Guide Dogs

Designing for Inclusion

The accessibility challenges of some active travel infrastructure for people with vision impairment and other disabled people

UCL

PEARL

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1. Introduction

This research was commissioned by Guide Dogs in response to concerns expressed by blind and vision-impaired people, about accessibility to particular elements of infrastructure in the public realm. The research focuses on bus stops and footways which have been designed to accommodate cycle lanes and the associated element of continuous footways, where sometimes the distinction between being on a footway and being in a roadway could be blurred.

People should not be denied access to the activities of daily living by impositions of inaccessible barriers, whether these are economic, social, or infrastructural. The Public Sector Equality Duty (Sections 149 to 157 of the Equality Act 2010) requires local authorities to pay due regard to the needs of people with protected characteristics, set out in Section 149(7) (age; disability; gender reassignment; pregnancy and maternity; race; religion or belief; sex; sexual orientation). This research looks at “disability”, which includes blind and vision-impaired people and other groups of disabled people. For this research, when we refer to ‘blind’ people, we mean people with no residual vision. The duty means that public authorities must pay due regard to the need to advance equality of opportunities for disabled people (as well as those with other protected characteristics).

Bus stops, cycle lanes, and footways are all examples of infrastructure within the public realm that fall under this requirement. This research is intended to assist local authorities and others concerned with infrastructure, in the public realm, such as designers, planners, constructors, or users, in meeting this requirement. This is an issue not only of law but also of society and human behaviour. Ensuring disabled people have equal access to opportunity by means of accessible public spaces and infrastructure has enormous social benefits.

This research is necessary because the current street design and transport infrastructure, we have, fails to meet the needs of disabled people. Various attempts to support the provision of accessibility have been introduced. Such as the Disability Discrimination Act 1995 and its attending Regulations (now the Equality Act 2010 in England, Scotland and Wales) and guidance on accessible design (for example, Inclusive Mobility in its various revisions), but the fact remains that public infrastructure still has many examples of inaccessibility.

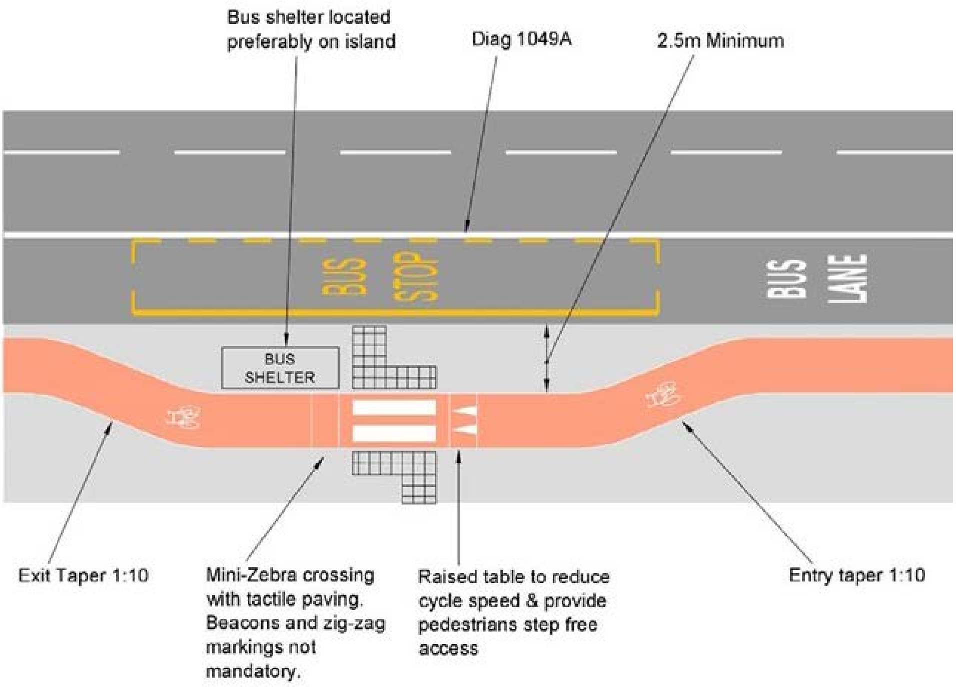
In recent years, the UK Government has encouraged active travel, focussing on the concept of “walking, wheeling and cycling”. This has resulted in a large increase in cycling, especially in busy cities such as London. This initiative has the welcome aim of creating an environment that is safer for cyclists and pedestrians. The results of this in London include the reduction in cyclist fatalities, from an average between 2005 and 2009 of 16.6 to 10 in 2021 and 7 in 2022. However, one of the results of the increasing amount of cycling on the road (from 1.1 million trips in 2015 to 1.26 million in 2023) [49], has been an increase in serious injuries to cyclists from a 2005-9, average of 721 to 989 in 2021 and 1,020 in 2022 [50]. This has highlighted the issue that although safety is improving for cyclists, in relation to fatalities, there is still much to do to protect them from serious injury. To combat this outcome, efforts have been made to protect cyclists by means of infrastructure. One of these measures has been the installation of cycle lanes, particularly segregated cycle lanes, to protect cyclists from traffic.

In the United Kingdom, some of the space needed for the cycle lanes has been taken from the pedestrian infrastructure. Sharing space between cyclists and pedestrians has inevitably resulted in some conflict between these groups of infrastructure users (some consideration of this is presented in the 'Differences in Speed' section of this report).

A particularly complex challenge arises when pedestrians require access to the roadway, for example, to cross the road or to board or alight from a bus. In these cases, the access issue involves several groups, each with their own needs: pedestrians, cyclists, traffic and buses. This means that there is ample scope for potential conflict between each of the groups in a space that could be highly contested. One solution to this that has emerged in recent years is the segregated cycle path-footway, where there is a delineator between the cycle path and the footway. The central delineator divides the pathway into two distinct spaces and thus removes the need to share the space.

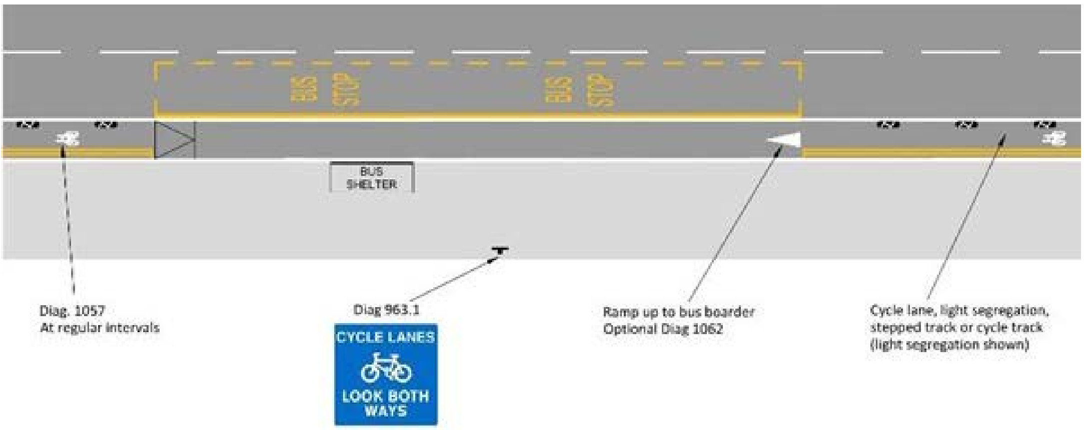
Another more complex example of an attempt to reduce conflicts between pedestrians, cyclists, buses, and traffic, is the bus stop. Where two main designs have emerged in recent years. The first of these is the Floating Island Bus Stop (Bus Stop Bypasses). Here the cycle lane is diverted from the kerbside of the roadway towards the rear of the bus stop, so that the kerb is free for buses to stop adjacently to allow boarding and alighting. The design for these is given in the Department for Transport's Guidance for Cycling Infrastructure Design LTN 1/20 and is shown in Figure 1.

Figure 1 - Design diagram for a Floating Island Bus Stop. Source: Cycle Infrastructure Design LTN 1/20 Department for Transport



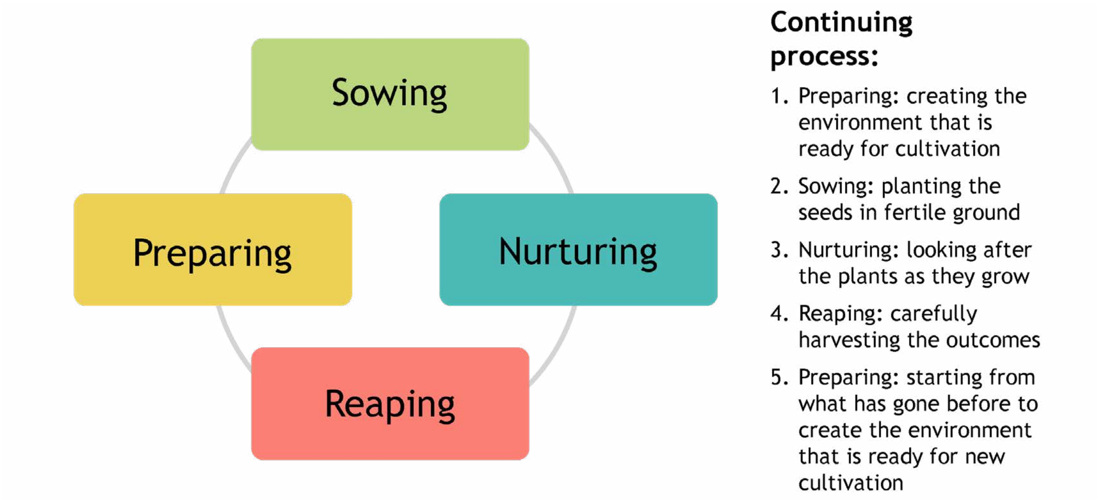
The second is the Shared Bus Stop Boarder. In this design, the cycle lane continues along the kerbside, but this is raised to the level of the footway at the bus stop, so that the bus stops adjacent to the cycle lane rather than the footway, meaning that boarding and alighting passengers need to cross the cycle lane to enter or leave the bus. The design for this as given in the Department for Transport's Guidance for Cycling Infrastructure Design LTN 1/20 is shown in Figure 2.

Figure 2 - Design layout for a Shared Bus Stop Boarder. Source: Cycle Infrastructure Design, Department for Transport LTN 1/20



Given the additional mobility needs of disabled people, each of these designs presents them with challenges. There are specific challenges for blind and vision-impaired people that this research explores, as well as wider challenges faced by other groups of disabled people. Given this, it is crucially important that disabled people, as well as other relevant communities, participate in the design of public infrastructure in general, and bus stops in particular, as early in the process as possible. A culture of meaningful consultation and involvement is essential if we are to ensure that public spaces meet the needs of all communities. The Chartered Institute of Highways and Transportation published a report "Creating a Public Realm for All" [55], in which they propose the term 'co-cultivation' to illustrate the nature of this process. This is illustrated in Figure 3 below.

Figure 3 - Co-Cultivation: Continuous meaningful engagement and representation from inception and design through construction, operation, monitoring, to evaluation and revision/renewal (Author, based on CIHT 2024)



The research used a series of focus groups, as well as site visits and experiments looking at these designs in a controlled environment. This allowed us to measure responses to events that arise as a person deals with the process of using bus stops and shared spaces in the presence of bicycles. The report sets out the findings of our research and makes clear recommendations based on this evidence of the steps that need to be taken, to ensure that both cyclists and disabled people can access and use our public spaces safely.

Measurements of Safety

This research looks at two major design issues: how to ensure that pedestrian infrastructure is both accessible and safe. Each concerns the design of the infrastructure, but the question of safety requires some explanation so that the research can be understood.

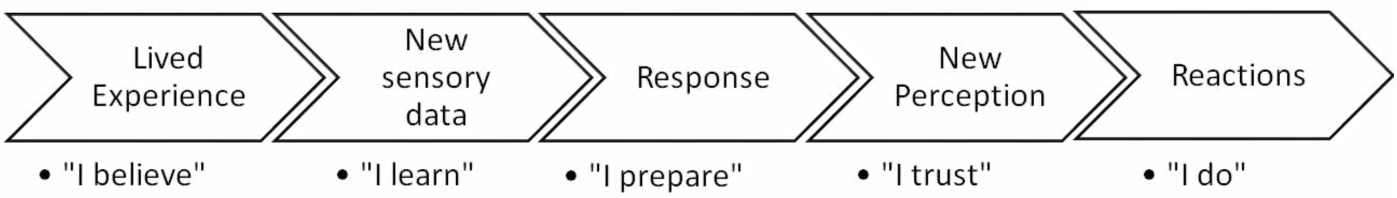
The normal measure of safety in transport is the severity of injuries to people, often represented as "Killed and Seriously Injured," or KSI. However, this is not an appropriate measure in the case of access to bus stops because, although it is not impossible, the likelihood of a collision between a cyclist and a pedestrian resulting in a fatality or serious injury, as officially defined (requiring overnight admission to hospital), is relatively low. Using KSI as a measure of safety, therefore, is prejudicial because it does not capture the actual nature of the problem and could lead to a superficial sense that these bus stops are 'safe'.

One of the reactions to problematic infrastructure of any sort, is to avoid using it. To understand this, we need to discuss here, the question of perception and how human beings create it. Perception, in this context, is not the popular sense of the word suggesting something that is ephemeral and not necessarily correct; Perception is a very precise process in the brain, that drives human survival, and this is the meaning of the word used in this research.

Your brain has just one job: to ensure your survival. It does this by a process of renewing, or updating, the Perception it has of the world. The brain does not actually see, hear, smell, taste, feel anything: it receives rapidly changing electrical signals stimulated by sensorial stimuli. How those stimuli turn into a Perception of something is a matter of processing them ("what am I experiencing now?") with the person's lived experience ("when did I last have signals like these?") to create a new best-guess – a new Perception – of the world that generated those stimuli. Every action a person takes, whether they are conscious of it or not (and mostly they are not), is based on this Perception, and this is why it is so important.

The lived experience is recreated selectively to start the creation of a new Perception [45]. This lived experience is updated on the basis of sensorial information, arriving via the various sensory pathways to generate responses in the brain, for example, the release of a hormone to stimulate action, to make you feel happy. This creates a new Perception, that relates to the world as it will be in the immediate future, and to which you react. The new Perception then becomes part of your new lived experience (a simple graphic to describe this process is shown in Figure 4). This is a constantly updating process, but because it is founded on lived experience, Perception is inevitably heavily affected by what has happened before.

Figure 4 - The transition from Lived Experience to Reaction (Tyler N., 2024)



The problem is that "what has happened before" does not necessarily need to be "what has happened before at a bus stop (let alone at this particular bus stop)": it could be anything that the brain selects as being a relevant previous experience. It may or may not be correct, it may or may not be relevant to the immediate situation, but it is all that we have. The resulting Perceptions then drive the responses in the brain, which in turn drive the reactions in the body – which might be to move or stop, turn the head in one direction or another, release a hormone to make you alert or happy, or energised, or sleepy. This is a remarkably successful way of working – it has served human beings well for several thousand years and is core to our survival as a species. However, it has not yet caught up with life in a modern city. So, we have to make the world fit with the way the brain works to keep us alive, not make the brain work to keep the world working. Examples of this not working well are observed in autistic people, where the 'niche construction' is needed to enable the brain to understand the world as it presents challenges throughout their daily lives [51].

This recent neurobiological research [52], which posits that the brain creates Perceptions based on a combination of lived experience to date and present information, provided by the sensory system, represents an important shift. The brain is seen as a predictive rather than a responsive organ. It means that a person creates a perception of how they see the world based on their previous experience of it, and updates this with the incoming sensory data. People are not trying simply to make sense of their sensations; they have to actively create their total picture of the environment around them, starting from their previous lived experience. This is called Active Inference. The 'new' Perception thus created, then becomes the latest addition to the 'lived experience' and thus lives on in future encounters. This means, that previous experience that has given rise to stress or fear will tend to dominate the way in which a person will perceive, and thus respond and react to, the present environment.

Looked at in a slightly different way, infrastructure or operations that give rise to fear or stress could be generating a stress response that could have long-term implications for the person affected in this way. This could be regarded as a kind of injury, psychological rather than physical, but an injury nevertheless, and one that can become worse over time, if the experience is repeated. Such "psychological injury inflicted by infrastructure" is a direct result of the responses to Perceptions stimulated by that infrastructure. This is akin to Post Traumatic Stress Disorder [43]. For example, people who cease venturing out of their houses because of fear of interactions with infrastructure are likely to become isolated and depressed, resulting in further problems, which may mean the need for psychiatric treatment in due course.

Psychological injury associated with infrastructure is not normally recorded in the transport safety literature, but the psychological effects of an accident can have devastating and long-running consequences, as is the case of Fear of Falling and Fear-related Activity Restriction [46].

Accordingly, in this research, we have explored a different way of looking at the effects of such interactions: the level of fear induced by the thought that a collision could occur. A potential outcome of this reaction is that people could cease to engage with the public transport system, thus limiting their access to activities that would help to improve their quality of life. In more severe cases, this results in ceasing to leave home entirely, leading to issues of isolation and depression [47].

There are measures intended to increase the sense of safety around infrastructure, for example, controls at pedestrian crossings, audible signals, rotating cones etc, to try and assist where the natural alert systems are not providing sufficient responses to the situations. These systems are not internal to the body, so they need to be learnt – where they are, when they work, how they work. They need to be always in place and working in a consistent way, so that people can expect and find them.

One difficulty, in terms of measurement, is that whereas "Killed and Seriously Injured" is fairly (but not completely) easy to measure, the concepts of "fear" and "psychological injury" are more difficult to measure.

In this research, we have sought to find ways of assessing this through the measurement of physiological responses that arise during the process of using a bus stop, using the controlled conditions of a laboratory experiment in order to do this.

This research is a first step in this direction, but it is potentially able to give a better measure of the effects of these bus stop designs on disabled people.

2. Definitions

2.1 Walking

As a general point in this report, for the purposes of this research, the term "walking" includes bipedal walking (as generally understood), the use of means of locomotion assistance, such as walking aids, the assistance of people or assistance dogs, and locomotion by means of wheelchairs or mobility scooters, but does not include cycling.

2.2 Disabled people

Under the Equality Act 2010, a person is disabled if they have a physical or mental impairment, that has a 'substantial' and 'long-term' negative effect on their ability to do normal daily activities.

The Social Model of Disability states that disabled people are 'disabled' by the barriers operating in society that exclude and discriminate against them. In this report, this refers to the question of whether certain elements of pedestrian infrastructure disables people as a result of their design or the way they are used [53].

The science included in the research is, in some cases complex, and we are concerned to ensure that this document is accessible to a wide audience. The style of writing and presentation is therefore aiming to be accessible, avoiding the use of technical jargon, presenting the material for non-technical people. Throughout the report we will point people, who wish to see the more technical aspects of the work, towards the more technical literature where it is available.

2.3 Bus Stops

This section sets out the key concepts to be considered when considering bus stop research, including design principles, waiting, boarding, and alighting, bicycle speed, manoeuvrability and how these elements apply to Floating Island Bus Stops and Shared Bus Stop Boarders (the focus of this research). It is important to understand what a bus stop needs to 'do', to understand how Floating Island Bus Stops and Shared Bus Stop Boarders might or might not, be able to provide the necessary facilities for disabled people.

2.4 Design principles

Bus stops are phenomenally important. They are often the first point of entry to motorised transport and the last point of departure from it in a journey. A bus stop is a transport interchange between two modes of transport: walking and bus. They are the most commonly used transport interchange of all, yet although in many cases, careful consideration is given to making bus stops accessible (for example, TfL has published an accessible Bus Stops Guidance document [54]). All too often very little attention is paid to ensuring their design requirements meet the needs of the diverse range of people who use them. Accessibility to a bus stop is paramount: if this interchange is not accessible, the rest of the journey is impossible. Therefore, it is essential to ensure that bus stops are accessible to all.

To achieve this, designs must meet a number of basic principles summarised below. This list is derived from previous research for London Transport, Department of the Environment Transport and the Regions, which included trials of bus stop designs off and on-street. This is reported in [41,42].

1. The bus must be able to come close enough to the kerb to enable a person to transfer from the bus stop platform (often simply a portion of the pedestrian footway, and sometimes just the road level) to the bus. This requires consummate skill on the part of the bus driver, which can be assisted by appropriate design, not just of the bus stop itself but also the approach path to the bus stop and the exit path.
2. Ideally, level access to and from the bus should be possible without the need for a ramp to be deployed. If a ramp is necessary, to afford movement into or out of the bus, this should be at no more than the acceptable gradient (see Public Service Vehicles Accessibility Regulations 2000 for details of the maximum permitted gradient).
3. The bus stop platform must be of sufficient size to accommodate the expected number of waiting passengers. The turning dimensions needed by a wheelchair (powered, self and assistant-propelled), recognising that any turning movement to reach the bus must be completed, before any interface with the bus doorway (or ramp, if it is necessary to deploy one), and, on leaving the bus no turning movement can start until the wheelchair and assistant are free of the doorway (or ramp, if one is deployed). The dimensions also need to take into account the manoeuvrability needs of people with carers or assistance dogs. Whether or not a bus stop platform is physically separated from the rest of the footway, this space should be clearly marked, on the footway. If there is a physical separation, this should ensure that the size within the bus stop space is adequate for these purposes.
4. The bus stop platform should be of a height that is similar to the expected height of the bus floor when the bus is stopped and ready for boarding. The bus has a regulated maximum capability of setting the bus floor at 240mm above the road level at a bus stop. The height of the kerb at the bus stop is not regulated, but the aim should be to ensure that it can deliver as close to level boarding as possible. Any height difference between the bus floor and the platform should be ameliorated by the use of a compliant ramp, bearing in mind that for some pedestrians, stepping onto a sloping surface can be painful and destabilising.
5. Bus stops should be easily detectable by disabled people, whether their disabilities are sensorial or cognitive. Consistency of design and appearance across a network is important, yet it should allow for distinctive identifiable characteristics in different locations that can help distinguish where the bus stop is within the town/city.
6. Bus stops should be designed to allow a clear view of oncoming buses. From about 100m it should be possible to see that a bus is approaching, from about 50m it should start to be possible to identify which bus service it is, so that the intending passenger is able to indicate to the driver that they wish to board the bus in good time for the bus to stop, without the need for sudden deceleration. At closer distances, the details need to become clearer – so the bus service number is important, followed by the main destination. It is

best to have the bus service number on the kerbside side of the destination sign, so that it is easier to see from the footway if there is more than one bus at a stop at the same time.

7. Within the bus stop platform, the space should be dedicated to people using the interchange – whether waiting for, boarding or alighting from the bus. Tyler (2015) points out that these activities include the transition from being a pedestrian to being a passenger (rearranging shopping bags, finding tickets/money etc.) and vice versa. It is necessary to allow for these actions within the bus stop platform space.

There are several other requirements for a bus stop space [40, 41, 42], but these are the ones of highest importance for the purposes of this research.

A bus stop platform should be a safe and reassuring space for people to wait for, board and alight from a bus and transition between being a pedestrian and a bus passenger.

The research described in this report concerns a particular situation where the bus stop is located in an environment where the infrastructure for cyclists is required. This requirement stems from policy decisions about the implementation of support for active travel, including cycling. Although the infrastructure needs and safety of cyclists are clearly very important, this research is focussed on the experience of disabled pedestrians.

As mentioned in the Introduction, this research concerns two types of bus stop, where a cycle lane has been incorporated into the design. These are the Floating Island Bus Stop, Figure 1, and the Shared Bus Stop Boarder, Figure 2 (outlined in more detail below). The research is concerned with the requirements of disabled people using these bus stops to transfer between walking and travelling on a bus. Using these bus stop designs, in particular, requires actions, responses and reactions from disabled people that are not needed when using an ordinary bus stop design. For example, if a bus stop requires someone to step up a high vertical gap to get on the bus and the person is unable to do this, the bus stop is inaccessible. The design of the bus stop would need to be changed to reduce the gap to an accessible level. However, if added to this difficulty, the person also has to detect an approaching bicycle travelling along a cycle lane, the complexity of dealing with that vertical gap is even greater.

Unlike most railway stations, for example, most bus stops are not equipped with staff or deployable equipment to assist users when they arrive: bus stops have to be designed in such a way that any prospective user can use them safely, with dignity and as comfortably as possible.

2.4.1 Waiting, boarding and alighting

All people, and disabled people in particular, have to carry out three types of activity at a bus stop: waiting, boarding, and alighting. A lot of these issues apply to all bus stops and could be affected by the particular situations encountered in Floating Island Bus Stops and Shared Bus Stop Boarders.

The situations of waiting, boarding and alighting are quite different and each needs to be treated separately. We will discuss the general points first and then refer specifically to the additional issues that arise in Floating Island Bus Stops and Shared Bus Stop Boarders.

2.4.2 Waiting

One of the needs of waiting passengers, is to be able to prepare themselves for boarding the bus. This involves, for example, the rearrangement of bags from the way they are carried along a footway to fit the relatively tighter physical constraints within the vehicle. The common case in the UK, is that fare payment/checking is undertaken on boarding the vehicle, so it is also necessary to prepare for this. Waiting may take some time, so it is often necessary to rest, and sometimes seating is provided for this purpose.

The space allowed for waiting should enable a wheelchair user to be able to park in such a way that they can see an oncoming bus, together with a person accompanying them, and without obstructing other waiting, boarding or alighting passengers (who may be waiting/boarding/alighting from bus services other than the one that the wheelchair user is intending to use). People travelling with carers or assistance dogs, also need to have additional space. The platform should be able to accommodate the expected number of waiting passengers (including disabled people that require additional space), plus the space needed for alighting passengers, and those preparing to board a bus on arrival.

When a bus stop is accommodated within a general footway, this space should be additional to the space required for pedestrian movement at that point. Originally, Bus Stop Boarders are built into the roadway, in order to make it easier for bus drivers to approach the kerb, by reducing the need for a large diversion from the 'driving line' along the road to meet the kerb at the bus stop. These also help to achieve sufficient space, so that there is no conflict between pedestrians moving along the footway and passengers waiting for a bus. When incorporating a cycle lane into a bus stop, in some cases, the option has been tried to create a Bus Stop Boarder, in which the space is shared between the cycle lane and the passengers waiting, boarding, or alighting the bus at a Bus Stop Boarder. These versions where the space is shared in this way are called Shared Bus Stop Boarders (see Figure 2).

If space for passengers or pedestrians at a bus stop is constrained, for example, by the existence of a cycle lane at either a Floating Island Bus Stop or a Shared Bus Stop Boarder, sufficient space can be more difficult to provide – in a normal bus stop, waiting passengers tend to wait a little distance away from the bus stop and thus, they extend the space to accommodate themselves more informally. Especially in a Floating Island Bus Stop, this possibility is reduced because of the fact that the waiting area is an island between the cycle lane and the roadway (see Figure 1).

Passengers should be able to detect an oncoming bus and to know if it is the bus they wish to use, from a distance that is far enough away for them to be able to indicate to the driver to stop. This requires a clear view, as far upstream as possible of the bus stop, particularly the closest 50m. Passengers that cannot detect oncoming vehicles visually, need to have other means of doing so. Buses fitted with an Acoustic Vehicle Alert System (AVAS) might be detectable from a few metres (e.g. 10-20m), but the AVAS will not indicate which bus service it is. Currently, the only buses fitted with AVAS tend to be all-electric buses, which are otherwise thought to be quieter than conventional diesel buses (although the audibility of rear-engined buses is also poor). Systems are being researched for providing better audible information about oncoming buses, but these are not yet in operation. The difficulty of knowing if a bus is coming, and if it is, which service it is, raises the stress levels of waiting passengers.

2.4.3 Boarding

Apart from the physical issues of boarding a bus, resulting from the difference in horizontal and vertical gaps between the bus and the platform, people with a vision impairment can be concerned about locating the door of a bus. For those people who need to use a ramp, this can mean using a different door. In London, where there is a centre door, the ramp is usually located at this door; the ramp user needs to indicate to the driver that they need to use the ramp (often doing this at the front door near the driver, then move alongside the bus to the centre door), then has to swing outwards to engage with the extended ramp, for which an appropriate space needs to be available. All of this means that there are several activities going on around the space near the doors of the bus. These all need space; sometimes the different needs for space conflict with each other, which can be distressing for people at the bus stop. This can mean that people boarding the bus are interrupted by other passengers and this adds to the tensions involved in trying to board the correct bus, in the time available.

2.4.4 Alighting

Although this aspect is often forgotten in the design process, people need to alight from buses. This requires space to be set aside on the bus stop platform. A number of conditions need to be considered, any one or more of which can happen at any time. Before anyone actually leaves the bus, they need to be sure that the exit is safe and clear of stationary or moving obstacles. This requires a visual check – something which is clearly not possible for many people with a vision impairment. This is also a challenge for people with baby buggies, wheelchair users and people with assistance dogs. Many people using baby buggies, and some people pushing manual wheelchairs, leave the bus backwards because they find it easier to manage the step height difference that way. However, this places them at a severe disadvantage in terms of being able to see the situation on or around the bus stop platform before they have to commit to leaving the bus.

People in a wheelchair, or people pushing a wheelchair, will need to have a clear sight of the platform area while they are still in the centre of the bus – leaving them with almost no clear sight of the area of concern. People with assistance dogs also have a problem, as the dog is trained to leave the bus first, requiring the user to cope with controlling the dog whilst trying to leave the bus. Unaccompanied people with vision impairment must determine their safe passage before leaving the bus. If they are checking their environment by listening, they need to accustom themselves to the 'new' local environment to determine the importance of the sounds they hear. This can make it difficult to determine if a sound is an oncoming bicycle or something else.

When taken altogether, a bus stop really needs to be seen as a kind of railway station platform, set in a pedestrian and traffic environment, in which a set of complex actions have to be completed. It requires safe treatment of its users, just like a railway station platform, but has the added complication that this has to be done within an environment which has lots of people and activities moving around it, who have other priorities than just using the bus stop. These include pedestrians, vehicle traffic and cyclists who may not be using the bus stop but are in the same environment. This research looks specifically at the interactions between disabled people and cyclists at the Floating Island Bus Stops and Shared Bus Stop Boarders.

2.5 Other aspects of bus stop operation – bicycles, speed, and manoeuvrability

2.5.1 Bicycles

The increase in cycling in the UK (10.6% since December 2013) [56] is a remarkable success of the promotion of active travel and is to be encouraged. This has given rise to a number of safety concerns, particularly with the interfaces between cyclists and vehicle traffic, particularly with heavy goods vehicles, which has caused a number of deaths and serious injuries to cyclists, as discussed in the Introduction.

As a result, there has been a move towards creating segregated cycle lanes, so that cyclists can move safely with much reduced interaction with vehicle traffic. Often these cycle lanes are incorporated into the road space by reducing space for vehicles. Sometimes, they are incorporated into pedestrian space by reducing the space of pedestrians to accommodate the space needed for cyclists. LTN 1/20 discusses in some detail the design requirements for these situations. This research is concerned only with the situation where cycle lanes interact with bus stops.

The design of bicycles means that they can reach quite high speeds when given the space to achieve this, which of course is what many cycle lanes allow. Cyclists can often achieve the local speed limits set for motorised vehicles (20 or 30 miles (30 or 40 kilometres)) per hour quite safely and without difficulty [37]. Statistics from Strava showed an average speed of 22.5km/h of over seven million logged trips during a period of one year. Of course, many Strava users are the type of cyclists who probably have a more sports focus, and so this is not representative of the entire cycling population. Observational, off-the-street study in [21] showed speeds from 10.8 to 12mph.

However, there is no practical control over cycle speeds. When thinking about the interactions between passengers at bus stops and cyclists, we need to consider the possible speeds they could attain, rather than the average speed, just as we design roads so that travel at the speed limit is within the design speed. When travelling in a well-designed, segregated cycle lane this is quite safe both for cyclists and other users of the road and footway space. The issue becomes more complex where the segregation ceases, for example, at an intersection, a pedestrian crossing or, as in the case discussed in this research, at a bus stop, where the speed needs to be restrained to the needs of the situation at hand.

When different movement types interact in a desegregated environment, there are two main causes of conflict: differences in speed and differences in manoeuvrability.

2.5.2 Differences in speed

Pedestrians walk at around 3-5 km/h, with older people, people with encumbrances such as shopping or heavy luggage at the lower end of this range. Users over 85 years old may walk as slow as 0.3m/s and 0.5 m/s, for female and men respectively (0.5 m/s SD=0.2, 0.7 m/s SD=0.2) [36]. People with children also tend to walk more slowly.

As established above, cyclists can move from around this speed to quite fast. [37] reports average speeds up to around 25km/h on cycle lanes in downhill situations, but the observed range goes up to around 40km/h.

The problem arises because of the difference in speed between pedestrians and cyclists. Differences in speed between vehicles and people affect the outcome of any collision between them: the greater the difference, the greater the severity of any injury incurred. This applies whether or not the two vehicles/people are travelling in the same direction, two vehicles travelling at different speeds will encounter more problems if the speed difference is greater. So, a collision between a pedestrian travelling at 4km/h and a cyclist travelling at 25km/h would tend to lead to a damaging outcome. There are various reasons for this, in addition to the physical speeds and difference. For example, the line of sight required to travel at a higher speed is much longer than that needed when travelling at a slower speed. Pedestrians normally have a line of sight directed towards the ground about 2.5-3m in front of them, with vision beyond that [44]. Visual acuity reduces quite rapidly after about 10m. Pedestrians typically also benefit from the stimuli received via peripheral vision, which informs them about the world outside the narrow focus of their acute foveal vision. In addition, whereas cars have had design modifications over several years with the aim of reducing injury to pedestrians in the event of a collision, bicycles still tend to have quite sharp extending features (e.g. pedals, handlebars) that, if coming into contact with a pedestrian, could inflict injury.

As speed increases, the necessary forward vision needs to increase, and less attention is paid to stimuli in the periphery. So, someone travelling at 25km/h (7 metres per second) will need a forward vision capability of around 50m (this distance would take around seven seconds to cover at this speed). If a cyclist is travelling in the same direction as a pedestrian, they will be able to see the pedestrian at some distance ahead, but the pedestrian will be unaware of the cyclist until they can hear them, or they appear in their peripheral vision (i.e. when the cyclist is almost level with the pedestrian).

If this pedestrian and the cyclist are travelling in an opposite direction to each other, the closing speed would be 28 km/h, and they will meet in about six seconds, but in that time the cyclist will have covered 42 metres and the pedestrian almost seven metres. There is an important question about the distance at which a cyclist travelling at such a speed would be detectable by a pedestrian, a question made even more pertinent to this research in the case of blind and vision-impaired people.

2.5.3 Manoeuvrability

Once a bicycle is travelling quite fast, their ability to manoeuvre is reduced. The result of this is that a cyclist will be planning their journey quite far in advance, but as speed increases the laws of physics mean that they become increasingly unable to deviate from this plan – wheels are not very manoeuvrable. Some pedestrians can manoeuvre to a much greater extent than cyclists, but they will do so slowly, and they need to be able to judge any avoiding manoeuvre in order to make sure that they are not avoiding one situation and placing themselves in a different danger zone. They also need to know that an avoiding manoeuvre is needed in the first place. However, for disabled pedestrians who may, for example, have a vision, hearing, mobility, or cognitive disability, this can be more difficult.

The normal way of reducing conflicts between objects that are moving at different speeds/directions is to keep their speeds/directions as near to each other as possible and to keep the objects themselves apart. This is why, for example, high-speed motorised vehicles are segregated away from slower traffic, including cyclists and pedestrians, for example on motorways. This is also the reason why segregated (with kerbed separation) cycle lanes are necessary to maintain the safety of cyclists. [38] Shows that the Cycling Superhighway 3 in London, with 78% of segregated lanes, reported fewer killed and seriously injured cyclists, and fewer bicycle collisions overall in the segregated sections compared to the others, which are mainly painted cycling tracks. The same principle of separating vehicles travelling at different speeds applies when cyclists are the 'fast' vehicles and pedestrians are the slow ones.

Although challenges arise where cyclists and pedestrians share the same road space, this is a particular problem at bus stops because the pedestrians are basically stationary, and when they move it is across the line of the direction of the cyclists. In addition, for the reasons stated above, the pedestrian movements are sporadic, and their attention is inevitably directed towards their main purpose of boarding or alighting from the bus.

This research looks at the two specific types of bus stop where cycling infrastructure needs to be considered in its design: Floating Island Bus Stops and Shared Bus Stop Boarders.

2.6 Floating Island Bus Stops

In the case of the Floating Island Bus Stop, a person wishing to use the bus stop needs to cross the cycle lane. To facilitate this, usually, there is a raised mini-zebra crossing constructed in the cycle lane so that there is a level crossing for pedestrians to reach the bus stop at that point. The rest of the cycle lane is maintained at road level. Tactile paving, as for zebra crossings, is installed on either side of the cycle lane to alert vision-impaired people of the crossing.

Figure 1 shows the design as presented in the Department for Transport Guidance for Cycle Infrastructure Design (LTN 1/20). The diagram shows the road, cycle lane and footway layouts around a Floating Island Bus Stop, together with measurements.

Arriving, waiting, boarding, and alighting have different challenges and requirements and should be treated separately.

2.6.1 Arriving at a Floating Island Bus Stop

The first challenge is to know that there is a bus stop at all. Then it is necessary to know how it is configured so that the user knows what to do. Typically, for a normal bus stop, the bus stop flag serves this purpose, but it is usually positioned to serve this purpose for the bus driver and is located at the kerbside. In many cases, this is also used as an indication to the driver of where to position the bus when stopped. At a Floating Island Bus Stop, the location of the flag is quite far away from the footway, so it is quite possible for a blind or vision-impaired person to miss the fact that there is a bus stop at all. [35]

To cross from the footway to the Floating Island Bus Stop, the tactile paving has to be detected. As for a normal zebra crossing, this should have a tail across the footway. Normally, there is no other signal to indicate that there is a crossing (so it is unlike a normal zebra crossing which has Belisha beacons, or a PELICAN or PUFFIN crossing, where there are traffic signals, (usually) audible signals and visual indicators to show when it is safe to cross).

Whether or not there is signage in place, the pedestrian has to decide whether it is safe to cross the mini zebra crossing to reach the Floating Island Bus Stop. This means detecting approaching cyclists. As the cycle lane will have deviated from the road line to be 'behind' the Floating Island Bus Stop, the pedestrian has to be able to locate where the cyclist would be coming from – it will almost certainly not be at a right angle to the position they are looking from. In this case, it is essential that there is a clear line of sight towards the cycle lane when it is still within the roadway – that is where the oncoming cyclists will be when the pedestrian has to make the cross/don't-cross decision, so that is where they will need to be able to detect them. The higher the expected speed of the cyclists, the clearer space there needs to be for this purpose. So, a key question is how far away is a cyclist when the pedestrian is able to detect them? For this we need to take a blind person as our example, so that we can consider the safety requirements to enable them to reach the bus stop safely.

Once on the island, if there is a shelter, the passenger can wait in the shelter away from the weather. LTN 1/20 suggests that the shelter is to the left of the mini zebra crossing so that it is nearer to the boarding point of the bus, but there is no requirement for it to be located there.

2.6.2 Waiting on a Floating Island Bus Stop platform

Once on the Floating Island Bus Stop platform, the user needs to establish where they need to wait. There is a case for making a standard design where, for example, the boarding point of the bus is always at the same place relative to the mini zebra crossing, so that passengers know where they can find the waiting area. For example, the mini zebra crossing could always be upstream of the shelter, so a person knows that once they have reached the island they need to turn left to reach the boarding point.

At this point there is little difference between a Floating Island Bus Stop and a normal bus stop, other than the 'island' meaning that there is actually a physical boundary to the 'back of the bus stop', which physically defines the amount of space available for waiting passengers: passengers in excess of this amount cannot just spread along the platform if it is already full: they would need to wait on the footway and then cross onto the platform as space becomes available. This means that careful attention needs to be paid to the passenger demand at the bus stop and to the space requirements of wheelchairs and other mobility aids, such as crutches, rollators, et-cetera. Space is also an issue for blind and vision-impaired people, especially when they are with an assistance dog or carer. The space requirement means that the space needs to be calculated to allow the wheelchair user to enter the island from the mini zebra crossing, turn so that they can wait under the protection of the shelter and manoeuvre into the bus, including navigating to the ramp, when it arrives. Details of these space sizes can be found in Inclusive Mobility [39].

2.6.3 Boarding a bus at a Floating Island Bus Stop platform

When the bus arrives, it should always stop at the same place so that passengers can board easily. At this point, there is no significant difference between a Floating Island Bus Stop platform and a normal kerbside or boarder bus stop. Knowing which bus service has arrived is always an issue. If blind and vision-impaired people are being encouraged to wait in the shelter, this should be equipped with an audible information system so that they can establish which bus service has arrived and, in the case of there being more than one, where the one they need can be found.

2.6.4 Alighting at a Floating Island Bus Stop platform

When the bus arrives at the Floating Island Bus Stop platform, the same procedures will apply as for a normal bus stop. The main issue is that the space constraint caused by the 'island' means that sufficient space has to be included to allow for wheelchair users and their assistants, guide dogs, carers etc. to be able to leave the ramp (if deployed) before they have to manoeuvre to navigate across the island.

On leaving the bus and its ramp, passengers will need to locate the mini zebra crossing, and wait there while they determine whether or not a cyclist is approaching. This raises the same issues as we saw when the passenger was crossing to enter the Floating Island Bus Stop. However, in the alighting case, the alignment of the cycle lane will mean that the cyclist will be coming from an angle to their left and behind the passenger. If the passenger is able to see, they would need to turn more than ninety degrees to their left to be able to see any oncoming cyclists. For passengers with a vision impairment, they will have similar sound detection problems as those raised when entering the island.

2.7 Shared Bus Stop Boarder

In the case of the Shared Bus Stop Boarder, a person wishing to use the bus stop may reach the bus stop directly from the footway because the bus stop is located within the footway, as in the case of a conventional bus stop. LTN 1/20 does not specify where the bus stop flag should be in a Shared Bus Stop Boarder. When the passenger wishes to board or alight from the bus they need to cross the cycle lane, which is situated at the level of the footway between the bus and the bus stop platform. LTN 1/20 shows no evidence of tactile paving to indicate where the footway ends, and the cycle lane starts.

Figure 2 hows the design diagram for the Shared Bus Stop Boarder as presented by the Department for Transport in their Guidance for Cycle Infrastructure Design LTN 1/20. The diagram shows the road, cycle lane and footway designs around a Shared Bus Stop Boarder. The diagram shows no dimensions.

2.7.1 Boarding at a Shared Bus Stop boarder

As mentioned earlier, a Shared Bus Stop Boarder is characterised by having the cycle lane following an alignment that places it between the stopped bus and the bus stop platform. Passengers boarding or alighting therefore, must cross the cycle lane when moving from the waiting position to boarding the bus. Some designs have a hatching or other marking to indicate an area at the edge of the kerb about 0.5m – 1m deep. This is intended to mark a 'safe area' for passengers close to the bus, but this marking is not included in the LTN 1/20 guidance.

Once they have detected the correct bus, the passenger needs to enter the cycle lane, in order to board the bus. The cycle lane is at the same level as the Shared Bus Stop Boarders platform.

The Shared Bus Stop Boarder presents a quite different challenge to the passenger, compared to a Floating Island Bus Stop. In the Shared Bus Stop Boarder, an oncoming cyclist has to be detected when the passenger has detected the approaching bus. There is an additional time pressure on the passenger as they know that the bus is arriving and therefore, they need to board it as quickly as they can, yet they have to know whether or not they can enter and cross the cycle lane safely. Their view of the cycle lane could well be obstructed by other passengers at the stop and so, quick detection of a cyclist could be quite problematic. In theory, the passenger could enter the hatched area independently of a bus arriving and wait there. However, there is nowhere for them to sit, and they would be exposed both to nearby traffic in the roadway and cycles passing on the cycle path, so this could feel quite unsafe. Once the bus comes, they can board it as usual. However, where buses deploy a ramp at the centre door, passengers who need to use the ramp would need to be able to manoeuvre along the bus and turn onto the ramp, which could entail them having to do this in the cycle lane itself (if they had to communicate with the driver to operate the ramp) and turn onto the ramp.

2.7.2 Alighting from the bus at a Shared Bus Stop boarder

In the case of the Shared Bus Stop Boarder, alighting from the bus means entering the cycle lane directly from the bus. Sightlines are very poor as the doorway obstructs a view towards the rear of the bus to see if any cyclists are approaching. Wheelchair users would not be able to see very far in this direction as they would be a metre or so inside the bus when having to make the decision to pass through the door. A wheelchair assistant would be even further inside the vehicle. As for assistance dog users, there is the risk of the dog being struck by a cyclist, as it walks out of the bus before its owner. Also, ambulant passengers will need time to step down from the bus. As with the Floating Island Bus Stop, in London, buses have an audible announcement before a bus stop with an associated cycle lane to advise passengers to "cross the cycle lane with caution", but it does not say whether the cycle lane is right next to the bus or further away at the back of an island.

2.7.3 Continuous footways and segregated cycle-footway

Continuous footways are installations where the level of the footway stays the same across the crossing of a minor road. This is usually installed where the road in question is a side road and the crossing is following the alignment of the footway along a major road. The idea behind this installation is that it suggests a priority for pedestrians as they cross the side road, and vehicles have to pass over a gradient to cross over the footway. This is intended to signal both the pedestrian priority and the sense that the vehicles are passing from a main traffic-priority road into a residential area.

The potential conflict here, is how a blind and vision-impaired person would know when they have left the pedestrian-only footway along the main road and have entered the road area of the side road, where there could be passing vehicles.

In some examples, there is tactile paving, as there would be for the crossing of a side road where a dropped kerb has been installed. In others, there is no tactile paving (see Figure 5), the idea being to emphasise the pedestrian priority by creating a continuous footway. In the latter case, it is harder for blind and vision-impaired people to know whether they are on a 'protected' footway, or are being exposed to the possibility of collision with a passing vehicle.

Figure 5 - Continuous paving across a side road with a cycle lane running alongside the road and across the side road. This example is installed without tactile paving and has a changed road surface (white-grey pavers). The surface of the cycle way is of a different colour (red-ish hue). Some examples do have tactile paving on either side of the crossing point.

The third type of infrastructure considered in this research is the segregated cycle/footway (Figure 6). This is usually installed on a footway, with a delineator in between the space for bicycles and the space for pedestrians. This delineator could be a painted line, or a form of physical delineator, which could be continuous (as in Figure 6), or with gaps every one or more metres. Sometimes the delineator is marked by a series of bollards, but this method is not considered in this research, as the question was more about the low-level delineators.

Figure 6 - A segregated cycle-footway with buff coloured surface on the pedestrian side and black asphalt on the cycle path with a low kerb delineator running down the middle of the path. (Source: Welsh Government (2021) Active Travel Act Guidance, https://www.gov.wales/active-travel-act-guidance, accessed 18 July 2024).

3. Literature review summary

3.1 Scope

Here we provide a summarised version of the most relevant findings from the literature review carried out for this research. The methodology and detailed review can be found in Annex 1.

The literature review was focused on identifying specific knowledge gaps in relation to blind and vision-impaired users and other disabled people, their interaction with the infrastructure in question and their specific needs in terms of safety, perceived feeling of safety and independence.

This review was used to inform the test methods and to define the variables of interest, rather than being an extensive review, in a broader sense. A Rapid Literature Review format was followed, in which the existing body of work was searched through a single database (Scopus). The search was further complemented with standard web-searching using the same keywords, but pointing towards grey literature, design standards and guidelines produced by government bodies and other relevant organisations.

The focus was placed on safety provisioning for users with vision impairment, but the review briefly extended the research questions to a wider range of disabilities, to provide an overarching view for common or opposing user needs that are relevant to the bus stop designs in this research.

3.2 General findings

One of the first things to be noticed is the extremely limited amount of literature directly aimed at studying the needs of blind and vision impaired people in the specific settings of Floating Island Bus Stop bypasses and Shared Bus Stop Boarders. The search queries from the Scopus database returned zero hits when searching for these matching terms. We did find some local guidance and test report references [8][15][17] and [21] had a corresponding section. The most recent of these was Living Street's 2024 report [8] that looks at inclusive design of bus stops with cycle tracks and included focus groups with disabled people (including those with a vision impairment) and an observational study.

Most of the scientific literature found was derived from observational studies and based on the movements (trajectories and speed) of the users across the cycling lane, or while waiting for the bus.

Arguably, the reports derived from observational studies cannot guarantee appropriate representation of vision impaired users in their samples, making it only possible to hypothesise certain behaviours or how some situations may extrapolate to the vision-impaired (VI) population. Furthermore, none of the studies (scientific articles) even acknowledged the particular needs of blind and vision-impaired users. This suggests a lack of understanding about the challenges posed to blind and vision-impaired people.

It was evident that, despite the amount of information available, in terms of urban infrastructure design for bus systems and the increasing interest in pedestrian-cyclist interaction at bus stops, there is still a substantial lag in the topic of safety research, not only for blind and vision-impaired people but in general for disabled users. Of 312 identified possible sources, only four contained a section dedicated to blind and vision-impaired people. This includes perceived safety and how it influences their independence.

The current literature covers well the topic of digital tools aimed to provide navigation assistance to blind and vision-impaired users. However, this is not reflected in the use of these methods and technologies to study safety of blind and vision-impaired users in the context of bus stop design.

Local regulatory frameworks and design guidelines for urban infrastructure tend to address, for the most part, general "accessibility" concerns. However, it seems that most of these concerns are aimed towards increasing usability or convenience, tending to leave out relevant factors that may be directly related to safety concerns.

Some of the relevant research, at least at local level, suggests that, if designed well, there is no substantial increased risk for pedestrians whilst using these types of bus stops [8][15][16][17][18][19][20][21][22][30][31][32][33]. It seems that there could have been a potential bias regarding the type of users that those observational studies managed to capture. Most of this infrastructure research stresses the need to provide, for disabled people and others with mobility challenges, some recommendations to make these amenities as inclusive as possible but fall short of providing quantitative evidence to discard potential increased risks to these users.

The literature seems to agree on some key aspects that are especially significant to help blind and vision-impaired users feel safer to navigate their environments [2][3][4][5][6][7][8][9][10][11][12][13][18][21][28][33]:

- Consistency in design and layouts (to aid navigation)
- Visual cues (contrasting surfaces, tone, colour, signage)
- Use of kerbs as indicators
- Use of tactile pavements
- Decluttering and obstacle-free navigation
- Information systems (at stop and on-board)

From this review we produced a set of refined research questions.

3.3 Refined research questions

Taking the literature review into account, we refined the research questions for this particular research. In trying to establish what is needed to create accessible bus stops, we should include everyone who might be reasonably expected to use buses in order to carry out their normal daily living activities, without undue psychological stress. This includes people with locomotory, sensory or cognitive disabilities.

From the literature review it seems that an important issue is consistency – what people might expect from bus stop infrastructure – and space. However, perhaps the most important aspect that is absent from the literature, is that of detecting potential danger from vehicles who have been directed into an area where people have a conflicting set of requirements. A good example of this situation, is where a cycle lane – installed to reduce conflicts between cyclists and general motorised traffic – is led into a situation where there are potential conflicts with pedestrians.

This report is concerned with this particular situation: how to ensure that bus stops, continuous footways and segregated cycle-footways are safe and accessible for disabled people, in the situation in which a cycle lane has to be incorporated into the infrastructure, to maintain their protection from general motorised traffic?

From the Literature Review, the potential places of conflict are:

Floating Island Bus Stops:

- Understanding that this is a bus stop that incorporates a cycle lane
- Crossing from the footway to the island: detecting oncoming cyclists
- Crossing from the island to the footway: detecting oncoming cyclists
- Crossing the cycle lane
- Locating the crossing on the island towards the footway

Shared Bus Stop Boarders Stops:

- Understanding that this is a bus stop that incorporates a cycle lane
- Crossing the cycle lane to board a bus: detecting oncoming cyclists
- Alighting from the bus into the cycle lane in order to leave a bus: detecting oncoming cyclists

There are several other issues mentioned in the literature, but these were excluded from this research as they also apply to bus stops more generally:

At the bus stop:

- Information about bus arrivals
- Detecting the bus (is it a bus? Which service/destination is it?)
- Preparing to board the bus

On a bus:

- Knowing where to alight the bus
- Knowing whether there is a cycle lane incorporated in the bus stop
- Knowing when it is safe to descend from the bus

These were not covered in the laboratory experiments but were discussed during the focus groups.The research question being addressed in this research in relation to Floating Island

Bus Stops and Shared Bus Stop Boarders is therefore: “how does the integration of a cycle lane into a bus stop affect people with disabilities and their capacity to interact with this infrastructure?”

In relation to continuous footways and segregated cycle-footways, the research question is “how well can people detect their position within this infrastructure relative to vehicles and/or bicycles, and how comfortable do they feel about this?”

4. Research methods

We used three methods to address these questions:

Focus group discussions with disabled people, who experienced various challenges in using the bus system, who had experience with either Floating Island Bus Stops or Shared Bus Stop Boarders (bus stops), or both. These were conducted in London, Cardiff, Glasgow, Birmingham, and Belfast. The topics discussed in the focus groups were agreed beforehand with the Guide Dogs for the Blind Association (Guide Dogs) and the focus groups were chaired and supported by Guide Dogs staff with UCL (University College London) researchers in attendance.

Site visits to an example of a Floating Island Bus Stop and a Shared Bus Stop Boarder. These visits took place in London. The topics discussed in the site visits were agreed beforehand with Guide Dogs for the Blind Association and the visits were led by UCL researchers.

Experiments conducted in the UCL PEARL facility, where an example of each of a Floating Island Bus Stop and a Shared Bus Stop Boarder were constructed according to the design specifications set out in the DfT (Department for Transport) Guidance LTN 1/20. It is important to note that the experiments were designed to establish the performance of the designs in the Guidance, and not to evaluate the performance of other designs that have been installed in various locations, but which do not comply with the Guidance.

An experimental layout was constructed in the UCL PEARL facility, with a variety of segregated cycle-footways with different delineators, continuous footways with and without tactile paving.

4.1 Focus groups

To increase our understanding of how disabled people feel about bus stops designed to accommodate cycle lanes, we held five focus groups, in Birmingham, Cardiff, London, Glasgow, and Belfast, each attended by about 12 people. They were facilitated and assisted by Guide Dogs and observed by UCL staff. In each case, the participants included people who were blind, vision-impaired, with hearing loss, neurodiverse and mobility impaired. All had experience of using bus stops which involved the interface with cycle lanes.

The topic guides used in the Focus Groups can be found in Annex 3.

The focus group discussions were analysed by topic across all the focus groups and the thematic analysis is described here. In general, the focus groups yielded a remarkably consistent view across the questions being asked. Given the consistency between the groups, this section will summarise the general points that were raised, with some quotes to illustrate the points where this is helpful.

Several participants made the point that cycle lanes are a necessary response to the difficulties that arise between cyclists and motorised traffic, and this is well understood. The problem arises for several participants when the answer to the cyclist-vehicle clash problem is to try to mix the cyclists with pedestrians. In this case, there is a real difference in need; thus, “wheels and feet don’t mix” [Birmingham], which is not met through the design.

The focus groups considered a number of potential clash sites in addition to the bus stops issue: shared paths, crossings, continuous footways, and the issues were broadly the same. They were unaware of cyclists; they did not know where they were coming from, and they go very fast. They said that the issues are intensified at bus stops where there is a combination of these problems concentrated into one specific place in the urban environment: the interchange between pedestrian mobility and public transport mobility, i.e. the bus stop.

People felt really vulnerable at the bus stop because they are already attending to the challenges of boarding/alighting from a bus: "you've got to find the right bus, find the door and so on – it's bad enough anyway without having to cope with the cycle lane" [Glasgow].

This means that people are diverting their attention to the cycle lane, when they need to concentrate on the real purpose of the interchange – to interact with the bus, and all that this entails. Crowds of people around the bus can mean that a bus is missed because people cannot reach the button by the centre door [London] or attract the attention of the driver at the front door and then move to the centre door to use the ramp [London]. There is a common plea for a design that allows the cyclists to stop. "Why can't they just stop?" was a question raised in all groups. The very possibility of physical conflict with cyclists at the bus stop was causing anxiety about these designs.

Some people said that they have stopped using buses where such bus stops are in use because they cannot cope with the anxiety of handling the complexity:

"As soon as I leave that kerb, there is danger in that and then, of course, it doesn't go very well next time you even think about crossing there. Well, the anxiety starts then, doesn't it? Or last time it was that cyclist I couldn't hear and came out of nowhere" [Cardiff].

As noted earlier, this becomes part of the lived experience for that person into the future and, therefore, colours all the decisions they make about using the stops again.

In terms of Floating Island Bus Stops, there were many comments about the size of the island, which is felt to be too narrow for either wheelchair users or for blind people, especially those using long canes, and neurodivergent people who felt trapped on a "long narrow island with too many people there" [London]. People also raised, that this is an issue with how a blind person can find the pathway to the crossing, to the footway from the place where the bus has actually stopped, as the buses may or may not be able to stop in a consistent place.

Some people noted that Floating Island Bus Stops are likely to stay, but they would like to be involved in finding a way to make them safer. People did note that they had experienced examples of Floating Island Bus Stops that worked well. However, these were all in other countries, and the general characteristic was that they had more space for everyone. "In this country, we do not have that amount of space and we have not yet come up with a good design" [Birmingham].

There is a distinct dislike of the Shared Bus Stop Boarders. People reported not knowing where things are and feeling very unprotected. For blind people in particular, this is a very scary place "I nearly stepped into a cycle"; "It's a no-go, isn't it?" [Birmingham]. There was a lot of concern about not knowing what people were stepping into, when alighting from a bus. There were a few comments about the situation in London, where "buses have an announcement that there was a cycle lane at the stop" [Glasgow]. This did not seem to be recognised as happening elsewhere. However, this announcement did not say which kind of cycle lane arrangement was in place [London], and it was noted that there is a big difference between stepping off a bus, where the cycle lane was on the other side of an island and doing so directly into the cycle lane.

Another point raised was that guide dog users have a problem "because the guide dog is trained to go first and the person to follow" [London]. This means that the dog, which is completely unaware of the design of the bus stop, can effectively draw their user into a cycle lane – the speed changes because the dog is stepping down (or proceeding down a ramp) from the bus this makes the problem even harder [London]. For carers assisting wheelchair users, the distance inside the bus that they have to be, when preparing to alight, means that they really cannot see to detect an oncoming bicycle, before having to push the wheelchair into the cycle lane. One person commented that her answer was to announce to the bus that she was blind and could someone help her, [Glasgow] and that this was embarrassing ("I feel like a prune, but I have to do it").

There were several calls to remove these bus stops completely, but there were also realisations that there was a need to be able to accommodate cyclists safely in the context of the overall traffic. There were a few suggestions that the space could be reassigned, so that the balance was better and could allow the cyclists to have a safe route as well as the pedestrians and to accommodate necessary traffic. However, there was recognition that cities in the UK were small with relatively narrow streets, so this question would inevitably be a matter of difficult compromises.

A number of people raised the question of 2-way cycle lanes. These do not appear in the LTN 1/20 guidance, but there are several examples around the country. The general feeling in the focus groups was that these were confusing and in the overall context of a bus stop, very dangerous. However, as there is no actual guidance for designing these, and the research was testing the published national guidance (i.e. LTN 1/20), these were not included in the laboratory experiments.

We were able to incorporate several of the concerns raised in the focus groups (in the laboratory experiments) to obtain relevant data, and also, by incorporating a questionnaire in the experiment protocol, to cover some of the concerns that could not be tested in the laboratory situation.

Important points from the Focus Groups include the general stressfulness of the mixing of pedestrians and cyclists, especially in situations where the pedestrian may be unaware of the presence or movement of the cyclists, the speed differentials, and surprise when they are suddenly made aware of them. All of these lead to increased stress, which extends beyond the immediate situation, sometimes to the extent of ceasing to use public transport altogether and thus losing their access to activities.

Focus Group participants were asked what improvements could be made to these designs. The first response was to remove them all completely. If they had to be retained, there was a general desire for consistent design and a request to increase the size of the Floating Island Bus Stop infrastructure. Perhaps the strongest feedback was a clear view that Shared Bus Stop Boarders could never be made safe, and are not appropriate, forcing interactions between cyclists and pedestrians to become more frightening.

In terms of continuous footways, the main issue for the focus group participants was whether, or not, they would know if they were on a footway or on a roadway. "…all of a sudden I realised I was in the road because I didn't realise it was" [London], "…it's got to have some tactile paving across that to warn you, at least that you've now approached a vehicle access area and you would take the same precautions, as if you were crossing a side road" [Birmingham]. Some participants felt that the surface should not be continuous: "it has to be a change in the surface because you can't just rely on the car" [Glasgow].

There was concern about the segregated cycle-footways. "It's not a segregation because you just walk straight into the cycle [side] because the guide dog does not recognise it, and they just walk straight into the side" [Birmingham]. There is also a question for blind and vision-impaired people of working out whether they are on the footway side or the cycle side of the delineator. This might be relatively easy at the start of the infrastructure if suitable tactile paving has been installed, but once moving along the path, or joining it after the start, it can be difficult: "5 minutes down my walk, I've forgotten which side is the pedestrian side [and] which side is the cycle side, and if there's no line or the line is stopped after a couple of metres, I can't remember which is which, so for me to have a really clear repeat reminder of the icon is helpful, as is changing the colour of the other side" [London].

There is also the challenge posed by people shifting from one side to the other of a delineator: "They'll [cyclists] nip onto the pedestrian side and zigzag" [Birmingham]. And there was a recognition that crossing over the delineator is not unique to cyclists: "I have to say a lot of people, whether they're aware of it or not, in Coventry, where we do have this sort of idea, people just walk on the cycling path anyway, and then the cyclists come along and swerve onto the footpath, you know, onto the pedestrian area" [Birmingham].

So, it does suggest that there is some investigation to be done, about how well delineators work, in terms of keeping people on the right side.

4.2 Accompanied site visits

A group of disabled participants attended, an accompanied site visit, that included one Floating Island Bus Stop (Figure 7), one Shared Bus Stop Boarder (Figure 8) and one example of a continuous footway (Figure 9) (located below). This visit further contributed to our understanding of how some design elements contribute or hinder disabled people's safety and sense of independence, in a real (uncontrolled) urban setting.

Due to some limitations in terms of safety and time constraints, we took a small rather than a large group of participants to the site. The group consisted of six participants with a range of disabilities, who were surveyed in each of the sites.

The locations: The two bus stops and the continuous footway examples were within the same area. The selected points were:

- Floating Island Bus Stop: Lea Bridge Stop LN (eastbound from Lea Bridge Station, Long 51.56670414006068, Lat -0.03474851729672434);
- Shared Boarder Bus Stop: Perth Road Stop LE (westbound towards Lea Bridge Station, Long 51.56712118305829, Lat -0.03409865795833351);
- Continuous Footway: Lea Bridge Rd and Burwell Rd junction. (eastbound from Lea Bridge, Long 51.567166198898896, Lat -0.03383378981780782)

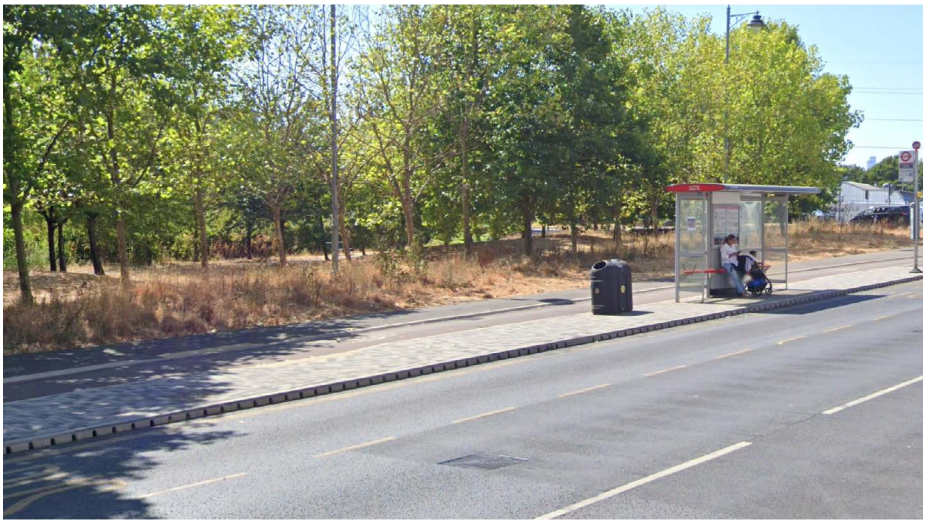


Figure 7 - A floating island bypass bus stop (FIBS), Stop LN, where the island extends further towards both ends. A woman with a child in the buggy waiting at the bus shelter. The layout is relatively free of clutter, the rubbish bin is closer to the cycling lane.

Figure 8 - A Shared Boarder Bus Stop (SBSB), Stop LE, with a buffer area demarcated by white-grey pavers covering approximately 1 meter. The cycling way and footway have a similar colour (red-ish hue). There is some clutter around the flag, a streetlamp, a rubbish bin, and one pole and bollard with no apparent function. There is no tactile paving indicating the transitioning from footway to cycling lane, instead a forgiving kerb is used.

Figure 9 - Lea Bridge Rd and Burwell Rd Junction, a continuous footway setup where the raised pavement uses white-grey pavers, the footway and cycling lane are of a reddish hue. The setup has no obvious clutter.

Table 1: Distribution of Participants (Site Visits)

[This table has 3 columns (Age, Number and Percentage) and 4 rows (over 65, 45-64 and 25-44)]

Age	Number	Percentage
Over 65	1	17%
45-64	2	33%
25-44	3	50%

Table 2: Distribution of Participant Type of Disability (Site Visits)

[This table has 3 columns (Type of Disability, Number, Percentage) and 4 rows (Neurodivergent, Vision Impaired, Blind, Stroller User)]

Type of Disability	Number	Percentage
Neurodivergent	3	50%
Visually Impaired	1	16.7%
Blind	1	16.7%
Stroller user	1	16.7%

Table 3: Distribution of Participant Sex (Site Visits)

[This table has 3 columns (Sex, Number and Percentage) and 2 rows (Male, Female)]

Sex	Number	Percentage
Male	3	50%
Female	3	50%

Below we present the findings from each site, the questions or discussion topics are presented first, followed by a general comments section.

4.2.1 Floating Island Bus Stop (FIBS)

Each of the participants was accompanied to the area of the bus stop and the surroundings. The participants were asked to use the bus stop as they normally would, although they were not allowed to cross on their own without having a safety signal from the researchers. The main objective of this exercise was to understand their navigation strategies, how current and previous designs help them, and the changes needed to make designs safer and easier to navigate.

Only open questions/topics were presented to the participants to allow them the freedom to respond to the designs and express whatever they wanted to, instead of focusing on rating a specific feature. The topic guide can be found in Annex 3.

General comments:

In general, the participants felt that the layout of the sites was confusing. Vision-impaired participants felt that there was no signage for the cyclists to give way to the pedestrians. Mentioning also that when people are standing around waiting for a bus, the cyclists may not be able to notice that a vision-impaired user is waiting to cross. One participant raised the question of why the tactile paving is provided at the ramp for wheelchair users (small ramp), suggesting there should be a layout which provides a hassle-free route for comfort and ease of use with wheeled aids, but also another different entry point with tactile paving to alert Vision-impaired users. Users raised the issue that when there is a crowded situation, in which multiple routes serve the same stop, people standing and waiting for other buses would obstruct the visibility for the bus driver to wait for a vision-impaired user, so their preference would be to stand by the flag, to increase the chances of being noticed by the bus driver.

Most users felt that it is virtually impossible to detect bicycles with the environmental noise around. They felt that the danger was increased by the speed at which cyclists are moving on the track and their tendency not to give way to pedestrians.

Design consistency and clarity:

One participant rated the stop as a 2 out of 5, which helpfully summarises how they felt about the design.

Another participant noted a flaw in the design. The two crossing points (across the cycling track) were at either side of the shelter, but once crossing to the island, they had no way of knowing if they needed to turn left or right, to find the shelter or the flag. This issue could be resolved by adding guidance tactile paving that would guide the pedestrian straight from the crossing point to either the flag or the shelter. It would then be a matter of design consistency to know where the flag is relative to the shelter.

Another issue that became clear, was the difficulty of identifying which bus had stopped. One participant mentioned shouting to the driver to ask which bus route it was. That makes it crucial for them to locate the bus stop flag, which is closer to the drivers.

Delineation and safety:

A user mentioned that the only way possible to know if they are stopping at a Floating Island Bus Stop or a Shared Bus Stop Boarder, for instance, are the on-bus announcements, but these are only present in some lines at the moment. There was a sense that the announcements only alert people to the danger, but do not help to avoid it.

One of the interviewees felt that standing on the island was safe and the size of the island was acceptable. However, when crossing from the footway to the shelter, this became complicated with the footway being slightly crowded, especially when combined with cyclists coming at a speed. A vision-impaired participant felt that it was possible to detect the arrival of the bus. In terms of detecting cyclists, they highlighted the lack of zebra crossing and any audible cue to pedestrians, to alert them to cyclists on the track. The same participant mentioned that more contrasts in the kerbs would be helpful to delineate the cycling track.

Vision-impaired participants felt the boarding and alighting of buses was “fine”. The main challenges were about readability and clearness in regard to crossing the cycle lane.

For Floating Island Bus Stops, it seemed the level of acceptance and perceived safety varied considerably, depending on the users and their previous experiences. For individuals with a vision impairment, they needed to get close to the bus to identify the route, and the next stop due to the lack of audible information. Detecting bicycles was hard for all users but was more difficult for those with a severe vision impairment, leaving the crossing to mere luck and the hope that any cyclist would detect them and stop in time.

4.2.2 Shared Bus Stop Boarder (SBSBs)

As with the Floating Island Bus Stop, the participants were taken to a site and asked to share their feedback after examining the bus stop and its surroundings. The topic guide can be found in Annex 3.

General comments

From the comments of the participants, we had the clear impression that the difficulty and hence, the focus level required to navigate Shared Bus Stop Boarders was considerably higher than for the Floating Island Bus Stop. All participants expressed concerns about their safety when using this particular bus stop. Many felt that, for this location, a full redesign would be necessary to achieve a suitable level of safety and comfort. Most agreed that the only way to make this safer would be to have a similar layout as a Floating Island Bus Stop, where the buffer zone is sufficient to cater for a safe boarding and alighting for the passengers, even if the shelter remained on the footway side.

Delineation and safety

A common concern among the participants was the difficulty in distinguishing the boundary between the footway and cycle lane. This lack of clear delineation led to confusion due to the lack of contrast between the surface of the footway and the cycling track. They both have a similar red hue, and the forgiving kerb (used as a delineator) was not easily perceived by participants. This is potentially dangerous for both pedestrians and cyclists alike. One participant recounted a recent incident where his cane got caught in the wheel of a cyclist, causing a fall. Participants said they felt unsafe, particularly when unaccompanied. One noted "I would give it a 1 out of 5, the other one [Floating Island Bus Stop] was a 2".

Bus stop accessibility

Locating and accessing the bus stop was another challenge for the participants. They found it difficult to detect the difference between the footway and the cycling track, and expressed nervousness about not being able to detect cyclists or navigate the stops, particularly when the footway was busy and other people standing around would impede the bus driver's ability to see them, or cyclists from noticing them trying to cross the lane.

Alighting a bus at these stops was considered confusing and very dangerous due to the narrow buffer zone. Participants suggested improvements such as, better delineation between the footway and cycling way, better tactile pavement guiding them to the flag or stop, and some indication of where the bus is going to stop by using a contrasting colour.

Design consistency and clarity

Participants, particularly those who were vision-impaired, found the layout of the shared spaces confusing and difficult to read due to inconsistent design elements. They also felt that the shared spaces provided the wrong message to cyclists, by what seemed to them, allowing the cyclists to mount the footway, even if it was a cycling lane, it felt more like cyclists riding on the pavement to some participants, exacerbated by the difficulty in interpreting the segregation. A couple of participants suggested that special cycle routes away from pedestrian areas, would be more desirable, if a Floating Island Bus Stop layout was not possible due to lack of space.

Need for redesign

The participants felt that a complete redesign of the shared spaces was necessary. They found the current layout very condensed and difficult to navigate, with too many things happening in a very small area, cyclists between two strips of pedestrians and pedestrians sandwiched very closely to the roadway and the cycling track. They suggested more graphics on the floor and a wider area for safety.

4.2.3 Continuous Footway

In the case of the continuous footway, the participants were asked to cross from one side of the road to the other. For safety reasons, all the participants were accompanied by one of the researchers who was guiding the visit. The participants were taken to the edge of the footway and asked to examine the interface between the actual footway and the continuous pavement (at the crossing). Then, they were asked to identify the crossing. After this, the participants were given a survey with some open and closed questions to answer. We present the results in Tables 4 to 7. The questionnaire can be found in Annex 3.

General comments

The participants had difficulty understanding the setup; some of them used the zebra crossings to locate the junctions. Some of the participants suggested that white paint should be used. The lack of road markings in the surroundings of the crossing was an issue for them, as the double yellow no-parking lines end further along the side road but the continuous pavement section itself was not painted. They mentioned that at least, if there is no kerb, there should be some tactile paving to alert them about stepping onto the carriageway.

One of the participants was not able to identify any difference in the crossing, not being aware that they were walking on the carriageway. They described this as plainly dangerous. The lack of tactile paving in this design was very concerning for them. This crossing had no other features that the participants could identify, some claiming that even the difference in asphalt vs concrete or pavers is helpful.

Table 4: How difficult would you consider it to navigate this footway section?

[This table has 2 columns (Characteristic, All Participants Score) and 3 rows (Junction Mean, Junction Median, Junction Mode)] (Low score means very difficult, high score means very easy)

Characteristic	All Participants Score
Junction Mean	1.60
Junction Median	1
Junction Mode	1

Table 5: How safe do you rate this setup?

[This table has 2 columns (Characteristic, All Participants Score) and 3 rows (Junction Mean, Junction Median, Junction Mode)]

Characteristic	All Participants Score
Junction Mean	1.20
Junction Median	1
Junction Mode	1

Table 6: How often do you find yourself using general road markings to navigate the footway?

[This table has 2 columns (Characteristic, All Participants Score) and 3 rows (Junction Mean, Junction Median, Junction Mode)] (Low score means very rarely, high score means very often)

Characteristic	All Participants Score
Junction Mean	2
Junction Median	1
Junction Mode	1

Table 7: How dangerous do you consider this footway?

[This table has 2 columns (Characteristic, All Participants Score) and 3 rows (Junction Mean, Junction Median, Junction Mode)] (Low score means very dangerous, high score means very safe)

Characteristic	All Participants Score
Junction Mean	2
Junction Median	2
Junction Mode	3

From these results, we can see that this junction was underperforming in terms of readability and perceived safety by this group of users. With most values reporting a mode value of 1, we see that most users appear to be very dissatisfied with this particular design, and considered it dangerous, with a mode of three.

These findings highlight the need for people with a vision impairment to have a means of identifying that they are about to step on a carriageway, either by the use of contrasting colours (like zebra crossings), kerbs or tactile pavements. For this group of participants, the contrast in colour and surface roughness between the original footway and the extension through the carriageway was not enough to be easily detected.

4.3 Professional and Technical workshops

Guide Dogs facilitated a number of workshops with relevant professionals to get their views on Floating Island Bus Stops, Shared Bus Border Bus Stops and Continuous Footways. These were attended by people from professional institutions, transport authorities, cycling and active travel advocates, and mobility advisors. All comments from the workshops were anonymised.

4.3.1 Bus Stops

One participant pointed out that although there had been research into the design for Floating Island Bus Stops, the Shared Bus Stop Boarders had been installed during a phase of rapid expansion of the cycling network and had not been researched, before they were implemented. The implementation instead might be considered to be the research.

There was strong advocacy for ensuring that the public realm was genuinely accessible to all. There were concerns about the accessibility of all of these interventions. There was agreement that the safety risks to cyclists, of cycling in a mixed traffic environment were high and that segregated cycle paths were the best solution to that particular challenge. There was also a basic sense that enabling cycling was a good thing to do. One participant asked whether these were actually the "biggest baddest problem on the roads for people for inclusive design."

However, there was less agreement about the impact of the way in which the cycle lanes had been integrated with bus stops. Some felt that the cyclists should have uninterrupted cycle lanes and that the design should follow that principle. The point was made that there are many examples of arrangements like these installed across Europe for some time, and that these had not raised problems. However, one participant raised the point that the examples in Holland could not just be lifted into the UK, as the culture was different, so it was necessary to make adaptations for the behaviour of cyclists and pedestrians using these facilities in the UK. Another pointed out that there was no training for people on how to use these designs properly. Others felt that there were issues at bus stops with the mix of cyclists and pedestrians, and that these bore disproportionately heavily on disabled people. There was a general sense that Floating Island Bus Stops were a better solution to the problem than Shared Bus Stop Boarders, though one person felt that Shared Bus Stop Boarders were better because they gave better sightlines for cyclists, especially to children who were cycling.

Issues of speed differentials were raised and the difficulty of navigating around the Floating Island Bus Stops where the island was too small. There was some discussion about the problem being that they might be installed in inappropriate places and that if the location and operation were appropriate, they could work well. This related to available space – how much space was taken from traffic lanes in order to accommodate a Floating Island Bus Stop or a Shared Bus Stop Boarder was an issue, especially where the location was on a major road. Another consideration was the bus service at the stop. One participant commented that where flows were low (e.g. six buses per hour) and space was tight, a Shared Bus Stop Boarder could work. Expecting cyclists to stop behind a stopped bus was felt to be inappropriate. There were some suggestions that maybe the traffic or the cycle lane could be diverted to another route, in order to make the space for an adequate design. There was no suggestion of mixing cyclists with traffic: the question seemed to be more of how to accommodate them at the points of interchange with the bus system.

In terms of guidance, there was some support for national guidance and a preference for this to be at the level of the devolved nations rather than the UK as a whole. It was felt that with such consistency across the country it would be easier to educate people about how to use these designs. There was also a call for "national research" into the design and implementation of these interchanges.

The workshop attendees discussed training people to use the Floating Island Bus Stops and Shared Bus Stop Boarders. Generally, the boarding and alighting at a Floating Island Bus Stop is similar to a normal bus stop, but there are issues for blind and vision-impaired people about finding the bus stop from the footway because the bus stop flag is on the island. So, the usual training point of looking for the bus stop flag does not work. It was recognised that the bus stop flag could not be moved onto the footway, as then it would not be visible to the bus driver. Navigating from the bus to the crossing to leave the island is hard because they cannot guarantee where the bus would stop in relation to the crossing point. If there is tactile guidance paving or the blister tail from the tactile paving at the crossing, that helps a lot, but does not resolve this issue of how the person knows whether to turn left or right on leaving the bus to find it.

Training people for the Shared Bus Stop Boarder is much harder because the first issue is that the cycle lane is not visible from inside the bus, so alighting passengers have no idea what might be happening immediately outside the bus. The general training suggestion is to be the last passenger off the bus, but it was acknowledged that it is not easy for a blind or vision-impaired person to know this, so is not a sufficient solution. Assistance dog users also have a problem as the dog is trained to go first and lead them in these situations.

The main problem for trainers (Vision Rehabililtation Specialists) is the inconsistency of the implementations, so some form of guidance would be useful to obtain a consistency across the country. It is often forgotten that people travel away from home, so simply having one set of design guidance in one place and a different one somewhere else is not helpful.

4.3.2 Continuous footways

There was discussion about whether the surface should change as the footway crossed the street. The comment was made that these used to be called "Entry Treatments" and consisted of a raised part of the road surface to give a flat surface for pedestrians instead of installing dropped kerbs, whilst retaining the difference between the road surface and the footway surface. It was felt that the change in surface helped vision-impaired people to know whether they were on a footway or on a road. However, others disagreed, saying that the continuous footway surface provided a statement about the priority of pedestrians over traffic. Others pointed out that there was a real issue for blind and vision-impaired people knowing where they were in terms of being on a road or footway. Other discussions related to the position of the crossing. Normally these follow the line of the footway along the main road and so are quite close to the main road, meaning that turning vehicles were difficult to detect and so these felt quite dangerous in terms of turning traffic. To mitigate this, the suggestion has been to move the crossing further into the side road. This necessitates turning into the side road for a short distance and then turning to cross the road, with the corresponding manoeuvre on the other side of the road to return to the main direction of travel. This was felt to be an added complexity, and although there were some who felt that this would be a good solution, this was by no means universal.

There was a general feeling that these should have tactile paving installed at the road edge, to warn people of the presence of the road. The main debate was about whether the road surface should be the same as the footway or the roadway. One participant cited the example of Holland, where side roads (within residential areas) are all categorised as low priority roads, with pedestrian priority and the continuous footways work because everyone knows that this is how it works.

4.3.3 Delineators between cycle paths and footways

There was a clear sense that some sort of vertical delineation between the cycle path and the footway is essential, and the trapezoidal profile delineator was thought to be adequate. Issues around signage were raised so that people would know on which side of the delineator they were. The space issue also came up – where footways were not wide enough, there were issues about splitting them for cyclists and pedestrians.

There were some comments about different indicators at the start and end of infrastructure elements where there are both cycle paths and footways. So that it is sometimes difficult to know that one has entered a footway or cycle path, or one is leaving it. The difference between being on a footway, which is understood to be free from bicycles and one in which bicycles could be present is considerable, especially for people with sight loss.

4.4 Experiments conducted at PEARL

Evaluating the performance of infrastructure requires understanding of specific parameters obtained directly from the interaction of users with it. To achieve this, it is necessary to isolate variables and control the environment in a way that is not possible in the real world. In doing so, it is crucial to keep the simulated environment as realistic and close as possible to reality. This is where the Person-Environment Activity Research Laboratory comes into place.

Full-size mock-ups of a Floating Island Bus Stop, a Shared Bus Stop Boarder, segregated and delineated cycle-footway and continuous footways with and without tactile paving were designed to evaluate their functionality and more specifically, how participants interact with such features.

4.4.1 Methodology

For health and safety reasons, the processes of approaching a bus stop and boarding/alighting were separated, so that there was a break between each phase of the process. This allowed us to collect data for each phase separately, which meant that participant responses could be more clearly detected and analysed. This meant, however, that the 'smoothness' of completing the whole exercise (of boarding or alighting) was lost. The detailed analysis made possible by this approach, more than offset the disadvantage of the contextual smoothness of the more ecological approach.

We created two bus stop environments based on the designs in LTN 1/20 (see Figure 1 an Figure 2) – a Floating Island Bus Stop and a Shared Bus Stop Boarder – incorporating a cycle lane 70m in length approaching the bus stop and an area of footway in each case. We positioned a bus at the bus stop with a horizontal gap of 500mm and a vertical gap of 60mm between the bus floor and the bus stop platform level. The bus was stationary throughout the experiment. We also provided a 4D soundscape of urban traffic sounds (i.e. 3 spatial dimensions spatially 1 temporal dimension) at a typical urban sound level (representing 65 dBA) in order to provide a suitable auditory context for the experiment. Lighting was set so that it matched a midday lighting environment.

The process for each bus stop type was similar, differing only in the extent to which, it was necessary to carry out the experiment for the different design of the bus stop. Each phase was run 3 times.

Experiment A: Floating Island Bus Stop

Phase A1 Detection of bicycles when crossing from the footpath to the island, but not crossing the cycle lane.

We gave the Participant a handheld button and asked them to stand on or near the tactile paving which indicated the presence and location of the mini zebra crossing, facing the island platform. We asked the Participant to press the button when they could detect an oncoming cyclist. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

Phase A2 Determination of Safe crossing

We positioned the Participant in the same place as they were for Phase 1. We asked the Participant to press the button when they felt that it would no longer be safe for them to cross the cycle lane. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

The combination of Phases 1 and 2 provide two times related to the Participants' detection of cyclists: (1) when they first became aware of the cyclist and (2) when they felt that they could no longer cross safely in front of the cyclist.

We then took them across the cycle lane to the island.

Phase A3 Boarding the bus from the island platform (shelter)

We asked the participants to stand where they would normally stand when waiting for a bus (normally near the front door, wheelchair users by the centre door). Then, when they heard the bus had approached and stopped and the door had opened, they boarded the bus.

Phase A4 Alighting from the bus to the island platform (shelter)

We asked the participants to leave the bus (wheelchair users from the centre door using the ramp, others from the front door).

Phase A5 Detection of bicycles when crossing from the island to the footway, but not crossing the cycle lane.

Phase A5 was similar to Phase A1, except in this case, the participant was simulating leaving the island platform and heading towards the footway.

We asked the Participant to press the button when they could detect an oncoming cyclist. We asked the cyclist to proceed along the cycle lane from a starting positions 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

We then repeated this process, except in this case we asked the participant to press the button when they no longer thought it would be safe to cross the cycle lane. This was also repeated three times.

So, we have two times related to the Participants' detection of cyclists: (1) when they first became aware of the cyclist and (2) when they felt that they could no longer cross safely in front of the cyclist.

Phase A6 Determination of Safe crossing

We positioned the Participant near the crossing point in the same place as they were for Phase 5. We asked the Participant to press the button when they felt that it would no longer be safe for them to cross the cycle lane. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

The combination of Phases 5 and 6 provide two times related to the Participants' detection of cyclists: (1) when they first became aware of the cyclist and (2) when they felt that they could no longer cross safely in front of the cyclist.

We then took them across the cycle lane to the footway and this part of the experiment ended.

Experiment B: Shared Bus Stop Boarders

Phase B1 Detection of bicycles when crossing from the shelter to the bus, but not crossing the cycle lane.

We gave the Participant a handheld button and asked them to stand near the shelter area (where they would normally wait for a bus). We asked the Participant to press the button when they could detect an oncoming cyclist. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

Phase B2 Determination of Safe crossing

We asked the Participant to stand near the shelter area (where they would normally wait for a bus). We asked the Participant to press the button when they felt that it would no longer be safe for them to cross the cycle lane. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

The combination of Phases B1 and B2 provide two times related to the Participants' detection of cyclists: (1) when they first became aware of the cyclist and (2) when they felt that they could no longer cross safely in front of the cyclist.

Phase B3 Boarding the bus

We asked the participants to stand near the shelter close to the point where they would normally board the bus (wheelchair users near the centre door, others the front door). stand where they would normally stand when waiting for a bus (normally near the front door, wheelchair users by the centre door). Then, when they heard the bus had approached and stopped and the door had opened, they boarded the bus.

Phase B4 Detection of bicycles when standing inside the bus

The Participant was positioned inside the bus where they would stand when preparing to leave the bus at a stop. The participant heard the sound of the bus slowing down and stopping at the bus stop and the doors opening (and, when appropriate, the ramp being deployed). We asked the Participant to press the button when they could detect an oncoming cyclist, but not to leave the bus. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

Phase B5 Determination of Safe crossing

We positioned the Participant in the same place as they were for Phase 1. The participant heard the sound of the bus slowing down and stopping at the bus stop and the doors opening (and, when appropriate, the ramp being deployed). We asked the Participant to press the button when they felt that it would no longer be safe for them to cross the cycle lane. We asked the cyclist to proceed along the cycle lane from a starting position 70m away from the bus stop and to maintain a constant speed of either 15 or 20 km/h.

Phase B6 Alighting from the bus and crossing the cycle lane

We asked the participants to leave the bus (wheelchair users from the centre door using the ramp, others from the front door) and cross to the shelter. This part of the experiment ended at this point.

In each bus stop type experiment, the simulation exercise was followed by a brief questionnaire.

4.4.2 Participants

Guide Dogs requested a sample consisting of Participants with varied demographics, including age, gender and a range of mobility and vision impairments.

The participants recruited for the bus stops experiments are shown in the following tables:

Participants were equipped with the following sensors:

Table 8: Distribution of Participant Groups (Overall)

[This table has 3 columns (Age, Number, Percentage) and 3 rows (Over 65, 45-64, 25-44)]

Characteristic	All Participants Score	Percentage
Over 65	4	16%
45-64	11	48%
25-44	9	36%

Table 9: Distribution of Participant Disabilities (Overall)

[This table has 3 columns (Disability, Number, Percentage) and 6 rows (Neurodivergent, Vision Impaired, Blind, Crutch User, Wheelchair (Carer-assisted), Wheelchair (Powered))]

Disability	Number	Percentage
Neurodivergent	6	24%
Vision Impaired	10	44%
Blind	3	12%
Crutch User	1	4%
Wheelchair (Carer-assisted)	2	8%
Wheelchair (Powered)	2	8%

Table 10: Distribution of Participant Sex (Overall)

[This table has 3 columns (Sex, Number, Percentage) and 2 rows (Male, Female)]

Sex	Number	Percentage
Male	9	40%
Female	15	60%

Table 11: Distribution of Participant Groups (Floating Island Bus Stops experiment)

[This table has 3 columns (Age, Number, Percentage) and 3 rows (Over 65, 45-64, 25-44)]

Age	Number	Percentage
Over 65	1	8.33%
45-64	5	41.7%
25-44	6	50%

Table 12: Distribution of Participant Disabilities

(Floating Island Bus Stops (FIBS) experiment) [This table has 3 columns (Disability, Number, Percentage) and 6 rows (Neurodivergent, Vision Impaired, Blind, Crutch User, Wheelchair (Carer-assisted), Wheelchair (Powered))]

Disability	Number	Percentage
Neurodivergent	4	33.3%
Vision Impaired	3	25%
Blind	2	16.7%
Crutch User	1	8.33%
Wheelchair (Carer-assisted)	1	8.33%
Wheelchair (Powered)	1	8.33%

Table 13: Distribution of Participant Sex

(Floating Island Bus Stops (FIBS) experiment) [This table has 3 columns (Sex, Number, Percentage) and 2 rows (Male, Female)]

Sex	Number	Percentage
Male	5	41.7%
Female	7	58.3%

Table 14: Distribution of Participant Groups

(Shared Bus Stop Boarders (SBSB) experiment) [This table has 3 columns (Age, Number, Percentage) and 3 rows (Over 65, 45-64, 25-44)]

Sex	Number	Percentage
Over 65	3	23.1%
45-64	7	53.8%
25-44	3	23.1%

Table 15: Distribution of Participant Disabilities

(Shared Bus Stop Boarders (SBSB) experiment) [This table has 3 columns (Disability, Number, Percentage) and 6 rows (Neurodivergent, Vision Impaired, Blind, Crutch User, Wheelchair (Carer-assisted), Wheelchair (Powered))]

Disability	Number	Percentage
Neurodivergent	2	15.4%
Vision Impaired	8	61.5%
Blind	1	7.69%
Crutch User	0	0%
Wheelchair (Carer-assisted)	1	7.69%
Wheelchair (Powered)	1	7.69%

Table 16: Distribution of Participant Sex

(Shared Bus Stop Boarders (SBSB) experiment) [This table has 3 columns (Sex, Number, Percentage) and 3 rows (Over 65, 45-64, 25-44)]

Sex	Number	Percentage
Male	5	38.5%
Female	8	61.5%

5. Results

5.1 Distance at which bicycles were detected

As every individual responds and reacts differently to stimuli, this research examined how individuals responded to the various stimuli, The results show the responses of the individual participants. We have summarised the detection data for both cases (aiming to board the bus and aiming to leave the bus) at each bus stop type. This means there are 6 data points for each participant (3 readings boarding, 3 readings alighting). What is important here is the range of distances involved, rather than the number of people able to detect at any particular distance: if a person cannot detect a bicycle until after it has passed them, it means that this is indeed possible, and we need to take this situation into account.

Distance to detection means that when the participant pressed the button to indicate that they could detect the bicycle, the bicycle was at this distance away from them. This indicates the time available for the participant to be able to decide whether it might be safe to cross, and the crossing time (if they decided to). Importantly, what this means is that until the bicycle is detected the participant may believe that there is no bicycle there – and thus that it may be safe to cross the cycle lane. Therefore, it would be reasonable to think that the greater the detection distance, the better.

We found that detection was marginally better in the Shared Bus Stop Boarders case than in the Floating Island Bus Stop case.

In the Floating Island Bus Stop case, the distance to detection of the bicycle shown by vision-impaired participants ranged from more than 20m upstream to 2m downstream. The distance range at which blind participants detected the bicycles was between 2m upstream and 3m downstream.

In the Shared Bus Stop Boarders case, the detection range for vision-impaired participants was from 8m upstream to 5 metres downstream. For the blind participants, the range was from 25m upstream to 1m downstream.

The detection range for Neurodivergent people ranged from 32m to 20m for Floating Island Bus Stops and between 32m and 0m for Shared Bus Stop Boarders stops.

Carers with wheelchairs failed to detect bicycles at either the Floating Island Bus Stops or the Shared Bus Stop Boarders stops.

The electric wheelchair user was able to detect the bicycles between 27m and 8m away at the Shared Bus Stop Boarders stop (they were not present at the Floating Island Bus Stop experiment).

The detection range for crutch users was 30m to 13m at Floating Island Bus Stops (there were no crutch users in the Shared Bus Stop Boarders stops experiment).

The Self-propelled wheelchair user failed to detect the bicycle at the Floating Island Bus Stop (there was no electric wheelchair user at the Bus Stop Bypass stops experiment).

There is a lot of variation in detection of bicycles in terms of the distance away from the bus stop at which they could be detected. Of course, the speed at which bicycles are moving will affect the time available to make any decision. For example, 15 km/h is 4.2 metres per second, so a 20m detection distance means that the participant would have less than 5 seconds to react. Participants who detected the bicycle when it was very close, or even had already passed them, were responding to the impression of the combination of the sound and the wind from the bicycle as it passed them.

We believe that the differences between Floating Island Bus Stops and Shared Bus Stop Boarders might result from the fact that there is a distinctive, but small, change in sound when the bicycle mounted the ramp. In the case of the Floating Island Bus Stop, the ramp is immediately adjacent to the mini zebra crossing. In the case of the Shared Bus Stop Boarders stop, this is about 12m away from the participant (although when the participant is inside the bus waiting to alight, this is less easy to detect).

5.2 Distances at which participants declared that it was Not-Safe-To-Cross

In the case of the participants' estimation of when it would not be safe to cross the cycle lane, this also needs a little interpretation. The distance to detect and the Not-Safe-To-Cross distance also have an important relationship to consider. It might be reasonable to think that the Detect distance would be greater than the Not-Safe-To-Cross distance – once the bicycle has been detected then the question arises about the sense of danger about crossing in front of it. Indeed, that is true, but there is more to this comparison than this. In order to unlink these data points, we set the exercise separately, so that in one set of experiments the participants were asked to indicate when they detected the bicycle and in a separate exercise, they were asked to indicate the Not-Safe-To-Cross distance.

Several participants indicated that the Not-Safe-To-Cross distance was greater than the Detect distance. The Not-Safe-To-Cross distance is a proxy for their fear or stress about the situation they have been presented with. If a person is scared about the possibility of a bicycle coming towards them, that is independent of whether or not they can detect it. The uncertainty arising from not knowing whether or not there is a bicycle drives this response. In some ways, detecting the bicycle could give a sense of relief that at least they know there is one and (roughly) where it is. The decision about whether or not to cross comes after that. When a participant indicated that their Not-Safe-To-Cross distance was greater than their Detect distance, they were expressing their stress/fear about the situation.

What this means is that at the point when they pressed the button, they no longer felt that it would be safe to cross the cycle lane. This phase of the experiment was deliberately separated from the first phase, so that the two issues could be separated in the participant's mind. The idea behind this task was to try and ascertain the decision-making time needed by the participants. In fact, in some cases, they failed to detect the bicycle in Phase 1 but might have determined a "Not-Safe-To-Cross" time in Phase 2. In some cases, they detected the bicycle in Phase 1 only after it had already passed them, so the determination of when it would not be safe to cross might or might not have been relevant in such a case. Importantly, the issue reverts to the point made in the previous section: if the bicycle is not detected, the participant may believe that there is no bicycle there, and so they may believe it is safe to cross the cycle lane, even if there actually is a bicycle there. Particularly for people who have experienced this case in the past, the fear resulting from this means, that they always believe that there might be a bicycle there and so, this makes the whole process of crossing the cycle lane very stressful.

The Not-Safe-To-Cross distance for blind people ranged from 21m upstream to 1m downstream at Floating Island Bus Stops, and between 15m upstream to 5m downstream at the Shared Bus Stop Boarders. In the latter case, the median is about 1m downstream, meaning that most of the participants only realised that it was unsafe to cross when they heard/felt the bicycle actually pass them. This reinforces the point about the effect of not detecting a bicycle: prior to this moment, the participant would have been feeling that it was safe to cross the cycle lane, when it would not have been safe to do so.

The decision range for blind and vision-impaired people was between 28m upstream and 1m downstream at Floating Island Bus Stops and 10m upstream to 5m downstream at Shared Bus Stop Boarders stops.

Neurodivergent people, who were detecting the bicycle at the Floating Island Bus Stop between 32m and 20m upstream, determined that it would no longer be safe to cross the cycle lane between 21m and 2m upstream, with the median about 10m, meaning that 50% of the participants declared this when the bicycle was less than 10m from them. At the Shared Bus Stop Boarders stop, they felt that it was Not-Safe-To-Cross when the bicycle was between 34m and 3m upstream of them.

Carers who were assisting wheelchairs, who could not detect the bicycles, felt that it was Not-Safe-To-Cross when the bicycle was between 25m and 0m upstream at Floating Island Bus Stops, and between 30m and 20m upstream (the median in this case was 23m, meaning that half the decisions were made when this distance was between 20m and 23m from the participant). There were no carer assisted wheelchairs at the Shared Bus Stop Boarders stop.

Electric Wheelchair users' decisions for the Not-Safe-To-Cross point at the Bus Stop Bypass stop 15m to 5m upstream (here the median was 8m, meaning that half of the decisions were made when the bicycle was between 5 and 8m away).

The Not-Safe-To-Cross point for Crutch users ranged from 21m to 18m upstream at the Floating Island Bus Stop.

Self-propelled wheelchair user cases showed the Not-safe-to-cross point to be between 30m and 22m, with a median of 25m upstream) at the Floating Island Bus Stop.

These results are tabled in Table 17.

Table 17a: Detection and Not-Safe-To-Cross distances (m) for Floating Island Bus Stop for different participant groups

(U = Upstream; D = Downstream; N/A this group was not present; FTD = Failed to Detect) [This table has 5 columns (Participant, Detect: Upstream, Detect: Downstream, Not-Safe-To-Cross: Upstream and Not-Safe-To-Cross: Downstream and 6 rows (Blind, Vision Impaired, Neurodivergent, Wheelchair (Carer-assisted), Wheelchair (Powered), Crutch Users)]

Participant	**Detect: Upstream**	**Detect: Downstream**	**Not-Safe-To-Cross: Upstream**	**Not-Safe-To-Cross: Downstream**
Blind	2 U	3 D	21 U	1 D
Vision Impaired	20 U	2 D	28 U	1 D
Neuro-divergent	32 U	20 U	21 U	2 U
Wheelchair (Carer-assisted)	0	0	25 U	0
Wheelchair (Powered)	FTD	FTD	30 U	22 U
Crutch users	30 U	13 U	21 U	18 U

Table 17b: Detection and Not-Safe-To-Cross distances (m) for Shared Bus Stop Boarders for different participant groups

(U = Upstream; D = Downstream; N/A this group was not present; FTD = Failed to Detect) [This table has 5 columns (Participant, Detect: Upstream, Detect: Downstream, Not-Safe-To-Cross: Upstream and Not-Safe-To-Cross: Downstream and 6 rows (Blind, Vision Impaired, Neurodivergent, Wheelchair (Carer-assisted), Wheelchair (Powered), Crutch Users)]

Participant	**Detect: Upstream**	**Detect: Downstream**	**Not-Safe-To-Cross: Upstream**	**Not-Safe-To-Cross: Downstream**
Blind	25 U	1 D	15 U	5 D
Vision Impaired	8 U	5 D	10 U	5 D
Neuro-divergent	32 U	0	34 U	3 D
Wheelchair (Carer-assisted)	N/A	N/A	N/A	N/A
Wheelchair (Powered)	27 U	8 U	15 U	5 U
Crutch users	N/A	N/A	N/A	N/A

To put this data in context,Table 17 shows as an illustrative example, the time it would take to cover 20 metres at different speeds, so that the distances shown in Table 17 can be put in context.

For example, a bicycle travelling at 20 km/h would reach a vision-impaired person at a Floating Island Bus Stop less than four seconds after the person had detected it. The Not-Safe-To-Cross distance is a rough indication of how the person feels about deciding to cross the cycle lane in the presence of a bicycle: until the time they press the button, they feel safe to cross the cycle lane. People indicating a Not-Safe-To-Cross distance greater than their detection distance, or where they do not indicate a detect distance at all, are expressing a general feeling of being unsafe in the presence of a cycle lane. To examine a little more about the effects of such an unhappiness, we looked at electrodermal activity (EDA) and Heart Rate Variability.

Table 18: Time of arrival of a bicycle at the participant after detection 20m away, for different bicycle speeds

[This table has 3 columns (Speed (Km/h), Distance (m), Time (s)), and 8 rows (5, 10, 15, 20, 25, 30, 35, 40)]

Speed (km/h)	Distance (m)	Time (s)
5	20	14.28
10	20	7.14
15	20	4.8
20	20	3.59
25	20	2.88
30	20	0.99
35	20	2.06
40	20	1.8

5.3 Heart rate variability

In the case of Heart Rate Variability, the general level of variability is quite low, suggesting that just being in the bus stop environment might be inducing stress. To ensure that this was due to the bus stop environment and not just the experiment situation itself, as with other experiments at PEARL, we compared the Heart Rate Variability with the resting state in the experiment environment. Comparing the two bus stop types, however, we see that the Shared Boarder Bus Stop case resulted in slightly lower heart rate variability than the Floating Island Bus Stop case, suggesting that it is creating more of a stressful situation than the Floating Island Bus Stop one.

When we look at the participant groupings, blind people have a low heart rate variability in both cases, for both detection and Not-Safe-To-Cross cases, the latter slightly lower than the former.

Vision-impaired people had slightly lower results for heart rate variability than the blind people, although there is more of a range between their responses, especially in the Not-Safe-To-Cross exercise in the Shared Bus Stop Boarders case.

Neurodivergent people showed high values for both types of bus stop. In the Detection exercise, they had the highest median. In the Not-Safe-To-Cross exercise the Neurodivergent people included the highest score of all, but the median score was the lowest. This issue of a wide range of scores is not surprising in this case. Neurodivergence encompasses a very broad spectrum of people, many of whom would have strong responses to specific situations. These responses are likely to be highly specific to any one individual, and thus it is no surprise that there are strong responses in either direction. For both Detection and Not-Safe-To-Cross cases, the data includes the lowest scores, suggesting that there is a strong possibility that either bus stop can be problematic for people in this group, but especially the Floating Island Bus Stop.

The Carer-assisted wheelchair users had much higher variability in the Floating Island Bus Stop case than in the Shared Bus Stop Boarders case, especially in the Not-Safe-To-Cross case. This suggests that once they had decided that they would not cross, their stress level reduced.

Similarly, for the crutch user (who only experienced the Floating Island Bus Stop), the range of variability responses in the Detect exercise was high, but their Not-Safe-To-Cross score was high, relative to the Detect score. The powered wheelchair user was high for the Floating Island Bus Stop and had a low heart rate variability in the Shared Bus Stop Boarder, suggesting a higher stress level in this case.

So, the sense from the Heart Rate Variability experiment was that notwithstanding, the very high and very low scores from the neurodivergent group, generally speaking the Shared Bus Stop Boarders case seemed to be more stressful than the Floating Island Bus Stop case. There is a slight suggestion that the participants who did not have vision impairments had lower heart rate variability than either blind or vision-impaired people in the Shared Bus Stop Boarders case, and this would suggest that perhaps this included a visually complex situation that caused them some difficulty, thus increasing their anxiety.

The summary data from all experiments are shown in Table 19.

Table 19a: Floating Island Bus Stop experiment summary data for experiments in PEARL

(bpm = beats per minute; D = detect; NSTC = Not-Safe-To-Cross; WCA = Wheelchair (Carer-Assisted; HR = heart rate); Relative Heart Rate means relative to the Resting Heart Rate) [This table has 8 columns (Disability, Trial, Bike distance: mean, Bike Distance: std, Heart Rate Variability: mean, Heart rate variability: std, Relative heart rate; mean, Relative heart rate: std) and 13 rows (BL:D, BL:NSTC); VI:D, VI:NSTC); ND:D, ND:NSTC); WCA:D, WCA:NSTC); CU:D, CU:NSTC); WP:D, WP:NSTC)]

Dis. (Group count)	**Trial**	**Bike distance (m): Mn**	**Bike distance (m): Std**	**HR variation (-): Mn**	**HR variation (-): Std**	**Relative HR (bpm): Mn**	**Relative HR (bpm): Std**
BL (12)	D	-1.6	2.1	0.034	0.031	3.2	8.7
	NSTC	7.8	9.4	0.030	0.015	3.0	8.0
VI (18)	D	7.8	9.2	0.024	0.015	0.7	7.9
	NSTC	16.4	9.0	0.023	0.016	3.4	5.5
ND (24)	D	28.0	4.8	0.063	0.039	12.1	17.8
	NSTC	11.7	6.2	0.041	0.033	5.1	10.0
WCA (6)	D	0.0	0.0	0.044	0.021	7.7	3.1
	NSTC	9.5	11.0	0.080	0.050	7.0	3.0
CU (6)	D	23.0	8.8	0.050	0.060	28.0	18.7
	NSTC	19.2	1.5	0.076	0.029	25.2	12.3
WP (6)	D	32.0	0.0	0.044	0.024	-2.3	1.5
	NSTC	27.0	3.1	0.037	0.023	8.4	22.6

Table 19b: Shared Bus Stop Boarder (OUTSIDE) experiment summary data for experiments in PEARL

(bpm = beats per minute; D = detect; NSTC = Not-Safe-To-Cross; WCA = Wheelchair (Carer-Assisted; HR = heart rate); Relative Heart Rate means relative to the Resting Heart Rate) [This table has 8 columns (Disability, Trial, Bike distance: mean, Bike Distance: std, Heart Rate Variability: mean, Heart rate variability: std, Relative heart rate; mean, Relative heart rate: std) and 13 rows (BL:D, BL:NSTC); VI:D, VI:NSTC); ND:D, ND:NSTC); WCA:D, WCA:NSTC); CU:D, CU:NSTC); WP:D, WP:NSTC)]

Dis. (Group count)	Trial	Bike distance (m): Mn	Bike distance (m): Std	HR variation (-): Mn	HR variation (-): Std	Relative HR (bpm): Mn	Relative HR (bpm): Std
BL (12)	D	-1.0	0.0	0.026	0.013	4.4	0.8
	NSTC	-4.5	0.7	0.023	0.005	2.4	1.7
VI (18)	D	4.0	6.7	0.032	0.021	6.5	5.6
	NSTC	3.6	4.7	0.028	0.018	9.5	8.3
ND (24)	D	14.2	10.0	0.041	0.017	17.0	5.7
	NSTC	14.2	9.1	0.033	0.024	18.2	4.9
WCA (6)	D	NA	NA	0.023	0.008	4.5	1.8
	NSTC	23.7	4.7	0.014	0.013	15.2	22.7
WP (6)	D	18.7	8.0	0.055	0.033	-3.4	4.1
	NSTC	12.3	4.0	0.024	0.000	3.8	0.0

Table 19c: Shared Bus Stop Boarder (IN BUS) experiment summary data for experiments in PEARL

(bpm = beats per minute; D = detect; NSTC = Not-Safe-To-Cross; WCA = Wheelchair (Carer-Assisted; HR = heart rate); Relative Heart Rate means relative to the Resting Heart Rate) [This table has 8 columns (Disability, Trial, Bike distance: mean, Bike Distance: std, Heart Rate Variability: mean, Heart rate variability: std, Relative heart rate; mean, Relative heart rate: std) and 13 rows (BL:D, BL:NSTC); VI:D, VI:NSTC); ND:D, ND:NSTC); WCA:D, WCA:NSTC); CU:D, CU:NSTC); WP:D, WP:NSTC)]

Dis. (Group count)	Trial	Bike distance (m): Mn	Bike distance (m): Std	HR variation (-): Mn	HR variation (-): Std	Relative HR (bpm): Mn	Relative HR (bpm): Std
BL (12)	D	9.7	13.3	0.024	0.012	1.1	0.4
	NSTC	6.3	8.1	0.030	0.010	2.0	2.1
VI (18)	D	6.2	6.7	0.029	0.021	8.7	7.2
	NSTC	3.5	3.2	0.036	0.045	8.9	7.1
ND (24)	D	14.7	11.3	0.035	0.019	16.0	9.0
	NSTC	17.3	14.1	0.041	0.020	15.3	2.6
WCA (6)	D	NA	NA	0.016	0.009	-0.8	0.1
	NSTC	25.5	4.9	0.022	0.006	3.4	4.3
WP (6)	D	9.3	0.6	0.020	0.021	4.9	5.7
	NSTC	7.5	2.1	0.024	0.009	3.2	2.1

Table 20a: Floating Island Bus Stop experiment summary table of distance, skin conductance, heart rate variability and relative heart rate

(bpm = beats per minute) [This table has 5 columns (Disability, Trial, Bike distance (m): median, minimum, maximum; Heart Rate Variability: median, minimum, maximum; Relative heart rate (bpm): median, minimum, maximum), and 36 rows (Bike Distance:BL:D, Bike Distance:BL:NSTC); Bike Distance:VI:D, Bike Distance:VI:NSTC); Bike Distance:ND:D, Bike Distance:ND:NSTC); Bike Distance:WCA:D, Bike Distance:WCA:NSTC); Bike Distance:CU:D, Bike Distance:CU:NSTC); Bike Distance:WP:D, Bike Distance:WP:NSTC); Heart rate variability:BL:D, Heart rate variability:BL:NSTC); Heart rate variability:VI:D, Heart rate variability:VI:NSTC); Heart rate variability:ND:D, Heart rate variability:ND:NSTC); Heart rate variability:WCA:D, Heart rate variability:WCA:NSTC); Heart rate variability:CU:D, Heart rate variability:CU:NSTC); Heart rate variability:WP:D, Heart rate variability:WP:NSTC); Relative heart rate:BL:D, Relative heart rate:BL:NSTC); Relative heart rate:VI:D, Relative heart rate:VI:NSTC); Relative heart rate:ND:D, Relative heart rate:ND:NSTC); Relative heart rate:WCA:D, Relative heart rate:WCA:NSTC); Relative heart rate:CU:D, Relative heart rate:CU:NSTC); Relative heart rate:WP:D, Relative heart rate:WP:NSTC)]

Disability (Group count)	Trial	Median	Min	Max
Bike distance (m)				
BL	D	-3	-3	2
	NSTC	5.5	-1	21
VI	D	5.5	-2	21
	NSTC	18	-1	28
ND	D	29.5	21	32
	NSTC	10	3	21
WCA	D	0	0	0
	NSTC	7	0	25
CU	D	23.5	14	31
	NSTC	19.5	17	21
WP	D	32	32	32
	NSTC	26	23	31
Heart rate variability (–)				
BL	D	0.031	0.000	0.116
	NSTC	0.033	0.000	0.046
VI	D	0.027	0.000	0.048
	NSTC	0.019	0.000	0.058
ND	D	0.046	0.014	0.148
	NSTC	0.039	0.000	0.098
WCA	D	0.040	0.018	0.078
	NSTC	0.064	0.041	0.174
CU	D	0.035	0.000	0.116
	NSTC	0.092	0.045	0.107
WP	D	0.040	0.023	0.074
	NSTC	0.038	0.000	0.070

Disability (Group count)	Trial	Median	Min	Max
Relative heart rate (bpm)				
BL	D	0.8	-3.3	27.1
	NSTC	-0.4	-3.1	21.3
VI	D	2.9	-13.2	12.7
	NSTC	4.5	-5.6	10.3
ND	D	8.2	-8.3	43.9
	NSTC	2.3	-6.4	27.1
WCA	D	7.4	4.1	12.2
	NSTC	7.9	1.3	9.7
CU	D	17.7	16.7	49.5
	NSTC	19.3	18.5	47.0
WP	D	-1.8	-4.4	-1.2
	NSTC	-0.6	-1.4	54.6

Table 20b: Shared Bus Stop Boarder (OUTSIDE) experiment summary table of distance, skin conductance, heart rate variability and relative heart rate

(bpm = beats per minute) [This table has 5 columns (Disability, Trial, Bike distance (m): median, minimum, maximum; Heart Rate Variability: median, minimum, maximum; Relative heart rate (bpm): median, minimum, maximum), and 36 rows (Bike Distance:BL:D, Bike Distance:BL:NSTC); Bike Distance:VI:D, Bike Distance:VI:NSTC); Bike Distance:ND:D, Bike Distance:ND:NSTC); Bike Distance:WCA:D, Bike Distance:WCA:NSTC); Bike Distance:WP:D, Bike Distance:WP:NSTC); Heart rate variability:BL:D, Heart rate variability:BL:NSTC); Heart rate variability:VI:D, Heart rate variability:VI:NSTC); Heart rate variability:ND:D, Heart rate variability:ND:NSTC); Heart rate variability:WCA:D, Heart rate variability:WCA:NSTC); Heart rate variability:WP:D, Heart rate variability:WP:NSTC); Relative heart rate:BL:D, Relative heart rate:BL:NSTC); Relative heart rate:VI:D, Relative heart rate:VI:NSTC); Relative heart rate:ND:D, Relative heart rate:ND:NSTC); Relative heart rate:WCA:D, Relative heart rate:WCA:NSTC); Relative heart rate:WP:D, Relative heart rate:WP:NSTC)]

Disability (Group count)	Trial	Median	Min	Max
Bike distance (m)				
BL	D	-1	-1	-1
	NSTC	-4.5	-5	-4
VI	D	1	-5	19
	NSTC	5	-5	10
ND	D	14.5	0	27
	NSTC	13.5	5	24
WCA	D	NA	NA	NA
	NSTC	22	20	29
WP	D	18	11	27
	NSTC	13	8	16
Heart rate variability (–)				
BL	D	0.021	0.015	0.041
	NSTC	0.024	0.018	0.028
VI	D	0.027	0.011	0.108
	NSTC	0.025	0.000	0.068
ND	D	0.033	0.028	0.067
	NSTC	0.025	0.016	0.081
WCA	D	0.023	0.016	0.031
	NSTC	0.020	0.000	0.023
WP	D	0.055	0.032	0.078
	NSTC	0.024	0.024	0.024
Relative heart rate (bpm)				
BL	D	4.7	3.4	4.9
	NSTC	3.3	0.4	3.5
VI	D	8.4	-4.2	14.5
	NSTC	9.8	-7.2	37.9
ND	D	16.4	10.2	25.5
	NSTC	16.9	13.3	26.5
WCA	D	5.1	2.5	6.0
	NSTC	3.4	0.9	41.4
WP	D	-3.4	-6.3	-0.5
	NSTC	3.8	3.8	3.8

Table 20c: Shared Bus Stop Boarder (INSIDE) experiment summary table of distance, skin conductance, heart rate variability and relative heart rate

(bpm = beats per minute) [This table has 5 columns (Disability, Trial, Bike distance (m): median, minimum, maximum; Heart Rate Variability: median, minimum, maximum; Relative heart rate (bpm): median, minimum, maximum), and 36 rows (Bike Distance:BL:D, Bike Distance:BL:NSTC); Bike Distance:VI:D, Bike Distance:VI:NSTC); Bike Distance:ND:D, Bike Distance:ND:NSTC); Bike Distance:WCA:D, Bike Distance:WCA:NSTC); Bike Distance:WP:D, Bike Distance:WP:NSTC); Heart rate variability:BL:D, Heart rate variability:BL:NSTC); Heart rate variability:VI:D, Heart rate variability:VI:NSTC); Heart rate variability:ND:D, Heart rate variability:ND:NSTC); Heart rate variability:WCA:D, Heart rate variability:WCA:NSTC); Heart rate variability:WP:D, Heart rate variability:WP:NSTC); Relative heart rate:BL:D, Relative heart rate:BL:NSTC); Relative heart rate:VI:D, Relative heart rate:VI:NSTC); Relative heart rate:ND:D, Relative heart rate:ND:NSTC); Relative heart rate:WCA:D, Relative heart rate:WCA:NSTC); Relative heart rate:WP:D, Relative heart rate:WP:NSTC)]

Disability (Group count)	Trial	Median	Min	Max
Bike distance (m)				
BL	D	2	2	25
	NSTC	5	-1	15
VI	D	5.5	0	29
	NSTC	4	-2	8
ND	D	11	5	31
	NSTC	17	3	34
WCA	D	NA	NA	NA
	NSTC	25.5	22	29
WP	D	9	9	10
	NSTC	7.5	6	9
Heart rate variability (-)				
BL	D	0.019	0.016	0.037
	NSTC	0.028	0.022	0.041
VI	D	0.025	0.000	0.075
	NSTC	0.021	0.000	0.208
ND	D	0.035	0.008	0.064
	NSTC	0.045	0.018	0.064
WCA	D	0.016	0.009	0.022
	NSTC	0.022	0.017	0.026
WP	D	0.012	0.005	0.044
	NSTC	0.022	0.015	0.034
Relative heart rate (bpm)				
BL	D	1.1	0.7	1.5
	NSTC	2.7	-0.3	3.7
VI	D	9.7	-6.3	21.3
	NSTC	9.8	-4.8	28.4
ND	D	14.1	6.9	30.1
	NSTC	13.9	13.4	19.4
WCA	D	-0.8	-0.8	-0.7
	NSTC	3.4	0.3	6.4
WP	D	2.1	1.2	11.5
	NSTC	2.0	1.8	5.6

5.4 Post-experiment questionnaire

After the experiment, we gave the participants a short questionnaire, to enable us to have a richer idea of their approaches to the bus stop setups they had experienced in the experiment. The questionnaire can be found in Annex 3.

5.5 Questionnaire results

5.5.1 General comments

The participants recruited for this experiment were a mix of different disabled people to take into account their different needs. For example, someone who is blind has very different needs compared with someone who is vision-impaired, and there is a wide variety of different vision conditions, each of which has a range of severity. We also recruited neurodivergent people and wheelchair users, crutch users, and a participant with learning disabilities, and each has different implications in terms of interactions with the environment. In analysing the responses, it is therefore inappropriate to attempt to summarise all the participants as one group and therefore, it is important to understand what matters for each group. In the case of the questionnaires, the questions are more generic and do not depend on the actual capabilities provided by the individuals. However, there are important differences between different people. To reflect this in the analysis, we have adopted a method of analysis that examines how the differences between people are captured. We do this by comparing three measures:

1. The mean score for each question
2. The median score for each question (to show how the number of participants is distributed)
3. The mode score (to show the score(s) supported by the largest number of people).

By comparing these, we can see quite clearly how the questions are being answered:

For example,

If the mean is greater than the median, this means that more than 50% of the people scored less than the mean value. The implication of this is that although some people felt strongly positive about the issue, many people were less convinced.

If the mean is less than the median, this means that more than 50% of the people scored above the mean value. The implication of this, is that although some people felt strongly negative about the issue, many people were more supportive.

If mean is the same as median, this means that as many people scored below as scored above the mean. The implication of this is that people were evenly balanced between a positive and negative response about the issue.

If the mean, median and mode are all equal, this would be characteristic of a normal distribution, so looking at these separately gives a better impression of how people felt about the questions when there is not necessarily a lot of agreement between them, for whatever reason.

Finally, as a guide, the answers were given as integers on a scale from 1-5. The 'central' number (i.e. the boundary between positive and negative) is 3. The scores are presented in a form so that a high score represents a 'positive' response and a low score 'negative' response in each question.

5.5.2 Questions

Q1. How difficult did you find it to detect the bicycles in the cycling lane?

Table 21: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): Difficulty in detecting oncoming bicycles

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.83	1.88	4.75
Shared Bus Stop Boarder Median	2.50	1.50	5.00
Shared Bus Stop Boarder Mode	1	1	5
Floating Island Bus Stop Mean	3.50	2.80	4.00
Floating Island Bus Stop Median	4.00	3.00	5.00
Floating Island Bus Stop Mode	5	1	5

This question is about difficulty, so a high score means that the participant finds it easy to detect an oncoming bicycle, and a low score means that they find it difficult. Thus, higher numbers suggest that participants could be more independent and less fearful; lower numbers indicate that the difficulty of using the bus stop could result in reduced independence.

The first point to make here is that the Shared Bus Stop Boarder seems to be more difficult than the Floating Island Bus Stop for all participants. However, unpicking the data further shows that across all participants the picture is a little more nuanced. Vision-impaired people (including Blind people) score both bus stop types below the 'neutral' score of 3, implying that they find them both slightly difficult, but that the Shared Bus Stop Boarder is more difficult than the Floating Island Bus Stop. The median of Vision-impaired participants for Floating Island Bus Stops is 3, which means that 50% of participants scored above 3, whereas the median for Shared Bus Stop Boarders was 1, which means that half the participants scored 1. This suggests that the difficulty was felt to be rather severe in this case. It should be noted that the Blind participants scored 1 for each bus stop type. The second point is that the mode for the Shared Bus Stop Boarders is 1 for all participants, and the median is lower than the mean showing that more than 50% scored above 2, but, importantly, 50% scored less than 2, with the mode at 1. This bus stop was found to be difficult. This was even more strongly the case for the Vision-impaired participants.

On the other hand, the mode in the Floating Island Bus Stop case is the least difficult, with the mean and median both slightly below the boundary between positive and negative. The fact that the mean for all participants is less than the median suggests that more than 50% of people gave answers above the mean value (or less than 50% were more negative than the mean value), in other words, there was a tendency towards finding it less difficult to detect an oncoming bicycle. However, Vision-impaired participants did not follow this trend. They found the Floating Island Bus Stop to be difficult in terms of detecting an oncoming bicycle, with the mean below the median and below the 'neutral' value of 3, suggesting that although some of them felt it was not difficult, those that did, found it very difficult.

On balance, the questionnaire responses suggest that there is a challenge for vision-impaired people in identifying oncoming bicycles at either bus stop, with a sense that the Shared Bus Stop Boarders is more difficult for them than the Floating Island Bus Stop. We should also note that there is a danger that the relative ease with which people with good vision could detect the bicycle could give the impression that there is not a detection problem, so it is important for designers and planners to realise that there is indeed a problem for vision-impaired people and that some find it very difficult.

Q2. How would you rate how understandable is the bus stop setup?

Table 22: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): Understanding the infrastructure setup

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	3.67	3.00	5.00
Shared Bus Stop Boarder Median	4.50	3.00	5.00
Shared Bus Stop Boarder Mode	5	4	5
Floating Island Bus Stop Mean	2.92	2.20	3.43
Floating Island Bus Stop Median	3.00	2.00	3.00
Floating Island Bus Stop Mode	3	3	5

This question is about understandability, so a high score means the participant finds it understandable and a low score that they do not.

The first point here is that, if considering all participants as a single group, the Shared Bus Stop Boarders shows as being slightly more understandable than the Floating Island Bus Stop, with the mean, median and mode all above the neutral value of 3.

The second point is that the mode for the Shared Bus Stop Boarders is 5, with the median well above the boundary between positive and negative responses to the question, and the mean rather lower. This suggests that more than 50% of people feel it is understandable. On the other hand, the mode in the Floating Island Bus Stop case is at the neutral boundary score, with the mean and median almost equal to this. This suggests that the distribution of people thinking it is understandable and those who do not are similar, so the answer is quite equivocal.

However, if we consider just the blind and vision-impaired participants, the Floating Island Bus Stop is not well understood, with a median of 2, suggesting that 50% of the blind and vision-impaired participants scored 2 or less. The mode of 3 suggests that the largest number of people scored 3 or 2. The overall impression for this group is that the Shared Bus Stop Boarder is not easy to understand.

The blind and vision-impaired group's scoring for the Shared Bus Stop Boarder suggests that they find it more understandable than the Floating Island Bus Stop. The median of 4.5 and Mode of 5 suggests a strong sense of understanding the design, and the mean of 4.5 would back this up. This might seem surprising, but actually the Floating Island Bus Stop is quite complex, with several different components to be navigated, whereas the Shared Bus Stop Boarder is relatively simple, and not dissimilar to a normal bus stop, the only complication being the presence of the cycle lane.

The group of 'Other' participants scored quite high for the Shared Bus Stop Boarder, and lower for the Floating Island Bus Stop. However, they scored higher than the vision-impaired people in relation to both designs.

On balance, the questionnaire responses suggest that the Floating Island Bus Stop is more complex to understand than the Shared Bus Stop Boarders. This makes some sense: the Shared Bus Stop Boarders is more similar to an ordinary bus stop in many ways, whereas the Floating Island Bus Stop has a number of different elements contained within it, each of which needs to be understood. So, a message for designers is to ensure that the Floating Island Bus Stop is indicated clearly to users, in advance and whilst they are at the stop. In addition, operators should take steps to ensure that buses always stop in the same place, so that the pathway from bus to footway is always in the same. Procedures should be in place to announce any differences to passengers before they attempt to leave the vehicle.

Q3. How safe would you rate this setup?

Table 23: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How safe is the bus stop setup

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.25	1.50	3.75
Shared Bus Stop Boarder Median	1.00	1.00	4.50
Shared Bus Stop Boarder Mode	1	1	5
Floating Island Bus Stop Mean	2.83	2.40	3.14
Floating Island Bus Stop Median	3.00	2.00	3.00
Floating Island Bus Stop Mode	4	2	4

*Note that in this case there was more than one mode point where the same (highest) number of people chose this value.

This question is about a feeling of safety, so a high score means the participant finds it safe and a low score that they do not.

The first point here is that there is a marked difference between the blind and vision-impaired participants and Others.

Overall, the Shared Bus Stop Boarders shows as being felt to be distinctly unsafe by all participants. The Floating Island Bus Stop is felt to be nearer to feeling safe, and is felt to be safe by some, but in general the sense is that this is fairly equivocal.

However, the difference in scores given by the blind and vision-impaired participant group and the Others is striking. People who did not express a problem with seeing had relatively high scores, whereas the blind and vision-impaired people clearly found both the Shared Bus Stop Boarder and the Floating Island Bus Stop unsafe, with the Shared Bus Stop Boarder worse than the Floating Island Bus Stop.

It is important to note, that although this question refers to the specific instance of a bus stop and oncoming bicycle, the feeling of being unsafe generated in such infrastructure can pass into a person's lived experience and colours other decisions for the long term.

Q4. How likely would you ask for assistance to navigate this setup (asking the bus driver, another passenger, video-calling a friend)?

Table 24: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How safe is the bus stop setup

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	3.00	2.63	3.75
Shared Bus Stop Boarder Median	3.00	2.00	3.50
Shared Bus Stop Boarder Mode	1	1	3
Floating Island Bus Stop Mean	3.25	2.20	4.00
Floating Island Bus Stop Median	4.00	1.00	5.00
Floating Island Bus Stop Mode	5	1	5

In this case, the question is seeking to know whether a person felt they might need to ask for assistance at the stop. The scores show that the larger values suggest that the participants feel that the bus stop design is sufficiently easy to navigate without requiring external aid to the users. Lower scores suggest that the participants would need to ask for assistance.

The first point here is that Vision-impaired and Blind people are more likely to need to ask for assistance than Others at either the Shared Bus Stop Boarder or the Floating Island Bus Stop. Blind and Vision-impaired participants found the Shared Bus Stop Boarder slightly easier to interpret than the Floating Island Bus Stop in this respect, but both received quite low scores. The Others group differentiated a little more between the bus stop types, with the Shared Bus Stop Boarder slightly preferred to the Floating Island Bus Stop.

The answer to this question might relate slightly to Question 3 (feeling of safety): if a participant feels unsafe, they might be more likely to ask for help – if they feel able to do so.

Whereas Q4 relates to the participant being at the bus stop (whether they are intending to board a bus or have just alighted from it), Q5 refers to their arrival at the bus stop on a bus with the intention of alighting at the bus stop.

Q5. How useful would you rate having an on-board recording on the bus informing the passengers which kind of bus stop they will find? (Let us say along with the name of the stop)

Table 25: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How useful would an on-bus recording advising on the type of bus stop be?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	1.25	1.38	1.00
Shared Bus Stop Boarder Median	1.00	1.00	1.00
Shared Bus Stop Boarder Mode	1	1	1
Floating Island Bus Stop Mean	1.50	1.00	1.86
Floating Island Bus Stop Median	1.00	1.00	1.00
Floating Island Bus Stop Mode	1	1	1

In this case, participants are considering what information they might need before starting to alight from the bus at a bus stop. Larger values suggest that the infrastructure provides more safety/ease of navigation without needing the aid of external tools, in this case, onboard announcements.

There is almost universal agreement that announcements on the bus before arriving at the bus stop would be helpful. We note (as did several people in the focus groups) that in London there is an audio-visual announcement on buses advising people to "exercise caution when crossing the cycle lane". However, it does not say which kind of bus stop design is going to be encountered. Given that the immediate circumstance (whether the cycle lane will be next to the bus or on the opposite side of a Floating Island) is a materially different situation when alighting from a bus, it would seem sensible to reword this announcement as appropriate.

Q6. How likely would you use a digital tool to navigate this setup (provided it was available, easy to use and intuitive)?

Table 26: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How likely would you use a digital tool to navigate the bus stop setup?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.83	2.88	2.75
Shared Bus Stop Boarder Median	2.50	3.00	2.00
Shared Bus Stop Boarder Mode	5	1	2
Floating Island Bus Stop Mean	2.75	3.20	2.43
Floating Island Bus Stop Median	2.50	3.00	1.00
Floating Island Bus Stop Mode	1	5	1

Similarly, to Q4, the scores are presented here so that larger values suggest that the infrastructure is easier to navigate without needing the aid of external tools such as a digital navigation tool.

The sense of the responses in this case suggest that the designs are fairly neutral, with a slight downward tendency, suggesting that a digital tool would not be terribly helpful, with Vision-impaired and Blind people slightly more in favour than Others. Reading the responses to this question in combination with those to Q2, Q4 and Q5, the sense is that the bus stop designs are rather confusing, that better information in advance or at the stop itself might be helpful, but that the core issue is the confusing design. Floating Island Bus Stops seem to be worse than Shared Bus Stop Boarders in this respect.

Q7. How much does it help to your perception of safety knowing in advance the setup and geometry of the bus stops (suppose the design is consistently used)?

Table 27: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How much does it help your perception of safety knowing in advance the setup and geometry of the bus stops?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.00	2.50	1.00
Shared Bus Stop Boarder Median	1.00	2.50	1.00
Shared Bus Stop Boarder Mode	1	1	1
Floating Island Bus Stop Mean	1.75	1.00	2.29
Floating Island Bus Stop Median	1.00	1.00	2.00
Floating Island Bus Stop Mode	1	1	1

In this Table, higher scores mean that the participants believe that the bus stop design contributes to safety, ease of use and/or readability, to the extent that knowing about the arrangement in advance would not really help their ability to use the stop. So lower scores mean that they feel they would need such information in advance.

There is almost universal agreement that such information would be useful. This concurs with the sense expressed in Q7.

Q8. How much is your previous cycling behaviour experience contributing to your difficulty with navigating this stop?

Table 28: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How much is your previous experience of cycling behaviour contributing to your difficulty with navigating this stop?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	1.58	1.50	1.75
Shared Bus Stop Boarder Median	1.00	1.00	1.50
Shared Bus Stop Boarder Mode	1	1	1
Floating Island Bus Stop Mean	2.33	1.80	2.71
Floating Island Bus Stop Median	2.00	1.00	3.00
Floating Island Bus Stop Mode	1	1	1

In this case, the participants are considering how their previous experience of cyclists at these bus stops has influenced their fear and stress in using them. Their responses are presented here, the higher scores mean that their experiences contribute positively to their sense of the bus stop being safe and easy to use. Lower scores mean that their previous experience of cyclists has increased the sense of stress and fear about using the bus stop.

In this case, the Shared Bus Stop Boarder seems to raise a greater fear and stress than the Floating Island Bus Stop, but neither is particularly good in this respect.

Q9. How much is the setup design (only infrastructure) contributing to your ability to navigate this stop?

Table 29: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How much is the setup design contributing to your ability to navigate this stop?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	3.75	3.25	4.75
Shared Bus Stop Boarder Median	4.50	4.00	5.00
Shared Bus Stop Boarder Mode	5	5	5
Floating Island Bus Stop Mean	3.33	3.00	3.57
Floating Island Bus Stop Median	4.00	3.00	4.00
Floating Island Bus Stop Mode	4	#N/A*	4

*Note that in this case there was more than one mode point where the same (highest) number of people chose this value.

This question is about how much the setup design contributes to the ability to navigate the stop, so a high score means the participant finds it contributes a lot, and a low score that they do not. Note that this question is not asking about the quality of the design, just about whether the design affects their ability to navigate the stop: this could be in a positive or a negative way.

The lower scores for Vision-impaired and Blind People compared with Others for both designs suggest that they may feel that the stops are so problematic in principle that the detailed design is immaterial. Quite a few comments in the focus groups were along the lines of 'just get rid of them all', which would suggest such a feeling. The scores given by others, and indeed some Vision-impaired and Blind Participants – note the mode is 5 and the median is high for the Shared Bus Stop Boarder in both cases), suggest that design is very important. These responses could therefore be interpreted as saying that if such bus stop designs are necessary, their design is very important.

Q10. How dangerous would you rate this stop setup, given all your previous experience?

Table 30: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): dangerous you would rate this stop setup, given all your previous experience?

(VI = Visually Impaired participants; BL = Blind Participants)

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.42	2.13	3.00
Shared Bus Stop Boarder Median	2.00	1.00	3.50
Shared Bus Stop Boarder Mode	1	1	4
Floating Island Bus Stop Mean	2.75	2.40	3.00
Floating Island Bus Stop Median	2.50	2.00	3.00
Floating Island Bus Stop Mode	2	1	4

This question is about how dangerous the participant feels that the bus stop setup is. We have presented the scores here so that a low score means that the participant finds it dangerous, and a high score that they do not. This is so that the high score would represent a 'better' outcome, i.e. a less dangerous bus stop.

The scores are nearly all low, especially for the blind and vision-impaired participants, suggesting that they find the bus stop designs to be dangerous in both cases. For the 'Others' group, the sense is that they find them neutral with a slight tendency towards feeling that they might not be so dangerous, but this is not strong. This is another case where the reliance on competent vision, in order to use the stop safely is evident: these are bus stops for people with good eyesight, and their performance for people whose sight is not so good is low.

Q11. How safe would you rate this stop setup supposing that the majority of cyclists give way to passengers boarding and alighting buses?

Table 31: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): dangerous you would rate this stop setup, given all your previous experience?

(VI = Visually Impaired participants; BL = Blind Participants)

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	2.92	2.25	4.25
Shared Bus Stop Boarder Median	2.50	2.00	4.50
Shared Bus Stop Boarder Mode	5	2	5
Floating Island Bus Stop Mean	3.25	4.00	2.71
Floating Island Bus Stop Median	3.50	5.00	3.00
Floating Island Bus Stop Mode	5	5	1

In this case, higher scores suggest that the participants feel that the setup would be safe, if the majority of cyclists were to give way to people boarding and alighting from buses.

The results suggest that Vision-impaired and Blind people are less confident about this than Others. For the Others group, if cyclists were to give way at a Shared Bus Stop Boarder would make it feel relatively safe, but they are slightly more hesitant on this for the Floating Island Bus Stop. There is a range of opinion though (note that the mode is 5 for both setups). Vision-impaired and Blind participants scored low in the Shared Bus Stop Boarder case. It is unclear from this, whether they thought that the design would be unaffected by cyclist behaviour or if they thought that the idea of a majority of cyclists behaving in this way is rather unlikely (some of the focus group comments would suggest the latter). However, they scored high in the Floating Island Bus Stop case, which suggests that they would feel more confident in this case.

Q12. How confident do you feel when identifying tactile pavements?

Table 32: Mean, Median, and Mode for Shared Bus Stop Boarder (SBSB) and Floating Island Bus Stop (FIBS): How confident do yo9u feel when identifying tactile pavements?

(VI = Visually Impaired participants; BL = Blind Participants) [This table has 4 columns (Characteristic, All Participants, VI & BL, Others), and 6 rows (Shared Bus Stop Boarder Mean, Shared Bus Stop Boarder Median, Shared Bus Stop Boarder Mode, Floating Island Bus Stop Mean, Floating Island Bus Stop Median, Floating Island Bus Stop Mode)]

Characteristic	All participants value	VI & BL value	Others value
Shared Bus Stop Boarder Mean	4.08	4.38	3.50
Shared Bus Stop Boarder Median	4.00	4.00	3.00
Shared Bus Stop Boarder Mode	4	4	3
Floating Island Bus Stop Mean	1.58	2.00	1.29
Floating Island Bus Stop Median	1.00	1.00	1.00
Floating Island Bus Stop Mode	1	1	1

This question is about how confident the participant feels about identifying tactile pavements, so a high score means the participant feels confident about this, and a low score that they do not.

The general sense from these responses is that the participants felt very confident in the Shared Bus Stop Boarder, and slightly less so in the Floating Island Bus Stop. This is the case for both Others and Vision-impaired and Blind people. The blind and vision-impaired people are confident about the Shared Bus Stop Boarder. In this case, the arrangement is relatively simple – a strip of tactile paving to warn about the adjacency of the cycle lane. In the case of the Floating Island Bus Stop, the arrangement of tactile paving is more complex. Not only is it needed at the mini zebra crossing, it is also needed to guide the person towards the mini zebra crossing. Although on the footway side, this is not very different from the arrangement at a normal zebra crossing, when having to cross the cycle lane in the other direction, to reach the footway from the bus stop, it is necessary to locate the tail of the tactile arrangement on departure from the bus. Which direction the person needs to turn, in order to do this, depends on where the bus stops in relation to the tactile tail. Unlike the situation at a normal bus stop, where such a directionality and position are not so relevant, in the situation of the Floating Island Bus Stop, it is critical – turning in the wrong direction could lead them off the island into the cycle lane or even into the roadway. The reason for this difficulty is that the bus may not always stop in the same place relative to the bus stop – for all sorts of traffic-related reasons. The seriousness of this problem is such that operators need to ensure that their drivers are trained so that they always stop at the correct position, and designers need to take this into account when designing the capacity of the bus stop island, so that the drivers are not pressured into stopping in incorrect places. A final last-resort possibility is that the buses carry a pre-recorded announcement to say which way people should turn after alighting from the bus in order to find the tactile tail, in the event of the bus not stopping in the correct position.

Figure 10 – A close-up photo of the profile of a white painted trapezoidal delineator which is 50mm high with sloped edges.

Cycle Path-footway infrastructure

Cycle Path-footway infrastructure is sometimes referred to as Shared Pedestrian and Cycle routes". However, this is confusing, as the main feature in infrastructure terms of such spaces is that they are not shared. This infrastructure consists of a single surface in the centre of which is a physical delineator to denote that one side is for bicycles and the other side is for pedestrians. The intention is to enable each group to feel unimpeded by the other.

We asked the participants to tell us about their capabilities in relation to the delineators that mark the boundary between footways and cycle paths. There were four types of delineators used in the experiment:

1. A raised trapezoidal continuous delineator, profiled to 50mm height, white colour
2. A raised trapezoidal delineator profiled to 50mm height (as in (1) but in sections with gaps between each section, white colour
3. A delineator formed by a kerb, with the cycle path at a lower level than the footway, kerb painted white
4. A delineator formed by a continuous painted white line

The participant started this exercise by standing in front of the footway/cycling track delineator, and before the buff tactile paving that marks the start of such a shared footway/cycle path arrangement.

We then asked them to proceed and move to the "correct" side of the path, as they would if they had encountered one in the urban environment, for example by feeling the orientation of the corduroy pavement and choosing the side on which the tactile paving was aligned at a right angle to the direction of travel (the cycling path side had corduroy paving aligned parallel to the direction of travel).

After completing this exercise, we asked them whether they had detected any colour contrast between the footway (which was plain concrete paving) and the cycle path (which was a black asphalt colour). The results are summarised in Table 33.

Table 33: Finding the correct side of the delineator

[This table has 5 columns (Disability, Able to find the correct side of the path? Find Path, Able to find the correct side of the path? Not Find Path, Able to detect colour contrast between footway and cycle path? Colour Contrast, Able to detect colour contrast between footway and cycle path? Not Colour Contrast), and 11 rows (Vision Impaired, Neurodiverse, Learning Disability, Wheelchair, Crutch User, Total All, % All, Total VI, % VI, Total Others, % Others)]

Disability	**Able to find the correct side of the path?**	**Not able to find the correct side of the path?**	**Able to detect colour contrast between footway and cycle path?**	**Not able to detect colour contrast between footway and cycle path?**
Vision impaired	8	5	7	6
Neurodiverse	4	1	5	0
Learning Disability	1	0	0	1
Wheelchair	2	0	2	0
Crutch User	1	0	1	0
Total All	16	6	15	7
% All	0.73	0.27	0.68	0.32
Total VI	8.00	5.00	7.00	6.00
% VI	0.62	0.38	0.54	0.46
Total Others	8.00	1.00	8.00	1.00
% Others	0.89	0.11	0.89	0.11

Table 33 shows that 62% of the blind and vision-impaired group detected the correct side of the path, and slightly more than half (54%) could detect the colour contrast. This compares with almost 90% of the other participants being able to detect the correct side of the path and a similar proportion being able to detect the colour contrast between the two surfaces. This suggests that vision-impaired participants do not necessarily detect an indicator surface (corduroy, in this case), for example, some vision-impaired participants said that they did not know about corduroy paving in this context.

Additionally, only one third of the blind participants was able to correctly read the tactile paving to choose the footpath side. From the rest of the vision-impaired participants, 6 out of 10 were able to both detect the delineator and the contrast between the different sides of the path. This shows the importance of having both means of identifying the different pathways.

We then looked at the four types of delineators noted earlier. In each case we asked participants four questions:

1. How would you rate the detectability of the delineator in this section?
2. How comfortable the delineator is when walking/moving on it?
3. How confident are you in using this delineator to navigate within the shared space?
4. How safe do you feel using the delineator to navigate the shared space?

Continuous Central Delineator

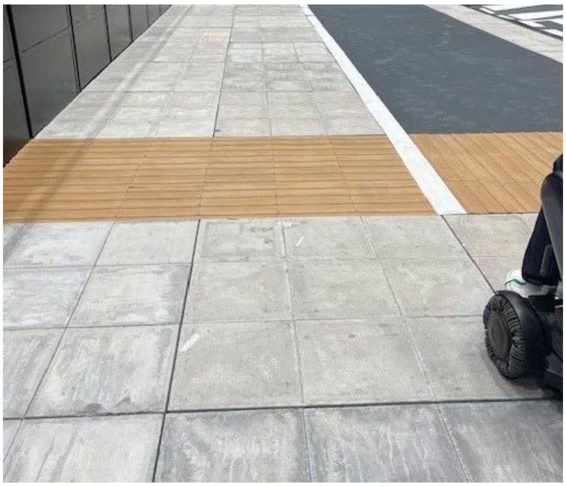
The results for the Continuous Central Delineator are shown in Table 34.

Table 34: Continuous Central Delineator

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How would you rate the detectability of the delineator in this section?	3.82	4.50	5.00	3.77	5.00	5.00	3.89	4.00	5.00
How comfortable the delineator is when walking/ moving on it?	4.05	5.00	5.00	3.92	5.00	5.00	4.22	5.00	5.00
How confident are you in using this delineator to navigate within the shared space?	3.82	4.00	5.00	3.77	4.00	5.00	3.89	4.00	3.00
How safe do you feel using the delineator to navigate the shared space?	3.77	4.00	5.00	3.85	5.00	5.00	3.67	4.00	5.00
Total (Mean), maximum possible=20	15.45	-	-	15.31	-	-	15.67	-	-
% Total Mean/ Maximum possible Mean	0.77	-	-	0.77	-	-	0.78	-	-

Figure 11 - Photo of the simulation of a segregated cycle-footway with a white trapezoidal continuous delineator with buff tactile paving laid ladder-like on the pedestrian side and tram-like on the cycle path. The surface for pedestrians is grey pavement and black tarmac for cyclists.



In the case of the Continuous Delineator, participants in general did not necessarily find it very detectable. The overall mean score (on a scale of 1 to 5) was 3.82, suggesting it was slightly better than neutral, but not by a great deal. It was slightly surprising that the participants without vision impairments rated the detectability of the delineator only slightly above the score given by the blind and vision-impaired participants. The mode for each group of participants was 5, and the median was high, so most participants could detect it easily. The issue is that there are some participants who find detecting the delineator difficult.

The next question was “how comfortable was the delineator when you moved on it?”. Vision-impaired and Blind Participants scored this rather negatively, slightly below the neutral score of 3. Other participants were a little bit more disposed towards this question, but still only scored slightly above the neutral score.

The third question was “how confident do you feel in using this delineator to navigate within a shared space?” Participants responded similarly to this question as they had to the previous one, with the blind and vision-impaired participants scoring slightly below neutral and the others slightly above.

Finally, we asked “how safe do you feel about using this delineator to navigate the shared space?”. The responses were slightly lower than for the previous two questions, with the blind and vision-impaired participants scoring below neutral and the other participants at exactly neutral (their scores resulted in the mean, median and mode all being 3.00).

In Table 34, we also show the total mean score for each group across all the questions, to give a sense of how each group felt about the delineator overall. If the mean for each question had been 5, then the total would have been 20. In the case of the Continuous Delineator, the total was 15.45 for all participants, 15.31 for vision impaired and blind participants and 15.67 for the other participants. This suggests that the continuous delineator is a little higher than neutral across all the questions by each of the groups.

Table 35: Delineator with gaps

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How would you rate the detectability of the delineator in this section	3.09	3.00	5.00	2.69	3.00	1.00	3.67	5.00	5.00
How comfortable the delineator is when walking/ moving on it?	2.77	3.00	1.00	2.23	2.00	1.00	3.56	3.00	5.00
How confident are you in using this delineator to navigate within the shared space?	2.77	3.00	1.00	2.38	2.00	1.00	3.33	3.00	5.00
How safe do you feel using the delineator to navigate the shared space?	2.68	3.00	1.00	2.46	2.00	1.00	3.00	3.00	3.00
Total (Mean) maximum possible=20	11.32	-	-	9.77	-	-	13.56	-	-
% Total Mean/ Maximum possible Mean	0.57	-	-	0.49	-	-	0.68	-	-

Figure 12 - Photo of the simulation of a segregated cycle-footway with a white trapezoidal delineator with gaps. The surface for pedestrians is grey pavement and black tarmac for cyclists.

In the case of the Delineator with gaps, similarly to the continuous delineator, the participants in general did not necessarily find it very detectable. In fact, they found it rather less detectable than the continuous delineator. The overall mean score (on a scale of 1 to 5) was 3.09, suggesting it was only very slightly better than neutral. The main outcome to this question is that the blind and vision-impaired participants found it worse than neutral, whereas the continuous delineator was a little better than neutral. The mode for the blind and vision-impaired participants group is 1, so very poor indeed. The Other participants have a mode of 5, and the median is also high, so most of this group could detect it easily. The issue is that there are some participants who find detecting the delineator difficult, but the performance of the delineator with gaps for Vision-impaired and Blind participants is poor.

The next question was "how comfortable was the delineator when you moved on it?". Vision-impaired and Blind Participants scored this even more negatively than the detection question, with a mean of 2 and a median of 2.23, meaning that more than half of the group scored less than 2. Other participants were a little bit more disposed towards this question

The third question was "how confident do you feel in using this delineator to navigate within a shared space?" Participants responded similarly to this question as they had to the previous one, with the blind and vision-impaired Participants scoring slightly below neutral and the others slightly above.

Finally, we asked "how safe do you feel about using this delineator to navigate the shared space?". The responses were more negative than for the continuous delineator.

In Table 35, we show the total mean score for each group across all the questions. In the case of the Delineator with gaps, the total was 11.32 for all participants, 9.77 for vision-impaired and blind participants and 13.46 for the other participants. This suggests that the delineator with gaps is not particularly liked by any of the groups, and rather less by vision-impaired and blind participants.

Table 36: Delineators with kerb

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How would you rate the detectability of the delineator in this section	2.55	2.00	2.00	2.08	2.00	2.00	3.22	4.00	5.00
How comfortable the delineator is when walking/ moving on it?	3.00	3.00	5.00	2.69	3.00	3.00	3.44	4.00	5.00
How confident are you in using this delineator to navigate within the shared space?	2.50	2.00	1.00	2.31	2.00	1.00	2.78	2.00	1.00
How safe do you feel using the delineator to navigate the shared space?	2.32	2.00	1.00	2.31	2.00	1.00	2.33	2.00	1.00
Total (Mean) maximum possible=20	10.36	-	-	9.38	-	-	11.78	-	-
% Total Mean/ Maximum possible Mean	0.52	-	-	0.47	-	-	0.59	-	-

Figure 13 - Photo of the simulation of a segregated cycle-footway with a white kerb upstand delineating both sides. The surface for pedestrians is grey pavement and black tarmac for cyclists.

In the case of the Delineator with kerb, this scored lower than either the continuous delineator or the delineator with gaps, so the participants in general did not necessarily find it very detectable. The overall mean score was 2.55, suggesting it was slightly worse than neutral. The main outcome to this question is that the blind and vision-impaired participants found it much worse than neutral. The mode for the blind and vision-impaired participants group is 2, so most participants scored it as poor but not the worst possible score. The median being also 2, suggests that half of this scored it as 2 or less. The Other participants have a mode of 5, and the median is also high, so most of this group could detect it easily. The issue is that there are quite a few Vision-impaired and Blind participants who find detecting this delineator very difficult.

The next question was “how comfortable was the delineator when you moved on it?”. Vision-impaired and Blind Participants scored this less negatively than the detection question, with a mean of 2.69 and a median of 3. Other participants were more disposed towards this question.

The third question was “how confident do you feel in using this delineator to navigate within a shared space?” Participants responded more negatively to this question as they had to the previous one, with all groups scoring below neutral.

Finally, we asked “how safe do you feel about using this delineator to navigate the shared space?”. The responses were more negative than the other questions, with all groups scoring well below neutral, and each group had a mode of 1.

In Table 36, we show the total mean score for each group across all the questions. In the case of the Delineator with gaps, the total was 10.36 for all participants, 9.38 for vision-impaired and blind participants and 11.78 for the other participants. This suggests that the kerb delineator is not particularly liked by any of the groups, and rather less by vision-impaired and blind participants.

Table 37: Painted Delineators

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How would you rate the detectability of the delineator in this section	2.55	2.00	2.00	2.54	2.00	2.00	2.56	2.00	2.00
How comfortable the delineator is when walking/ moving on it?	3.00	3.00	5.00	3.15	3.00	5.00	2.78	3.00	1.00
How confident are you in using this delineator to navigate within the shared space?	2.50	2.00	1.00	2.38	2.00	1.00	2.67	3.00	3.00
How safe do you feel using the delineator to navigate the shared space?	2.32	2.00	1.00	2.31	2.00	1.00	2.33	3.00	3.00
Total (Mean) maximum possible=20	10.36	-	-	10.38	-	-	10.33	-	-
% Total Mean/ Maximum possible Mean	0.52	-	-	0.52	-	-	0.52	-	-

Figure 14 - Photo of the simulation of a segregated cycle-footway with a painted white line used as the delineator. The surface for pedestrians is grey pavement and black tarmac for cyclists.

In the case of the Painted Delineator, this scored lower neutral overall and for both groups of Blind and Vision-impaired Participants and Others, so the participants in general found it not very detectable. Each group had a mode and median of 2, so half the participants in each group scored below 2 in terms of detectability. The main outcome to this question is that all groups found it poor in terms of detectability. This seems like a poorly performing delineator.

The next question was "how comfortable was the delineator when you moved on it?". Blind and Vision-impaired Participants scored this less negatively than the detection question, with a mean of 3.15, a median of 3, and a mode of 5. Other participants were less disposed towards this question.

The third question was "how confident do you feel in using this delineator to navigate within a shared space?" Participants responded more negatively to this question as they had to the previous one, with all groups scoring below neutral.

Finally, we asked "how safe do you feel about using this delineator to navigate the shared space?". The responses were more negative than the other questions, with all groups scoring well below neutral, and each group had a mode of 1.

In table 37 above, we show the total mean score for each group across all the questions. In the case of the Painted Delineator, the total was 10.36 for all participants, 10.38 for Blind and Vision-impaired participants and 10.33 for the other participants. This suggests that the painted delineator is not particularly liked by any of the groups, and rather less by Blind and Vision-impaired participants.

Continuous paving

We then turned to the question of paving that is 'continuous' over the crossing of a street. This means that, instead of having a kerb and/or dropped kerb to lower the walkway to the level of the roadway, the footway level is maintained across the street. Traffic is raised to the level of the footway by ramps on either side. This arrangement is quite commonly used when a road is turning onto/off a main road and the ramps are used to warn drivers that they are entering a residential zone. There are two versions of this, one which includes tactile paving to warn participants that they are about to enter a roadway, and the other which has no indication of entering a roadway. We tested both.

In this case we asked four questions:

1. How difficult would you consider it is to navigate this footway section?
2. How safe do you rate this setup?
3. How often do you find yourself using general road markings to navigate the footway?
4. How dangerous do you consider this footway?

Table 38: Continuous footway at junctions with tactile paving

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How difficult would you consider it is to navigate this footway section?	3.55	4.00	5.00	3.31	3.00	5.00	3.89	5.00	5.00
How safe do you rate this setup?	3.45	3.50	5.00	3.69	4.00	5.00	3.11	3.00	5.00
How often do you find yourself using general road markings to navigate the footway?	3.55	4.00	2.00	3.46	4.00	2.00	3.67	5.00	5.00
How dangerous do you consider this footway?	3.23	3.00	5.00	3.62	4.00	5.00	2.67	3.00	1.00
Total (Mean), maximum possible=20	13.77	-	-	14.08	-	-	13.33	-	-
% Total Mean/ Maximum possible Mean	0.69	-	-	0.70	-	-	0.67	-	-

In this case of the Continuous footway with tactile paving, the first question, “How difficult would you consider it is to navigate this footway section?”, scored slightly above neutral overall and for both groups of Blind and Vision-impaired Participants and Others, so the participants in general found it only just detectable. The overall mode for each group was 5 although Blind and Vision-impaired participants had a median of 3, suggesting that half of this group scored lower than neutral.

The next question was “How safe do you rate this setup?”. Blind and Vision-impaired Participants scored this more positively than the difficulty question, with a mean of 3.69, a median of 4, and a mode of 5. Other participants were less disposed towards this question.

The third question was “How often do you find yourself using general road markings to navigate the footway?”. This question was really to determine how participants used the markings in the footway and road environment to guide them in using the continuous footway. Participants responded reasonably above neutral.

Finally, we asked “How dangerous do you consider this footway?”. The responses were that it was better than neutral, but not by a great margin.

In Table 38 above, we show the total mean score for each group across all the questions. In the case of the footway with tactile paving, the total was 13.77 for all participants, 14.08 for Blind and Vision-impaired participants and 13.33 for the other participants. This suggests that the setup with tactile paving to signalise an intersection is better than neutral for most participants.

Table 39: Continuous footway with no tactile paving

[This table has 10 columns (Question, Mean All, Median All, Mode All, Mean VI, Median VI, Mode VI, Mean Others, Median Others, Mode Others), and 6 rows (how would you rate the detectability of the delineator in this section?, how comfortable the delineator is when walking/moving on it?, how confident are you in using this delineator to navigate within the shared space, how safe do you feel using the delineator, Total (Mean), maximum possible=20, % Total Mean/Maximum possible Mean)]

Question	Mean All	Med. All	Mode All	Mean VI	Med. VI	Mode VI	Mean Et al.	Med. Et al.	Mode Et al.
How difficult would you consider it is to navigate this footway section.	2.32	2.00	1.00	1.85	2.00	1.00	3.00	3.00	1.00
How safe do you rate this setup?	2.36	2.00	1.00	2.08	1.00	1.00	2.78	3.00	1.00
How often do you find yourself using general road markings to navigate the footway?	3.41	3.00	5.00	3.15	3.00	3.00	3.78	5.00	5.00
How dangerous do you consider this footway?	2.14	1.50	1.00	1.69	1.00	1.00	2.78	3.00	1.00
Total (Mean), maximum possible=20	10.23	-	-	8.77	-	-	12.33	-	-
% Total Mean/ Maximum possible Mean	0.51	-	-	0.44	-	-	0.62	-	-

In the case of the Continuous footway without tactile paving, the first question, “How difficult would you consider it is to navigate this footway section?”, scored poorly overall, and especially poorly for Blind and Vision-impaired Participants, so the participants in general found it only just detectable. The mode for each group was 1, suggesting that many participants, especially Blind and Vision-impaired participants, found this difficult.

The next question was “How safe do you rate this setup?”. Although the mean score is higher for Blind and Vision-impaired participants than Others, the median and mode were both 1, showing that half the participants in this group scored it as extremely poor.

The third question was “How often do you find yourself using general road markings to navigate the footway?”. This question was really to determine how participants used the markings in the footway and road environment to guide them in using the continuous footway. Participants responded reasonably above neutral.

Finally, we asked “How dangerous do you consider this footway?”. The responses were that in every group it was very unsafe.

In Table 39 above, we show the total mean score for each group across all the questions. In the case of the footway without tactile paving at the junction, the total was 10.23 for all participants, 8.77 for Blind and Vision-impaired participants and 12.33 for the other participants. This suggests that the continuous footway without tactile paving is bad for all participants.

6. Discussion

6.1 General points

From the various focus groups, site visits and experiments, a common theme is that neither Floating Island Bus Stops nor Shared Bus Stop Boarders are currently perceived to be safe. This leads to a general sense of fear about using them, which causes some people to avoid using bus services. The issue is therefore about how we can improve the infrastructure to increase its safety and reduce disabled people's fear.

The research found that the Shared Bus Stop Boarder causes a greater concern than the Floating Island Bus Stop. This is despite the Floating Island Bus Stop being considered to be more complicated and harder to understand. The clear sense that the Shared Bus Stop Boarder are considered inherently unsafe came across very strongly in the focus groups and was supported by the results from the experiments.

There was a sense in the focus groups that Floating Island Bus Stops are considered to be unsafe and therefore should be avoided. However, if they are the only way to accommodate an essential cycle lane and an essential bus stop, then there are a number of issues with Floating Island Bus Stops that were identified during the research that need to be resolved.

6.2 Floating Island Bus Stop

Width of the Floating Island

The main comment about the Floating Island was about size. The fact that it is an island means that its size is a limit. In a normal kerbside bus stop, if there is not enough space 'in' the bus stop area, people can spread along the adjacent footway. Although this can cause congestion for other pedestrians at busy times, it remains basically safe in relation to the traffic. However, with a Floating Island Bus Stop, the area available to people using the bus stop is limited by the size of the island, and any extra space would involve some incursion of either the cycle lane or the traffic lane adjacent to the stop, either of which would create safety issues. This basic safety problem is made worse by the fact that some people require more space than others at a bus stop, for example, wheelchair users, people travelling with a carer or assistance dogs, or using other mobility aids. Blind and Vision-impaired people find it difficult to find their way around a bus shelter if there are people sitting in it as they have to navigate around feet and legs. Although this arises at any bus shelter, it can be worse at Floating Island Bus Stops because the width of the island is a constraint on the space available to move around.

Therefore, there is a real issue about the size of the island. LTN 1/20 shows the width to be 2.5m [35], but our research suggests this is inadequate. Informal tests with a carer-propelled wheelchair indicated that a minimum width of 3.5m would be required to enable a carer and the wheelchair to be able to leave a bus and navigate to the mini zebra crossing without encroaching into the cycle lane. The dimensions suggested by Inclusive Mobility for people with assistance dogs is 1.2m, which should be measured from the normal position of a person's feet, when seated in the shelter. The length of the island depends on the number of buses expected to be stopped at the bus stop at the same time. Given the length of a current bus (11-12m) and its manoeuvrability and the need to maintain capacity at the bus stop with controlled stopping spaces, this suggests that an island may need to be of the order of 30m in length (this length is about to be tested in Ireland by the National Travel Authority there). This is a subject for urgent research as it materially affects the accessibility of Floating Island Bus Stops in general.

Location of buses at the bus stop

This arose because of concerns expressed in the focus groups about finding the location of the crossing to leave the island. People did not know if they should turn left or right on leaving the bus, and thus became disorientated and could not find their way to the crossing. We think this requires firmer control over where the buses stop at a bus stop (this applies to all bus stops), and a suitable protocol for when there is more than one bus at the bus stop at a time. Thought should be given to road markings to help the driver, not only at the stop itself, but upstream so that they can start the alignment process in good time.

It would also be helpful if the design of the island could be consistent so that the blister paving could always be in the same place in the island in relation to where the bus stops, so that alighting passengers could know which way to navigate to find the mini zebra crossing. It is impossible to predict whether or not a bus will be able to stop at precisely the same place, so there will be a need for some sort of information system with a capability to adjust the wording of an announcement to inform passengers of this direction according to the location of the bus in relation to the platform. This could be controlled by the driver, once they know where the bus has actually stopped, or there could be some automated device, although it might be a challenge to obtain the required level of accuracy for the purpose of giving appropriate information to the people who need it.

Control of cyclists' speed at the bus stop

As discussed earlier, in the end, whether the bus stop in question is a Floating Island or Shared Bus Stop Boarders, there are two moving entities: the passenger and the cyclist. Passengers walk at about 0.75 to 1.2m/s, and some pedestrians walk much more slowly than this (Steenbekkers [48] suggests speeds of 0.25m/s in some cases); cyclists could travel at speeds of up to 10 m/s. There is a massive difference, and added to this is the possibility of passengers moving at right angles to the cyclists' direction of travel, thus reducing their relative speed to zero. Although bicycles are highly manoeuvrable, they do require quite a considerable distance to make those manoeuvres. The combination of these two factors means that cyclists necessarily have to view quite far ahead to prepare for their trajectory in advance. Interruptions to the smooth directionality of the bicycle can be dangerous for both the pedestrian and the cyclist. The pedestrian, on the other hand, is quite manoeuvrable, but their speeds are slow, and their mind may well be on other matters – conversing with someone, or looking for a particular shop or bus, for example. Thus, we have a combination of higher speed less manoeuvrable vehicles in conflict with slow manoeuvrable and unpredictable pedestrians. At a bus stop, these conflicts are made much more immediate and real.

Apart from the physical damage resulting from a collision, the relative silence of bicycles means that the sudden realisation of the presence of a bicycle presents a considerable psychological shock. This is one of the principal causes of the ongoing fear of using the bus stops: the fear that a bicycle might appear is enough to drive all the preconscious stress and fear responses. This can be driven by a single experience, and although repeated non-experiences might eventually serve to reduce the shock, the likelihood of achieving this in the short term for all potential pedestrians is very low indeed. The real danger of the Shared Boarder Bus Stop is that the path of the cyclists' conflicts with the space used by people boarding and alighting from the buses, so there is no avoiding the issue without guaranteeing that cyclists do not enter this area at all when there is a bus there.

From the experiments, it seems that detecting a bicycle is a real challenge, and doing so in time for a pedestrian to be able to make a decision about whether to cross a cycle lane is an even greater one. From the focus groups and questionnaires this question seems clear: people find it difficult to detect cyclists approaching bus stops.

It is generally agreed, including in the focus groups, that there is good reason to have cyclists in cycle lanes segregated from general traffic. However, there is also a clear sense from the questionnaires and even more from the focus groups that moving the conflict zone from a vehicle-bicycle one to a cycle-pedestrian one is not a societally responsible or good solution. The comments from the focus groups, and the evidence of increases in stress and anxiety from the experiments, suggest that even though fatalities are unlikely from bicycle-pedestrian collisions, the stress caused by the thought that there could be a collision is a major source of concern for the mental health of pedestrians. From the focus groups it is clear, that this anxiety causes disabled people to stop using some bus stops, and this would reduce their ability to get out and about independently.

It seems to be very difficult to control the speed of cyclists near bus stops to levels that are commensurate with the safe speed limits needed in interactions with pedestrians (basically the speed of the slower vehicle). The ramps do not seem to cause a change in speed. This is a matter for further research, but it might be worth taking into consideration the island size issue mentioned above. For an enlarged Floating Island Bus Stop, the deviation in the cycle lane would be rather larger. If the longitudinal length for this deviation were maintained as it is, the curve would be sharper and thus there is more chance that the speed would be reduced, but this needs investigations to be conducted under controlled conditions with cyclists.

6.3 Shared Bus Stop Boarders

The results suggest that Shared Bus Stop Boarders are more problematic than Floating Island Bus Stops. The cyclists' speed would be harder to control than would be the case at a widened Floating Island Bus Stop as there is no (or at least less) deviation from the direction of travel, so the issues of dealing with this issue would be a lot harder.

The design places three aspects of urban activity in the same place: cyclists travelling in what they believe to be – and should be – a segregated safe place, pedestrians perceiving the same-level nature of the cycle lane at this point as being a part of the footway, and the bus passengers believing they are in a safe space for waiting, for boarding and alighting from buses. These are fundamentally incompatible.

Then, we need to add to this the fact that passengers alighting from buses have to detect the oncoming cyclists from inside the bus before they can commit to alighting. As commented on during the focus groups, guide dogs, carers, various assistances to mobility, each has implications on the ability of a person, to make the manoeuvre from the bus down to the level of the footway and this needs to be done, whilst seeking confidence that there is not a cyclist approaching. It is hard to see how the issues raised throughout this research, could be resolved in such an infrastructure setup. At the very least, there is a strong case for conducting further research on the situation, so that appropriate designs could be investigated and, if successful following the investigations, implemented.

Ultimately, if the speed of cyclists cannot be reduced to a safe level at bus stops, the implementation of combined facilities such as Shared Bus Stop Boarders and Floating Island Bus Stops should not proceed.

6.4 Segregated Cycle-Footway

In principle a segregated Cycle-Footway, where there is a physical segregation between the part of a space where a bicycle can travel and the part of the space reserved for pedestrians, is a very sensible idea. The problem seems to be where the delineation between the two paths is absent for some reason. A delineator that is just a painted line is insufficient and likely to invite or at least make it easier to cross from one side to the other. A continuous raised delineator makes it easier for blind and vision-impaired people using a cane to detect, and thus this should be a preferred option. However, this alone is not sufficient.

Another important element of the infrastructure is the tactile paving at the start/end of the cycle-footway. This should be corduroy paving, aligned ‘ladder style’ for the pedestrian side (i.e. the ribs of the corduroy are aligned across the direction of travel for the pedestrians), and the corduroy ribs on the cyclists’ side should be aligned in the direction of travel (i.e. at a right angle to the pedestrian side). Focus group participants noted that this tactile paving is not always installed, even though it is included in the DfT Guidance on the use of Tactile paving surfaces. They also reported that it is easy for a person to forget that they are in a protected zone if they had been travelling in it for some time. Additionally, if they were joining the segregated cycle-footway part way along, there is often no indication of how the infrastructure had been implemented, so it is impossible to know whether they are on the pedestrian or cycle side of the delineator. This would suggest that some sort of repeated application of tactile paving periodically along the cycle-footway might be helpful (this is also in the DfT guidance section 5.4). There was recognition that on occasion pedestrians and cyclists may need to leave ‘their’ side of the infrastructure to avoid an obstacle in order to continue their journey safely. It is also important to recognise that a blind or vision-impaired person needs to know when such ‘protected’ infrastructure has come to an end by ensuring the installing of tactile paving.

6.5 Continuous footways

The research found that the main problem with continuous pavements is for a pedestrian to know when they are actually in the roadway and when they are on the footway. There was a range of views from professional attendees at the workshop about whether continuous footways should continue with the footway surface across the roadway. Some felt that continuing with the footway surface emphasised to pedestrians that this was ‘their’ space and to car drivers that they were crossing a pedestrian space. However, there was strong representation in the focus groups and in the experiments that blind and vision-impaired people need to know when they are on a roadway which could have vehicles on it. Tactile paving at the road edge is therefore necessary to help people identify where the pavement ends, alongside a change in surface to emphasise the change in use of the space as people cross the road.

7. Conclusions and recommendations

This research was set up to provide some scientific data about how disabled people respond to the design of Floating Island Bus Stops, Shared Bus Stop Boarders, Delineators between cycle paths and pedestrian footways and junctions with Continuous footways. The research project was not intended to generate solutions to any challenges that were identified – this would require further targeted research, so that potential solutions could be tested and evaluated. However, it is possible to draw some conclusions and recommendations from the research.

7.1 Bus stops Incorporating Cycle Lanes: general comments

The fundamental problem for blind and vision-impaired people that is generated by bus stops that incorporate cycle lanes, is a fear of the unknown. This is manifested in the sense that they do not know if there is a bicycle in the vicinity and so they have to assume that there is. The experiments show that this fear is real. The general principle behind ensuring that the difference between speeds of different moving vehicles should be minimised, in order to reduce collisions, applies to the situation between cyclists and pedestrians. This has particularly frightening outcomes for blind and vision-impaired people, as their means of detection of the cyclist are reduced. The frightening experience of encountering a bicycle travelling at a much higher speed, relative to the pedestrian, raises the justified fear that such an experience could happen again. This makes them feel that the infrastructure is constantly a threat to their safety. This is their natural response, as human beings, to their perception, which is in turn based on lived experience. Even a single bad experience will create a fear response to which the body will respond - this is a preconscious response to any perceived threat and, as with any threat, the only real way to avoid the fear of it recurring, is to avoid the threatening experience. This is not an irrational fear. This is how human beings have evolved to respond to danger. The response to this in future is to avoid the situation. Several people in the focus groups said that they avoided using bus services which had bus stops incorporating cycle lanes, so there is reason to believe that one outcome of these designs, is that people's access to activities and independence is reduced. We should not be implementing infrastructure that sets off such a response: this is as serious a matter as implementing infrastructure that routinely causes physical injury.

A second general problem arises because of the difference in speed between cyclists and pedestrians and what this means for their dynamic visual perception of the world which is quite different. If a person has a visual impairment this difference is dramatically increased. Also, if the pedestrian movement is not in the same direction as the cyclists' movement, the speed of the cyclist relative to the pedestrian will be increased: if the pedestrian is crossing the path of the bicycle, the speed difference between them will be the same as the speed of the bicycle. In such circumstances, the normal safety approach would be to reduce the speed difference to one that can be managed by the slower of the two. This would mean slowing the cyclists down in some way.

At a bus stop, the activities of people mean that people are standing or sitting, possibly moving a small amount (e.g. to read a timetable or other information, or to see more easily if a bus is coming), and the number of directions in which movement might be made is near to infinite. From an external perspective, this presents a considerable challenge to predict what people at a bus stop might do next. Once the bus stops at the bus stop, there is a focus on moving towards or away from the bus door, so once again there are several distinctly different movements involved. This does not mix well with a distinctly unidirectional vehicle such as a bicycle travelling at relatively high speed.

Based on our findings and conclusions we have developed some general recommendations that apply to bus stops incorporating cycle lanes, as well as specific recommendations for each of the four designs.

General recommendations:

Recommendation 1: In all cases, involve local people in the detail of how pedestrian infrastructure should be conceived, planned, designed, constructed, and operated, in a context of co-cultivation, where this is an ongoing and continually improving process

Recommendation 2: Investigate different ways of enabling cycle lanes and bus stops to interact which do not raise safety concerns amongst passengers and pedestrians using the bus stop. It is important to realise that a single bus stop can neither be considered in isolation of the circumstances around it, nor in isolation from the traffic and infrastructure upstream and downstream of the proposed bus stop, so a full consideration of the area as a whole needs to be conducted. This investigation should include consideration of alternative routes in the area and alignments within the road space for the cycle lane in order to ensure that both cyclists and pedestrians can make the journeys they need to make safely and in comfort without the need for infrastructure such as Floating Island Bus Stops or Shared Bus Stop Boarders. This should include the reallocation of road space where necessary in order to achieve this. If it is necessary to incorporate a cycle lane within a bus stop, then the investigation should include how to make sure that everyone is safe in and around the bus stops. Our recommendation is that until definitive general guidance based on such research has been published, any intended implementation of this type of infrastructure should be researched on a case-by-case basis along the lines recommended here.

Until Recommendation 2 has been resolved, the following recommendations should be adopted:

Recommendation 3: Investigate signalling, signage, and other technologies to ensure that cyclists are aware of bus stops and take suitable action to ensure that any interactions with boarding, alighting, waiting, arriving, or leaving passengers are safe.

Recommendation 4: Investigate revisions to the audible and visual announcements on buses so that the bus stop is identified as a Shared Bus Stop Boarder (with the cycle lane immediately adjacent to the bus and between the bus and the footway) or, as appropriate, a Floating Island Bus Stop (with the cycle lane 'behind' the bus stop and between the bus stop and the footway).

Recommendation 5: Investigate methods for identifying for vision-impaired people where different buses are at stops where there is a possibility for different bus services to be using the same stop. This applies to all bus stops but is especially important at Floating Island Bus Stops and Shared Bus Stop Boarders, where space is more limited and conflict greater than at 'normal' bus stops.

This research examined designs of Floating Island Bus Stops and Shared Bus Stop Boarders that are published in Department for Transport Guidance LTN 1/20. We did not examine other designs. Several comments in the focus groups referred to bus stops with two-way cycle lanes incorporated into them, and noted that these were much worse than the one-way versions examined in this research. Undoubtedly the multi-directional aspect of such infrastructure will make using the bus stop much more complicated for passengers, and this should be examined rigorously to come to a view about whether or not they should be deployed. The comments below refer to the bus stop designs we examined and represent a basic case without the added complications of, for example, multidirectionality.

7.2 Floating Island Bus Stops

There were plenty of concerns expressed by participants in the focus groups, site visits and experiments about Floating Island Bus Stops. The experimental data show that this concern is measurable in the form of expressions, about the environment and responses to the design in association with the presence of bicycles. This was felt most strongly by vision-impaired and blind participants, but other groups also had difficulties, such as neurodivergent participants who were concerned about crowding within the constrained space of the island and wheelchair users who were concerned with the space for manoeuvring on the island.

One important point is that, although participants (with one exception in the professional workshops) felt that Shared Bus Stop Boarders were less safe than Floating Island Bus Stops, they were less confusing. The difficulty for Floating Island Bus Stops is that there are several separate segments – locating the bus stop from the footway, crossing the mini zebra, finding the shelter, and the bus, and then, when alighting, trying to locate the mini zebra to regain the footway. The last point especially is highly variable as it depended on where the bus stops in the bus stop. The Shared Bus Stop Boarder was considered unsafe, but at least it was simple. There is therefore a key issue about information related to the design and operation of the Floating Island Bus Stop.

With a Floating Island Bus Stop, the cycle lane is diverted to the rear of the bus stop island, necessitating a deviation in their travel path, and a pedestrian crossing between the rest of the footway and the bus stop island. This crossing is the main point of conflict at the Floating Island Bus Stop. To retain the bus stop and cycle lane, but to remove this point of conflict means some way of stopping the cyclists at the pedestrian crossing. In traffic-pedestrian conflict zones this would normally be done by legislation (e.g. at a zebra crossing, or the general right of way priority for pedestrians on streets in general), or, where the situation is more complicated, by traffic signals (with attendant legislation). The sense in the focus groups was that this would be helpful, but they were not confident that the cyclists would actually obey the signals. This is an outcome of the combination of the fear factor mentioned earlier and the potential, within the design, of a collision occurring. The design of the infrastructure has to deliver a sense of consistent safety, through being inherently safer. The fear will reduce only when a sufficient number of safe experiences have been realised.

The question of the size of the island is also important. This suggests that the island should be wider. The length of the island should be determined by the number of buses to be accommodated simultaneously. Making the island wider would mean that a Floating Island Bus Stop could only be installed where sufficient space exists to allow for the island to have a sufficient width and for there also to be a sufficient width for the footway. The wheelchair manoeuvrability issue, means that the width of an island would need to be about 3.5m minimum. This is to allow a wheelchair plus carer-assistant to leave the ramp from the bus, before having to start their turn towards the pathway towards the mini crossing, or to line themselves up in order to board the bus. Similar dimensions apply to people with assistance dogs, and people with baby buggies.

It is also important to manage the stopping position of the buses at the bus stop so that they always stop in the same place relative to the route across the island from the bus to the crossing. Vision-impaired and blind people need to know where to find the guidance path before they can engage with it to find their way towards the crossing. If they know that this path is 'always to the right of the bus door' they can find it easily enough, but if they do not know that this is the case, they could miss it completely and end up in an unsafe situation. This kind of reliability is achievable, but it requires the combination of good design, good markings at the stop and good training of drivers.

The wider island would also mean a greater deviation for the cyclists, and the possibility of achieving this dimension within the same longitudinal distance might help to slow the cyclists down as they approach the bus stop. There is a need for research to see exactly what the dimensions need to be in order to have a safe and accessible Floating Island Bus Stop – and one that is neither safe nor accessible is not an acceptable item of public infrastructure.

It would also be worth investigating the possible uses of technology, for example to detect cyclists in advance of the bus stop, or to detect pedestrians near the crossing, but at this time there is no such technology with the requisite consistent capability to give confidence.

Recommendation 6: Investigate the minimum dimensions requirement of a Floating Island Bus Stop for all types of passengers.

Recommendation 7: Investigate the communication of the design and operation of the Floating Island Bus Stop and the consequent training needs to all users.

Recommendation 8: Investigate different methods of reducing the speed differential between cyclists and pedestrians at and around Floating Island Bus Stops (and other infrastructure containing possible conflicts of this nature).

Recommendation 9: Investigate how to ensure that buses always stop in the same place at a Floating Island Bus Stop, so that alighting passengers know how to navigate across the island.

7.3 Shared Bus Stop Boarders

The results from the focus groups, site visits and experiments show that Shared Bus Stop Boarders are considered less safe than Floating Island Bus Stops.

In the case of Shared Bus Stop Boarders, the speed differential issue mentioned earlier is potentially worse than it is at Floating Island Bus Stops, because there is no directional deviation for the cyclists. These bus stops cause a higher level of fear in participants compared with the Floating Island Bus Stops. There are particular issues with alighting from the bus, where the alighting passenger may be positioned quite far into the bus when they need to make the decision to move outside the bus, and thus expose themselves to any oncoming bicycle. This situation applies to many passengers, for example wheelchair users (especially if a carer-assistant is pushing the wheelchair), and people with baby buggies, those helping older people, using assistance dogs or travelling with children. For people in these groups to have confidence they need to know that there is no cyclist there, and with the current design this is a situation that simply cannot exist: nobody could ever have that level of certainty. It would seem, that the Shared Bus Stop Boarder places passengers in direct conflict with the cyclists following the cycle lane, and this means that the bus stop is neither safe nor accessible. As such this design, as it is currently invoked, is incapable of delivering a safe and accessible service.

Recommendation 10: Research is required to explore if it is possible to provide a continuous cycle lane through a bus stop area respecting the access and safety requirements of disabled people, including the psychological aspects of stress and fear. It is important to realise that a single bus stop can neither be considered in isolation of the circumstances around it, nor in isolation from the traffic and infrastructure upstream and downstream of the proposed bus stop, so a full consideration of the area as a whole needs to be conducted. This research needs to be co-cultivated with representatives of all groups of people affected by the co-location of cycle lanes and bus stops. Our recommendation is that until definitive general guidance based on such research has been published, any intended implementation of this type of infrastructure should be researched on a case-by-case basis along the lines recommended here.

Recommendation 11: Research is needed to find alternative routes for cycle lanes which currently involve Shared Bus Stop Boarders so that these can be avoided. This will mean that alternative cycle routes will need to be explored, including considerations of rerouting traffic or cyclists in order to ensure that an appropriate level of safety can be delivered to cyclists, traffic, and pedestrians, including disabled people.

Recommendation 12: Investigate in detail the psychological stress caused by the nature of the interactions between bicycles and pedestrians at this design of bus stop. This is essentially new applied psychology research.

7.4 Continuous footway

The basic problem with footways crossing a road at the normal footway height, is for a pedestrian to know when they are actually in the roadway and when they are on the footway. There is a secondary problem as well, which is that in order to create the ramps for the vehicles to rise to the height of the footway, the crossing may need to be moved along the road in question so that the crossing no longer meets the desire line, and pedestrians have to deviate from their line of route in order to use it to cross the road. The focus groups reported a sense of not knowing where they are on these crossings. This situation is made worse when there is no tactile paving in place. The experiments showed quite clearly that having tactile paving made a positive difference for Blind and Vision-impaired people, so this should be routinely installed at these crossings. Tactile paving does have its detractors, namely people who find the surface, which is necessarily ‘tactile’, so not smooth, difficult to cope with. However, there are still benefits for these pedestrians of a continuous crossing with correctly installed tactile paving as they do not have to contend with dropped kerbs or ramps. It was notable that no group scored these crossings very positively, but the no-tactile version performed much less well than the crossing with tactile paving included.

The experiment did not include other factors that apply to these crossings, for example, noise, the detectability of turning vehicles (including bicycles and scooters) or the effect of deviations from the desire line. The addition of these complexities, to the sense of knowing whether or not such a crossing exists, adds a cognitive load to the experience which we could not test due to the time limitations. This would be important to investigate because we simply do not know, whether the cognitive load question means that the benefit of, for example, having tactile paving is sufficient to make these crossings safe, or whether having to concentrate on the movements of vehicles and other factors, means that further design alterations are required. Testing the paving and design of these crossings under such conditions would be really useful for determining how they should be designed and operated.

Recommendation 13: Investigate the cognitive load associated with navigating junctions where the 'usual' vertical delineation between footway and roadway is absent, in the context of the local environment (for example, noise, lighting, traffic routes etc.) that could act as a distraction for someone trying to use the crossing.

Recommendation 14: Local authorities should ensure they have a consistent approach to the use of tactile paving and other signalling to assist disabled people at all continuous footway crossings so that there is a consistency of approach.

7.5 Segregated Cycle-footway

Despite the clear benefits of segregated cycle-footways, our research identified problems for people with a vision impairment when the delineation between the two paths is absent. A delineator that is just a painted line is insufficient and likely to invite or at least make it easier to cross from one side to the other. As well as a tactile paving delineator, the findings showed the importance of installing tactile paving in line with the Department for Transport guidance. This should be at the beginning and end of a segregated cycle-footway, as well as at regular intervals within the cycle-footway, so people with a vision impairment can easily identify they are still on the appropriate side and when the 'protected' infrastructure has some to an end.

Recommendation 15: A tactile paving delineator should be used at all times rather than a painted white line. Investigate different designs and profiles of continuous central delineators on segregated cycle-footways. Such routes should only be considered if the recommended space can accommodate the requirements for both users.

Recommendation 16: Tactile paving should be installed at the beginning and end of each section, as well as at regular intervals within the segregated cycle-footway, in line with the guidance.

Our final recommendation is that guidance is amended to reflect the findings of the research so that the recommendations can be consistently applied:

Recommendation 17: We would recommend a research investigation to explore how LTN1/20 and other relevant guidance might be revised to take account of the technical findings of the research undertaken for this report, including involvement of disabled people and other users of such infrastructure so that guidance can be created that enables infrastructure that is accessible, safe, equitable and works well for all.

Annex 1 – Literature review

Section 1. Introduction

Initial scoping

The literature review was focused on identifying specific knowledge gaps regarding vision-impaired users, their interaction with the infrastructure in question and their specific needs in terms of safety, perceived feeling of safety and independence. The literature was used to guide and inform suitable methods for quantitatively testing the appropriateness of current and future design choices in the context of safety for vision-impaired users.

This literature review does not intend to provide an extensive coverage of all the possible design aspects, policy or legal framework surrounding the use and implementation of these infrastructures. Nor to present all the current body of knowledge in terms of geographically changing design guidelines (i.e. the differences between England, Northern Ireland, Wales, and Ireland).

Furthermore, the search for evidence has been tailored to the tentative timeline allowed by the project, accounting for the subsequent stages in the scope: focus groups, site visits and controlled experiments. The review of the literature followed a Rapid Literature Review format, in which the existing body of work was searched through a single database (Scopus) and subjected to articles only in English. Different search queries (available in Annex 2) were tailored to the research topic.

The initial scoping review returned minimal work coincident with all the requested search parameters even when scanning for abstracts, rather than just the titles. We therefore widened the scope to include other sources indirectly relevant to the research in question. The search was further complemented with standard web-searching using the same keywords, but pointing towards grey literature from government bodies, design standards, guidelines, as well as other relevant organisations. The results were restricted to literature available in English and relevant geographical regions.

Although the focus is placed on safety provisioning for users with a vision impairment, the research briefly extends the research questions to a wider range of disabilities, although these do not drive the inclusion criteria for the literature review. Instead, provide an overarching view for common or opposing points of interest from the design and use perspectives of the urban features covered here.

Keywords

Bus, bus stops, terminal, boarding, cycling, safety, bypass, shared pavement, design, standard, vision-impaired, mobility impaired, visual impairment, blind, disabilities, disabled, perceptions, experience, urban environment.

Methodology

The returned hits from the search queries were each individually exported to comma-separated values containing the relevant fields for the initial screening, then combined in a single spreadsheet, also available in .csv format. The merged database queries returned a total of 389 sources, of which 312 were identified as unique after the deduplication process consisting of two runs, first by DOI (Digital Object Identifier), then by title, to account for publications that were lacking DOI information or had inconsistent formatting.

Each of the unique sources was then assessed for relevance by examination of their abstract, assigning either zero to those not relevant; one, when apparently directly relevant and; two for those indirectly relevant to some area of the research. Quality metrics such as impact factor, number of citations, etcetera, were omitted due to the already reduced body of literature yielded after the relevance assessment and the rapid review style already mentioned.

The number of articles and sources found reiterate a clear need for more methodologically backed evidence with scientific grounding. The query-based review can be summarised as follows:

- 16 articles assessed as directly relevant for full assessment, three discarded for other reasons after analysis.
- 94 articles assessed as indirectly relevant, and
- 202 articles not relevant to the research.

The additional search queries that were performed using conventional web-browsing included, in addition to different combinations of the research keywords, the following possible sources of information: TfL - Transport for London, Department for Transport, TRL -Transport Research Laboratory, Living Streets, Sustrans, Systra, Ramboll, Sweco, COWI, Guide Dogs for the Blind, American Foundation for the Blind. Those searches and the additional snowballing effect yielded the following sources being identified as relevant:

- 15 documents derived from test reports or survey studies;
- 18 building guidance documents;
- 6 scientific articles, including one master's dissertation; and
- 11 articles related to relevant news and media.

The total of documents included after the detailed analysis phase being 34 out of 39, (news and media articles were used only for local context).

Overview

The findings of the literature review are presented in three sections:

Section 1: presents the literature findings directly related with the design considerations for vision-impaired users for bus stops and continuous pavements. This section covers information from the documents located via database queries and grey literature otherwise found through web searching. At the end of the section, we provide a similar but more general scope extending to other users whose special needs could place them in a contextually similar challenging situation.

Section 2: contains the results of the queries regarding the design of Bypass and Shared Bus Stop Boarders and, continuous pavements, along with the grey literature found. This section covers some of the testing performed in the UK prior or during the implementation of these infrastructures, either derived from preliminary off-the-road experiment, surveys, observational studies, or a combination. The relevant sections covering visual impairment needs within these sources have been extracted and presented already in section 1.

Section 3: is a brief overview of the existing design guidelines covering. This is a complementary section to further inform the setup design for the design of experiments.

Sections 1 and 2 are structured in a way that they first present a narrative synthesis of the relevant sources, in which mostly key points and findings, or gaps are drawn and briefly discussed in the context of the current experimental design. Following the initial section, an analysis of each of the relevant sources is provided. Note that this section is not a meta-analysis, and in some way, it is composed of extracts from relevant sources, in some cases showing graphics or tables borrowed directly from the document under analysis.

Section 2. Design considerations for users with a vision impairment

Relevant findings

During the review of the literature it was evident that despite the amount of information available in terms of urban infrastructure design for bus systems (and navigation aids) and the more recent interest in topics like interaction of pedestrians (in this case, bus passengers) and cyclists is already picking up interest within the research community, there is a substantial lag in the provisioning not only for vision-impaired users, but in general, disabled users and how this may impact them in terms of safety, including perceived safety and their potential impacts on their use of these features of the built environment, and their feeling of independence.

Local regulatory frameworks and design guidelines for urban infrastructure address, for the most part, general "accessibility" concerns, however, it seems that most of these concerns are aimed towards increasing usability or convenience, tending to leave out relevant factors that may be related to safety concerns.

While we acknowledge that the piloting and early adoption of novel infrastructure has not gone without relevant off-street testing, and that some of the relevant research, at least at local level, appears to indicate that, if designed and implemented well, there is no substantial increased risk for pedestrians whilst using these infrastructures [8][15][16][17][18][19][20][21][22][30][31][32][33], it seems that there may be a potential bias regarding the type of users that those observational studies managed to capture, meaning that there is no specific section dedicated to analysing specifically how people with disabilities use them. However, most research works acknowledge the need to provide for them, giving some recommendations to make these amenities as inclusive as possible, but they fall short of providing quantitative evidence to discard potential increased risks to groups of disabled users.

During the screening process of the available scientific evidence, it was notable the amount of research on interaction, behaviour and development of novel digital navigation tools aimed to increase independence of vision impaired and mobility impaired users, from mapping solutions to live-remote-assistants and AI-based solutions. The body of scientific evidence is generous in these terms; however, there is some disconnect in how research (and quantitative methods used) supporting this type of technologies is transferred to implementation, furthermore, integration with current public transport systems.

The current literature certainly lacks in terms of quantitative methods to investigate safety in relation to perceived safety by the users. Most of the literature is qualitative in nature, and while this provides valuable information about the users, and works as starting point to define variables suitable for investigation, if falls short of providing sufficient evidence to support implementation.

Studies based on observational data or accident statistics are necessary and valuable at providing information at population level, with the downside of bringing along inherent under representation of disabled users. Furthermore, studies based on statistical information of reported accidents between pedestrians and cyclists is doubtful, as arguably, many of these interactions result in only minor injuries to both parties and end being unreported.

A study derived from a European project, Access4All [1], studied the preferences of elderly users at bus stops, in the context of tactile pavement for improving accessibility. The aim of the study was to set a design baseline for a pilot accessible bus stop for the Faro Airport. The authors highlight the high variability in design practices across different cities in terms of tactile paving solutions. They performed qualitative analysis based on questionnaire data collected from elderly tourists, their data is based on a sample of 51 respondents 60 years old and older. Their data showed little interest on tactile paving from the user group, interestingly, decreasing further with age.

The authors comment on the contrasting needs of vision-impaired people and users with more limited mobility, in this case, elderly users. The most applicable comment is that the use of tactile pavement should be minimal, both to avoid confusion to vision-impaired users and to minimise discomfort or risk of tripping or falling to mobility impaired users. No specific recommendations are done in terms of stops sharing space with cycling lanes.

In [2] the authors examine the implications of the variation of uses of tactile pavement within bus stops in various European locations, and Dubai. With focus not only in vision-impaired users, but with a wider scope to accessibility for all, including those using wheeled equipment that not necessarily are experiencing a disability. They do highlight that the use of accessible features for people with a vision impairment directly implicates safety, however these solutions may be contradictory for other uses, and only some examples of tactile pavement provide a reasonable compromise for most groups. They found that the layouts employed vary significantly from one city to the other, posing big challenges for people with a vision impairment, however, no mention of the use of tactile pavement in relation to cycling infrastructure in bus stops.

A study from New Zealand [3] examining the barriers to public transport for users with disabilities, highlighting that the main safety concerns for users with mobility impairments and visual disability occur primarily when boarding and disembarking, and because of improper design of the platform, the bus, or a combination. For people with a vision impairment specifically, the lack of audible information regarding their journey. For most, the lack of accessible paths to the bus stop itself. However, the author does not make any mention of cycling infrastructure in connection with bus stops.

As to methods to quantify stress in people with a vision impairment whilst experiencing an unfamiliar environment either indoors or outdoors. The authors from [4] take a machine learning approach to attempt to infer the setting that the user is experiencing using a pre-trained model. The experiments based in Reykjavik showed that both indoor and outdoor features can be identified using EDA, EEG and HR, or a combination of these. While the intention of the authors is to lead towards emotionally aware navigation assistance devices, their findings are relevant to the setup of the experiments, in the context of quantification methodologies of physiological responses to stress in people with a vision impairment.

A U.S. based study [5] analysed multiple stress factors from a sample of vision-impaired people in relation to transportation. They determined that the greatest elements of stress, from around 350 surveyed participants, were: walking in unfamiliar places or using unfamiliar bus routes, arranging transportation in unfamiliar locations. They found that transportation stress in those participants with visual impairments decreased with age and with the use of a guide dog, according to their sample and urban setting. In opposite fashion, they found that stress increases with age, but it decreases with frequent use of public transport. There is no specific mention about bus stop layout related navigation stress, nor cycling infrastructure in such context.

A study covering haptic cues for people with a vision impairment [6] ranked the top 10 most useful features according to 32 participants' qualitative input. Changes in surface texture, kerbs, ramps, and bus stops being frequently used by users with a vision impairment to navigate their environment. However, no mention of how they are used in terms of safety, nor the strategies of the users to interpret the meaning of these features.

In [7] the authors present an interview-based qualitative analysis based in the city of Nanjing in China. Where people with a vision impairment evaluated a series of infrastructure improvements. The main outcomes resonate with some of the obstacles faced by vision-impaired people in relation to the improper use and application of design guidelines for tactile pavement. In terms of bus stop navigation, audio cues were also included in the study as potential aids, ranked 3.16 out of 4 of perceived usefulness by the users.

The work from Living Streets [8] included focus groups work with participants of various disabilities, where important aspects were collated for each group of users. Of particular concern for this research are those surrounding users with visual impairments.

Some of the key aspects for this group are clarity (related to consistency of layouts), the use of tactile information, the use of contrast in surfaces (and appropriate lighting), and how vision-impaired users employ sound cues from traffic to aid their navigation.

More importantly than the aspects mentioned, is the knocking effect that poor design choices can have over the users' confidence and independence due to fear of not being able to read their environment to navigate it in a safe way.

Remarkable to mention the highlighting of bus stops as crucial infrastructure for vision-impaired users, by providing them a way to bypass other more complicated infrastructure that otherwise would be impossible to navigate on their own. Meaning that, even if the complexity level of crossing a cycling lane to a bus stop is no greater than crossing any other cycling lane or carriageway, it has a profound impact on the users' independence as in many cases that is the only option that the user has to achieve a desired trip, with no reasonable re-routing choice.

In [9] Two groups of users, A (control), B (vision-impaired). Performed walk-along interviews while following a predefined route in central London. The main findings from the author in distinct categories is listed here:

- Wayfinding, 40% of references for problematic element, followed by clutter (street furniture, etc), steps and tactile pavement.
- Station interchange, some of the most relevant comments for this case is the use of contrasting colours to aid the navigation
- Streetscape design, crossings, revealed preference for signalled (80%), followed by zebra ones.
- Vehicles (motor, bicycles, scooters) main comment "prevalence of cyclists and e-scooter users traveling at high speed whilst ignoring the traffic signals."
- Shared space, mention to vast, non-demarcated areas (as in large interchange stations).
- Continuous footways, was not favourably perceived by group B, as they rely on the motorists' will to adhere to the driving code.
- Pedestrian space, was positively seen 60% as reduced noise and 40% as risk reduction, both from motor traffic.
- Main convergence point between both groups were: safety (bikes and scooters not respecting pedestrian areas), wayfinding (confusing, or lack of), continuous pavements (80% considered unsafe and false sense of safety), shared spaces (confusing, increases the alertness level required to the pedestrians).

The applicable recommendations from the author based on the findings are:

In terms of layouts: standardisation of design, reduce variety of crossing types, extended pavements should stick to original demarcation style, the removal of continuous footways. On the appearance side, ensure the use of visual contrast between the pavement, road and cycling lanes, use colour coding to assist wayfinding, illuminated signage and add audio information.

In [10] an analysis of shared space (including cycling tracks near bus stops) showed that the main concern for vision-impaired individuals is the lack of demarcation of a "safe zone". Some schemes incorporate elements to make a distinction but is not widely adopted or consistent.

- Only a fraction of the users crossing the cycling track did so because of the bus stop.
- From a cyclist perspective, the crowdedness of the cycling tract heavily impairs the ability of the cyclist to look further ahead for pedestrians, as they are caring for their own safety navigating next to other cyclists and obstacles too close to the cycling track (posts, bollards, trash bins, et-cetera).
- At most of their observed locations, the time that pedestrians needed to stop at the cycling track to be able to cross was less than five seconds.
- Most pedestrians ignore the zebra crossing in practice, and many that use it had a reason for doing so, as the crossing is at level, many users with varied wheeling needs crossed through the zebra.

In [11] journey experience of people with a vision impairment in London to identify the biggest barriers the use of public transport. They found that participants complain from the planning of the trip, by not being able to access all the information they need for their desired journey, access to where and when disembark is sometimes restricted due to malfunctions.

On-trip RTI is essential to people with a vision impairment, but many times it is not available in an accessible way to them, increasing their reliance on other passengers or digital tools. The authors highlight that digital tools have helped to overcome some of these issues by providing screen reading (text to audio) and the use of GPS-based voice services. They mention the issues with the provision of reduced fares such as the Freedom Pass, highlighting that they are not enough to provide equitable access to all users with disabilities, and it is necessary to tackle the operational areas to make travel more accessible.

Consistency (lack of) is mentioned as a main barrier to people with a vision impairment, as they tend to rely on their mental maps to execute a trouble-free navigation, encountering different layouts of tactile paving of bus interiors becomes an obstacle, rendering navigation challenging and confusing.

Another study from 2006, based on over 1000 interviews [12] also analysed the opinion of vision-impaired people in terms of mobility and their travel preferences. Despite being almost two decades old, and many changes in RTI systems have been implemented, these are sometimes failing or inconsistently adopted across locations, thus, the study remains relevant for the purposes of this study.

The study found that 56% (516/953) of people with a vision impairment rely on private car for their trips, however, the buses take the second place with 41% (416/953), highlighting their importance for the mobility of this group of users. The rest are 21% by train, 10% other public transport, 17% taxi, 1% dial a ride. Furthermore, the proportions are remaining more or less constant for all age groups, except for train use decreasing considerably to 5% for the older users.

Users on working age cite lack of confidence as a barrier, at 18% and general transport issues at 33%, while those in retirement age rated it at 11%, but blamed more their mobility and general health (33% and 25%, respectively), and 19% general issues with transport.

It looks that beyond the proportions for general issues with transport, can carry over to impact on the lack of confidence of the users, potentially reaching higher numbers if an analysis of what causes the lack of confidence reveals that is infrastructure related.

A study performed to analyse the trial site of Exhibition Road [13] revealed that delineator paving was detected by all vision-impaired participants in their experiment, either with their feet, their cane, or by means of visual clues (those with partial sight). However, the detectability of the pavement was not directly related to whether the users would stop or not when detecting it: 31% of the users answered that it was highly unlikely that they would stop by feeling the tactile paving under analysis, only 63% of the participants answered that they would likely or very likely stop upon detecting the corduroy pavers, the remaining 7% as unsure about how to react). This reveals that some users would need to be trained to recognise the meaning of the paving, and the safe use of these signs.

Another study [14], from TRL published in 1994 provides an insight on the proportions of vision-impaired people that may be able to have some navigation abilities based on their adjusted capabilities. From a survey with about 2400 respondents, about 200 reported to have severe visual impairment and 489 some level of visual impairment.

From the 201 severely impaired, almost a half reported to always be able to distinguish between colours, and only 20 percent to never distinguish colours. From those 201, 62 reported being cane users, six guide dog users, 33 to rely on an escort always and 17 sometimes, the rest either did not specify or did not use an aid.

This helps to set the context and importance of visual cues that can make easier for users that are partially sighted, to navigate their environment, by using of tonal contrast, colours, and appropriate lighting.

TRL performed targeted evaluation of Floating Island Bus Stops (namely, bus stop bypasses) with users with a wide range of disabilities in [15]. The study only considered participants with a vision impairment who had neutral or no negative views towards this type of bus stops to reduce bias on the answers. Participants were presented with a 3D scale layout of the bus stop setup beforehand, to familiarise with it. One layout was designed with an uncontrolled crossing, and a second layout had a zebra crossing implemented with belisha beacons.

The users evaluated different aspects of the layouts: ease of getting on the bus, the space on the island, feeling of safety whilst crossing from the bus stop to the footway, ease of understanding where to cross, the ease of use of this crossing, and from the footway to the bus.

They were asked to rate from 1 to 5 (1 being very difficult, and 5 being very easy) different aspects of the layouts. The reasons assigning scores of 1 and 2 (which were primarily from the blind and partially sighted participants) were related to either the participants getting lost, being confused regarding the tactile paving, because the need for bolder colours, or because they would prefer an audible signal instead of the uncontrolled crossing, and flashing beacons for the zebra crossing.

Less than 20% (3 of 17) of blind and partially sighted participants felt ‘safe’ with the uncontrolled crossing and none felt ‘very safe’; around 47% (8 of 17) were ‘neutral’. However, with the zebra crossing around 35% (6 of 17) felt ‘very safe’ and a further 30% (5 of 17) felt ‘safe’. The proportion feeling ‘unsafe’ or ‘very unsafe’ fell from around 35% (6 of 17) to under 20% (3 of 17).

As for the ease of using that type of crossing the uncontrolled crossing was rated less than 10% as very easy and almost 40% very difficult and difficult by people with a vision impairment, while the zebra crossing setup was rated at 60% for very easy and around 30% for very difficult.

The study in general showed that for blind and partially sighted:

- Tactile information is key to finding the bus stop and telling you where the crossing is after you’ve got off the bus.
- Challenge in hearing cyclists coming.
- Need for consistency in layout in assisting navigation.
- Potential to get rehabilitation workers up to speed on FIBS so that they can better inform blind people.

- As kerbs are used to navigate, a bin right by the crossing means the crossing can be missed.
- Were confused by layout and expected cyclists to be between the bus stop and bus, not behind them on the island.

People who are Deaf or those with hearing loss:

- Needs strong visual indicators (such as signs/lines).
- Did not notice cycle path and confused by arrows on either side of the crossing (triangles).

The main observations from users with mobility impairment were:

- Narrowness of island makes access difficult, especially when passenger flows are high.
- The markings on the road bus stop U marking, line across lane, cycles next to each other- makes it easier to see its two-way traffic (Blackfriars).
- Bus stop flag can obscure wheelchair users from visual line of sight of driver.
- The bus stopped in a place too narrow to get the ramp out for the wheelchair.
- Limited room on island to manoeuvre on to the bus.
- Bus overshot bus shelter so had no room to let on wheelchair.

Sustrans produced a report [16] of a series of workshops with different disabled groups, in which proposals from users with different needs were collated, captured and refined with professionals to increase the awareness of their needs in terms of policy-making. This mentioned that "41% of disabled people in the UK told us they often experience problems reaching their destination due to the accessibility of the environment around them on a typical walking or wheeling journey. This increased to 55% for those with mobility impairments or learning disabilities, 58% of deaf or hard of hearing people and 64% for blind or vision-impaired people".

Among the relevant findings for the design of bus stops, specifically for bus Floating Island Bus Stop is the need to improve number and quality of the crossing points across roads and cycling paths. Indirectly related they raised the point of making wayfinding and journey planning fully accessible, with 77% of the participants willing to use digital aids for this.

Section 3. General design considerations

This is a non-exhaustive section that covers some of the research that has been used to inform the existing design guidelines in regards of the infrastructure of FIBS and SBSB, as well as continuous pavements. Most of this literature is local in context of the UK, primarily England. And it serves the purpose of understanding the rationale for design choices that are then transpired to different guidelines that are then geographically adapted across the UK.

Living Streets has recently released a report that could be considered as the most exhaustive and complete investigation available to date regarding the design and use of cycle track treatments at bus stop in the UK. The report is very comprehensive and covers from basic terminology to design recommendations.

They highlight that there are mainly two chosen strategies to ameliorate the impacts of cyclists moving at speed in bus stops where pedestrians usually linger and queue. The first approach is informing people with a vision impairment about the movement of bicycles on the lane. The second is to inform cyclists about the presence of pedestrians crossing the track.

While the general recommendations are aligned in three axes: simplification, speed reduction and space provisioning.

The key principles and minimum design quality suggested by the study are as follows:

- Simplicity and clarity for pedestrians
- General accessibility
- Simplicity and safety for cycling
- Visibility
- Highlighting crossing locations
- Highlighting the bus stop location
- Preventing extreme speed

The options and enhancements, however, need to be tailored to the specific conditions of the stop in question, the level of usage of the footway and the track, the complexity of the environment, etcetera.

On their observational study, there were some sites with signalised crossings at cycle lanes. Their data revealed that whilst the signal for the main road was frequently activated, the signal for crossing the cycling lane was not used at all. This only provides one end of the story, as it is not possible to know if cyclists would respect at all the signal and stop for the pedestrians.

The study does mention that many of the disabled groups can be absent from the observational study as they may avoid these sites, especially those with high complexity and very busy cycling tracks, this not only limited to users with visual impairment, but impacting a much wider range of challenged users.

The document [17] is a report from TRL intended to provide a guidance on topics to update the Inclusive Mobility, and Use of Tactile Paving Surfaces.

The reports highlights (about bus stops):

"Reservations were expressed by organisations representing the interests of people who are blind or partially-sighted as to the safety of Floating Island Bus Stops. However, these concerns are counter-balanced by a great deal of work that is being undertaken on the benefits to cyclist safety, and to designing Floating Island Bus Stops so that they are safe for everyone to use. A section on their accessible design should be included in the revised guidance."

We have identified that there is work to improve the accessibility and safety for users of these types of infrastructure, however, there seems to be a lack of consensus on the methodologies and variables to be able to better capture these requirements in a quantitative way, and match that to the qualitative information already available, if possible.

"Additional guidance is recommended on:

- Floating Island Bus Stops – reflecting concerns about their impacts on people with impaired mobility, but acknowledging the benefits to cyclists
- Discouraging the mixing of cycle and pedestrian traffic on the same pathway
- Making cycling facilities accessible to disabled cyclists and the use of cycles as a mobility aid"

And

"Although updating the guidance would have clear benefits, this study has also identified various other ways in which inclusivity could be improved, including:

- Stricter implementation of guidance
- Greater collaboration between organisations
- Improved inclusivity training and education for all organisations and staff involved in transport and active travel, pedestrians, and other road users"

Adding to this, perhaps would be the point of providing a wider road education and inclusivity campaign targeting multiple groups and demographics, not only planers and staff working on these matters, as the responsibility of the proper use of the infrastructure resides, ultimately, on the individual choices of each user. More careful policing of the application of the relevant legislation could be added as a side note, although this is understandably a bigger challenge.

After the analysis, the study summarises future areas of research, in their own words:

"Overall, attention should focus on the wider health agenda behind encouraging active travel and on encouraging a greater degree of empathy in society. This study has also identified the following areas which require further research:

- Improving understanding of specific aspects of the pedestrian environment that discourage people from walking
- Exploring the extent of the issues faced by individuals when navigating the pedestrian environment
- Identifying key differences or similarities between specific requirements of each demographic when navigating the pedestrian environment
- Determining whether implementation of the existing Inclusive Mobility guidance encourages active travel by certain demographics."

It is notable the mention "encouraging a greater degree of empathy in society". This resonates profoundly with some of the principles that we observe as key factor to a successful implementation of different types of infrastructure, and how to design it to encourage or facilitate an appropriate, empathetic behaviour is matter of further research certainly.

These last points very much highlight the need for further research and acknowledge that challenges will be experienced differently by different groups of users, and it is responsibility of the designers and planners to understand and cater for it in a responsible manner.

3.1. Floating Island Bus Stops (FIBS)

In a survey-based study commissioned to TRL by TFL [18] found that the introduction of zebra crossings at the selected bus stops (Floating Island-type bypass) increased considerably the perception of who had the right of way compared to the same layout but with an uncontrolled crossing. Pedestrians and cyclists recognised the pedestrians' right of way at the zebra crossing by 73% and 82%, respectively, compared to 35% and 30% at an uncontrolled crossing.

Despite a different initial level in the understanding or interpretation between the two bus stops about who had the right of way with an uncontrolled crossing prior to the pilot, both locations showed a similar level of agreement after the implementation of the zebra crossings.

More pedestrians noted that there was a designated crossing point by the introduction of the zebra crossing, but the proportion of cyclists that noted it remained almost unchanged, highlighting the possibility that cyclists' behaviour is merely a choice, rather than caused by distracted riding, as opposed to some pedestrians, who might be genuinely inattentive and inadvertently step on the cycling track, causing unnecessary interactions.

The study also found that the perceived safety by the pedestrians, increased from 58% to 68% in the categories ranked as safe or very safe after the introduction of the zebra crossings.

Cyclists self-reported that they modified their riding behaviour after the introduction of the zebra crossings, although the study does not provide further detail on this.

Similarly to other reviewed literature, there is no reference made to vision-impaired or other users with different disabilities, for whom the introduction of zebra crossings may have a lesser effect in their perceived safety or confident to navigate the environment in question.

A study performed by Sustrans [19] commissioned by the Council of Cambridgeshire analysed two pilot bus stops in which Floating Island setups were implemented. The study resonates with other studies showing that the number or interactions relative to the total number of cyclists observed in the locations was relatively if not very low (6 out ~1200, and 36 out of ~2400). The observational study video recorded both stops for three days. All the interactions recorded by the study were at least including a pedestrian and a cyclist, where the lowest score used was 1, meaning no change in behaviour in any of the parties and no risk involved. Collision would be ranked as 5. The study showed that only normal and very low risk interactions occurred (1 or 2).

They also analysed whether interactions occurred between cyclists and buses, and cyclists and other vehicles with only one (risk-free) car-cyclist interaction. They reported very low number cyclists using the pavement, most of them shifting to the cycling lane before or at the stop.

The analysis distinguished from pedestrians arriving to the island and pedestrians departing from the island. Each of the bus stops showed more interactions in one of the above, but the difference was not big. This could be influenced by the type of stop and the location, some stops would have more passengers naturally arriving from one or other direction, due to being closer to attracting or repelling nodes in the network. To correct for this, it would be important to record the total number of passengers arriving and departing, and simply passing by the stop, but the authors did not count the number of pedestrians (or passengers) in the vicinity and using the stop, or at least it was not reported, but the pictures provide a cue on the type of surroundings, clearly it was not a high street or a very busy area in terms of footfall. However, by their description it was a frequently used road (by all modes), in one case, somewhat close to a school, as it mentions high number of children using the stops during the busy times.

Despite the relatively high number of young users, the number of interactions and the level of risk of each interaction seem low, as young users are more frequently less aware of their surroundings or less risk averse, however, most of the interactions seemed to happen between children and cyclists, likely because of an over-representation of that group of users within that bust stop.

The study does not include a layout description nor details of the design features of each of the stops, nor any dimensions. Looking at the images provided, the islands seem to have a width of approximately 2.4 m, a length between 15 and 20 m, raised and give-way marked crossing point (but no zebra lines) with cycling markings around, no obstructions in the sight lines of both user groups, no cluttering, colour contrast between the cycling lane (red) and the pavement and island, and tactile paving with apparently good tonal contrast with the surrounding surface, the shelter is completely transparent with no obstructions from the sides, no advertising can be seen, and in both stops the shelter faces the footway. The layout of both stops seems well thought, however is difficult to assess if they followed any guideline, or which one.

Unfortunately, the report does not consider of any potentially vision-impaired users being noted in the footage, nor any intention of looking at data specifically pointing at risks of this or other groups of disabled users. The authors do rise the point that due to the high number of children using the stop, the potential risk has to be carefully considered, this somewhat confirms that each bus stop has to be carefully assessed for the surroundings and its regular use prior to making a full design choice, considering also its context and not only the road geometry, footfall, et cetera.

Lastly, the study did not collect data of these bus stops prior to the layout modification, so there is not possible to compare previous risk levels directly, although nearby stops could be analysed to provide a reference, ideally before a pilot is introduced, a data collection study should be performed to evaluate current design against the proposed pilot design.

In the document produced by TfL [20], New cycling infrastructure monitoring report, accessible bus stop design includes several design considerations for Shared Bus Stop Boarders.

Main findings related to Floating Island Bus Stops with implemented zebra crossings are listed below:

- Number and/or severity of interactions between pedestrians and cyclists is reduced 2 to 1 ratio (uncontrolled vs zebra crossing)
- More cyclists give way at the crossing was marginally improved 31 to 38%.
- People feel safer and more comfortable, 60% vs 70%.
- Disabled people find and use the zebra crossing more easily by using tactile paving and on-bus announcements about the stop they are about to encounter.
- More people notice the crossing (especially cyclists) 75% vs 82%.
- More people know cyclists should give way, a large increase was seen from 34% 76%. The increase was even larger for cyclists 32% vs 82%.
- More people cross at the crossing-point, 39% vs 53%.
- No reduction in percentage of cyclists using the track, 90% vs 93%.
- There was no reduction in cycling speed on approach to the crossing.

Previous off the road studies were performed to the implementation and piloting above discussed, a report from TRL [21] analysed design concept variations in order to determine the capacity of the island, the occupancy level when the queuing for the bus becomes disorganised, the interactions between cyclists and pedestrians, the most attractive features to maintain cyclists on the track.

Four different combinations of crossing point style were trialled, no ramp/no zebra, no ramp/zebra, ramp/no zebra, ramp/zebra. Where ramp refers to levelling the cycling track on the crossing point to provide a level crossing for pedestrians.

Accessibility was also evaluated by wheelchair users, people with a vision impairment and hearing aid users.

In agreement with other studies, the zebra crossings provided clarity for both, pedestrians and cyclists about where the crossing point was, contributing to the clarity of the layout. The zebra crossing also improved visibility for both groups. And while for the cyclists it made it easier to spot pedestrians, it did not contribute to their ability to negotiate with them. It also provided that the priority at the crossing point corresponds to the pedestrians. Interestingly, cyclists considered the pedestrian priority at the crossing even stronger than pedestrians themselves 70% vs 60%. However, 70% seems low, provided that all cyclists should give priority in zebra crossings. Pedestrians also felt safer when using the zebra crossing, but only 10-15% compared to other variations.

3.2. Shared Bus Stop Boarders SBSBs

We provide a brief reminder of that the Highway Code rule 223 mentions that vehicles (including cycles) must yield to buses and watch for people getting off a bus or tram and crossing the road, although this falls short of setting the responsibility on cyclists to stop, it makes clear they should actively look for pedestrians in readiness to yield for them to cross, more so if there is a zebra crossing indicating priority.

In the observational study by Living Streets, stops with this type of setup exhibited different behaviours, but a key one was people queuing across the cycling lane to board the bus, in such cases, most cyclists proceeded with caution and at a low speed, many dismounted, but others cycling around the queue.

Some of the challenges highlighted for vision-impaired users in this type of stops were that they need to perform many tasks when alighting the bus. To this we need to add the difficulty for cyclists to anticipate when a passenger who is a guide dog or white cane user is alighting from the bus, as they would step directly onto the cycling lane (or the buffer zone) and require extra space. This presents extra safety risks to both users as they can get into contact much easier if the cyclist is for some reason distracted.

They point out that less desirable behaviour both from cyclists and pedestrians is also matter of familiarity with the infrastructure. Suggesting that many users will find themselves in the wrong side of a shared pavement until they realise and move to the correct side.

One issue highlighted is the obstructions caused by pedestrians waling of standing on the cycling lane. Important to note that this behaviour was observed even when the space in the footway and the pedestrian footfall was low, suggesting that pedestrians were either careless or obnoxious. This tended to be reported more but not exclusively on less busy cycling tracks. Many of these distractions (for cyclists) were caused by infrastructural issues within the vicinity of the cycling track, including poor condition of the rolling surface and cluttering.

TFL studied piloted three Shared Bus Stop Boarders in Waltham Forest and video recorded evidence for analysis [22]. The study found that most of the interactions happened between cyclists and pedestrians passing by or waiting for the bus (80, 73 and 100% at each of the stops).

It is important to note that these three sites (from the pictures provided) appear to be shared-use paths, with only painted demarcation between the pedestrian and cycle lane, no kerb used in between. This is important as the report highlights that most of the interactions occurred with pedestrians walking by or waiting. This detail is a key detail in favour of further investigation needed, as empirical information shows that in this type of shared use infrastructure, is very common to find pedestrians wandering all across the surface, providing more chances of conflicting interactions with cyclists. Analysis of sites where clear a physical delineation (rather than just painted) is provided between cycling track and footway, as this potentially will alter the rates of interaction between only passengers and not passer-by pedestrians, potentially even more in the cases where a kerb is chosen as delineator. Similar to setups widely used in Denmark, where a staggered design is employed, providing a level of segregation for cyclists from the vehicular traffic, and for pedestrians from cyclists.

The stops had very different use in terms of the passenger counts. One stop was biased towards boarding passengers, one was balanced, and one towards alighting passengers, and number of interactions reported for passenger movements tend to be biased in a similar fashion, except for one stop where no interactions were reported.

Regarding the reason for the outlier with no reported interactions (stop 3) is very likely due to it being located at a downhill, where cyclists prefer to ride on the carriageway, rather than using the provided cycling track. Again, a kerb-segregated cycling track could have a very different outcome, potentially cyclists choosing to remain on the track instead of the carriageway, increasing not only the likelihood of interactions with passengers (where, not only in number, but at higher speeds naturally achieved when cycling downhill.

Again, this study reports low number of interactions, most of them being low-risk interactions, with six near-misses recorded across the three locations. However, a key factor missing in the data is on which side of the shared path the near miss occurred, on the cycling track side, or on the pedestrian side.

Finally, the research questions of this document state: "In what contexts can such infrastructure reliably be used without compromising pedestrian and bus passenger comfort? Does cyclist behaviour give us confidence that there is minimal risk to bus users?" which seem to not consider or acknowledge that disabled users are within the users, and who are likely to be underrepresented in the sample.

A document from TFL [23] covering Shared Bus Stop Boarders guidelines mentions that the assessment for a potential Shared Bus Stop Boarder location shall consider operational elements such as cyclists flow, pedestrian flow and, lines services from buses. This is in line with the observations provided in other documents regarding Floating Island setups and also by Living Streets. In these terms, the London cycling design standards categorise as low or very low when the number of cyclists passing a point is 200 and 200 pedestrians.

The document also calls for a Pedestrian Comfort Level assessment to be performed to determine crowding situations that may be inconvenient or unsafe for users. This assessment should not include the buffer zone provided as a refuge for passengers boarding or disembarking, nor the cycling track. In their own words "if these areas are needed for pedestrian use, then the sustainability of the [Shared Bus Stop Boarders] would likely need to be called into question".

The document establishes that the key components of the bus setup require to be well differentiated by using materials and surfaces of different characteristics. And that all components of footfall should be taken into consideration for the location (people pushing carts, high number of wheelchair users, etcetera).

The dimensions and some other design parameters mentioned by the document are:

- Cycle track: between 1.2m and 1.5m (including buffer zone for pedestrians)
- Buffer zone: between 0.5m and 1m (to discourage being used as a dwelling area for pedestrians)
- Footway: 2m is desirable, 1.5m in constricted locations (to allow pedestrian-wheelchair interaction), when a bus shelter is present, 1m free after the shelter is the minimum.
- Kerb to carriageway: 100mm as minimum, 125-140mm as preferred.
- Bus shelter: "Where constrained, shelters without end panels or narrow panels (0.65m end panels) could be considered. Designers should consider the inter-visibility between pedestrians and cyclists at the bus shelter"
- The footway, cycle track and buffer zone should be at the same level, separated by a "flush kerb" with distinctive tonal difference and 100-150mm in width.

- "Tramline tactile paving can be used to act as the transition point from the approaching footway into the area where cyclists will be at footway level. This paving should be 800mm in depth and cover the relevant parts of the cycle track at either end of the Shared Bus Stop Boarder"

"A 'cycle give way' marking to TSRGD Diag. 1003B could be considered to encourage considerate cycle behaviours and highlight the area where people may be boarding and alighting buses at the stop, however, this needs consideration by the designer in terms of placement and how the messaging might be interpreted by cyclists. There is currently a lack of Shared Bus Stop Boarders arrangements that feature a give way marking and so there is insufficient monitoring data to recommend this feature at present"

A document from Camden Cyclists [24] seems to suggest a very similar arrangement and dimensions to the one just described with the difference of a well demarcated buffer zone of 75cm and a cycling track of 2m, and the use of corduroy tactile pavers along the raised paving section.

Due to the lack of more literature with local context for the topic, we decided to include some other literature with similar relevance in terms of similarity of the setup. The authors of a study made in the region of Nanjing in China [25] examined two types of bus stops, the closest equivalents to the UK would be a conventional bus stop and a Shared Bus Stop Boarder with a narrow buffer area for passengers. They recorded and examined almost 1400 passengers (boarding and alighting combined) and 1700 cyclists across different stops. One of the most relevant findings from the study was the give-way behaviour of passengers and cyclists at the two setups, revealing that cyclists tend to not give way at Shared Bus Stop Boarders, this may be due to the local regulations, giving priority to cyclists on the cycling lane. Interestingly their study finds that "the severity of conflicts between passengers and cyclists at Type II bus stops is lower than that at Type I bus stops, which indicates that the existence of the dedicated cycleway at Type II bus stops serves as a buffer zone for bus passengers (especially On-passengers)", even further, recommending the use of Shared Boarders (type II in their study) whenever the space constraints allow for this. It is notable that there is no information related to the use of these stops by vision-impaired users, nor there is any mention in the paper about the possible impacts to other groups of users with disabilities.

It is needed to highlight that in another publication from the same lead authors, they provide further explanation of the curb side bus stop layout (type I, in the study) which seems to imply that it is a normal practice for the bus driver to leave space between the kerb and the doors of the bus, in most cases, a large gap where cyclists are allowed to pass, navigating between the passengers boarding and alighting, however, in such cases, the pedestrian has the right of way, as the authors point out. In such case, it resembles more to a Shared Bus Stop Boarder without buffer zone provision.

Another study from the previous authors, also from the city of Nanjing [26] analysed a series of safety factors in relation to the frequency and severity of the interactions between cyclists and passengers (distinguishing between boarding and alighting). The highlights from the study, considering the previously described type I and type II bus stops (shared boarder, with no buffer zone and either a Floating Island Bus Stop with a very narrow island, or a Shared Bus Stop Boarder with a clearly demarcated but narrow buffer zone). The authors found that the type II (FIBS with narrow island) stops present a higher number of interactions (1.7 times) than the type I (SBSB), however, the severity of those interactions was higher for type I than for type II stops. The study mentions that although passengers alighting the bus are more likely to be involved in some interaction with cyclists, the severity of the interactions is lower, compared to those of passengers boarding the bus, which could be explained by passengers trying to catch the bus more aggressively if they are rushed. They found that the density of users, in this case, passengers boarding or alighting and cyclists, influences the odds of interactions. They found that the use of mobile phones by users increase both the odds and severity of interactions with cyclists. Lastly, they showed that the speed of the cyclists is directly related with the severity of the interactions they recorded. Although these findings cannot be directly translated to the context of UK roads, it is sensible to consider that some of these factors will hold true. Despite the analysis is quite comprehensive, there is not a single mention of the needs of vision impaired users.

Another article from the previous authors [27] investigates the Floating Bus stop configuration in which they captured movements from passengers boarding and alighting, as well as their trajectories from the footway to the bus and vice-versa, they compared the speeds of both groups finding that the passengers boarding have a much faster pace than those alighting. This is significant as it demonstrates that the passengers may walk at a faster pace or run to catch the bus, potentially taking less time to analyse their surroundings, in particular, the cycling lane. They also found that four that particular bus stop, the urban furniture had a notorious effect on the displacements of the passengers. Their recommendations are to pay special attention to cluttering in the surrounding of the bus stops, clearly defined crossing path, an unimpeded sightline for both pedestrians and cyclists and sufficient waiting space for the passengers. Again, the authors do not make mention as to what provisions could be relevant for individuals with visual impairments or other disabilities.

In [28] the authors perform a mapping review of the available infrastructures aimed to facilitating access to users with different disabilities. The review covered forty-one articles after which the authors note “further investigation is needed to better analyse whether each proposed measurable built environment feature answers the needs of IPD and understand conflicting and congruent needs between different users in order to attain a more inclusive perspective, by proposing product- or technology-oriented as well as user-oriented studies.” However, no mention of what the implications of situations are where pedestrian infrastructure meets cycling infrastructure, nor direct mention of safety measures.

To finalise this section, we provide a minimum information of basic Pedestrian Comfort Level Assessment dimensions for different cases, further information can be obtained directly from the source [29]:

Minimum width of sidewalk:

- for a flow <600pph, a recommended width of 2.9m, with furniture, 2.6m without furniture but with streetlamps and, 2m without obstructions.
- for 600-1200pph: 4.2m, 3.3m and 2.2m
- for >1200pph: 5.3, 3.3m

The recently published research by Living Streets [10] mentions “that none of the designs studied to date may be of the standard that is required to ensure safety, and to achieve the intended effects”

“We found anecdotal evidence, rather than systematic studies” this, regarding how continuous pavements contribute to inclusion/exclusion. Relevant literature in Dutch suggest that it is consistency in design that generates a perception of safety. The most relevant design suggestion in terms of people with a vision impairment is the introduction of some tactile pavement solution to warn the users of an area which is potentially driven on by traffic. Along with this, other recommendations mainly aligned to increase visibility, slow vehicle traffic to walking speed through use of adequate ramp and gradients, and geometric constraints.

Detailed considerations when designing “continuous footways” catering for people with a vision impairment:

- The need for simplicity and predictability, and in particular standardised indications of the presence of side roads – providing both a navigational feature and an indication of the transition between footway space and areas where pedestrians are at raised risk from vehicles. The simplicity and effectiveness of kerbs in producing this effect.
- The effects of raised areas of carriageway, and kerb-free transition points, whether at continuous footways or elsewhere, in regard to the above point.
- The difficulties in traversing a larger open area in a straight line, and the need to have clear physical features that enable them to orientate themselves – both in terms of direction and so that they can recognise beginning and end points (and preferably also physical features that indicate when a mistake is made, and which allow for this to be corrected)
- The limited ability of many blind and partially sighted pedestrians to use the alignment of blisters on tactile paving for correctly orientating themselves before crossing, and the consequent importance of kerbs
- The difference between the easy interpretation of a slope at a dropped kerb with blister tactile paving on entering and exiting an area of carriageway, compared to the difficulties interpreting level area of tactile paving
- The way in which many blind and partially sighted people navigate by seeking particular familiar features, or by counting the occurrence of certain obvious features, and the role of side roads in this regard
- The basic challenge of keeping track of movement and progress on a journey while navigating with limited sight – with a long cane / by using a guide dog / by feeling for features with hands and feet.

3.3 Continuous footways

Change of material over the driven section, (perhaps the contrast works by informing those with partial vision loss about the presence of an intersection)

Research from TRL on Zebra Crossings [30] reports "Give way behaviour by vehicles increased at each site, with an increase of around 30 percentage points in the proportion of motorists at both sites now giving way at the non-prescribed zebra when they were not giving way with only give-way markings."

The introduction of zebra crossings as compared to give-way markings only did not alter the level of risk of the interactions, which were all low, however it did have an effect on the propensity of the motorists to give way to the pedestrians, favouring the zebra crossing.

This is important in the context of continuous pavements, research would be necessary to determine if continuous pavements also present similar results, however, the report fails to determine what are the implications to disabled users, specifically to people with a vision impairment.

Dimensions for cane users and walking aids:

One thing that the previous documentation did not include, or failed to consider in more detail are the dimensional needs of cane and crutches users. We present information from an American standard (TAS, Texas Accessibility Standards and the Texas accessibility board [34], to inform further discussions that may arise from crowding situations within the bus stops. The standard mentions through drawings that the range of the cane extends approximately 150mm to either side of the user, meaning that if the user' shoulder width is 800mm, the total width to be considered if they are a cane user should be calculated as 1100mm, to account for the sweeping motion. For a crutches user the approximated dimensions to use for a comfortable width is 920mm, this should be projected upwards from the ground for 300mm, to allow free and unobstructed movement of the crutches, this is particularly important when there are elements like trash bins, ticketing machines, fire extinguishers that may need to be installed on the wall.

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Annex 2 – Database queries

Queries employed in Scopus

query 1
ABS ((bus OR autobus) AND (design OR guidelines OR standard) AND (boarding) AND (stop OR terminal))
hits: 57

query 2
ABS (((bus OR autobus) AND (stop OR terminal*)) AND (safety) AND (visually AND impaired OR blind))
hits: 4

query 3
ABS ((bus OR autobus) AND (design OR guidelines OR standard) AND (stop OR terminal)) AND (visually AND impaired OR blind)
hits : 30

query 4 – cycling centred
TITLE (bus OR autobus) AND (ABS ((bus OR autobus) AND (stop OR terminal) AND (design OR guidelines OR standard)) AND (cycling OR bypass OR shared))
hits: 27

query 5

TITLE (bus OR autobus) AND (ABS ((bus OR autobus) AND (stop OR terminal) AND (design OR guidelines OR standard) AND (cycling OR bypass OR shared)))
hits: 8

query 6 – including visually impaired

TITLE (bus OR autobus) AND (ABS ((bus OR autobus) AND (stop OR terminal) AND (design OR guidelines OR standard) AND (cycling OR bypass OR shared) AND (blind OR visually AND impaired)))
hits: 0

query 7 broad (superseded by query 9)
ABS (bus AND stop* AND (blind OR visually AND impaired))
hits 46

query 8 broad bus stop + cyclist +visual impairment
abs(bus and stop and cyclist and (blind or visually impaired))
hits: 0

query 9 broad
ABS (bus AND stop AND (blind OR (visual AND (impair OR disab))))
hits 97

query 10 cyclist + broad
ABS (bus AND stop AND cycli AND (blind OR (visual AND (impair OR disab*))))
hits 0

query 11 broad + safety
ABS (bus AND stop AND safe AND (blind OR (visual AND (impair OR disab))))
hits: 19

query 12 broad + perceptions
ABS (bus AND stop AND (perception OR experience) AND (blind OR (visual AND (impair OR disab*))))
11 hits

query 13 broad + perceptions + including other disabilities
ABS (bus AND stop AND (perception OR experience) AND (disab OR (blind OR (visual AND (impair OR disab)))))
24 hits

query 14
ABS (urban environment AND (perception OR experience) AND ((blind OR (visual AND (impair OR disab)))))
120

Annex 3 – Topic guides and questionnaires

Section 1. Focus groups topic guides

Topic Guide and starting script for the focus groups:

"Good morning. I would like to thank you all for taking the time to join our discussion on certain features within the street and how they impact on you getting out and about safely and independently. My name is [insert name] and I am based in Guide Dogs' [insert team name]. Assisting me is my colleague [insert name] also from the [insert team name].

We are facilitating this focus group session with UCL observing virtually.

Guide Dogs has decided to commission some new research on design trends that are on the increase within our streets. We are concerned that these might be posing barriers to people with sight loss and other disabilities. Guide Dogs has been involved in consultations about street design and representing the views of people with a vision impairment and our mobility staff. However, there is little formal academic research into the impact of these design features on disabled people. We would like to know more about your experiences, so we can incorporate this into our research that will help us influence present and future designs to make them as inclusive and safe as possible.

Some design features are more of a priority than others and therefore this research will focus on:

- Bus stop design and cycle infrastructure with bus stop bypasses and boarders
- Shared pedestrian and cycle routes
- Continuous pavements (sometimes identified as blended crossing)

You were invited to participate because of your experience as a disabled person of getting out and about and some of the challenges you might face in your day to day lives because of the way the streets are designed. Your lived experience will be a vital element of this research.

Consent

UCL has consent of the participants. This should be confirmed on arrival. If you have not given your consent, please can you do so verbally before we proceed (go through the list).

We are recording the session because we do not want to miss any of your comments. Only your first names will be included in the recording just to make the session more inclusive for participants with a visual impairment. No names will be included in any reports. Your comments are anonymised.

Ground rules

There are no right or wrong answers; we will simply be discussing your views, opinion and experiences in relation to the specific features listed above, so please feel comfortable to say what you honestly feel.

We expect that you will have differing points of view! Don't worry if your experience is different from what others have said, we want to hear from everyone to have a range of views. We don't want to miss anything that is said, so it's important that only one person talks at a time. To make this session inclusive, can we ask you to say your first name when you want to speak, so participants who cannot see, know who is speaking. Please remember that to ensure this is a safe space and people feel comfortable contributing, we are asking you not to share people's individual comments and ideas after the focus group. This is an anonymized discussion.

During the discussion [insert name] will be taking notes and reminding me if I forget to ask something! We would like to spend about two and half hours together discussing these four design features and how they might be able to be improved. There will be a break in the middle so that everyone can get a drink.

Are there any questions before we start?

Let us begin. To start with let's find out more about each other by going around the table one at a time...

Ice Breaker (15 minutes)

Can each of you tell the group your name and, in a few words, why being able to go out and about in the street is important to you?

Introductory question (15 minutes)

1. Can you give an example of some helpful street designs or features that have made it easier for you to get out and about?

Transition questions (20 minutes)

We have now a series of questions aimed to document some relevant aspects of how you navigate streets.

2. How do you feel when crossing a street at a non-signalled crossing?
3. What are your strategies to cross streets at non-signalled crossings?
4. How do you feel about crossing a cycle lane?
5. What are your strategies for this?
6. How do you feel about interacting with cyclists in general, why?
7. Do you trust motorists to yield?
8. Do you trust cyclists to yield?
9. Have you been involved in a near-miss with any other road user?
10. Do you have any close relatives or friends cycling regularly? What is their attitude towards pedestrians, what is their experience with motorists?

Key questions (60 minutes)

Each feature is going to be discussed one by one in the following order:

- Bus stop bypasses
- Bus stop boarders
- Continuous or blended pavements
- Shared pedestrian and cycle routes – Shared routes

We will have a break halfway through discussing the features. If anyone wants a drink or comfort break at any time, please feel free to.

We will start with Bus stop bypasses

A 'bus stop bypass' involves a cycleway running behind the passenger boarding area at a bus stop so the cycleway runs parallel between the bus stop and the pavement. This means cyclists do not need to negotiate around stationary buses and buses do not have to overtake cyclists on busy roads. The bus stop is an 'island', so when a bus passenger wants to get on a bus, they need to walk from the main pavement across the cycleway to the bus stop. We have some raised drawings of this feature, which we are now going to pass round so you can get a better sense of the design.

We would now like to ask you a few questions about 'bus stop bypasses', which are sometimes referred to as Floating Bus stops

11. Please describe your experience using bus stop bypasses.
12. What design elements of bus stop bypasses do you consider crucial to feel safer about using them?
13. What is your opinion on the presence of a bus stop bypass in the street?
14. If you have had any difficulties, what would help to reduce the impact?
15. Is there anything else that could be done to make bus stop bypasses more accessible and safer for you?
16. How do you feel about bus stop bypasses?

1.1 Shared Bus Stop Boarders

A Shared Bus Stop Boarder is a platform onto which bus passengers board and alight. In this setup, a cycling track runs along the kerb (between the footway and the carriageway).

There is a build-out platform at footway height, which extends from the footway and meets the carriageway. This section of the road is shared by both passengers boarding/alighting and cyclists, however, markings (painted/tactile pavement) on the ground delimitate a cycling-free zone provided for the passengers as a refuge to board and alight. Give-way marking is considered as advised in the cycling lane.

We have some raised drawings of this feature, which we are now going to pass round so you can get a better sense of the design.

We would now like to ask you a few questions about 'bus stop boarders'.

17. Please describe your experience using bus stop Boarders.
18. What design elements of bus stop bypasses do you consider crucial to feel safer about using them?
19. What is your opinion on the presence of a bus stop Boarders in the street?
20. If you have had any difficulties, what would help to reduce the impact?
21. Is there anything else that could be done to make bus stop Boarders more accessible and safer for you?
22. How do you feel about bus stop Boarders?

Bus Information Systems (Focus, ask for each feature of the research).

23. Have audio information systems in buses helped you navigate the environment?
24. How do you think these audible systems can work in conjunction with these types of bus stops designs? Ask for the two types of bus stops.

1.2 Continuous pavements (continuous footways) or blended crossings

Blended or continuous pavements/footways are where the pavement carries on at the same height uninterrupted, often in the same material as the rest of the pavement, such as paving slabs or bricks, across a side road where cars are able to cross these points. We have some raised drawings of this feature which we are now going to pass round so you can get a better sense of the design.

We would now like to ask you a few questions about 'continuous pavements', which are sometimes referred to as blended pavements or crossings.

25. How do you feel about continuous pavements?
26. Describe your experience using one?
27. What is your opinion on the presence of a continuous pavements in the street?
28. If you have had any difficulties, what would help to reduce the impact?
29. Is there anything else that could be done to make continuous pavements more accessible and safer for you?
30. What behavioural elements of motorists can we work on so that you feel safer on the road?

1.3 Shared pedestrian and cycle routes

A shared pedestrian and cycle route is where pedestrians and cyclists share the pavement. The cycle track is taken off the carriageway and placed on the pavement. Some shared routes have a central delineator (tactile raised strip) separating the two sides with corduroy paving laid ladder-like on the pedestrian side and tram-like for cyclists. Others do not have the central delineator but just a painted white line. We have some raised drawings of this feature, which we are now going to pass round so you can get a better sense of the design.

We would now like to ask you a few questions about 'shared pedestrian and cycle routes', which are sometimes referred to as shared routes.

31. How do you feel about shared pedestrian and cycle routes?
32. Describe your experience using one?
33. What is your opinion on the presence of a shared pedestrian and cycle routes in the street?
34. If you have had any difficulties, what would help to reduce the impact?
35. Is there anything else that could be done to make shared pedestrian and cycle routes more accessible and safer for you?
36. What behavioural elements of other pedestrians have helped you or detracted you from feeling safe on the streets?
37. What behavioural elements of cyclists can we work on so that you feel safer using shared paths?

Summary and ending questions (10 minutes)

Small questionnaire

10 being the best possible and 1 the lowest, please answer:

38. From 1 to 10, how do you rate crossing non-controlled crossings on the road?
39. From 1 to 10, how do you rate crossing a controlled crossing?
40. From 1 to 10, how do you rate a crossing a cycling lane?
41. From 1 to 10, how important would you rate consistency in design?
42. From 1 to 10, how would you rate empathy of other road users towards you?
43. From 1 to 10, how would you rate empathy of motorists towards you?
44. From 1 to 10, how would you rate empathy of motorists towards cyclists?
45. From 1 to 10, how would you rate audible information systems in buses?

We have had a chance to reflect on:

1. Bus stop bypasses
2. Bus stop boarders
3. Continuous or blended pavements
4. Shared pedestrian and cycle routes – Shared routes

I've taken a lot away from this - summarise key points.

- Is this an adequate summary? Have we missed anything? Is there anything else you'd like to say about making these features more accessible and safer for you?

Closing section

Thank you for taking part in this focus group, your insight has been invaluable. Everything shared today will be kept confidential and will form part of a vital piece of research. The next step is carrying out controlled trials based on the feedback from the focus group, all of which will feed into a final report that we hope to be published at the end of May or early June. Guide Dogs will then be working to use the findings to improve the built environment and streets for disabled people".

Section 2. Site visits topic guide

2.1 Floating Island Bus Stop

Topic guide to discuss before analyzing the bus stop

When waiting for the bus

1. Floating Island
2. Locating the bus stop
3. Reaching the bus stop platform (including crossing the cycle lane and how easily they can detect an oncoming cyclist)
4. Where they want to wait at the bus stop
5. Where they want to wait at the bus stop
6. Do they have to wait in a different place at this bus stop compared with at other bus stops?
7. How easily they can detect a bus
8. How they know it is the right bus
9. How easy it is to board the bus
10. How safe they feel when boarding the bus

When alighting the bus

11. Locating the bus stop whilst they are on the bus
12. Knowing that there is a cycle lane at the bus stop that they will have to cross
13. Knowing that this cycle lane is 'behind' the bus stop, between the platform and the footway)
14. Alighting from the bus: how easy, safe is this process
15. How easily they can detect an oncoming cyclist
16. How they know that it is safe to leave the bus
17. What they do after leaving the bus [I would expect things like "stop, arrange my bags, work out which way to go..."]
18. Would that process be different at this bus stop compared with others?
19. How they know it is safe to leave the bus stop platform
20. How safe they feel when alighting the bus

Questionnaire after inspecting the bus stop

21. What characteristics of this bus stop did you find challenging?
22. What are the difficulties here in terms of detecting oncoming cyclists?
23. Do you feel calm and safe whilst waiting for the bus? If not, why not.
24. Is it easy to know when a bus has arrived?
25. Can you board the bus safely?
26. What about getting off the bus?
27. Would you feel safe when leaving the bus?
28. Do you feel safe leaving the bus stop?
29. What improvements would you like to see?

2.2 Shared Bus Stop Boarder

Topic guide to discuss before analysing the bus stop

Boarding the bus

1. Locating the bus stop
2. Where they want to wait at the bus stop
3. Do they have to wait in a different place at this bus stop compared with at other bus stops?

How easily they can detect a bus

4. How they know it is the right bus
5. Reaching the bus (including crossing the cycle lane and how easily they can detect an oncoming cyclist)
6. How easy it is to board the bus
7. How safe they feel when boarding the bus

Alighting the bus and crossing the cycling lane

8. Locating the bus stop whilst you are on the bus
9. Knowing that there is a cycle lane at the bus stop that they will have to cross
10. Knowing that this cycle lane is between the bus and the bus stop and that they will have to enter the cycle lane as they alight from the bus
11. How easily they can detect an oncoming cyclist
12. How they know that it is safe to leave the bus
13. Alighting from the bus: how easy, safe is this process
14. What they do after leaving the bus [I would expect things like "stop, arrange my bags, work out which way to go…"]
15. Would that process be different at this bus stop compared with others?
16. How they know it is safe to leave the bus stop platform

Questionnaire to complete after using the bus stop

17. What characteristics of this bus stop did you find challenging?
18. What are the difficulties here in terms of detecting oncoming cyclists?
19. Do you feel calm and safe whilst waiting for the bus? If not, why not?
20. Is it easy to know when a bus has arrived?
21. Can you board the bus safely?
22. What about getting off the bus?
23. Would you feel safe when leaving the bus?
24. Do you feel safe leaving the bus stop?
25. What improvements would you like to see?

Section 3. Experiments questionnaires

3.1 Continuous pavements

1. Did you identify any features on the footway?
2. If you identified, how did you do it, what clues did you use?
3. Do you have a way to interpret the road markings (paint)?
4. How tasking would you consider it is to navigate this footway section.
   - Rate from 1 to 5, 1 being not at all, 5 being quite much.
5. How safe do you rate this setup?
   - Rate from 1 to 5, 1 being not at all, 5 being quite much.
6. How often do you find yourself using general road markings to navigate the footway?
   - Rate from 1 to 5, 1 being not at all, 5 being quite much.
7. How dangerous do you consider this footway?
   - Rate from 1 to 5, 1 being not at all, 5 being quite much.

3.2 Bus Stops

The questions were asked in relation to each bus stop type and are as follows:

1. How difficult did you find it to detect the bicycles in the cycling lane?
   - 5 very easy, 1 very difficult.
2. How would you rate how understandable is the bus stop setup?
   - 5 very much, 1 too little.
3. How safe would you rate this bus setup?
   - 5 safe, 1 unsafe.
4. How likely would you ask for assistance to navigate this setup?
   - 5 very unlikely, 1 very likely.
5. How useful would you rate having an on-board recording on the bus informing the passengers which kind of bus stop they will find?
   - 5 very useful, 1 very irrelevant.
6. How likely would you use a digital tool to navigate this setup?
   - 5 very likely, 1 unlikely
7. How much does it help to your perception of safety knowing in advance the setup and geometry of the bus stops?
   - 5 it would help a lot; 1 it would not help.

8. How much is your previous cycling behaviour experience contributing to your difficulty with navigating this stop?
   - 5 it contributes a lot; 1 it contributes very little.
9. How much is the setup design contributing to your ability to navigate this stop?
   - 5 the design helps a lot, 1 the design is unhelpful
10. How dangerous would you rate this stop setup, given all your previous experience?
    - 5 not dangerous at all, 1 very dangerous
11. How safe would you rate this stop setup supposing that the majority of cyclists give way to passengers boarding and alighting buses?
    - 5 very safe, 1 not safe
12. How confident do you feel when identifying tactile pavements?
    - 5 very confident, 1 not confident.

Each question asked the participant to provide a score between 1 and 5, with 1 being the most negative response and 5 the most positive response to the question.

[End of Document]

Guide Dogs