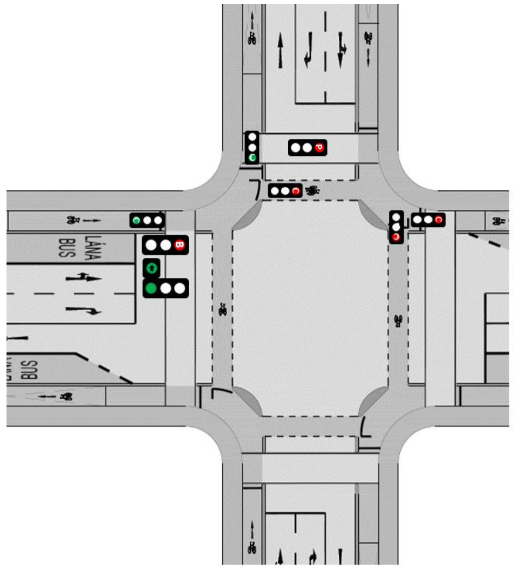


Figure 21b: Junction Staging for Straight Ahead / Left-Turning Traffic where left-turning volumes > 150 PCUs per hour

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7 Signalised Junctions

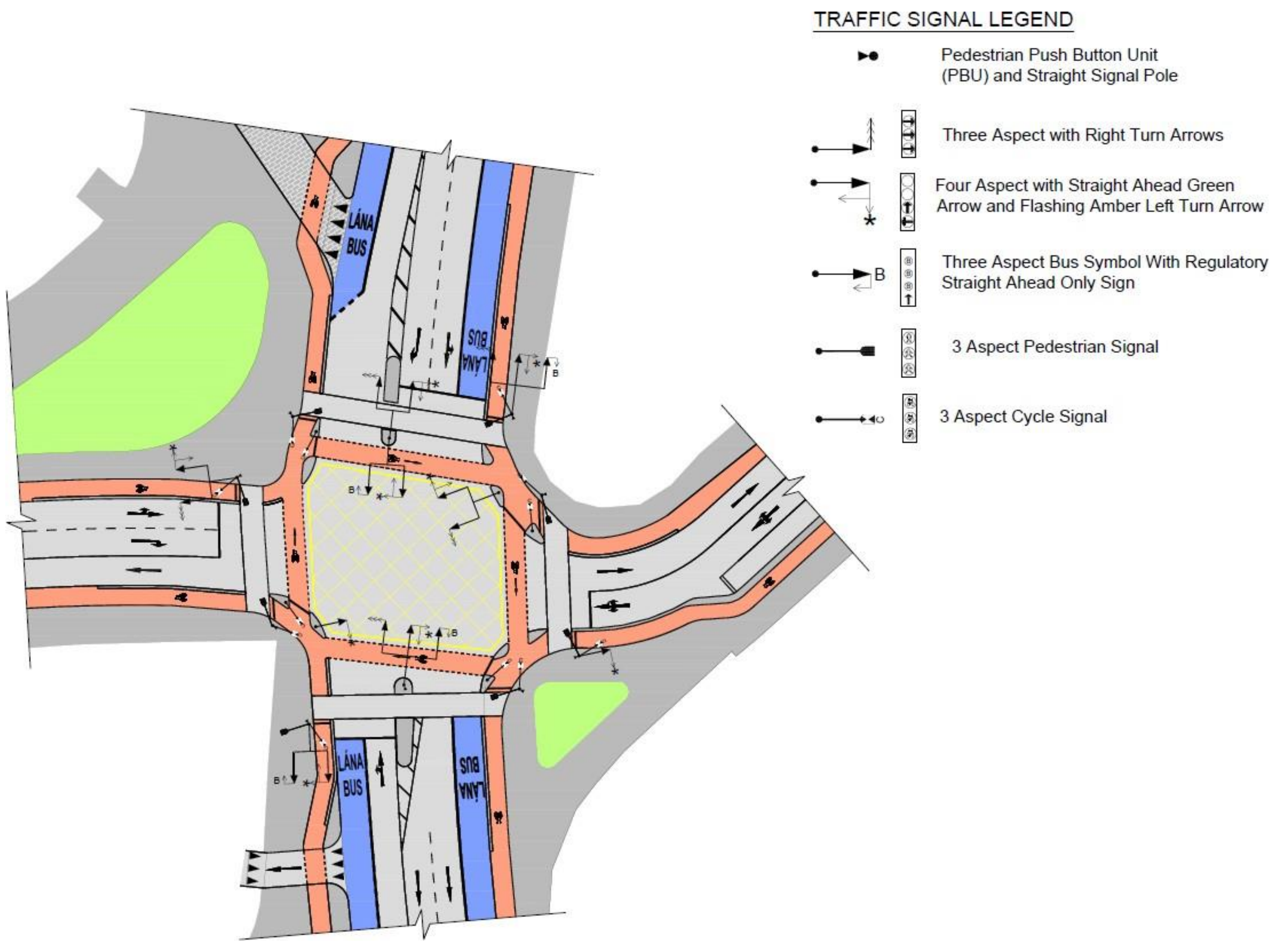


Figure 22: Indicative Traffic Signal and Phasing Layout

7 Signalised Junctions

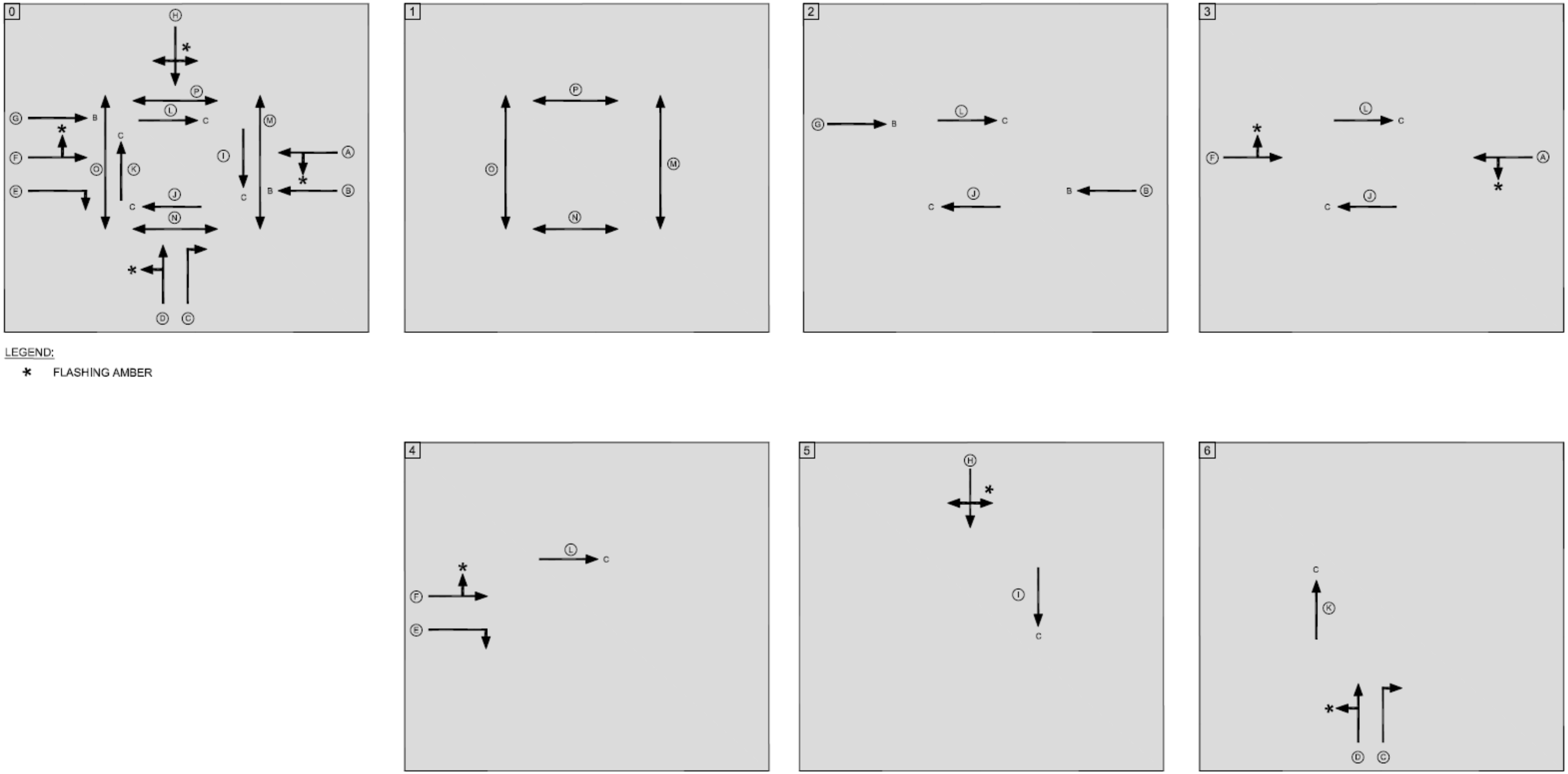


Figure 23: Indicative Junction Phasing and Staging Diagram

7.4 Typical Protected Junction Types

7.4.1 Junction Type 1

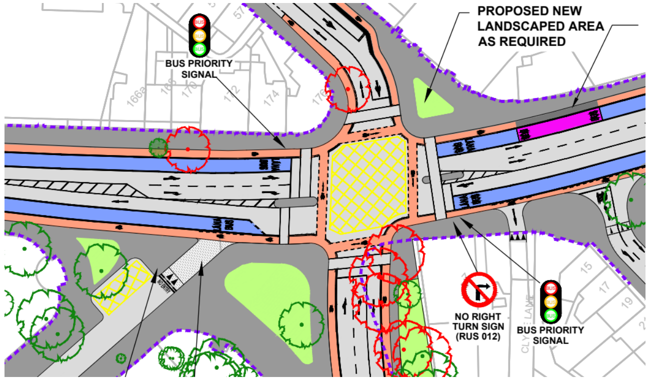


Figure 24: BusConnects Junction Type 1 example

Junction Type 1 illustrates a signalised crossroads in an urban setting. The CBC mainline accommodates an inbound and an outbound bus lane. Both bus lanes are dedicated lanes up to the junction stop line. Due to space constraints, general straight ahead and left-turning traffic is restricted to one lane.

Junction Type 1 is chosen for the following reasons:

- Volume of left-turning vehicles greater than 100 PCUs per hour,
- Urban setting; No space available for a dedicated left-turning lane/pocket.

In this instance, mainline cyclists proceed with the bus phases. The bus lane then gets red, allowing the general traffic lane to proceed. If the volume of turning vehicles is greater than 150 PCUs per hour, then the cyclists are also held on red whilst the general traffic proceeds on green. For turning volumes between 100-150 PCUs per hour, the mainline cyclists can still proceed with general traffic and left turners from the mainline will be controlled by a flashing amber arrow.

Cyclists from the side roads can proceed with general traffic from the same arms. Again, the left-turners from the side arms will be controlled by a flashing amber arrow and cyclists should receive an early start. As with the mainline, there may be circumstances where turning traffic from the side arms exceeds 150 PCUs per hour, in which case the cyclist phase from the side arm can be separated from the turning traffic phase.

7.4.2 Junction Type 2

Figure 25: BusConnects Junction Type 2 example

Junction Type 2 illustrates a signalised junction in a sub-urban context, where there is room for additional lanes. The CBC mainline accommodates an inbound and an outbound bus lane. Both bus lanes are dedicated lanes up to the junction stop line. At approximately 30m back from the stop line, there is a yellow box to allow left-turners to cross the bus lane to enter a dedicated left-turn pocket, where space permits.

Junction Type 2 is chosen for the following reasons:

- Sub-urban setting where space is available for a dedicated left-turning lane/pocket,
- Hi volumes of left-turning traffic which can be controlled separately with exiting traffic from side roads.

In this instance, left turners are held and mainline cyclists proceed with the bus phases. Mainline cyclists can proceed also with straight ahead general traffic if left turners are held. If the volume of turning traffic is less than 150 PCUs per hour, the mainline cyclists could still proceed when left-turners from the left-turn pocket are given a flashing amber arrow. Alternatively, the left turners could go whilst the side road traffic proceeds, in which case, the mainline cyclists will be held on red.

As with Junction Type 1, cyclists from the side roads can proceed with general traffic from the same arms, and the left-turners from the side arms will be controlled by a flashing amber arrow and cyclists should receive an early start. As with the mainline, there may be circumstances where turning traffic from the side arms exceeds 150 PCUs per hour, in which case the cyclist phase from the side arm can be separated from the turning traffic phase.

7.4.3 Junction Type 3

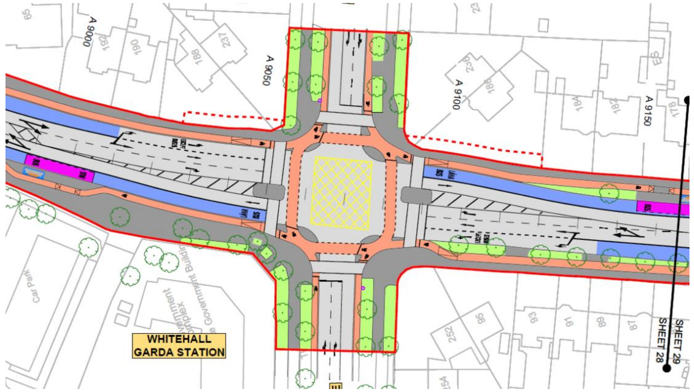


Figure 26: BusConnects Junction Type 3 example

Junction Type 3 illustrates a signalised junction where the CBC mainline accommodates an inbound and an outbound bus lane. Unlike Junction Types 1 and 2, the bus lanes are terminated just short of the junction to allow left-turners to turn left from a short left-turn pocket in front of the bus lane. Buses can continue straight ahead from this pocket where a receiving bus lane is proposed.

Junction Type 3 is chosen for the following reasons:

- Volume of left-turning vehicles less than 100 PCUs per hour,
- Urban setting; No space available for a dedicated left-turning lane/pocket.

In this instance, mainline buses and general traffic (including left turners) from the mainline proceed together, but before they do, mainline cyclists are given an 'early start' of approximately 5 seconds (minimum of 3 seconds) to minimise any conflict with left turners. When this early start is complete, the mainline cyclists can still proceed, assuming turning volumes are less than 150 PCUs per hour. Left-turners from the left-turn pocket are given a flashing amber arrow.

To avoid any indiscriminate use of the bus lane to queue to turn left, the bus lane shall be physically protected on the approach to Junction Type 3 which will ensure the performance of the bus lane isn't compromised by the left turners. The form that such protection takes will need to consider private accesses along the approach to the junction and could be supplemented by other enforcement options. The length of the left-turning pocket in front of the bus lane shall be minimised to approx. 15-20m in length, capable of accommodating three cars or one HGV.

As with Junction Type 1 and 2, cyclists from the side roads can proceed with general traffic from the same arms, and the left turners from the side arms will be controlled by a flashing amber arrow and cyclists should receive an early start. As with the mainline, there may be circumstances where turning traffic from the side arms exceeds 150 PCUs per hour, in which case the cyclist phase from the side arm can be separated from the turning traffic phase.

7.4.4 Junction Type 4

Junction Type 4 illustrates a signalised junction where the CBC mainline accommodates an inbound and an outbound bus lane but which also positions the pedestrian crossings on the inside of the cycle lanes across the arms of the junction. Pedestrian crossing distances are minimised as a result, similar to the CYCLOPS junction in Manchester. Unlike the CYCLOPS junction concept, signalised pedestrian crossings are proposed across the cycle tracks to allow the pedestrian to cross from the footpath to the pedestrian crossing landing areas, thus avoiding any uncontrolled pedestrian-cyclist conflict.

The key design features and considerations relating to this junction type are listed below:

- An orbital cycle track is provided, with controlled crossing points to allow pedestrians to cross to large islands within a central signal-controlled area.
- Left-turning cyclists can effectively bypass the junction, while giving way to pedestrians crossing as well as cyclists already on the orbital cycle track.
- Signal controlled pedestrian crossing distances are reduced when compared to traditional junction layouts, due to the fact that pedestrians cross the cycle track in a separate signalised movement. Pedestrian crossings are also close to the pedestrian desire line. However, the number of crossings for pedestrians is increased as pedestrians must cross the cycle track to access the central signal-controlled area.
- This junction arrangement typically requires a larger footprint to construct than the protected junction discussed herein, due to the large pedestrian islands.

Similar to Junction Type 3, the bus lanes are terminated just short of the junction to allow left turners to turn left from a short left-turn pocket in front of the bus lane. Buses can continue straight ahead from this pocket where a receiving bus lane is proposed.

Junction Type 4 is chosen for the following reasons:

- Volume of left-turning vehicles less than 100 PCUs per hour,
- Sub-urban setting; No space available for a dedicated left-turning lane/pocket,
- High incidence of HGV movements (e.g. at entrance to Industrial Estate),
- Low pedestrian volumes.

In this instance, mainline buses and left turners from the mainline proceed together. Depending on the prevailing site conditions, mainline cyclists can proceed with left-turners from the mainline (who are controlled with a flashing amber arrow) or cyclists can be held on red until it's time to share a full pedestrian 'wrap around' stage where all vehicular traffic is held and the green man is activated across all arms of the junction. The use of 'early start' stages for cyclists will have to be considered in the context of the proposed signalised pedestrian crossings across the cycle tracks, which have the potential to halt the progression of cyclists if demand-activated.

To avoid any indiscriminate use of the bus lane to queue to turn left, the bus lane shall be physically protected on the approach to Junction Type 4 which will ensure that the performance of the bus lane isn't compromised by the left turners. The form that such protection takes will need to consider private accesses along the approach to the junction and could be supplemented by other enforcement options (currently being examined). The length of the left-turning pocket in front of the bus lane shall be minimised to approx 15-20m in length, capable of accommodating three cars or one HGV.

As with Junction Type 1, 2 and 3, cyclists from the side roads can proceed with general traffic from the same arms, and the left turners from the side arms will be controlled by a flashing amber arrow and cyclists should receive an early start. As with the mainline, there may be circumstances where turning traffic from the side arms exceeds 150 PCUs per hour, in which case the cyclist phase from the side arm can be separated from the turning traffic phase.

The proposed use of Junction Type 4 will require prior approval from the NTA.

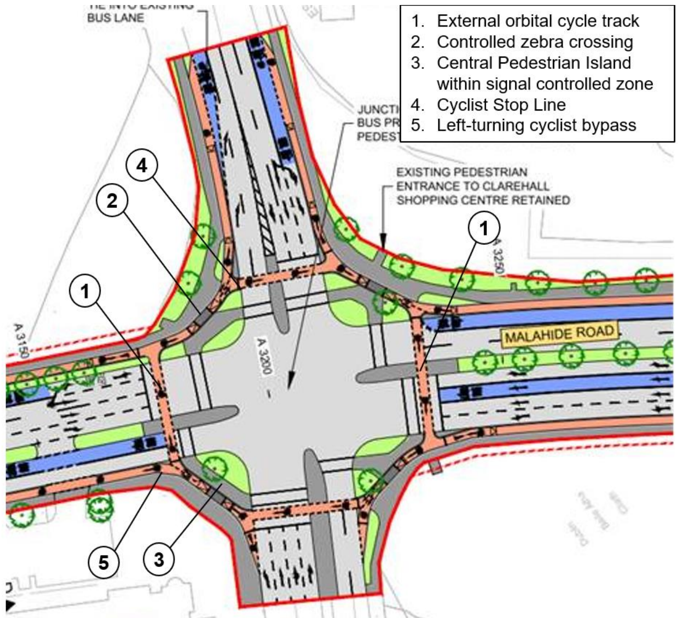


Figure 27: BusConnects Junction Type 4

7.4.5 Pre-Signals

In some circumstances, Bus Priority Signals (or Pre-Signals) can be utilised on the approaches to junctions to give priority to buses and/or to gate general traffic at traffic signals. This may be necessary if there is a large volume of left-tuning traffic that needs to turn left from a dedicated lane in front of the bus lane, in which case the signals can control the use of the left turn and maintain bus priority through the junction. This may also be necessary if the bus lane continues straight ahead but there is also a right turn demand for some bus services. In this instance, the pre- signals can be utilised to ensure that the bus gets priority to relocate from the nearside bus lane to an offside right-turn lane.

7.5 Cyclist Waiting Area at Toucan Crossings

Access to Toucan crossings will be necessary in certain circumstances from the main cycle track, for example where protected junctions cannot be provided (due to spatial constraints) or at mid-block Toucan crossings. In these situations, the detail shown in Figure 28 is the preferred approach, providing a waiting area for cyclists waiting to use the Toucan crossing which is out of the way of straight-ahead cyclists. Where minimum footpath widths don't allow for a separate waiting area to be provided, the detail shown in Figure 29 should be provided.

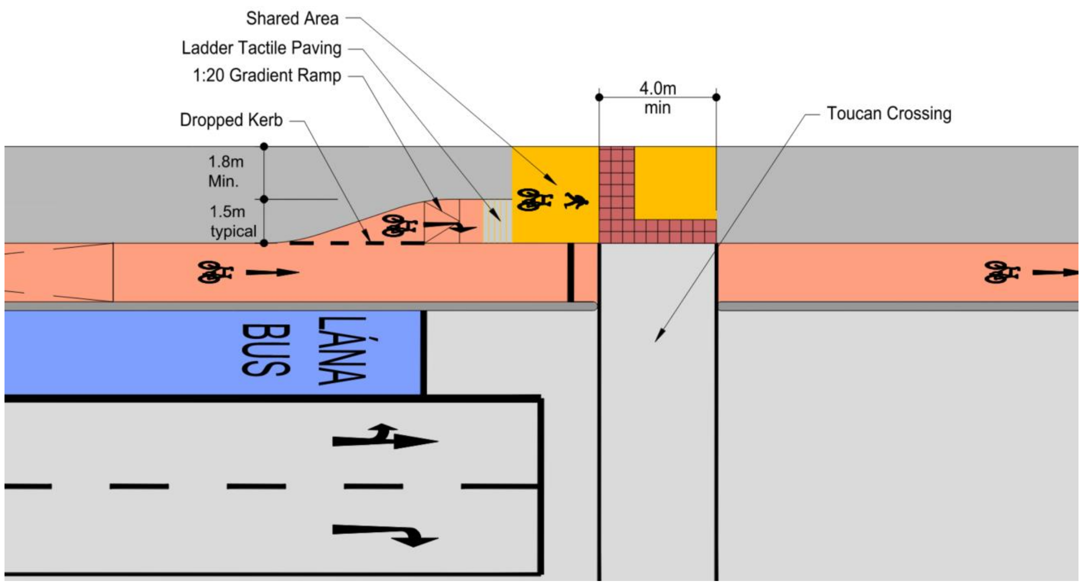


Figure 28: Preferred Cyclist Waiting Area Detail at Toucan crossing

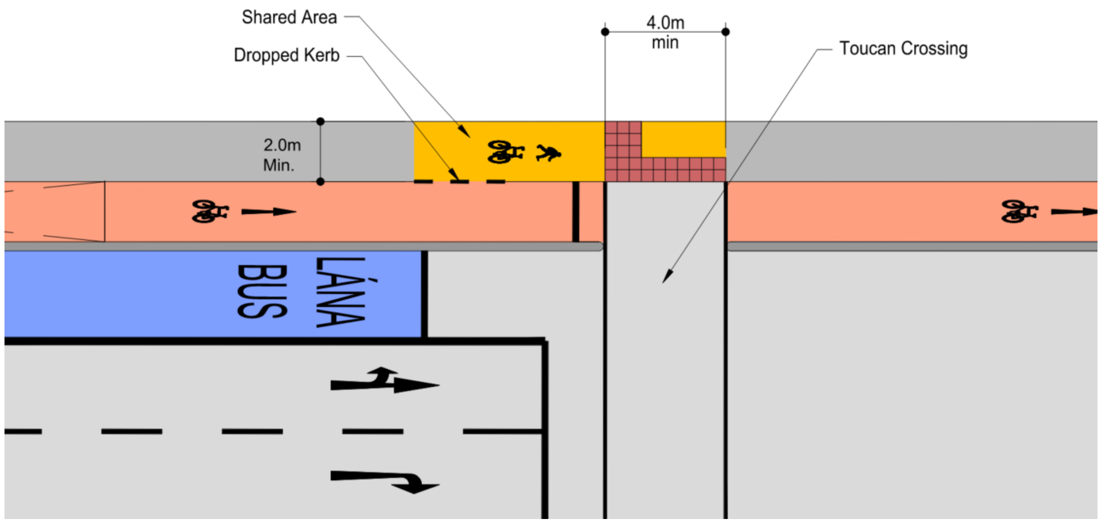


Figure 29: Alternative Cyclist Waiting Area Detail at Toucan crossing

8 Priority Junctions

In general, it is preferable that left-turning vehicles from the mainline make the left turn from the general traffic lane, giving way to buses continuing along the CBC, i.e. without merging into the bus lane before the turn.

8.1 Raised Table Treatment

The preferred priority junction arrangement for the CBC project consists of a single-direction, with-flow cycle track continuing with priority across the front of the side road on a raised entry treatment. This will avoid a change in level for the cycle track.

The key design features and considerations relating to this junction type are listed below:

- The minor arm stop/yield line is located behind the raised table and footpath crossing to encourage a "courtesy crossing" for pedestrians.
- Splayed kerbs provide a step change between the carriageway and cycle track and the cycle track and footpath.
- Cycle symbol markings are to be used on the cycle track across the junction.
- Consideration must also be given to cyclists crossing the mainline to enter or exit the side road. Where a significant demand is found for these movements then consideration should be given to provision of a signal crossing.
- Tactile paving may be required to alert visually impaired persons of the crossing point at busier side streets. However, the preferred arrangement is for the footpath to continue across the junction without a break and for pedestrian priority to be maintained (as shown in The National Cycle Manual on Page 136).
- There is the potential for conflict between turning traffic yielding to cyclists and buses continuing on the mainline.
- Consideration must also be given to cyclists crossing the mainline to enter or exit the side road. Where a significant demand is found for these movements then consideration should be given to signalising the junction.

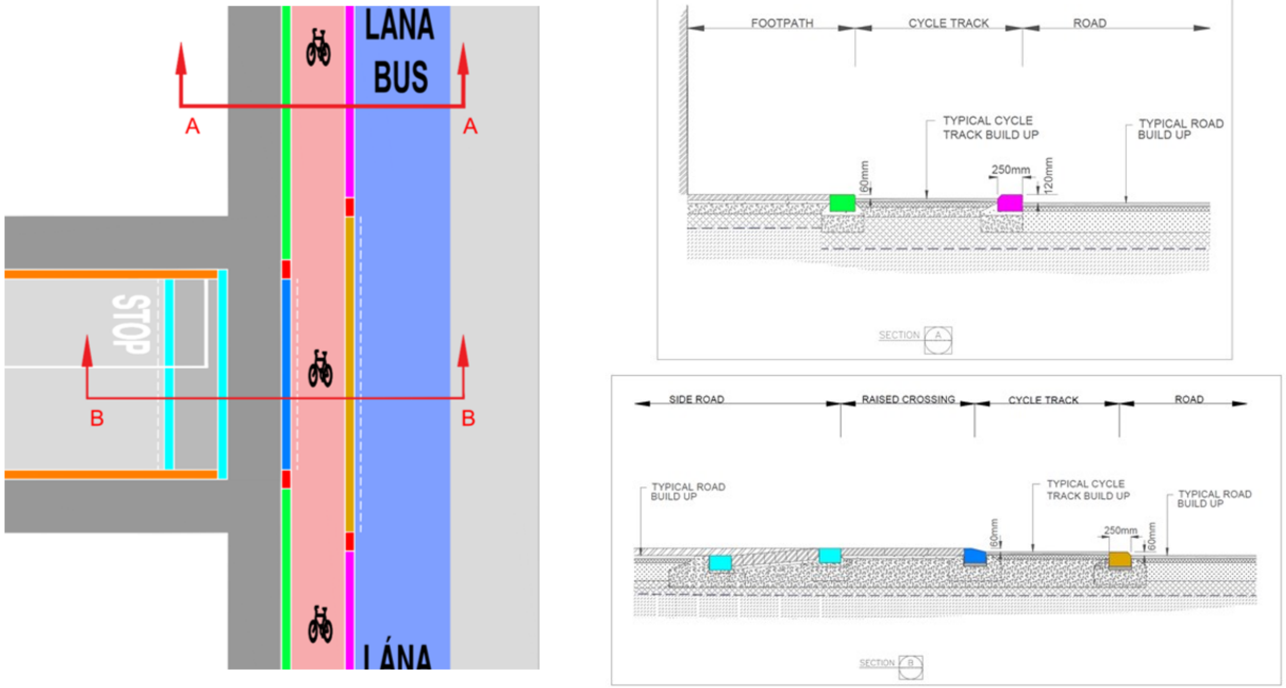


Figure 30: Raised Table Priority Junction Treatment

A similar detail should be provided where a two-way cycle track crosses an uncontrolled side road, as shown in Figure 30a, whereby the cycle track should be narrowed as it crosses the mouth of the junction and deflected slightly away from the mainline carriageway. The narrowing will act as a traffic calming measure to cyclists, albeit cyclists will still maintain priority.

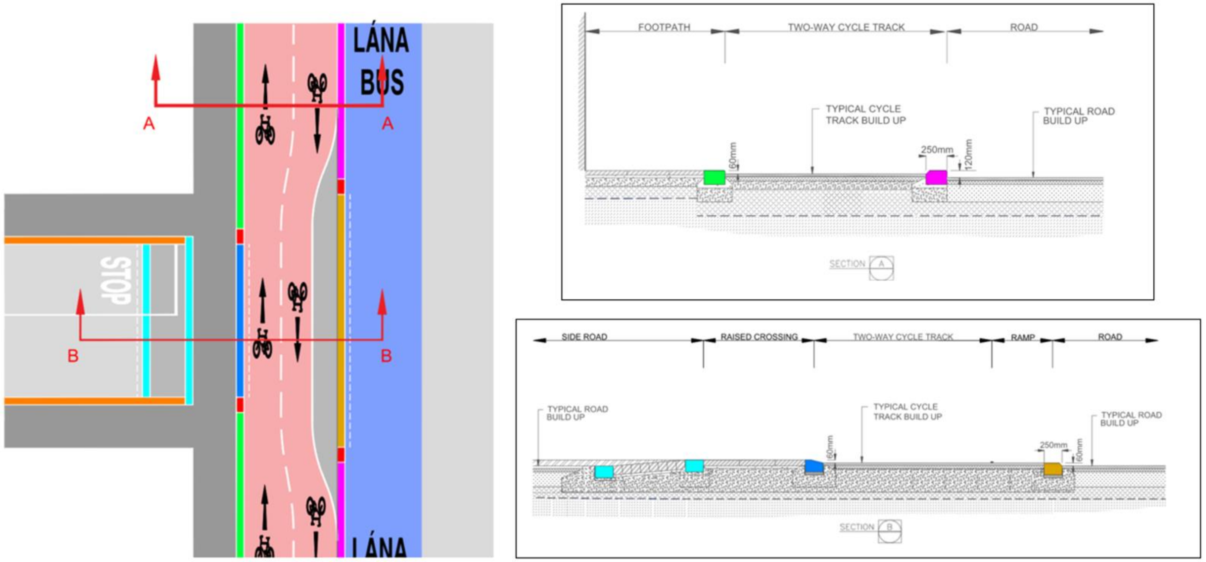


Figure 30a: Raised Table Priority Junction Treatment with 2-way cycle track

8.2 Raised Table Treatment with adjacent Parking

In some specific locations, where there are parking spaces in close proximity to uncontrolled side roads, with the cycle track diverted behind these parking spaces, an alternative arrangement of the preferred uncontrolled junction type described in Section 8.1 is recommended. Under this arrangement, rather than diverting back to the carriageway edge, the cycle track is still separated from the carriageway by a verge on either side of the junction and would cross the junction on the same level, set back from the carriageway. This arrangement is illustrated in Figure 31. See Section 6.1 relating to consideration of visibility splays when designing parking/loading bays close to side roads.

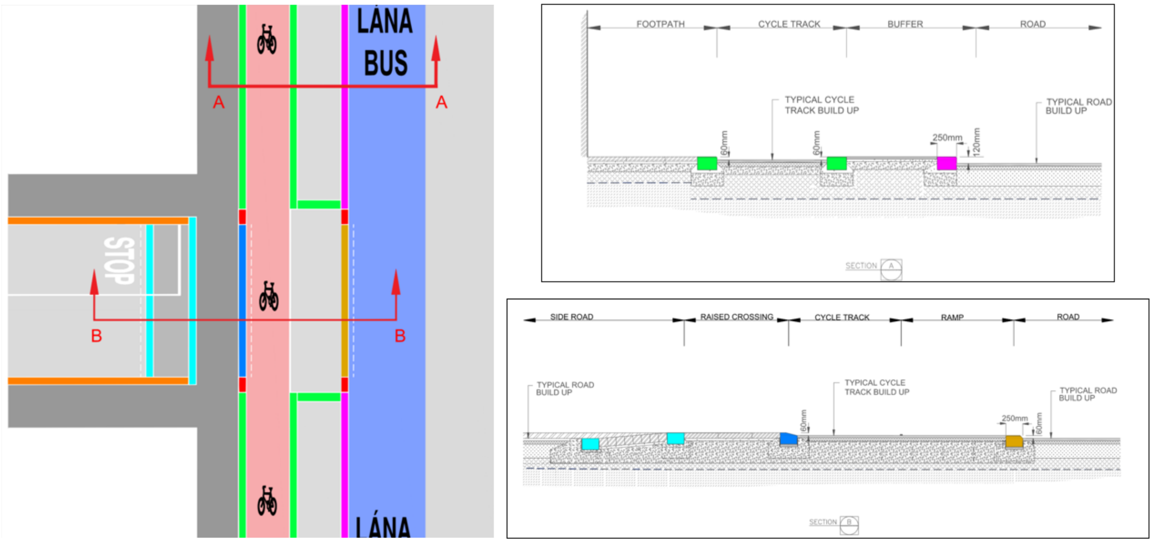


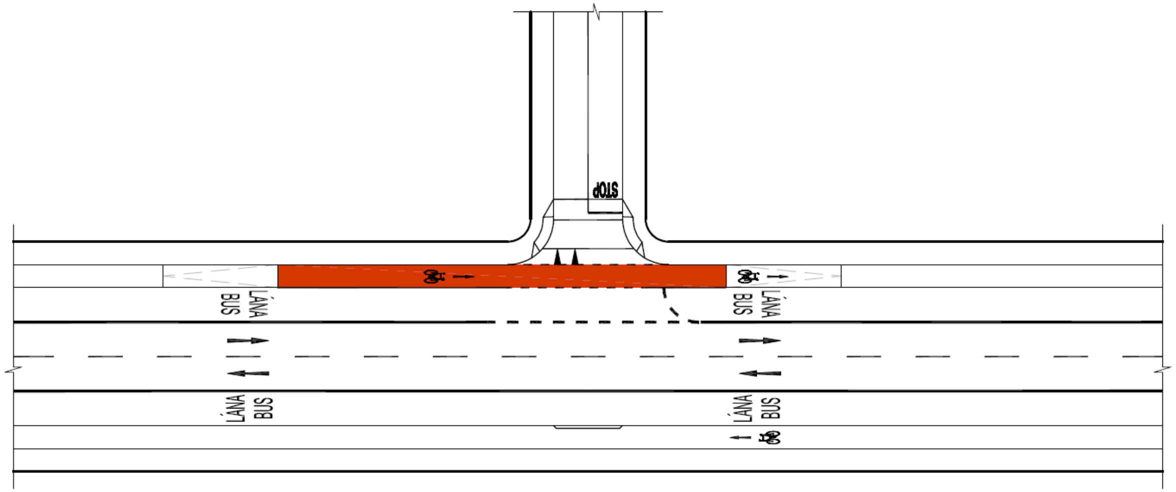
Figure 31: Raised Table Priority Junction Treatment with adjacent parking/verge

8.3 On-Road Cycle Lane

Where providing a raised table treatment across the side road is not feasible, an on-road cycle lane should be provided along the CBC main line across the junction.

The key design features and considerations relating to this junction type are listed below and illustrated in Figure 32:

- The cycle track should be ramped down to road level 20m in advance of the junction to alert cyclists of the junction ahead. A separator upstand kerb should be provided on the traffic side to protect the cycle track from the traffic until 10m before the corner. A 1:10 gradient ramp should be provided for a smooth ride for cyclists. The cycle lane should be coloured red across the mouth of the junction to highlight the need for drivers to yield to cyclists in the cycle lane.
- Whilst priority is retained for cyclists across the mouth of the junction, pedestrians will not have priority and will navigate the crossing using the uncontrolled tactile paving arrangement, as per typical entry treatment details.



9 Roundabouts

The design of roundabouts is not explicitly covered in this design booklet. Designers should refer to relevant design guidance including DMRB, DMURS and the National Cycle Manual in the design of Roundabouts on CBCs.

Where feasible, in urban locations, the preference is to replace existing roundabouts with signalised junctions to improve facilities for Vulnerable Road Users including pedestrians and cyclists as well as enabling improved priority for buses.

Figure 32: On-Road Cycle Lane Priority Junction Treatment

10 Signal Controlled Bus Priority

Bus priority traffic signals providing queue relocation should be considered in areas where physical constraints cannot be overcome, and physical bus priority cannot be provided through the delivery of a bus lane such as village centre areas where the built form is close to the carriageway edge. Bus Priority Traffic Signals allow the bus to achieve virtual priority through a section where the bus shares a lane with general traffic through the management of queues within this section and providing priority to the bus on approach.

The scenarios in which a bus priority traffic signals can operate effectively requires assessment on a case-by-case basis, however, designers should consider the following factors:

- The corridor length through which the bus will share the lane with general traffic should be reasonably clear from potential disruption. A bus priority traffic signal is not likely to operate effectively over a long distance with a large number of accesses for instance, or where a major junction is contained within this area.
- The availability and appropriateness of stacking space for traffic upstream should be considered as queues will be relocated to this area.
- Downstream queue detection will be used to ensure a clear route for the bus through the section without a bus lane.

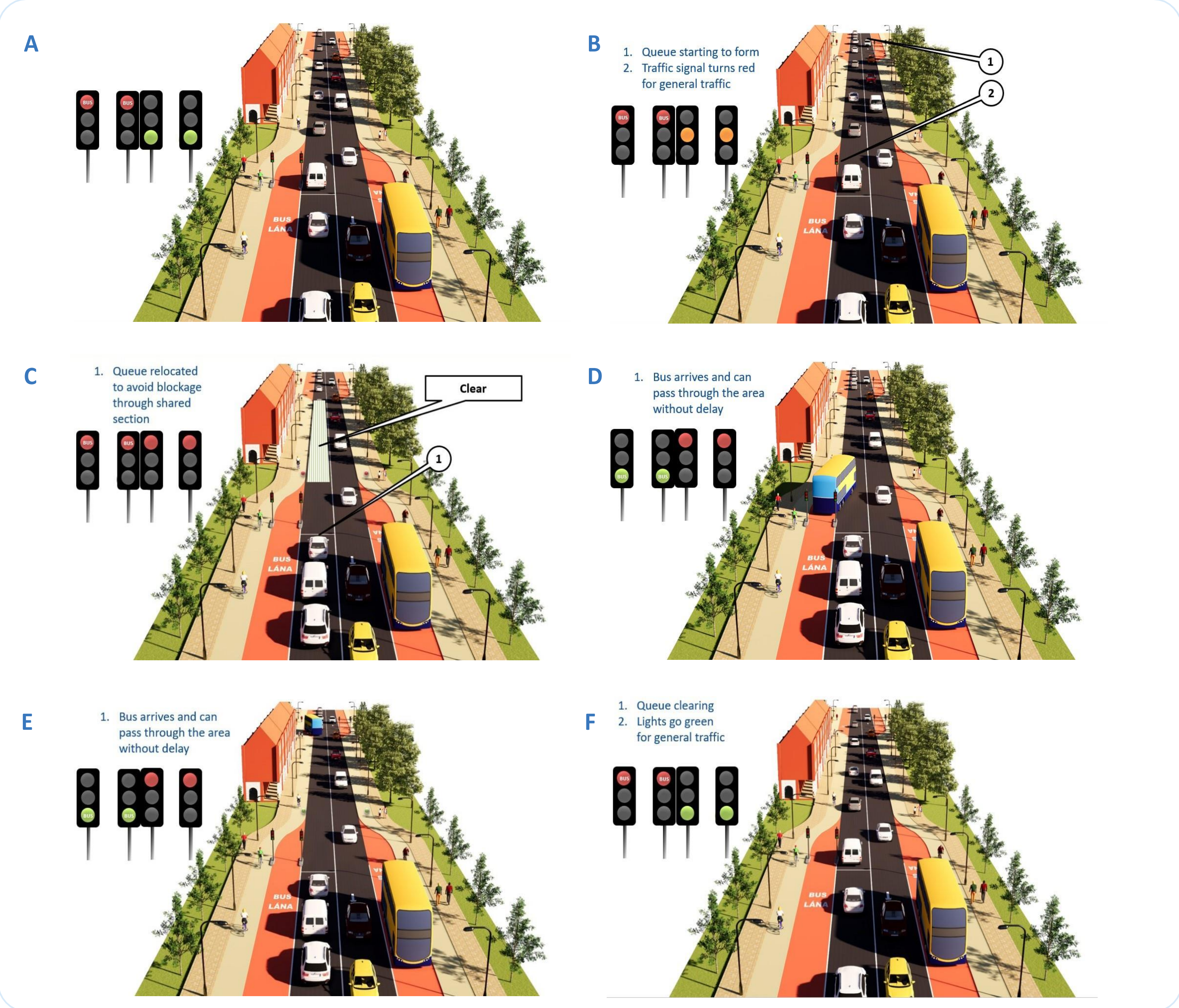


Figure 33: Bus Priority Traffic Signal Schematic Operation

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11 Bus Stops

The following presents a principle-based approach to the design of bus stops and presents a hierarchy of bus stop options to be considered by designers. For further detail on the design of Bus Stops, reference should be made to the BusConnects Bus Stop Guidance Note.

Bus boarding platforms with 160mm high containment (Kassel) kerbs should be installed at all bus stops to assist level access for wheelchairs and buggies.

Where existing bus stops on a route are in close proximity to each other they may be amalgamated into a single stop. This must be assessed on a case-by-case basis.

11.1 Island Bus Stop

Island Bus Stops are the preferred bus stop option to be used as standard on the CBC project where space constraints allow.

The key design features and considerations relating to island bus stops are listed below:

- Conflict between cyclists and stopping buses is removed as cyclists are deflected behind the bus stop.
- To address the pedestrian/cyclist conflict, a pedestrian priority crossing point is provided for pedestrians accessing the bus stop area. Part-time signals will enable controlled crossing when required (as provided for example at junctions on the Grand Canal Cycle Route in Dublin). Visually impaired pedestrians may call for a fixed green signal when necessary and the cycle signal will change to red.
- The cycle track should be deflected behind the bus stop sufficiently to reduce cycling speed for safety through the crossing area so cyclists can give way to pedestrians crossing to the bus stop area. Recommended minimum radii are indicated in Figure 34. The cycle track will rise in level to meet the footpath level. (Yellow bar markings could also be provided to alert approaching cyclists but the narrowing and deflection should suffice when the approaching cycle track is the nominal 2m width);
- Figure 34a illustrates an island bus stop layout which caters for 2-way cycle tracks.
- The cycle track should narrow from 2.0m to 1.5m for single file cycling through the bus stop, as overtaking is not required in this area;
- Appropriate signage and lighting should be provided at these locations to ensure that all road users are aware of the potential conflicts in this area; and
- At least 2m must be provided between the bus shelter and crossing to ensure sufficient visibility.

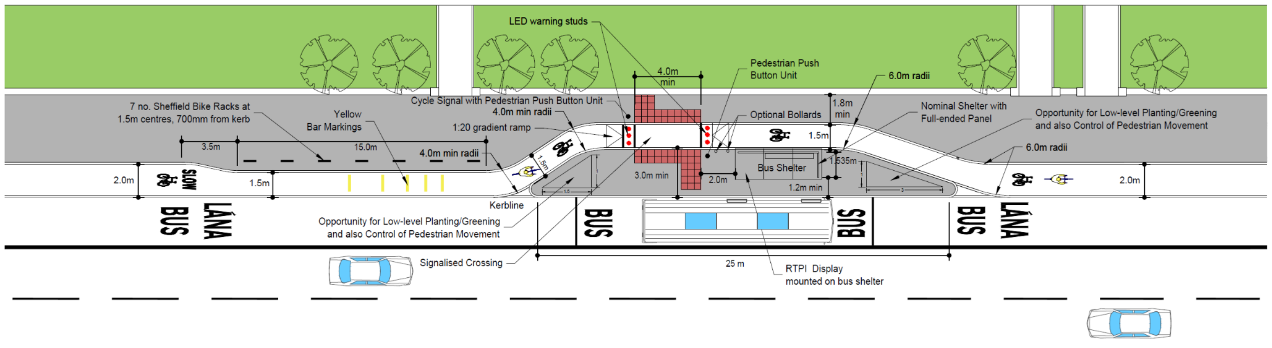


Figure 34: Island Bus Stop Arrangement

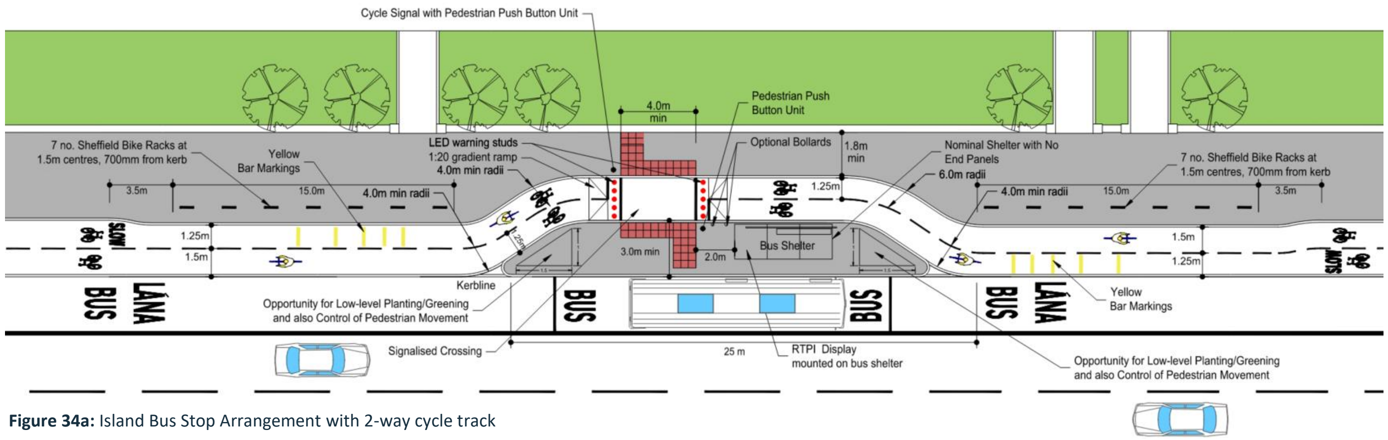


Figure 34a: Island Bus Stop Arrangement with 2-way cycle track

11 Bus Stops

11.2 Shared Bus Stop Landing Zone

Where space constraints do not allow for an island bus stop, an option consisting of a shared bus stop landing zone may be considered.

The key design features and considerations relating to shared bus stops are listed below:

- Conflict between cyclists and stopping buses is removed by ramping cyclists up to footpath level where they continue through the stop;
- To address the pedestrian/cyclist conflict, the cycle track should be narrowed on approach to the bus stop and yellow bar markings should be provided to alert cyclists to the potential conflict ahead. In addition to this, at the bus stop, the cycle track should be deflected to provide a 1.0m wide boarding/alighting zone for bus passengers;
- Appropriate tactile kerbing should be provided to ensure that visually impaired users are aware of crossing areas.

In particularly constrained locations within urban centres, where the provision of a bus shelter at the rear of the footpath is not possible due to the presence of frontages, a variation of the Shared Bus Stop Landing Zone arrangement may be considered. This option is presented in Figure 36. This option provides a cantilever bus shelter adjacent to the carriageway, to maintain access to frontages at the back of the footpath.

Figure 37 shows a shared bus stop landing zone where a two-way cycle track is present.

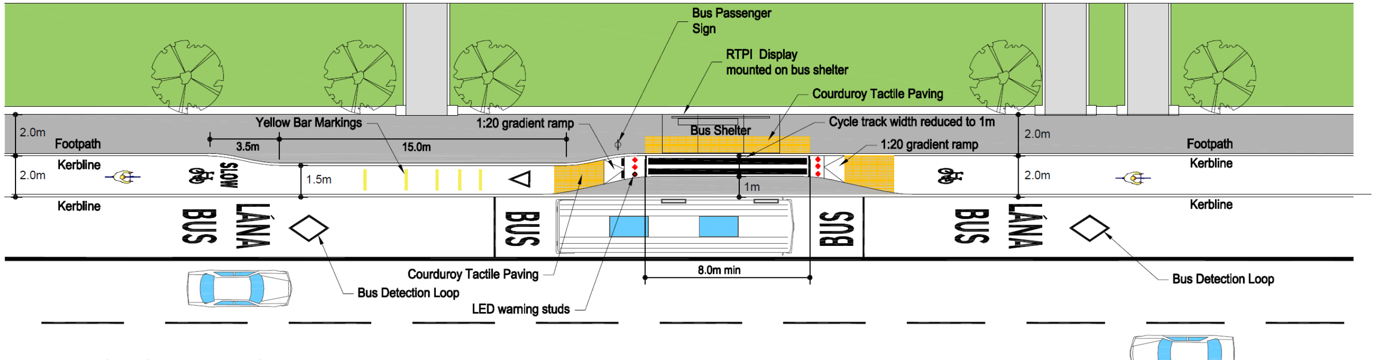


Figure 35: Shared Bus Stop Landing Zone Arrangement

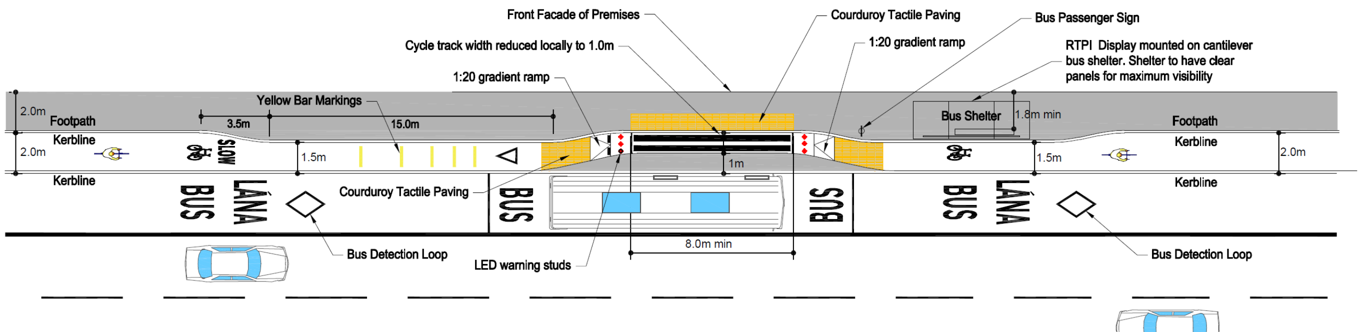


Figure 36: Shared Bus Stop Landing Zone Arrangement (Urban Centres)

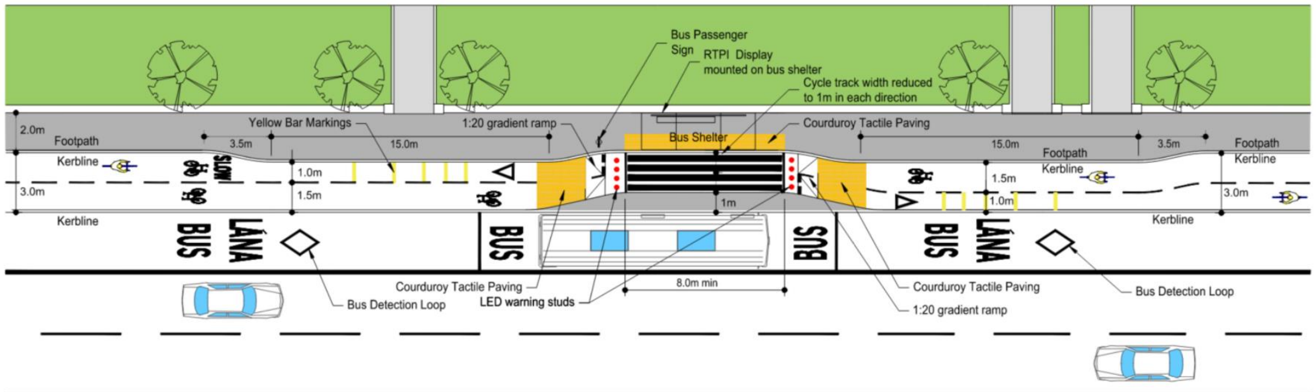


Figure 37: Shared Bus Stop Landing Zone Arrangement (Two-way cycle track)

11.3 Layby Bus Stops

Lay-bys can be an effective solution for bus stops for coaches but present significant operational problems for urban bus services and negative impacts for bus users in terms of journey time impact. Figure 38 shows a lay-by bus stop landing zone arrangement and should only be used in urban areas where there is compelling safety or road capacity reasons. Designers should consider in-line and boarder bus stop options first. Generally, in urban areas, it is acceptable for general traffic to wait behind buses that are stopped at in-line bus stops. For further guidance on the provision of lay-by bus stops, refer to the BusConnects Bus Stop Guidance Note.

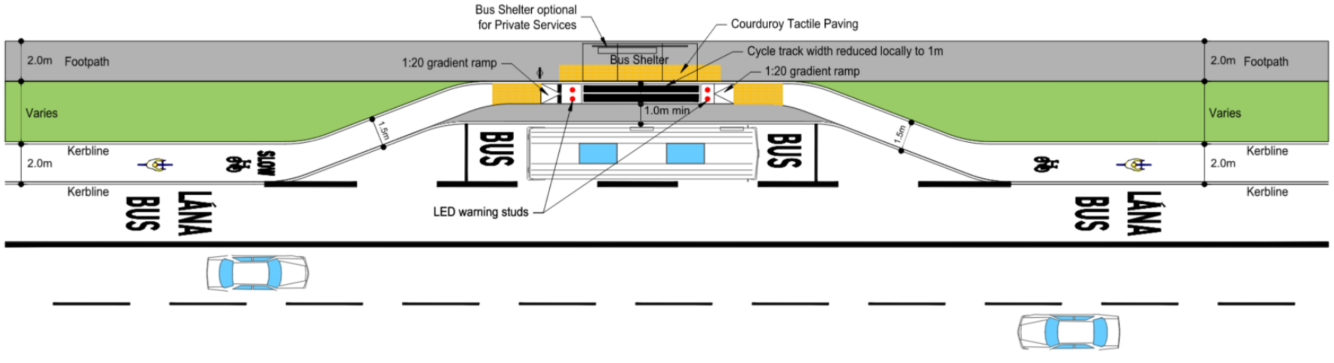


Figure 38: Lay-by Bus Stop Landing Zone Arrangement (Private Service Coaches)

12 Accessibility

Accessibility should be a key design consideration at all times during the design process. For example, locations where orbital routes and radial corridors cross each other should be considered as locations of bus stops for transport interchange efficiency.

Gradients and crossfalls of footpaths are to be compliant with the relevant standards and/or guidance. Dropped kerbs are to be provided as required.

Pedestrian crossing points should be provided with tactile paving in each direction of approach, as indicated in the publication 'Guidance on the use of Tactile Paving Surfaces' by the UK DETR Nov 98. Further guidance on the use of tactile paving may also be taken from Section 13.3 of the Traffic Management Guidelines (DTO 2003).

13 Signage

The signage provided along the CBCs should be designed in accordance with the Traffic Signs Manual (TSM). While it is recognised that the TSM is advisory only, it is regarded as best practice and non-compliance with it brings a high risk of claims. Accordingly, the practical status of the TSM is more than discretionary guidance.

The BusConnects project has enabled a fresh look at the existing signage provision for Irish road schemes, and this is being assessed by the NTA in parallel as a separate exercise with a view to amending and/or supplementing existing legislation in this regard.

13.1 Proposed use of Left-turn Flashing Amber Arrows

Figure 39: Suggested 'Mini-Yield' Sign for use with Flashing Amber Arrow

Due to the novel nature of some of the BusConnects proposals, in particular the provision for left turning vehicles at signalised junctions to proceed under a Flashing Amber left-turning arrow while yielding to cyclists continuing straight, additional signage will be required.

Figure 39 shows the suggested use of a 'Mini-Yield' Sign with a Flashing Amber Arrow. Figure 40 shows a proposed additional sign to the Traffic Signs Manual to warn turning motorists to yield to cyclists in the cycle lane to their left.

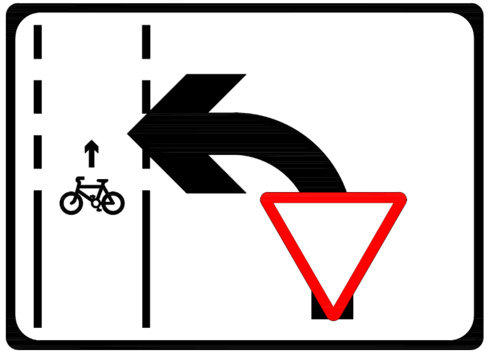


Figure 40: Proposed Bespoke Left-turn Yield Signage

Application/Implementation

- To be placed before a junction where there is a conflict between cyclists proceeding straight ahead and left turning vehicles.
- To be implemented in conjunction with a flashing amber left-turn direction arrow and yield sign at the junction.

Amendments

- New sign to be included in the Traffic Signs Manual.
- Appropriate legislation to be amended if sign is considered a regulatory requirement.
- Agreement on the inclusion of an additional 'mini-yield' sign under the flashing amber left-turning arrow.

13.2 No Left Turns from Bus Lanes

As mentioned in Section 7.3.1, new bespoke signage is proposed for the approaches to Junction Type 1 where a ban on left turns from the bus lane is proposed to improve cyclist safety and bus journey times. In this scenario, any taxis, buses or coaches using the bus lane but wishing to turn left off of the main CBC corridor, will be asked to exit the bus lane and merge with general traffic, and the left turn will be made from the general traffic lane. Signage with the message 'NO LEFT TURN FROM BUS LANE' is proposed as illustrated in Figure 19.

14 Traffic Signals

Junctions represent potential journey time constraints along any CBC corridor. Delays at junctions for buses can significantly impact the transport service performance and reliability. Traffic signals, and the priority afforded to buses, therefore form a significant element of the design of any Bus Corridor.

The following should be applied at signalised junctions (See also Section 7.4 of this Design Guidance Booklet):

- Bus Lanes should be signal-controlled through all main junctions.
- The traffic signal staging/phasing should be developed to facilitate bus priority (i.e. providing bus phases/stages to ensure that buses can be operated at any stage of the cycle). This will require stage skipping within the traffic signal design (subject to local authority agreement and compatibility with UTC system). The traffic signal staging/phasing should be agreed with the relevant local authority for each signalised junction.
- In instances where the bus lane cannot continue to the signal stop line and left-turners must turn from in front of bus lane, the interaction between buses and general traffic will be controlled by appropriate road markings and / or signage to clarify priority arrangements.
- Vehicle detection should be provided on all approaches at each of the signal-controlled junctions to detect when a bus is approaching a junction. The methods of Bus Detection (for the purposes of providing priority) may vary from junction to junction and will be dependent on the layout of the signalised junction and its proximity to other junctions along the route. The most appropriate method of bus detection should be agreed with the relevant local authority for each signalised junction.
- SCATS should be the normal method of control at signalised junctions along the length of the scheme. This should include priority measures utilising AVLS, such as the implementation of Public Transport Information and Priority System (PTIPS), to ensure high priority and integration with SCATS.
- Signal-controlled junctions should be capable of operating efficiently and with priority for buses with Vehicle Actuated and Fixed Time control as fall-back modes.
- Pedestrian and cycle signals should be provided at all signalised junctions.
- The location and type of traffic signal equipment (signal heads, detection, poles locations, use of overhead mast arms/gantries, etc.) will be agreed with the relevant local authority for each signalised junction.
- The traffic signal operation plans and timings may vary from junction to junction and will be dependent on the layout of the signalised junction and its proximity to other junctions along the route. The traffic signal operational plans and timings should be agreed with the relevant local authority for each signalised junction.

A closed loop of traffic signal ducts should be provided at each junction to facilitate traffic signal related equipment and cabling for Intelligent Transportation Systems (ITS). If ducting is not already existing between junctions or has no capacity for new cabling, new ducting for linking adjacent junctions should be laid between junctions.

15 Intelligent Transport Systems (ITS)

As part of active traffic management, traffic signals should be provided or upgraded as necessary at all key junctions along the CBC routes.

ITS should be provided at specific locations along the length of the CBC schemes where dedicated bus priority bus lanes cannot be provided for practical reasons.

The type, location, communications, technical, operational and functional specifications and infrastructure for such ITS measures should be agreed with the respective road authorities and respective departments.

ITS measures may include:

Real Time Passenger Information (RTPI)

- RTPI should be provided at all passenger waiting facilities, given that buses are fitted with an automatic vehicle location system (AVLS).

Variable Message Signage (VMS) and Parking Guidance Signage (PGS)

- VMS and/or PGS should, where practicable, be provided in advance of junction locations where traffic routing options may be deployed as part of corridor traffic management.
- The VMS and/or PGS location identification should consider provision of power, communications, visibility, constructability, spatial constraints etc.;

Close Circuit Television (CCTV) cameras

- CCTV should generally be provided at all signalised junctions.
- The CCTV locations should consider the provision of power, clear visibility, constructability and any spatial constraints.
- The CCTV masts should be positioned to minimise glare from the sun.
- It should be noted that ducting should be provided at each junction to facilitate power connection between supply points and traffic signal and ITS equipment.

16 Lighting

16.1 Lighting Along the CBC

A separate 'Road Lighting Basis of Design' is being developed for the BusConnects project and should be referred to in the first instance.

All new public lighting should consider the following:

- IS EN 13201:2003 Parts 1-4
- ET211:2003 'Code of Practice for Public Lighting Installations in Residential Areas'
- BS 5489-1 'Code of practice for the design of road lighting'
- Institution of Lighting Engineers 'Guidance Notes for the Reduction of Obtrusive Lights'
- In locations where road widening and/or additional space in the road margin is required, it is proposed that the Public Lighting columns should be replaced and relocated to the rear of the footpath where possible, and the existing removed once the new facility is operational.
- Where significant alterations are proposed to the existing carriageways; the existing public lighting arrangement should be reviewed in association with the Public Lighting Departments of the relevant Local Authority to ensure that the current standard of public lighting is maintained or improved.
- To determine where new public lighting is required or whether existing public lighting is to be improved / relocated, an inspection should be carried out in association with the relevant Local Authority, to identify any new column locations required for particular sections of the scheme.
- Applications for any power supplies required for new public lighting are to be organised by the relevant Local Authority.
- All new lighting should aim to minimise the effects of obtrusive light at night and reduce visual impact during daylight.
- Light Emitting Diode (LED) lanterns should be the preferred light source for any new public lighting provided.
- At junctions, stand-alone pelican crossings or zebra crossings, the appropriate LUX level of illumination should be provided.

16.2 Lighting at Stops

The design should include for the provision of lighting in covered areas, open areas and the passenger waiting areas.

The location of the lighting column should be dictated by light spread of fittings to give the necessary level of illumination (the columns at stations provide clearance for buses).

17 Utilities

There are certain areas along a CBC alignment where there may be a requirement for utility diversions. This could be due to a specific conflict or due to a particular utility or the service providers' requirements.

The extent of potential works, where there will be an absolute requirement to divert and also other possible scenarios (which might also require diversionary works to be carried out to accommodate service level agreements and reduce likely interruptions), are discussed below.

17.1 Utility Diversion Scenarios

Existing utilities will be assessed under the following headings to establish a requirement to divert or protect them in relation to the new construction works for the proposed CBC:

- Change in depth caused by CBC horizontal or vertical alignment solution.
- Change in lateral position within the highway (e.g. moving from footway into carriageway).
- Apparatus at risk during construction or changed risk profile due to the CBC once operational (e.g. adjacent overhead lines).
- Change in type of highway construction (e.g. changing from flexible to rigid construction type).

17.2 Utility Diversion Requirements

Particular areas of interest for utility diversion works include but are not limited to:

- Proposed bus stop locations.
- Re-grading of existing road surfaces (including replacing roundabouts with signalised crossroads).
- Changes in carriageway alignment; occupying median, thus, requiring additional paving.
- Requirement to alter traffic signal sequences at junctions.
- CCTV, public lighting, VMS and passenger information systems.
- Uncharted services.
- Future planning, accessibility and maintenance.
- Use of new surface materials – existing drainage capacity along the proposed route would need to be assessed and consequently increased in capacity, if required, following a complete drainage analysis.

Interface	Footway	Carriageway	Green Area	Rise/Fall	Additional Info
IW Water Mains	900min.	900min.	900min.	22.5 degrees (but can take 45)	Irish Water Technical Standard IW-TEC-1000-01: 250mm or less- 900mm cover. 300 to 400mm -1050mm cover. 450 to 500mm -1200mm cover. 600 to 900mm -1300mm cover. 1000 to 1500mm -1500mm cover.
IW Water Service	600	750	600	N/A	
IW Sewer	900	1200	900	Depending on hydraulic requirements	
Gas Main	600 (750 if trafficked)	750	600 (750 if trafficked)	22.5 degrees (but can take 45)	
Gas Service	600 *	600	600	N/A	*can reduce to 375mm within 1.5m of meter box.
Eircom	450	750	750 Verge 450 Parks	No greater than 1m in 7m	
Virgin	450	750	450	No greater than 1m in 7m	
ESB HV (38kV & above)	950	950	950	2.5m bending radius.	950min. to Elec. Trefoil. 750min. to comms.
ESB MV	450*	750	750	1.2m bending radius min. although 2.5m encouraged	*450mm applies to "established footways". 600mm is desired and required in new footways.
ESB LV	450*	750	750	1.2m bending radius min. although 2.5m encouraged	*450mm applies to "established footways". 600mm is desired and required in new footways.

Table 2 Minimum Cover to Underground Services and Utilities

Certain routes will require a re-grade of the carriageways surface. In such instances this may reduce the existing cover to the underground services.

There are particular requirements for cover to each service laid as illustrated in Table 2.

Note: Should the alignment reduce the cover substantially, then the service affected should be assessed for either diverting or lowering in-situ.

17.3 Existing Uncharted Infrastructure

Utility and services information is gathered through a number of different methods:

- utility record information
- Utility Survey to PAS 128 incl. GPR (Ground Penetrating Radar) & Service Scanning
- Slit-Trenching

The radar mapping and the slit-trenching would often highlight unchartered services which are most likely abandoned, in many cases the identification of these services is not possible due to their age and the type of material used.

It is standard practice to assume that these services are still live and as such, once excavations are underway, they need to be tested and decommissioned and/or removed as necessary.

During the construction phase of utility works, the finding of unchartered services or shallow services can on occasion lead to additional utility works, although the comprehensive surveying and assessments mitigate this as much as possible.

Table 3 below shows methods for establishing existing positions of utilities affected by proposed CBC construction.

17 Utilities

Method	Pros	Cons
Utility Record Information	• With certain utilities (ESB) additional information may be present highlighting depths, distance to kerbs/buildings and configuration of the cabling/ducting. • Records also give an indication to the historical abandonment of ducting and pipework. • Having the latest record information from each of the relevant service providers should give an accurate account and quantity of the ducts and pipework that they have present underground.	• Record information is rarely point accurate and should be used as a guide only as to the position of the ducting and pipework present. It has been found that the quantities are usually quite accurate. • Chambers and manholes are not usually detailed on records so size and special dimensioning is not available without a comprehensive survey being undertaken. • The latest as-laid records have not always been up-dated to reflect the most recent services laid.
GPR(Ground Penetrating Radar)	• Comprehensive view of interactions of utilities in congested areas. Providing designers with a very good understanding of constraints and requirements. • Overall approximately 80% Accurate. • 3 Dimensional information available. • Non-invasive process. • Minimal Traffic and/or associated pedestrian management. • Suitable for all surfaces except overgrown rough terrain. • No permits required, liaison with the local authorities on method of work and agreement to hours of presence on site is usually all that is required.	• Some utilities can evade capture by radar (particularly Gas/Water). • Some difficulties encountered in interpretation of data collected in the survey during the post-processing process. Therefore, can be quite iterative when liaising with the utility companies for confirmation. • Quality of the interpretation during the post-processing: the accuracies or otherwise is dependent on which mapping company completes the task, the last contracts received went to two different contractors and it was found that one was more accurate than the other.
Slit Trenching	• Accurate and exact, however, this is limited to within the excavated focus area only. • Suitable for all terrains and surfaces, very few exceptions. • Ability to send survey team to survey precise GPS (XYZ) coordinates of exposed utilities within the excavated trench. • Invasive process requiring Local Authority traffic permits and agreement. • Relatively quick to complete once permits and agreement is in place.	• Comprehensive traffic and pedestrian management required to be agreed in advance of works with local authorities. • Invasive / excavations. Noise, vibration and dust/debris being present during the process. • No ability to recheck of queried data received, except through photographs taken while the trench is open. • Strict time restrictions placed upon the contractor with regard to hours of work.

Table 3: Methods for Establishing Existing Underground Utilities

17.4 Future planning, Accessibility and Maintenance

As part of the assessment of utility impacts it is also considered as to how the designed diversions may be accessed for maintenance and repair in the future.

It is sometimes deemed necessary to place in strategic joints and crossings to allow a service provider to connect into their existing supply without interference with the system during its operational phase.

Each proposal is assessed on an individual basis and only those deemed necessary are placed into the design,
assessments are also done to see if there is potential for the service providers to take a feed from an adjacent supply to try to reduce the amount of additional services placed as part of the utility works.

Manholes and chambers should be sited in locations which give safe access and egress to the maintenance crews who have to access them, and if required be rebuilt to modify the access points rather than a complete relocation of the chamber.

Rebuilding in-situ means that all of the ducting entering and exiting, including the joint-work contained within the chamber (if at adequate depth), can remain in place and be protected during the re-build of the chamber.

17 Utilities

17.5 Required Areas of Diversions

17.5.1 Bus Stops

This would mean that all services within a distance prescribed by the local authority and/or utility provider should be assessed in full to see if there is a requirement to move them away from the stop area.

For the most part this will affect chambers and manholes but there will also be requirements to divert gas and water as joints and valves should be accessible.

With respect to communication services, depending on where the chambers are located, there might be little impact and requirement to relocate the ducting, as once the chambers are accessible, then future cable pulling is possible.

The design of bus stops may encroach into the existing footway and result in the widening of the carriageway. In this case the considerations described in section 17.5.4 will apply.

17.5.2 Congested Junctions

Within the city centre areas there may be a requirement to divert additional utilities particularly at congested junctions and areas which may give rise to complex traffic management plans during future maintenance of services.

Utilities should be assessed on a case-by-case basis to see if diverting associated chambers and manholes to more suitable locations where viable would be best practice.

The same assessment should be carried out if the junctions are substantially altered.

17.5.3 Reduction in Carriageway Cover

As a consequence of alignment design there are times when the vertical profile of a carriageway must be lowered.

A primary example of this is where there is a bus stop adjacent to buildings, whereby lowering of the vertical alignment and carriageway is required to maintain the existing thresholds to the buildings.

This re-grade can be up to 200mm in depth which leaves the existing services at a level higher than the required standard cover.

Any services below a carriageway must be at a minimum depth (See Table 2) and may have to be lowered or protected in-situ as required.

17.5.4 Realignment of Carriageway

In conjunction with re-grading the vertical alignment or separately, there are sometimes requirements to re-align kerbs.

In an instance where a kerb is being re-aligned further into a carriageway there should be no problem from a depth perspective for utility cover.

However, chambers may need to be re-located to accommodate the new kerb line.

It would also require chamber and manhole access lids to be adjusted to meet the new level of the footway which requires removal of the top layer of the chamber and re-setting of the chamber access lid to suit.

Where the opposite scenario arises, and the existing kerb line is being re-aligned further into the footway it is likely that cover over existing utilities will not have provided for carriageway requirements. In this scenario utilities may have to be protected in-situ, lowered/relocated locally or diverted.

17.6 Utilities Summary

Where the footway utility service falls within the carriageway area it will likely need to be lowered to achieve carriageway utility minimum cover.

This may also require manholes and chamber accesses to be modified or diverted to suit.

This will present options to table to both the service or utility providers for agreement and approval, but also to the other in-house design disciplines allowing for a collaborative and cohesive finalised design.

In comparison to, say, the diversionary requirements of an LRT system for example, there is significantly less requirement for utility diversions on core bus corridors and through close collaboration between the design disciplines, this could be further reduced by designing out conflicts during the design process.

18 Drainage

A separate Design Guidance document for drainage is being developed for the BusConnects project and should be referred to in the first instance.

- All new surface water sewers shall be designed for no flooding in return periods less than 30 years.
- Physical drainage investigations are required to precise details of existing drainage along the route, the size, number, depth, and location etc. of each drainage infrastructure present along the route; this information is vital to ensuring a robust drainage design that is cognisant of all existing drainage present along the proposed route and accommodates realignment where works are required.
- The additional hard standing area resulting from the introduction of the proposed CBC scheme should be assessed with reference to the capacity of the existing surface water drainage infrastructure within Dublin city and immediately along and adjacent to the CBC routes. A determination to be made as to what, if any, additional infrastructure is required to accommodate the surface water run-off from the CBC scheme.
- The drainage design may require alterations to the existing drainage system (adjacent to the scheme route) and further identification regarding suitable storm flow attenuation for the scheme may be required.
- All run-off from road pavement or any other paved areas are proposed to be collected in a positive drainage system and not be discharged over the edge of embankments. Spillways are not therefore proposed.
- The drainage design should include suitable measures for draining the sub-grade of road pavements and for the draining of areas which are confined by existing buildings and the proposed road edge.
- Side-entry kerb drainage should be considered for all new kerblines that must accommodate rainwater run-off. Bus stop lay-bys should be designed with reversed cross fall to avoid complete reconstruction of the roadway camber and relocation of the drainage system.

18.1 Storm Water Management

It is important to check the effect (erosion and flooding) of the design on the upstream and downstream infrastructure, especially where the natural run-off is concentrated.

The storm water drainage within the CBC road reserve should thus be designed in such a manner as to ensure that the run-off from these structures is conveyed in a controlled manner that will not adversely affect upstream, adjacent or downstream properties.

Where the existing downstream system is clearly inadequate to accommodate the excess storm water run-off from the drainage structures, the following storm water management facilities must be investigated:

- The retarding of the run-off by means of detention facilities. The effect of possible backwater must be checked and investigated; and
- The provision of emergency flood channels to discharge the excess run-off into the existing downstream major drainage system.

18.2 Sustainable Urban Drainage Systems (SuDS)

Where practicable, and in new areas of public realm gained as part of the design, a sustainable drainage system should be considered in the form of rain gardens, swales, tree pits etc.

The Greater Dublin Strategic Drainage Study introduces SuDS and the available techniques to control the quantity and quality of runoff. It provides guidance on the selection of SuDS for particular sites and discusses issues such as operation and maintenance, cost effectiveness, recreation and amenity, habitat potential and safety.

19 Pavement

A separate Design Guidance document for pavement surfaces is being developed for the BusConnects project and should be referred to in the first instance: "Pavement Investigation and Design Strategy".

The CBC pavement design should seek to address problems identified on previous bus corridor schemes, in terms of rutting and on-going maintenance issues. The prevailing principle to be followed by the CBC project pavement design will be the provision of a low maintenance 'stiff' pavement construction. Pavement structures are here defined as general traffic carriageway, bus lanes, on-road cycle lanes, off-road cycle tracks and footways. The design of each type of pavement structure should be based on the following five elements:

- Forecasted traffic loads,
- Proposed road geometry,
- Current pavement structure make up,
- Current pavement surface and structure condition, and
- Load bearing capacity of the subgrade.

Forecasted Traffic Loads

The calculation of traffic loads in million standard axles (msa) for each part of the BusConnects network and for each type of pavement structure is the base for the design of each pavement structure, be it new or rehabilitated. Particular attention should be given to areas of pavement with specific loading requirements such as:

- On-line and off-line bus stops,
- Bus terminus stations,
- Bus lanes (channelised traffic),
- Loading bays, and
- Trafficked cycleways and footways.

New carriageway pavement structures such as widenings for general traffic, bus lanes or on-road cycle lanes should have a design life of 40 years. The rehabilitation of existing carriageway pavement structures should be done in line with volumes 1 to 3 of the DTTAS (Department of Transport, Tourism and Sport) manuals published by the RMO (Road Management Office):

- Rural Flexible Roads Manual – Pavement Condition Index (vol.1 – 2013),
- Urban Flexible Roads Manual – Pavement Condition Index (vol.2 – 2013), and
- Urban Concrete Roads Manual – Pavement Condition Index (vol.3 – 2013).

Surface course materials specified for any new or rehabilitated pavement area should have a minimum lifespan of 10 years.

Proposed Road Geometry

The design of the BusConnects network is bringing geometry changes to an existing road network. Such geometry changes include:

- No changes,
- Widening,
- Narrowing,
- Horizontal realignment leading to relocation of pavement longitudinal joints (in relation to location of wheel tracks),
- Increase in vertical alignment,
- Decrease in vertical alignment,
- Relocation of traffic islands, and
- Any combination of the above.

Widened and narrowed areas of pavement will respectively identify needs for pavement full depth construction or removal. Where vehicular trafficked pavement areas are being horizontally realigned, attention should be paid to the relocation of longitudinal joints so as to not fall into the wheel tracks.

Changes of vertical alignment is relevant to pavement areas to be rehabilitated. Increase in vertical levels is likely to add structural life to the existing pavement. Decrease in vertical levels will, however, remove structural life to the existing pavement. It is therefore essential to ensure that the rehabilitated pavement will still be able to sustain the forecasted traffic loads. Where vertical levels are being lowered resulting in the existing pavement being inappropriate for the forecasted traffic loads, the existing pavement should be structurally rehabilitated. The identification of traffic islands removal, addition and relocation will dictate where the pavement should be fully reconstructed.

Current Pavement Structure Make Up

The pavement structure make up of areas to be retained should be investigated in order to allow for the design of widened areas. A GPR (Ground Penetrating Radar) survey should be conducted across the BusConnects network to collect such information.

Current Pavement Surface and Structure Condition

Understanding the condition of the pavement areas to be retained is essential for the rehabilitation design. The preliminary design will rely on condition data from the RMO and TII (Transport Infrastructure Ireland). A Visual Condition Survey will also be conducted to identify areas of great structural distress reflected to the surface of the pavement. It will be down to the designer in charge of the detail design to procure further appropriate pavement surveys. Such surveys should be conducted no earlier than 12 months before construction to ensure currency of data.

Load Bearing Capacity of the Subgrade

Where the pavement design identifies a full depth construction or reconstruction, this includes the pavement foundation. The preliminary design of the foundation should either be based on survey data or the assumed lowest permitted CBR (California Bearing Ratio) of 2.5%.

Pavement Materials

The choice of pavement materials should be based on the following considerations:

- Which pavement structure is the most appropriate and compatible with existing pavement (i.e. Fully flexible vs. Flexible Composite vs. Rigid pavement),
- Which materials are most appropriate from a noise, permeability, colour, texture, etc. perspective,
- Which materials, from a whole lifecycle perspective, provide the best value in terms of environmental impact, durability, maintainability, repairability, recyclability, cost, etc.,
- Do areas with specific loading require the use of specific materials,
- The choice of surfacing materials should be in agreement with the Landscape Architect.

The ambition in terms of pavement materials should be to reuse or recycle as much of the excavated materials as possible within them. The specification of materials and processes with a reduced environmental impact should be prioritised (e.g. Low Energy Bound Materials, Warm Mix Asphalt, reclaimed asphalt…).

Reuse and Recycling Considerations

Opportunities for reuse and recycling of secondary materials should be identified and quantified throughout the design process. Current opportunities include but are not limited to:

- Incorporation of minimum 20% of Reclaimed Asphalt into new base and binder layers of the pavement,
- Reclaimed Asphalt to be reused in LEBM (Low Energy Bound Materials) materials where appropriate,
- Excavated capping layer material to be reused as new capping material if compliant with current standards,
- Excavated subbase layer material to be reused as new subbase material if compliant with current standards.

20 Landscape Design

Landscape, in the context of the CBC project, refers to the built and natural elements that define a wide variety of streetscapes, roadways and public open spaces along transport corridors connecting the suburbs, outer city and city centre. Landscape includes hard and soft landscaping, but also includes 'townscape' and 'public realm', with all aspects contributing to the character and identity of different sections of corridors.

- As part of the overall design approach to the CBC project, it will be necessary to facilitate the introduction of continuous, uniform and legible infrastructure that optimises movement and safety for all road users, while retaining and enhancing the individuality and distinctiveness of suburban and urban places.

20.1 Character

The linear nature and length of project corridors is such that their character and scale varies significantly. Character is informed by both context and function. Context and function changes along corridors, and can include:

- Sections that are compact and urban, either traditional or contemporary, and with a high proportion of pedestrian and cycle use as well as vehicular use;
- Sections that are established or developing suburban settlements and local centres, with lower intensity of pedestrian and cycle use, and catering for high volumes of local and through vehicular traffic; and,
- Outer suburban sections that have a primary function of connecting and facilitating movement, with reduced pedestrian use, strong cycle demand, and generally high volume and higher speed vehicular traffic.

The built and natural elements of streets and roadways include the carriageway itself, and some or all of verges, medians, cycle and pedestrian facilities, street trees and furniture, and boundary walls, fences and hedgerows. The edges of streets are defined in a variety of manners, and can include buildings directly facing the street, buildings set back from the street with private gardens or grounds, and public open spaces.

20.2 Introducing New Elements

The CBC project will necessitate changes to the allocation of existing carriageway space in order to facilitate dedicated bus lanes. In many instances, the carriageway space, including allocation for cyclists, will need to be increased, requiring realignment of some or all of existing kerb lines. This in turn, will result in changes to the edge condition of the streets, including modifications to existing verges, footpaths and street trees.

Where space is limited, and where traffic management measures alone cannot provide the necessary space, realignment of private boundaries will be required to deliver the necessary space. Where private boundaries are realigned, the private property boundary will be reinstated to match (or enhance in particular cases) the original boundary.

In general, new infrastructure and upgrade of existing infrastructure will be to current engineering design standards as described in preceding sections of this guidance, as well as details and design principles described within this design guidance booklet. Where deemed necessary, the engineering design may be adapted to integrate with the specific details or character of particular locations.

The role of landscape and public realm design is to assist in integrating such infrastructure within the existing streetscape in a manner that responds to the existing streetscape.

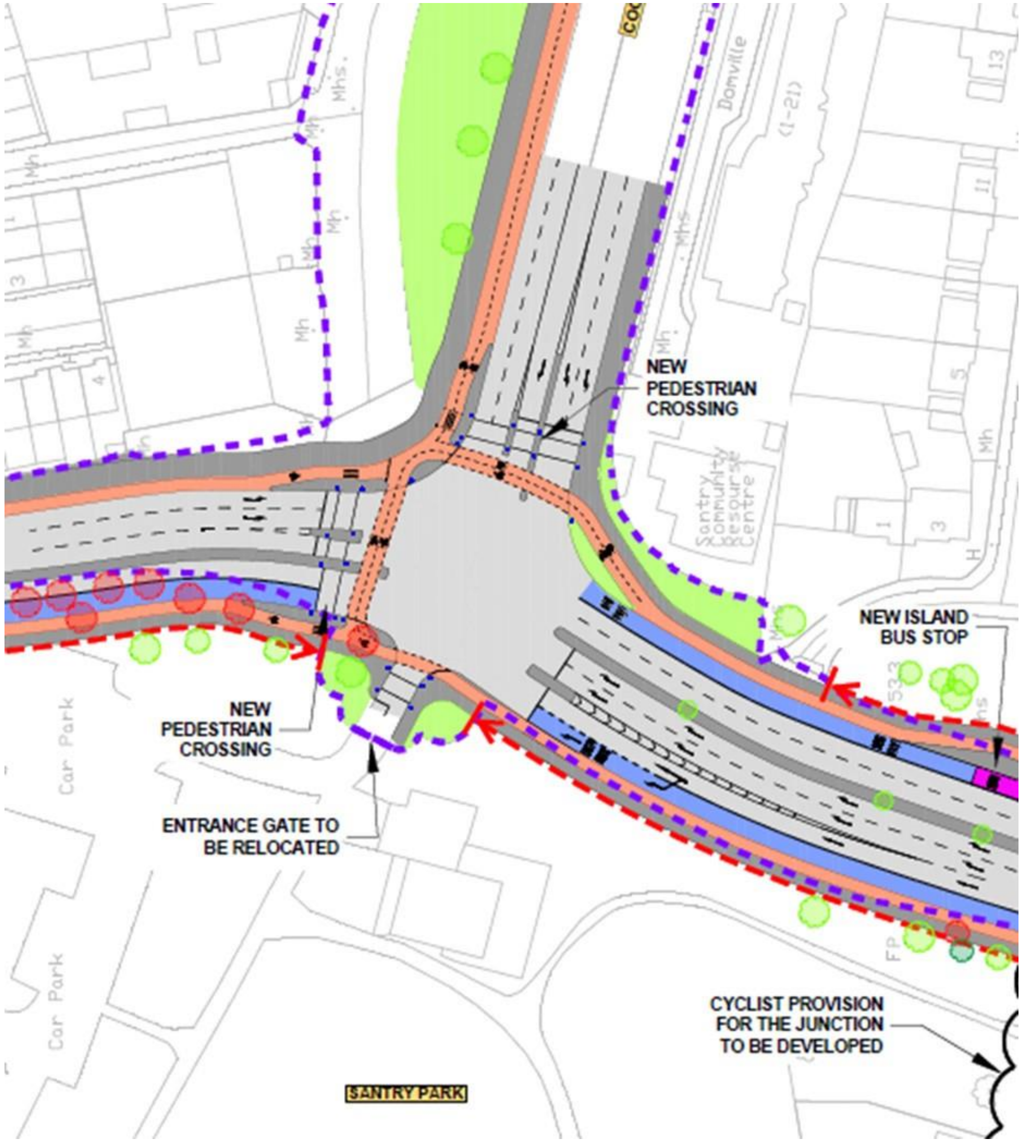
20 Landscape Design

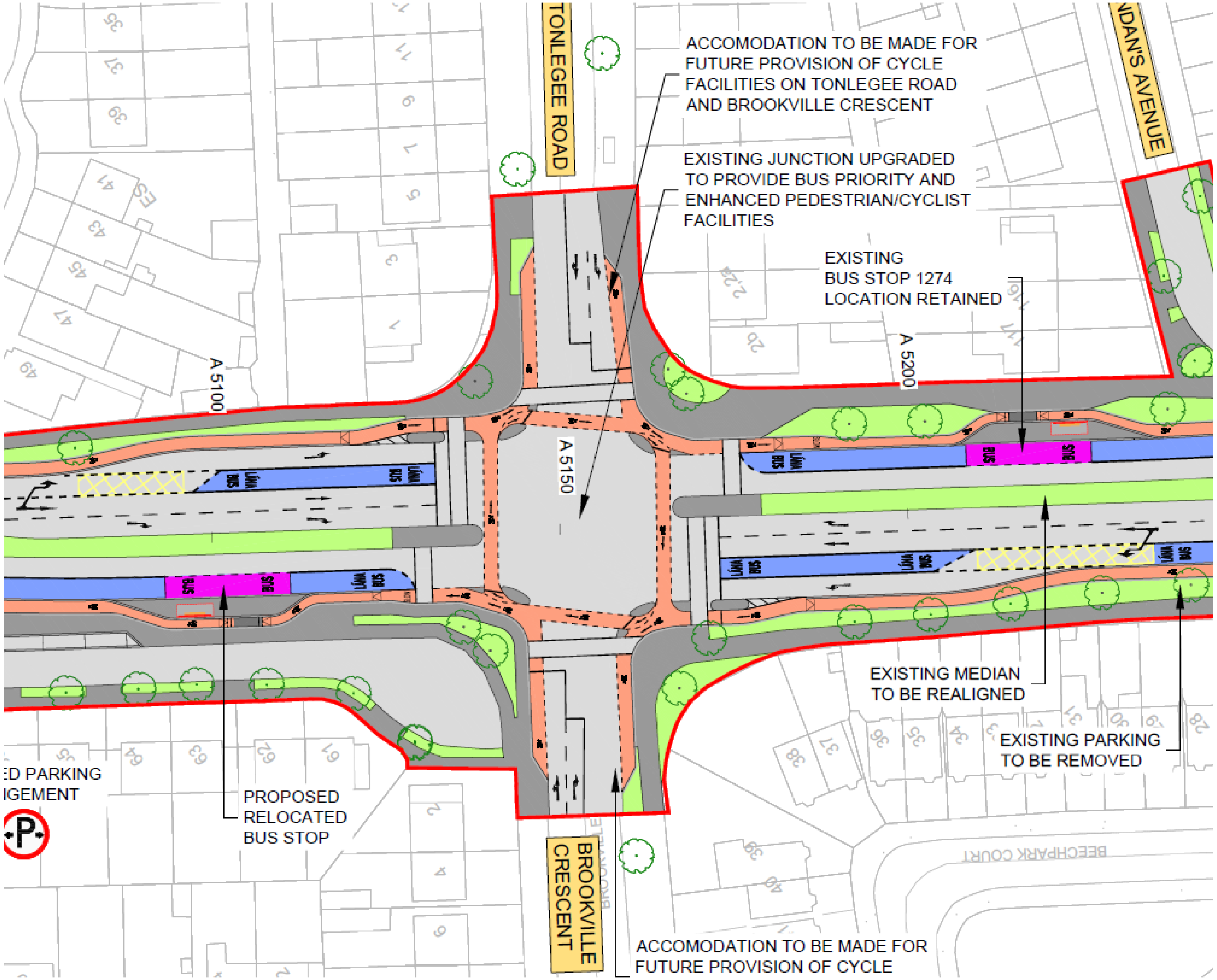
20.3 Landscape and Public Realm

There are a number of overarching objectives for the landscape and public realm design, including:

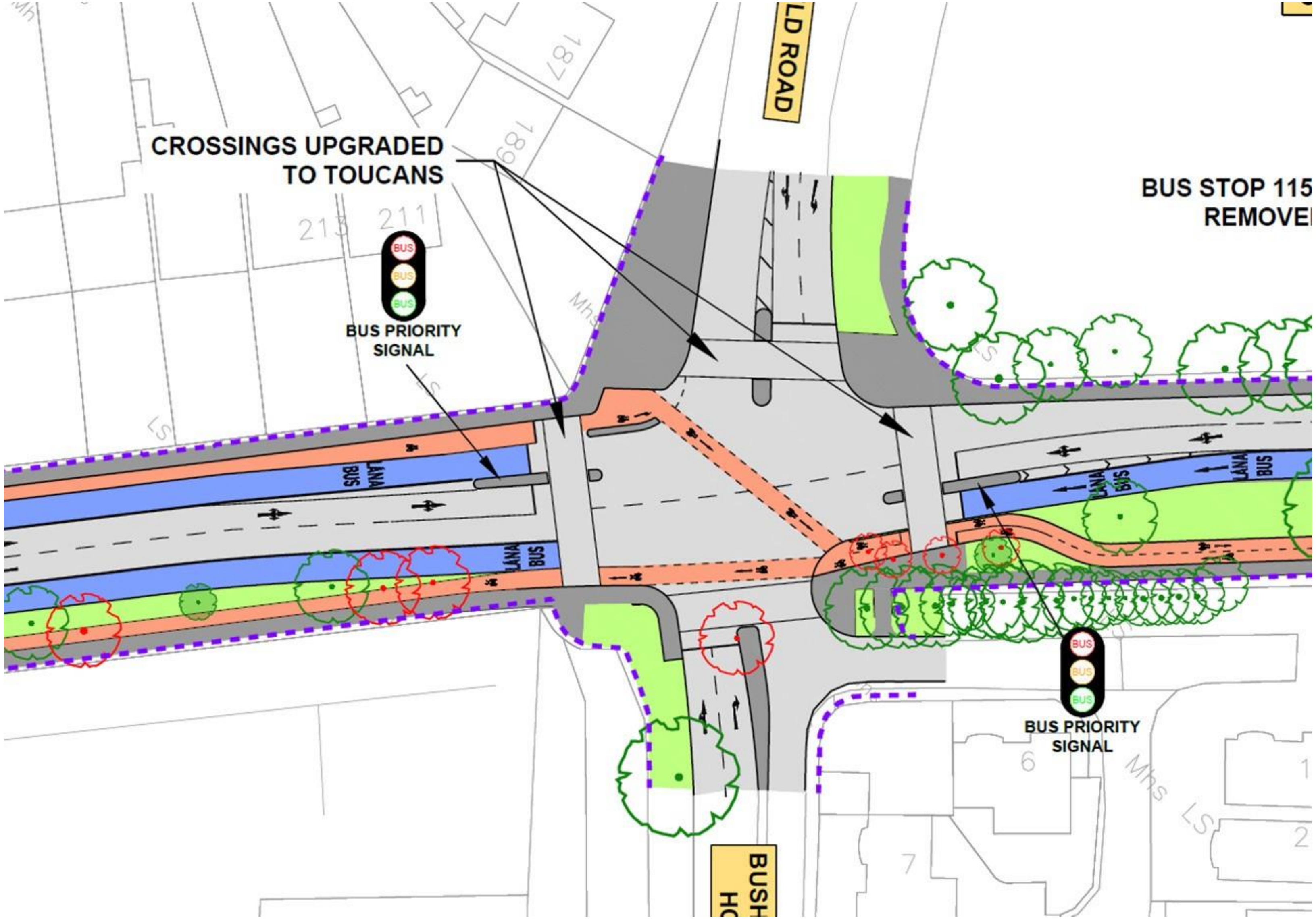
- Identifying the defining characteristics of each section of each corridor that contribute to the identity of each locality, including:
  - the type and quality of materials, soft landscaping and trees, and street furniture, etc;
  - the nature, scale, use, quality and character of adjacent buildings and lands.
- Identifying relevant planning policy pertaining to landscape, including views and vistas, protected structures, tree protection orders, green infrastructure, public realm objectives, architectural conservation areas, and biodiversity.
- Categorising sections or localities along route corridors that warrant different levels of intervention, such as:
  - Replacing and repairing like for like;
  - General upgrade of the type and quality of materials, or possible introduction of additional streetscape elements to enhance streetscape character;
  - Comprehensive upgrade of streetscape materials and components to establish or reinforce higher quality landscape and public realm at neighbourhood and urban nodes; and,
  - Interventions to historic streetscapes, or streets comprising heritage elements, so as to protect important features.
- Integration of new and revised infrastructure within existing streetscapes, including:
  - reinforcing, reinstating or enhancing the essential character of the streetscape;
  - identifying opportunities for extending or improving the landscape or public realm where additional space becomes available;
  - understanding the quality of existing pedestrian and cycling facilities, and ensuring upgraded facilities are continuous and of a high quality along streets, at junctions, crossings and entrances, and within local and urban centres. Upgraded facilities should encourage more pedestrian and cycle movement, as well as enhancing the character and appeal of streets and places as appropriate;
  - identifying design solutions to mitigate impacts on private properties, including reinstatement of property boundaries, reconfiguration of gardens and driveways, and replanting;
  - incorporation of arboricultural recommendations for management, maintenance, removal and replanting of trees within the streetscape and adjoining lands, and for the introduction of additional tree planting where appropriate. This should be cognisant of local area plans and Development Plans where necessary.

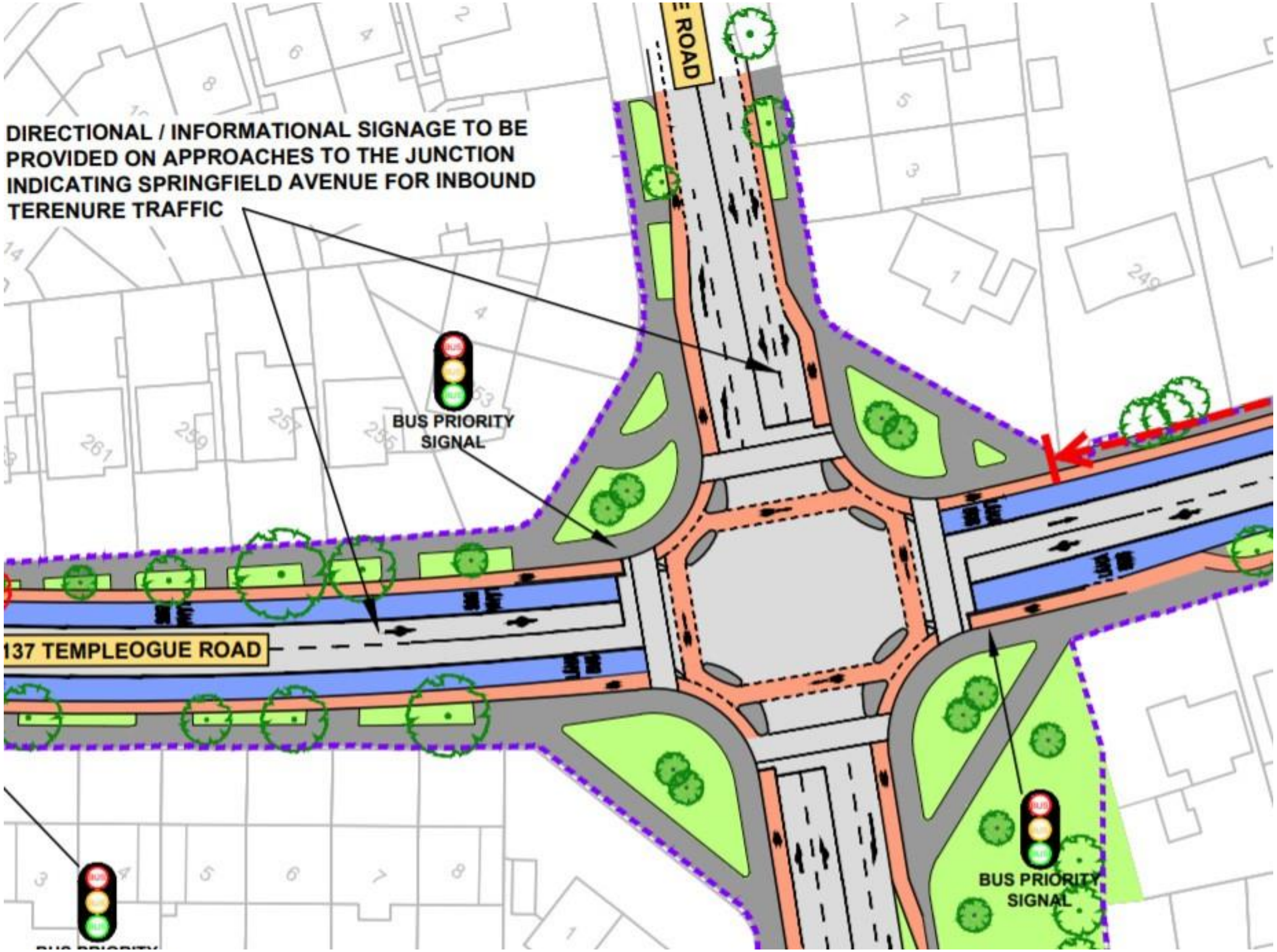
Appendix A
Suite of Sample Protected Signal Controlled Junction Layouts

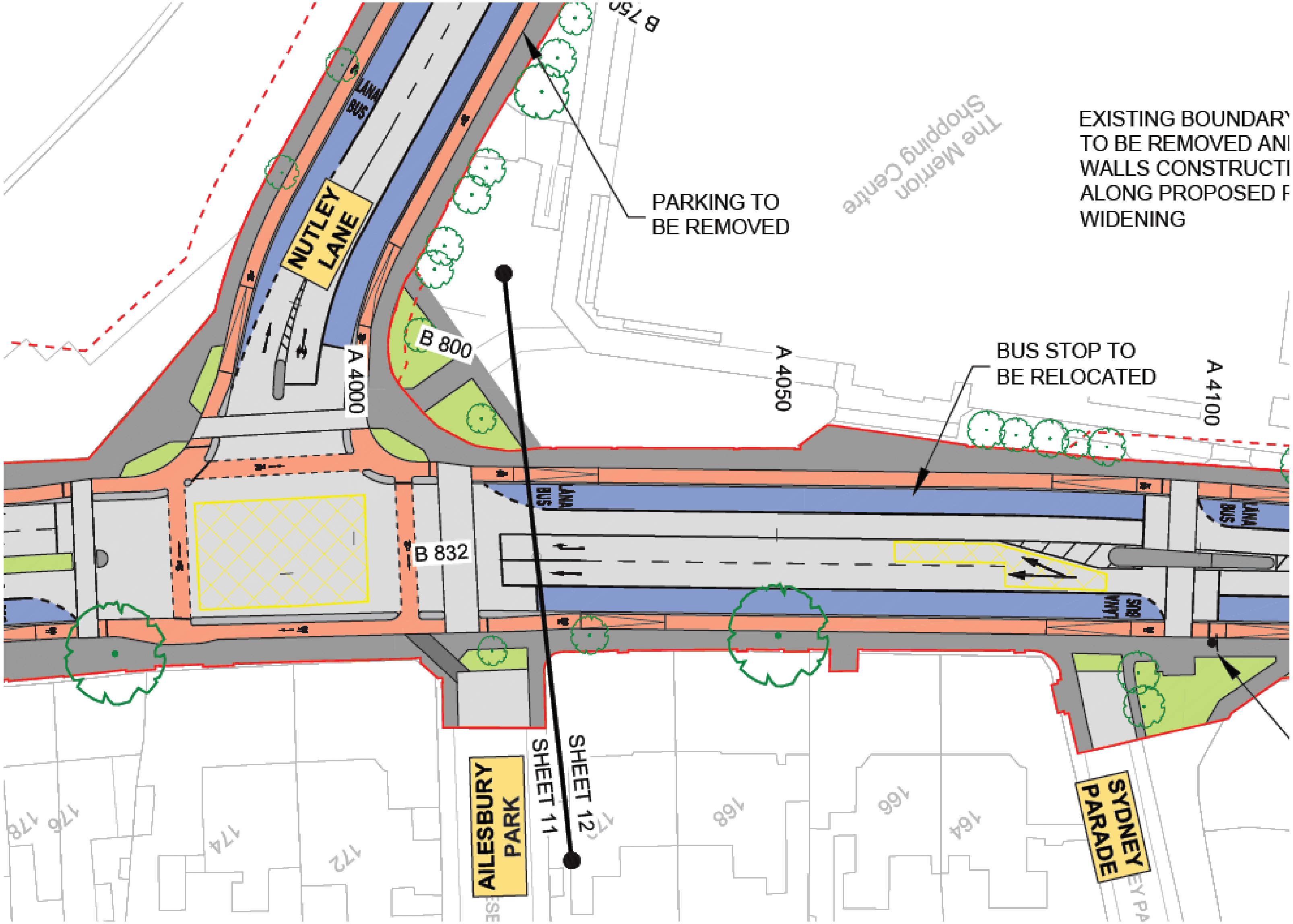

NEW PEDESTRIAN CROSSING
NEW ISLAND BUS STOP
NEW PEDESTRIAN CROSSING
ENTRANCE GATE TO BE RELOCATED
CYCLIST PROVISION FOR THE JUNCTION TO BE DEVELOPED
SANTRY PARK
Car Park
Car Park
Domville
Santry Community Resource Centre

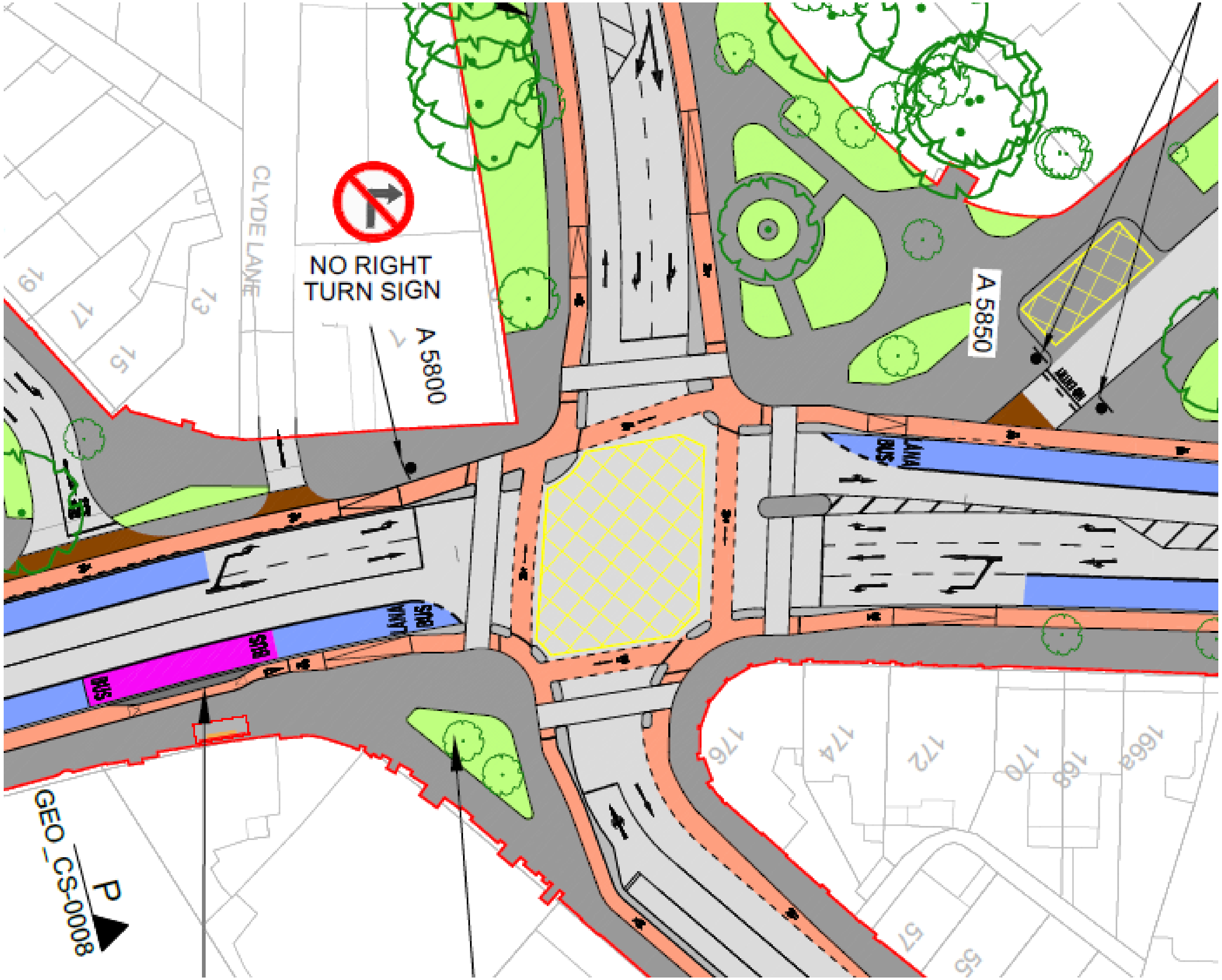

ACCOMODATION TO BE MADE FOR FUTURE PROVISION OF CYCLE FACILITIES ON TONLEGEE ROAD AND BROOKVILLE CRESCENT
EXISTING JUNCTION UPGRADED TO PROVIDE BUS PRIORITY AND ENHANCED PEDESTRIAN/CYCLIST FACILITIES
EXISTING BUS STOP 1274 LOCATION RETAINED
TONLEGEE ROAD
A 5100
A 5150
A 5200
EXISTING MEDIAN TO BE REALIGNED
EXISTING PARKING TO BE REMOVED
ED PARKING
IGEMENT
PROPOSED RELOCATED BUS STOP
BROOKVILLE CRESCENT
BEECHPARK COURT
ACCOMODATION TO BE MADE FOR FUTURE PROVISION OF CYCLE


TYMONVILLE COU
Mhs
Mh
Mh
3C 13D
BUS LANE
BUS LANE
BUS LANE
BUS LANE
BUS
BUS
BUS

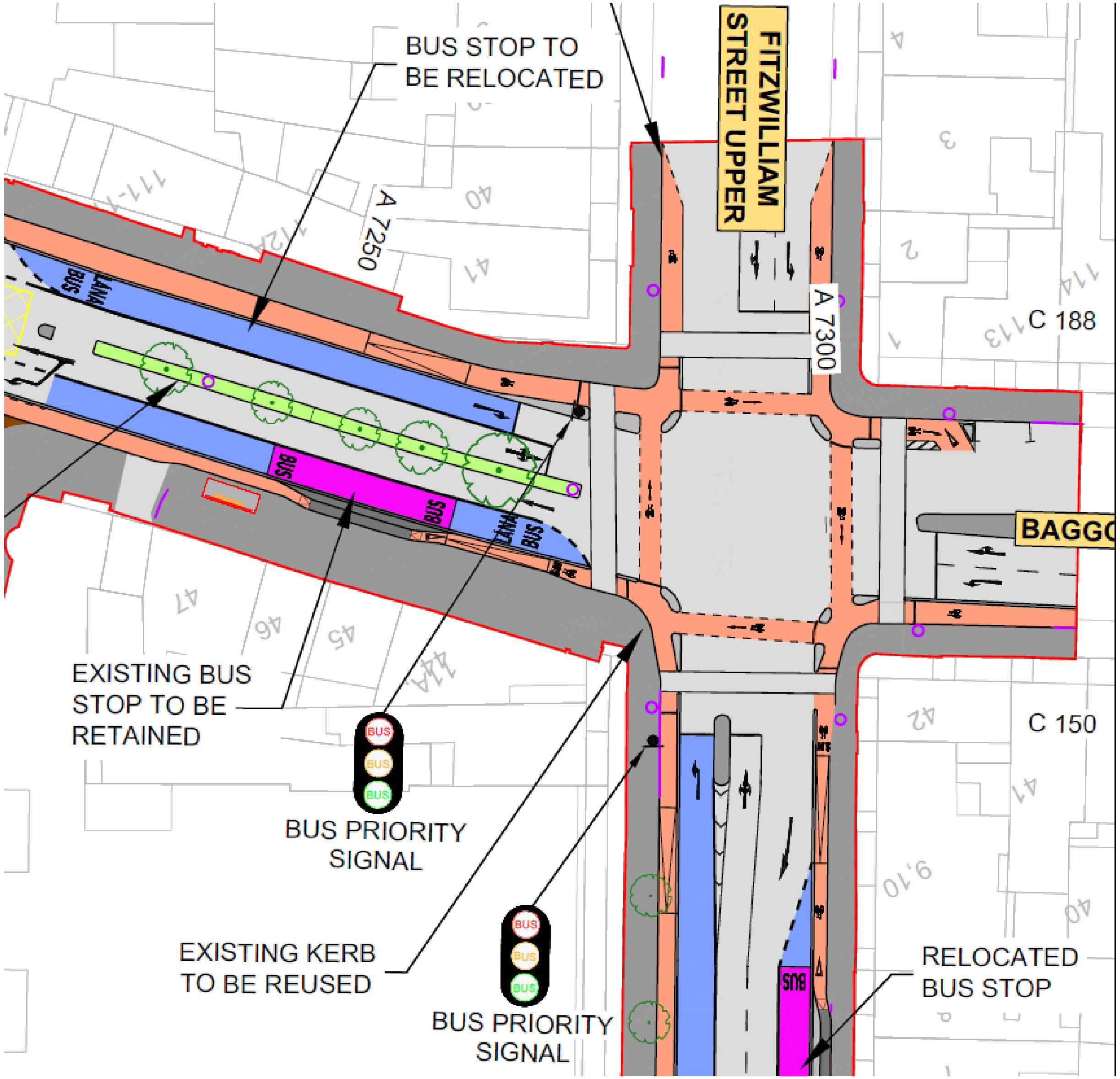

LD ROAD
CROSSINGS UPGRADED
TO TOUCANS
BUS STOP 115
REMOVE
BUS PRIORITY
SIGNAL
BUS LANE
BUS LANE
BUS LANE
BUS LANE
BUS PRIORITY
SIGNAL
BUSH
H


DIRECTIONAL / INFORMATIONAL SIGNAGE TO BE PROVIDED ON APPROACHES TO THE JUNCTION INDICATING SPRINGFIELD AVENUE FOR INBOUND TERENURE TRAFFIC
BUS PRIORITY SIGNAL
BUS PRIORITY SIGNAL
137 TEMPLEOGUE ROAD
ROAD


B 750
NUTLEY LANE
BUS LANE
PARKING TO BE REMOVED
The Merrion Shopping Centre
EXISTING BOUNDARY TO BE REMOVED AN WALLS CONSTRUCTI ALONG PROPOSED F WIDENING
B 800
A 4000
A 4050
BUS STOP TO BE RELOCATED
A 4100
B 832
AILESBURY PARK
SHEET 11
SHEET 12
178
176
174
172
168
166
164
SYDNEY PARADE

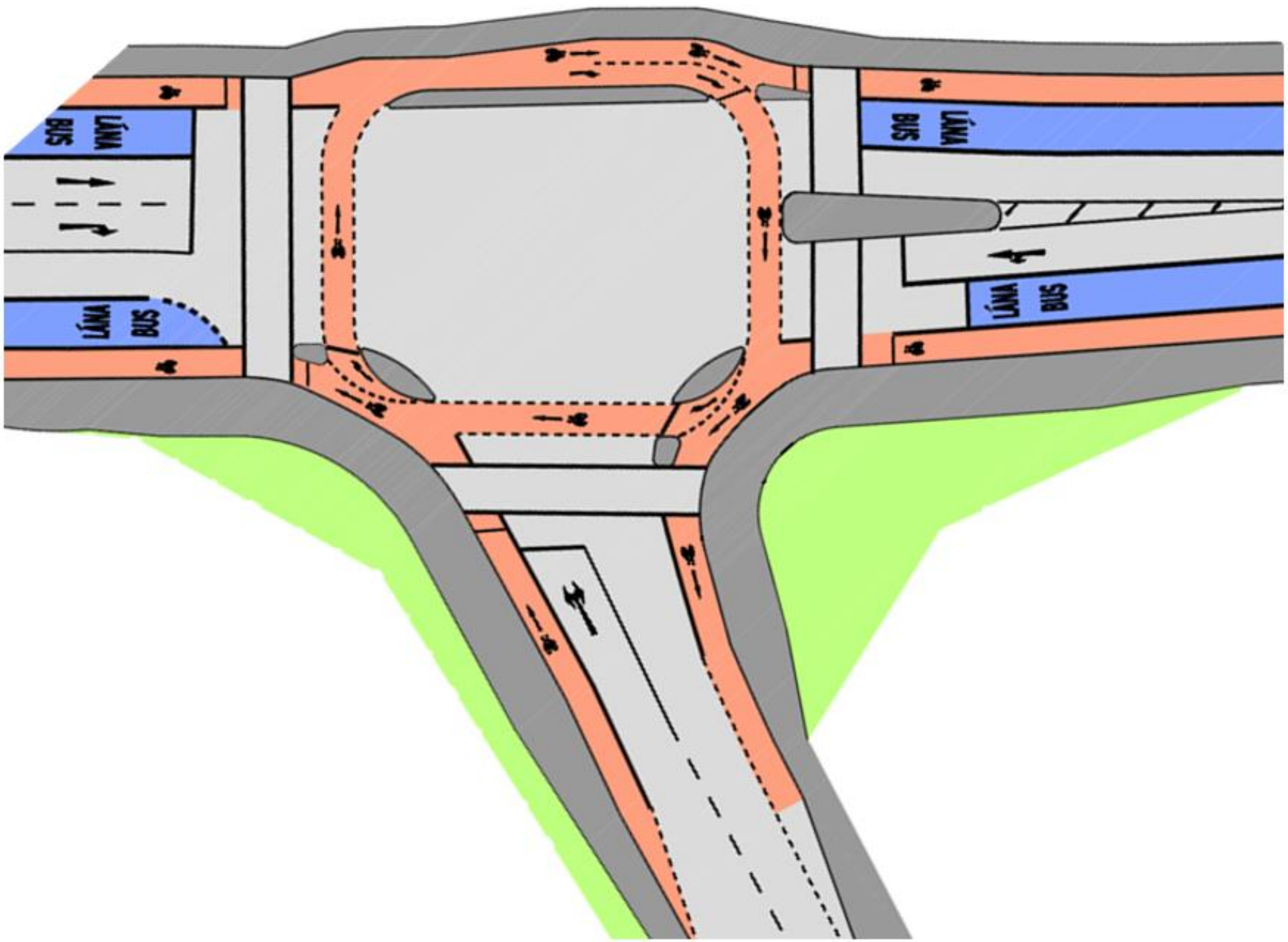

NO RIGHT
TURN SIGN
CLYDE LANE
A 5800
A 5850
GEO_CS-0008
P

Preliminary Design Guidance Booklet
for BusConnects Core Bus Corridors




700
750
EXCEPT BUSES
BUS LANE
EXISTING ROUNDABOUT TO BE UPGRADED TO SIGNAL CONTROLLED WITH PEDESTRIAN & CYCLE FACILITIES


A 5400
Car P
BUS LANA
BUS
BUS
BUS LANA
RELOCATED BUS STOP


BUS LÁNA
BUS LÁNA
LÁNA BUS
LÁNA BUS

Údarás Náisiúnta Iompair
National Transport Authority

National Transport Authority
Dún Scéine
Harcourt Lane
Dublin 2
D02 WT20

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